Total Factor Productivity Index Specification Issues

Report prepared for
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CONTENTS

EXECUTIVE SUMMARY

Background

The Australian Energy Market Commission (AEMC) is undertaking a review into the possible uses of total factor productivity (TFP) methodologies for the regulation of prices and revenues in the national energy networks.

The AEMC has requested Economic Insights to review the current state of knowledge on the specification of energy network TFP growth and to identify areas where further work needs to be done.

In its recent Design Discussion Paper the AEMC (2009) noted that there have been two different broad specifications used in previous Australian energy network TFP studies. The major electricity distribution TFP studies undertaken in Australia have been a series of studies by Lawrence (2000, 2005a) and Pacific Economics Group (PEG 2004, 2008a and ESC and PEG 2006). A report by Lawrence (2003) also formed the basis of productivity–based electricity distribution regulation in New Zealand.

The major differences between the Lawrence and PEG TFP reports for both electricity and gas distribution relate to the way outputs are measured and whether system capacity is included, the way output quantities are weighted together to form a total output index, the way capital input quantities are measured and the way the annual cost of capital inputs is calculated.

Economic Insights (2009c) reviewed the sensitivity of TFP growth estimates to different specification choices using electricity distribution data for Victoria and found that a wide range of TFP growth rates can be obtained depending on the specification choices made.

A further recent development noted by AEMC (2009) is the derivation by Economic Insights (2009a) of a unified theory of productivity–based regulation which, among other things, incorporates the important regulatory principle of financial capital maintenance (FCM). This framework has important implications for TFP specification. Economic Insights (2009b) has subsequently implemented key parts of this framework for the New Zealand electricity distribution industry.

Network TFP

Productivity is a measure of the physical output produced from the use of a given quantity of inputs. To operationalise this concept index number theory is used to combine changes in diverse outputs and inputs into measures of change in total outputs and total inputs.

To measure productivity performance we, therefore, need to specify the price and quantity of each output and input. We need to accurately specify quantities because productivity is essentially a weighted average of the change in output quantities divided by a weighted average of the change in input quantities. Although the weights are complex and vary depending on the index technique used, they are derived from the share of each output in total revenue (in the case of competitive industries) or information on revenue and marginal cost (in the case of natural monopolies) and the share of each input in total costs.

Output specification issues

It is desirable to include both billed outputs and key unbilled functional outputs in the TFP specification and to allow for differences between billed prices and marginal costs. Adopting this approach allows regulatory pricing principle issues to be taken account of directly in setting the X factor and allows DBs to be put on an even footing by identifying the impact of the wide range of pricing structures observed in the industry which directly impact on measured TFP.

The key billed outputs that have been included in previous energy distribution TFP studies include fixed charges, throughput charges and capacity reservation charges. The other functional output which has been included is system capacity. Other important functional outputs which have not been included in previous studies are service quality and system security.

A number of important issues remain to be resolved in practice as follows:

- What is the desirable level of disaggregation of billed throughput and fixed charge outputs to be included?
- How can a satisfactory measure of the quantity of reserved capacity (or contracted demand) be formed (given that the current proxy of non–coincident peak demand is unsatisfactory)?
- Is the product of distribution transformer capacity and line length the best measure of overall electricity distribution system capacity?
- Is the standardised volume of gas held in the distribution network the best measure of gas distribution system capacity?
- Is there a satisfactory way of transforming reliability indexes into output measures that can be used in TFP measurement?
- Is it important to include dimensions of service quality other than reliability as outputs?
- Can a satisfactory measure of the insurance output associated with increased system security be developed?
- Are there unbilled functional outputs other than system capacity, service quality and system security that should be included in the TFP specification?
- How can measures of the cost associated with each output component be best formed?
- Can processes currently in place to demonstrate compliance with regulatory pricing principles or for internal DB planning purposes be utilised in forming output cost measures?

Another important issue that needs to be resolved is exactly what the coverage of DB activities to be included should be. Economic Insights (2009e) identified differences in coverage both across jurisdictions and over time as an important problem with currently available data. Common coverage of activities is a necessary requirement through time and a highly desirable requirement across jurisdictions for forming TFP growth rates that are sufficiently robust for use as the primary instrument in setting price or revenue caps.

Input specification issues

Most network TFP studies have included two broad input categories: operations and maintenance expenditure (opex) and capital. The specification of opex inputs is relatively straight–forward although a number of implementation issues do remain.

After a period of debate, the appropriate specification of capital inputs now appears to be clear. Since network assets approach the physical characteristic of one hoss shay depreciation, the service potential or input quantity of capital inputs should reflect this pattern. Using physical quantity proxies is a relatively robust way of doing this although other options such as the use of hyperbolic age efficiency profiles (as are widely used in National Accounts multifactor productivity) are also available. Using constant price depreciated asset value proxies (which do not reflect the true physical service potential of assets) will introduce significant biases and compromise the ability of the regulated DBs to recover efficient costs. If ex ante financial capital maintenance (FCM) is regarded as an important regulatory requirement then the approach to forming the annual user cost of capital should be broadly similar to that used in building blocks.

Some issues remain to be resolved in practice including:

- What should be the specified constant opex activity coverage and should this be the same across all DBs?
- Is there common treatment of expenditure on isolated asset refurbishment both over time and across DBs?
- Are cost allocation practices comparable and consistent across multi–utilities?
- What is the most appropriate way of handling pass–through costs?
- What refinements need to be made to the opex price index?
- Should labour prices be proxied by sectoral AWOTE or the sectoral LPI?
- Do the water industry and the generation/production and transmission parts of the electricity and gas industries unduly influence Electricity, gas and water sector price indexes?
- What combination of Producer Price Indexes best captures the price of the non–labour components of opex?
- Which method best proxies in practice the physical depreciation of network assets: physical measures, constant price gross capital stocks or the use of a hyperbolic age–efficiency profile to form a productive capital stock measure?
- What MVA–kilometre conversion factors are most appropriate for Australian EDBs and should these vary across EDBs?
- How should the quantity of non–system fixed assets be proxied?
- What WACC value should be used in forming the capital amortisation charge?
- What profile of amortisation charges should be used?
- Should allowance be made for transmission/distribution boundary differences?

Other matters

Dr Lawrence Kaufmann (2009) has made a personal submission to the AEMC which has an extensive discussion of TFP specification and related issues. This submission misinterprets and, consequently, mischaracterises many aspects of the Economic Insights (2009a) framework. We respond to this submission in detail in the appendixes to this report.

The way forward

The AEMC (2009, pp.26–27) set five criteria for the assessment of TFP specifications for use in TFP–based regulation. These criteria are that the specification:

- results in a stable index over time;
- creates no systematic bias in the TFP growth estimate;
- is consistent with promoting economic efficiency and does not result in any perverse incentives;
- is consistent with the service provider's regulatory asset base; and
- results in reporting requirements which are proportionate and not onerous.

Based on an assessment of the various aspects of TFP specification against the AEMC's criteria we conclude that the key features of the TFP specification should be as follows:

- both billed and non–billed functional outputs should be included
- key outputs covered should include throughput, customer numbers, contracted reserved capacity and overall system capacity
- a better measure of contracted reserved capacity is required
- more work is required to develop a system security output
- the difference between output component revenue and underlying costs should be taken account of
- more disaggregation of throughput and customer numbers should be included if possible
- a consistent specification of opex activity coverage needs to be developed along with consistent application of capitalisation and cost allocation methods
- capital input quantity proxies need to reflect the key characteristics of network assets including their relative lack of deterioration in carrying capacity over their lifetime – physical measures of capacity represent a robust and easily implementable proxy
- capital amortisation charges need to explicitly incorporate the principle of financial capital maintenance and should be broadly similar to those used in building blocks (except they are applied to historical data rather than forecast data)
- the depreciation profile used in forming amortisation charges should reflect the asset's actual length of life and be as consistent as possible with its service potential profile

Implementation of a TFP specification along these lines would make a clear and demonstrable contribution to improving economic efficiency while ensuring DBs are given the opportunity to recover efficient costs.

1 INTRODUCTION

The Australian Energy Market Commission (AEMC) is undertaking a review into the possible uses of total factor productivity (TFP) methodologies for the regulation of prices and revenues in the national energy networks. In its recent Design Discussion Paper the AEMC (2009) set out a 'strawman' model of many of the possible key design features of a TFP–based regulation framework. However, the appropriate specification for calculating the TFP growth rate (ie outputs, inputs and weightings to be used, the indexing method and the method used to calculate index growth rates) was left open.

The AEMC noted that there have been two different broad specifications used in previous Australian energy network TFP studies. The major electricity distribution TFP studies undertaken in Australia have been a series of studies by Lawrence (2000, 2005a) and Pacific Economics Group (PEG 2004, 2008a and ESC and PEG 2006). A report by Lawrence (2003) also formed the basis of productivity–based electricity distribution regulation in New Zealand. This study was updated in Lawrence (2007b). The major study of gas distribution TFP in Australia is that of Lawrence (2007a) while a less detailed study using a different methodology was undertaken by PEG (2008b).

The major differences between the Lawrence and PEG TFP reports for both electricity and gas distribution relate to the way outputs are measured and whether system capacity is included, the way output quantities are weighted together to form a total output index, the way capital input quantities are measured and the way the annual cost of capital inputs is calculated. Economic Insights (2009c) reviewed the sensitivity of TFP growth estimates to different specification choices using electricity distribution data for Victoria and found a wide range of TFP growth rates can be obtained depending on the specification choices made.

A further recent development noted by AEMC (2009) is the derivation by Economic Insights (2009a) of a unified theory of productivity–based regulation which, among other things, incorporates the important regulatory principle of financial capital maintenance (FCM). This framework has important implications for TFP specification. Economic Insights (2009b) has subsequently implemented key parts of this framework for the New Zealand electricity distribution industry.

The AEMC has requested Economic Insights to review the current state of knowledge on the specification of energy network TFP growth and to identify areas where further work needs to be done.

The following section of the report briefly reviews how TFP estimates are constructed and some of the major methodological choices which have to be made. Sections 3 and 4 review output and input specification issues, respectively. Indexing method and growth rate calculation issues are reviewed in sections 5 and 6, respectively, while conclusions are drawn in section 7. Finally, Dr Lawrence Kaufmann (2009) has made a personal submission to the AEMC which has an extensive discussion of TFP specification and related issues. This submission misinterprets and, consequently, mischaracterises many aspects of the Economic Insights (2009a,b) framework. We respond to this submission in detail in appendix A.

2 NETWORK TFP

Productivity is a measure of the physical output produced from the use of a given quantity of inputs. All enterprises use a range of inputs including labour, capital, land, fuel, materials and services. If the enterprise is not using its inputs as efficiently as possible then there is scope to lower costs and, hence the prices charged to energy consumers, through productivity improvements. This may come about through the use of better quality inputs including a better trained workforce, adoption of technological advances, removal of restrictive work practices and other forms of waste, and better management through a more efficient organisational and institutional structure.

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

To operationalise this concept index number theory is used to combine changes in diverse outputs and inputs into measures of change in total outputs and total inputs. Growth rates for individual outputs are weighted together using information on revenue and the cost of producing each output while inputs are weighted together using input cost shares. In other words, the TFP index is essentially a weighted average of changes in output quantities relative to a weighted average of changes in input quantities. Different index number methods form this weighted average change in different ways.

Mathematically, TFP is given by:

(1) $TFP \equiv Q/I$

where Q is an output aggregate and I is the corresponding input aggregate pertaining to a period of time. We then define TFP growth between periods 0 and 1 as:

(2) $TFPG \equiv TFP^1/TFP^0 = [Q^1/I^1]/[Q^0/I^0] = [Q^1/Q^0]/[I^1/I^0]$.

To measure productivity performance we, therefore, need to specify the price and quantity of each output and input. We need to accurately specify quantities because productivity is essentially a weighted average of the change in output quantities divided by a weighted average of the change in input quantities. Although the weights are complex and vary depending on the index technique used, they are derived from the share of each output in total revenue (in the case of competitive industries) or information on revenue and marginal cost (in the case of natural monopolies) and the share of each input in total costs.

3 OUTPUT SPECIFICATION

There have been two broad approaches to output specification in energy network TFP studies: one argues that only 'billed' outputs should be included while the other argues that all 'functional' outputs (of which billed outputs are a subset) are important. In both cases data limitations have meant that relatively aggregated proxies have had to be used in practice. In this section we review the issues surrounding billed and other functional outputs and the adequacy of proxy measures that have had to be used in both cases. We then highlight priority areas for further work.

3.1 Billed and other functional outputs

Early sector–wide energy supply TFP studies simply measured output by system throughput (eg Lawrence, Swan and Zeitsch 1991). However, once the focus changed to energy distribution specifically it was recognised that this simple measure ignored important aspects of what energy distribution businesses (DBs) really do. Like all network infrastructure industries, a major part of DBs' output is providing the capacity to supply the product. In this sense, there is an analogy between an energy distribution system and a road network. The DB has the responsibility of providing the 'road' and keeping it in good condition but has little, if any, control over the amount of 'traffic' that goes down the road. Other outputs the DB provides are directly related to its number of connections ('local access roads') as well as call centre operations responding to queries, connection requests, etc. However, for convenience or historical reasons the DB may actually charge customers on a 'traffic' or throughput basis, even though the marginal cost of additional throughput is typically very low. This has often led to prices not being cost reflective.

To capture this complexity, some have argued that the DB's output should be measured by the availability of the infrastructure it has provided and the condition in which it has maintained it as well as by the dimensions it actually charges for. This has led to a distinction between 'billed' outputs (those items the DB actually charges for) and the broader concept of 'functional' outputs (what services the DB actually provides). It should be noted that this distinction will typically not be necessary for competitive industries since competitive pressures will lead to prices for all outputs being relatively cost reflective. However, since energy distribution is a natural monopoly, there can be significant departures from cost reflective pricing across outputs.

To capture these multiple dimensions of electricity DB output, Lawrence (2003) measured distribution output using three outputs: throughput, connection numbers and system line capacity. The first two of these were billed outputs while the third was a functional output. This also had the advantage of incorporating the major density effects (consumption per customer and customers per adjusted kilometre of line) directly into the output measure. System line capacity was measured by MVA–kilometres, an engineering measure which takes account of line length, voltage and the effective capacity of an individual line based on the number, material and size of conductors used, the allowable temperature rise as well as limits through stability or voltage drop. A broadly analogous measure for gas distribution output was developed in Lawrence (2007a).

Pacific Economics Group (2004, 2008a) also included three output dimensions in their electricity DB TFP study: throughput, customer numbers and non–coincident peak demand. This measure of peak demand was used as a proxy for maximum contracted demand. These three outputs were intended to capture the major billed outputs that DBs charge for and were weighted using revenue shares.

Economic Insights' (2009a) technical report for the NZ Commerce Commission shows that TFP can be decomposed into a pure technical change term and terms showing the divergence between price and marginal cost for each output and the divergence between capital prices and the marginal saving in operating costs from capital investment where the industry is characterised by non–competitive conditions. It is desirable to recognise this decomposition to take account of the increasing returns and sunk cost characteristics actually observed in energy distribution networks. This means the most appropriate measure of output to use in measuring TFP if the Economic Insights approach is used is an output measure that includes all relevant functional outputs irrespective of whether they are explicitly billed for or not. Note, however, that billed outputs will be a subset of functional outputs. The appropriate weights to apply are the difference between price and marginal cost for each output.

Some parties have claimed that the use of functional outputs (in isolation) may compromise the ability of DBs to recover efficient costs (PwC 2009, Kaufmann 2009). But the Economic Insights approach does not entail the exclusive use of an 'abstract' output measure with no market price. Rather, it involves recognising a fuller range of network outputs of which billed outputs are a subset.

For non–billed functional outputs, market prices would be treated as zero in deriving the X factor but the input costs associated with those outputs would be captured. This is because the weight is the difference between marginal cost and market prices, which in this case is simply marginal cost. For billed outputs, changes would be weighted by the differences between marginal costs and market prices. Thus, the appropriate measure of output in the Economic Insights approach is one that includes all relevant functional outputs irrespective of whether they are explicitly billed for or not. However, all outputs that are priced would also need to be included (ie these would, by definition, be a subset of functional outputs), along with terms to reflect operating cost and capital cost increases in order to ensure financial capital maintenance. An empirical example from Economic Insights (2009b) is reproduced in appendix B of this report.

Including non–billed outputs as well as billed outputs is thus more informationally demanding as it requires estimates of marginal cost as well as current prices but the inclusion of the divergence between marginal cost and prices is important in terms of addressing underlying economic welfare considerations and is likely to be important in practice where the divergences across firms may be very significant. Note that although some DBs will have chosen not to price some output dimensions for convenience, political or other historical reasons, to ensure revenues align with costs, the prices of those outputs that do have a market price will be higher than they would be if all outputs were priced.

It should be noted that the importance of pricing structures is recognised in current building blocks regulation but it is effectively tacked on as an afterthought rather than being integrated into the price cap setting process. This is because DBs' price caps are typically set at an aggregate level and the DBs then have to demonstrate that they have complied with the specified regulatory pricing principles in setting their pricing structures. Cost reflective pricing is typically an important component of the regulatory pricing principles (see IPART 2004, Commerce Commission 2007). Thus, DBs are already required (at least in principle) to supply information on underlying costs as part of their regulatory pricing principles reviews.

It should also be noted that the framework advocated by Kaufmann (2009) involving billed outputs only is based on an axiomatic approach (ie satisfying high level accounting identities only) rather than a fully developed economic approach that recognises the objective of maximising economic welfare. Since the fundamental purpose of utility regulation is to improve economic welfare, it is important to recognise the link between DB output prices and consumer welfare and not just focus exclusively on the production side and the aggregate recovery of efficient costs. The Economic Insights (2009a) framework which recognises both billed and functional outputs provides such an integrated approach.

A further feature of the Economic Insights (2009a) framework is that DB TFP growth is made up of the three components listed above (a pure technical change term, a term showing the divergence between price and marginal cost and a term showing the divergence between capital prices and the marginal saving in operating costs from capital investment). An important implication of this is that while technical change may be relatively similar across DBs (or at least those with similar operating environment conditions), the second and third terms are likely to vary widely across DBs depending on the pricing practices adopted.

The Kaufmann (2009) approach is predicated on the assumption that achievable TFP growth should be relatively similar across all DBs. However, while technical change may be relatively similar across DBs (with similar operating environments), the pricing structures adopted may be quite different and hence the second term involving the deviation of prices from marginal costs may be quite different. This will lead to the DBs' achievable TFP growth rates being different. Failure to recognise this in either setting the structure of the regulatory regime or the composition of peer groups in setting a group–wide X factor is likely to cause difficulties. Consequently, while including functional as well as billed outputs would be more informationally demanding, it is necessary to ensure the regulatory regime achieves its key objective of improving economic welfare.

The need to recognise functional as well as billed outputs and the importance of departures from cost reflective pricing in this industry have been recognised by DBs in the current AEMC review. For example, Energex (2009, p.12) noted in its submission:

> '.. the [Economic Insights] approach appears more intuitively appealing and practical at this point in time. This is because ENERGEX gives some weight to the view that the current revenue shares may not reflect outputs delivered to customers (particularly residential customers); that is there may be some disconnect between tariff structures and outputs due to metering constraints and retail price regulation.
>
> 'In addition, due to differences in tariff structures across electricity distribution service providers, using billed outputs and revenue weights may result in an unrepresentative estimate of TFP growth being calculated. Clearly, any TFP estimates that are derived need to be representative of the service providers to

which the X Factor will be applied (regardless of whether an industry–wide X Factor or multiple X Factor approach is adopted).'

Jemena Limited (2009, pp.4–5) also provided the following illustration of the disparity that can exist between network output and the basis of charging:

> 'Actual throughput and actual peak demand are not significant cost drivers in the short term: the provision of capacity to accommodate forecast maximum peak demand is a much more significant driver of input requirements and costs.
>
> 'Despite the fact that capacity is one of a distribution business's principal outputs, it is accepted practice to set network tariffs for some classes of end use at least, on the basis of end user throughput and consumption. A significant proportion of costs may be recovered in that way, but that does not alter the fact that network users are actually buying (and being supplied with) guaranteed capacity. …
>
> 'As an example of the disparity that can exist between network output and the basis of charging, the following table describes the sources of network revenue and related network throughput and peak demand values for the Jemena Gas Network in NSW.

Market Segment	Percent of annual throughput	Percent of peak day throughput	Percent of annual revenue	Charging basis contribution to revenue
Demand users (>10TJ per annum)	66%	51%	10%	≈100% on contracted capacity reservation (remainder is meter charges)
Volume users (<10TJ per annum)	34%	49%	90%	≈20% fixed charges ≈80% throughput charges

We turn now to the measurement of both billed and other functional outputs.

3.2 Billed outputs and proxy measures

DBs usually charge for distribution services on three broad bases:

- fixed charges which have to be paid by the consumer regardless of energy use;
- throughput charges which reflect the volume of energy used by the consumer; and,
- capacity reservation charges which guarantee the user a given amount of capacity, even at peak times, and which are normally only applied to large (usually industrial) users.

Most users pay some combination of these three types of charges.

As noted above, previous studies have adopted relatively aggregated proxies when measuring these three broad billed output dimensions. For instance, Lawrence (2003, 2007b) used total throughput as the quantity measure for throughput charges while PEG (2004) used separate measures of peak throughput and off–peak throughput. Both studies simply used the total number of customers as the quantity measure associated with fixed charges. These measures are very aggregated and relatively crude.

A priority in future work should be to include more detailed measures of both throughput and customer numbers. In other industries moving from very aggregated output measures to more disaggregated measures has proven to be quite material. For example, a study of Australia Post's TFP growth by Lawrence (2002) included price and quantity data for 7 outputs (reserved letters, other addressed mail, unaddressed mail, money orders, agency services, accommodation and other outputs). The output quantities for the major mail categories of reserved letters and other addressed mail were simply taken to be the overall number of mail articles in each – an approach broadly similar to that adopted in the energy distribution TFP studies. Significant improvements in Australia Post's information systems allowed Lawrence (2007c) and Economic Insights (2009) to include considerably more detail on the outputs provided by Australia Post. The number of output categories increased from 7 to 25 (with the increased detail all being in the key reserved service and other addressed mail areas), allowing the construction of more accurate output indexes.

The effect of this increased level of disaggregation was to increase Australia Post's measured TFP growth rate. In Lawrence (2002) the postal articles within each of the broad groups of reserved letters and other addressed mail were effectively given equal weight in forming the output index. This would be a reasonable assumption if the different types of postal articles within each of the broad groups had increased at a similar rate. But if higher value articles such as packages are increasing at a faster rate than low value articles such as letters then the true increase in total output would be underestimated using the assumption in Lawrence (2002). Australia Post has been increasing its relative throughput of higher value articles in recent years so being able to recognise this had a material impact on measured productivity growth.

A similar result may be observed in energy distribution if those throughput categories and customer types that have higher per unit charges have been increasing faster than those that have lower per unit charges. Increasing the detail included on throughput and fixed output components should be a relatively straightforward improvement to make to current specifications.

The proxy that has been adopted for the quantity of the third billed output – reserved capacity – is, however, more problematic. PEG (2004, 2009) used 'non–coincident demand' as a proxy for reserved capacity. It is presumed this variable is formed as the summation of observed peak demand for each EDB (and those individual EDB peaks will not all occur at the same time). However, this measure represents the peak energy entering the network at the bulk supply points and is likely to be a poor proxy for the contracted demands that large customers pay for. This is because diversification of demand within the network means that the total peak energy entering the network at any one time will be less than the sum of maximum demands at the final customer level (which will all occur at different times). Rather, the final distribution level of transformer capacity for each EDB would be likely to provide a better proxy. It should also be noted that many larger customers pay both throughput and capacity charges rather than just a capacity charge.

The peak demand proxy is also quite volatile with erratic movements from year to year. Economic Insights (2009c, pp.8–14) sensitivity analysis report demonstrated that non–coincident peak demand was by far the most volatile of a range of possible output proxies and that this volatility fed straight through into the PEG (2008a) output and TFP indexes. Contracted reserved capacity is likely to move in a relatively smooth and monotonic fashion rather than to shift erratically form year to year which again makes non–coincident peak demand a poor proxy for the quantity of this output.

A better treatment of the reserved capacity billed output is therefore required.

3.3 Other functional outputs and proxy measures

Apart from the three billed outputs discussed above, the other functional output which has been included in previous energy distribution TFP studies is system capacity. Other important functional outputs which have not been included in previous studies are service quality and system security.

System capacity

As noted above, Lawrence (2003, 2007b) used system line capacity as a proxy for overall electricity distribution system capacity. This was measured by MVA–kilometres, an engineering measure which takes account of line length, voltage and the effective capacity of an individual line based on the number, material and size of conductors used, the allowable temperature rise as well as limits through stability or voltage drop. A broadly analogous gas distribution pipeline capacity measure was developed in Lawrence (2007a) where the volume of gas held within the gas network was converted to standard cubic meters using a pressure correction factor based on the average operating pressure. The volume of the distribution network was calculated based on pipeline length data for high, medium and low distribution pipelines and estimates of the average diameter of each of these pipeline types. The quantity of gas contained in the system is a function of operating pressure. Thus, a conversion to an equivalent measure using a pressure correction factor was necessary to allow for networks' different operating pressures.

Economic Insights (2009b) included a broader measure of electricity distribution system capacity that recognised the role of transformers as well as lines. Electricity distribution output capability to serve consumers depends on the throughput capacity of the distribution transformers at the final level of transformation to utilisation voltage, as well as on the length and capacity of mains over which supply is delivered. The MVA–kilometres measure used in Lawrence (2003, 2007b) did not recognise the role of transformation in the delivery capacity.

One measure that recognises the role of transformer capacity as well as mains length is a simple product of the installed distribution transformer kVA capacity of the last level of transformation to the utilisation voltage and the totalled mains length (inclusive of all voltages but excluding streetlighting and communications lengths). The advantage of including such a measure is that it recognises the key dimensions of overall effective system capacity. It also avoids the inclusion of elements of the MVA–kilometres variable on both the input and output sides of the TFP specification (which was a criticism that had been made of the earlier Lawrence 2003 specification).

Further refinement of system capacity measures and closer tailoring to Australian conditions is possible.

Service quality

Service quality is an important dimension of energy DB output but it is not one that is typically charged for explicitly. Service quality can, therefore, be considered as a non–billed functional output but attempts to include the principal aspects of service quality as outputs in energy distribution TFP studies have proven unsuccessful. Reliability is likely to be the most important aspect of service quality. Outputs in TFP studies need to be measured in such a way that an increase in the measured quantity of an output represents more of the output. But both the frequency and duration of interruptions are measured by indexes where a decrease in the value of the index represents an improvement in service quality. It would be necessary to either include the indexes as 'negative' outputs (ie a decrease in the measure represents an increase in output) or else to convert them to measures where an increase in the converted measure represents an increase in output. Most indexing methods cannot readily incorporate negative outputs and inverting the measures to produce an increase in the measure equating to an increase in output leads to non–linear results. Since most systems are interrupted for a relatively small number of minutes each year, using the number of minutes the system is uninterrupted effectively produces a constant variable that is of no practical use in TFP measurement.

While ways of including a negative output can be developed, there remains the problem of how to value service quality as this requires evaluating consumer willingness to pay for improved quality.

In principle it would be desirable to include service quality as an additional output variable. This is because providing a more reliable service will require more inputs to be used and, without including a service quality output, there will be no recognition or 'credit' on the output side for the better quality service while higher input usage is recognised leading to an underestimate of true TFP growth.

Most jurisdictions address service quality considerations by way of a separate 'S' factor scheme so that the overall price cap becomes of the form CPI–X+S. There is some concern that this may lead to DBs being rewarded twice for improved service standard performance – once through the S factor allowing greater real price increases as a reward and secondly through a reduced X factor if expenditure aimed at facilitating improved service standards is included in the TFP calculations (assuming the entire industry engages in such expenditure). However, expenditure aimed at improving service standards is generally treated no differently from other expenditure in jurisdictions that include 'S' factors and inclusion of an S factor is generally considered the most practical way of allowing for service quality.

If it were possible to include service quality as an additional output in TFP calculations then increased expenditure to improve service quality would be offset by increased output resulting from achieving improved service quality. But it would still be necessary to include an S factor to provide the incentive to improve service quality (given that service quality is generally not priced). It would, however, potentially remove the scope for DBs to be 'double rewarded'.

In practice, the 'least worst' way of allowing for reliability considerations is most likely to not include it as an output in the TFP calculation and not to treat expenditure aimed at improving reliability differently from other expenditure while also including an S factor. To the extent that improving service quality is generally desirable then any resulting 'excess' incentives to improve service quality are not likely to be a problem.

System security

'System security' refers to the pressure being placed on DBs – and particularly those covering major CBD areas – to meet increasingly higher system security benchmarks (either explicitly or implicitly) (eg moving from n–1 to n–2 redundancy levels). System security is currently an unbilled functional output.

The system security issue is problematic. The CBD DBs are having to spend large amounts to strengthen their systems and provide higher levels of redundancy but current measures of output do not show any corresponding increase in 'output'. It should also be noted that allowing for this by including reliability measures as outputs (if that could be satisfactorily done) is not the answer as these may not reflect any change in output either. Rather, improving system security is providing an 'insurance' output that customers value but which it is very hard to measure. One option could be to give DBs a score depending on what redundancy level they achieved (eg 1 for n–1, 2 for n–2, etc). But the issue is then how to value this output. If the event being insured against by the system strengthening does not come to pass then the extra output would not be reflected in different reliability performance but insurance against such an event has been provided nonetheless.

If the system security output is not allowed for then DBs will have a lower rate of measured TFP growth than would otherwise be the case. To the extent that this results in lower X factors then there may be at least some reward for DBs and an extra incentive provided to the industry to improve system security and reliability.

It should also be noted that allowance for capital expenditure during the period could be made at the subsequent reset. If the subsequent P_0 adjustment is made recognising financial capital maintenance (FCM) then capex during the last regulatory period would be rolled into the next period's opening cost base by allowing a return on and return of capital from the point the expenditure was made through to the end of the last period. Thus, even if increased capex reduced the EDBs' productivity growth rate below that used to set the X factor, recognising actual capex and FCM on that capex in the subsequent price reset would greatly reduce the disincentive to undertake necessary capex in excess of that initially allowed for.

3.4 Issues to be resolved

This section has demonstrated that it is desirable to include both billed outputs and key unbilled functional outputs in the TFP specification and to allow for differences between billed prices and marginal costs. Adopting this approach allows regulatory pricing principle issues to be taken account of directly in setting the X factor and allows DBs to be put on an even footing by identifying the impact of the wide range of pricing structures observed in the industry which directly impact on measured TFP.

A number of important issues remain to be resolved in practice and these are listed below:

- What is the desirable level of disaggregation of billed throughput and fixed charge outputs to be included?

- What is the 'right' measure of output to include in TFP growth calculations?
- How can a satisfactory measure of the quantity of reserved capacity (or contracted demand) be formed (given that the current proxy of non–coincident peak demand is unsatisfactory)?
- Is the product of distribution transformer capacity and line length the best measure of overall electricity distribution system capacity?
- Is the standardised volume of gas held in the distribution network the best measure of gas distribution system capacity?
- Is there a satisfactory way of transforming reliability indexes into output measures that can be used in TFP measurement?
- Is it important to include dimensions of service quality other than reliability as outputs?
- Can a satisfactory measure of the insurance output associated with increased system security be developed?
- Are there unbilled functional outputs other than system capacity, service quality and system security that should be included in the TFP specification?
- How can measures of the cost associated with each output component be best formed?
- Can processes currently in place to demonstrate compliance with regulatory pricing principles or for internal DB planning purposes be utilised in forming output cost measures?

Another important issue that needs to be resolved is exactly what the coverage of DB activities to be included should be. Economic Insights (2009e) identified differences in coverage both across jurisdictions and over time as an important problem with currently available data. Common coverage of activities is a necessary requirement through time and a highly desirable requirement across jurisdictions for forming TFP growth rates that are sufficiently robust for use as the primary instrument in setting price or revenue caps.

4 INPUT SPECIFICATION

Most network TFP studies have included two broad input categories: operations and maintenance expenditure (opex) and capital. Some North American studies have separated opex into labour and materials and services. However, with the increase in contracting out, separate measures of labour input have become increasingly difficult to obtain and potentially unrepresentative.

There has been considerable debate over the appropriate specification of both the quantity and annual user price of capital that should be used in energy network TFP studies. However, recent developments have helped resolve this issue.

In this section we first review issues associated with the specification of opex before looking at capital quantities and prices.

4.1 Opex inputs and proxy measures

Since opex covers a diverse range of inputs that are consumed in the production process each year, it is generally not practical to measure the quantity of opex by aggregating up the quantities of each individual component of opex input. Instead, the quantity of opex input is generally measured indirectly by deflating the value of opex inputs by a representative input price index. The main issues involved in measuring opex inputs include:

- the coverage of opex activities
- the extent of capitalisation of asset refurbishment
- the appropriate allocation of corporate overheads in ‘multi–utilities’
- the treatment of pass–through costs, and
- choosing the appropriate opex price index to use.

Opex coverage issues

Opex should include all costs of operating and maintaining the network, including inspection, maintenance and repair, vegetation management and emergency response. Depreciation and all capital costs (including those associated with capital construction) should be excluded. Just as common coverage of activities was a necessary requirement through time and a highly desirable requirement across jurisdictions for outputs in forming TFP growth rates that are sufficiently robust for use as the primary instrument in setting price or revenue caps, then the same applies to the coverage of opex activities.

There should be uniform treatment of asset refurbishment in cost reporting over time and also across DBs where possible. That is, items such as isolated cases of pole replacement or sleeving of poles should be consistently capitalised (or not as the case may be). Changes in reporting practices over time can give the appearance of improving or worsening opex partial productivity when no change in actual productivity may have in fact occurred.

Similarly, consistent and rigorous allocation of corporate overheads over time is important. Changes in corporate overhead allocation policies across businesses in a ‘multi–utility’ may otherwise give the false appearance of opex partial productivity (and TFP) improvements or deteriorations for distribution operations. Most cost allocation methodologies leave a relatively wide band of justifiable overhead cost allocations across constituent businesses. The important requirement for robust and reliable TFP results is that the allocation method used remains as consistent as possible over time for each DB and preferably is as similar as possible across DBs.

Some components of opex might be considered to be 'uncontrollable' by the DB and that it would subsequently be unreasonable to expect them to achieve productivity improvements in regard to. This is typically handled by allowing these costs to be simply 'passed through' to consumers. In the case of TFP–based regulation such pass through mechanisms may lead to some degree of double counting of these costs and inadvertently generous treatment for the DB.

In the New Zealand electricity distribution thresholds regime major 'uncontrollable' pass–through costs were excluded from both opex and revenue when forming the TFP measure. They included items such as transmission charges and avoided transmission charges. Appropriate treatment of these excluded costs is important for both the X factor and P_0 calculations. This approach is appropriate if the price cap is applied on an 'unbundled' basis to just those items which are controllable (eg if distribution charges are separate from transmission charges). If the price cap is applied to a bundled charge including uncontrollable costs (eg to a combined distribution and transmission charge) then additional adjustments will be necessary to avoid growth in output and uncontrollable costs causing distortions.

Lowry and Kaufmann (1995) have proposed a method for avoiding double counting of uncontrollable costs by the inclusion of a 'Z' factor in the (bundled) price cap. The price cap is then of the form CPI–X+Z and uncontrollable costs are included in both revenue and opex. Under this approach the Z factor is equal to the product of the share of uncontrollable costs in total revenue and the difference between the growth in uncontrollable costs per unit of output and CPI–X. The Z factor is non–zero only if the growth in unit uncontrollable costs differs from CPI–X and so there is argued to be no double counting of uncontrollable costs.

Opex price index

The majority of opex costs comprise labour costs (both direct and contracted). Remaining opex costs cover a wide range of intermediate inputs spanning operational consumables, office activities and contracted and in–house professional services. PEG (2004) developed a detailed opex price deflator for electricity DBs made up of a 62 per cent weighting on the Electricity, gas and water sector Labour cost index with the balance of the weight being spread across five Producer price indexes (PPIs) covering business, computing, secretarial, legal and accounting, and advertising services. Lawrence (2007d) requested information from the Victorian gas DBs on their estimated direct and indirect labour shares in opex and these were consistent with the 62 per cent figure used by PEG (2004).

While the share of labour costs in opex may be relatively similar across DBs, we have to decide which is the appropriate measure of labour prices to use. The two most commonly used measures are average weekly ordinary time earnings (AWOTE) and the labour price index (LPI), previously known as the labour cost index. AWOTE shows average employee earnings from working the standard number of hours per week and includes agreed base rates of pay, over–award payments, penalty rates and other allowances, commissions and retainers, bonuses and incentive payments (including profit share schemes), leave pay and salary payments made to directors. It excludes overtime payments, termination payments and other payments not related to the reference period.

The LPI, on the other hand, is a measure of changes in wage and salary costs based on a weighted average of a surveyed basket of jobs. It excludes bonuses and also excludes the impact of changes in the quality or quantity of work performed and compositional effects such as shifts between sectors and within firms.

AWOTE is, thus, more likely to accurately capture compositional changes in the workforce. This means it will capture the effect of upskilling as employers rely less on unskilled labour and as capital is progressively substituted for labour. Moreover, AWOTE will better reflect labour price pressures in a tight labour market as it picks up the effect of employers prematurely promoting individuals they want to retain and 'reclassifying' jobs as a means of paying staff more to prevent them from being poached by other organisations. The LPI will fail to capture these important characteristics of a tight labour market situation in a particular industry as it uses a fixed basket of job classifications that is not updated to reflect changing circumstances.

Table 1: **Allocation of Producer Price Indexes to opex components**

Opex component	PEG (2004) PPI	Lawrence (2007e) PPI recommendation
Meter data services	Computer services	Data processing services & Information storage & retrieval
Billing & revenue collection	Computer services	Data processing services & Information storage & retrieval
Advertising/marketing	Advertising services	Advertising services & Market research services
Customer service	Secretarial services	Secretarial services
Regulatory	Legal and accounting services	Legal and Accounting services
SCADA maintenance	Computer services	Computer maintenance
Other	Business services	Business services

Source: Based on Lawrence (2007e, p.22)

Lawrence (2007e) reviewed the allocation of PPIs to the non–labour opex components used in PEG (2004). The allocation used by PEG and the improvements proposed is reported in table 1. Lawrence (2007e) agreed with PEG on the allocation of the Secretarial services PPI to Customer service opex, the Legal and accounting services PPI to Regulatory opex and the Business services PPI to Other opex. These opex components account for around 75 per cent of the weight in the overall PEG non–labour opex price index. However, a review of the PPIs used by PEG (2004) for Meter data services opex, Billing and revenue collection opex, Advertising/marketing opex and SCADA maintenance opex indicated that they were not the best proxies for these components.

For Meter data services and Billing and revenue collection PEG (2004) used the Computer services PPI. The Computer services PPI is, however, a higher level PPI that aggregates four lower level PPIs. The lower level PPIs are those for Data processing services, Information storage & retrieval, Computer maintenance and Computer consultancy. The first two of these are likely to closely reflect activities contained in both Meter data services and Billing and revenue collection. However, neither Computer maintenance nor Computer consultancy services are likely to be closely linked to Meter data services and Billing and revenue collection. Therefore, taking a weighted average of the PPIs for Data processing services and Information storage and retrieval is likely to more closely match these opex activities.

For Advertising/marketing opex PEG (2004) used only the Advertising services PPI. This effectively neglects the marketing component. The ABS prepares a Market research services PPI which is at the same level of aggregation as the Advertising services PPI. To more accurately represent this opex component Lawrence (2007e) proposed taking a weighted average of the PPIs for Advertising services and Market research services.

And for SCADA maintenance PEG (2004) used the Computer services PPI. As noted above, this is a higher level index and only one of its four component indexes, namely Computer maintenance, appears directly relevant to SCADA maintenance. Lawrence (2007e), therefore, proposed using the PPI for Computer maintenance for this opex component.

While the overall approach adopted by PEG (2004) to forming an opex price index appears reasonable, there is scope for refinement of both the labour and non–labour price indexes used.

4.2 Capital inputs and proxy measures

There are a number of different approaches to measuring both the quantity and cost of capital inputs to be used in TFP series for use in TFP–based regulation. The quantity of capital inputs available to the production process each year can be proxied either directly in quantity terms (eg using pipeline length measures) or indirectly using a constant dollar measure of the depreciated value of assets. Similarly, the annual cost of using capital inputs has in the past been measured either directly (or exogenously) by applying the sum of an estimated depreciation rate, a rate reflecting the opportunity cost of capital and the rate of capital gains to the depreciated asset value or indirectly as the residual of revenue less operating costs.

There has been extensive debate over which combination of these capital input measurement options is most appropriate. Unfortunately much of this debate has been characterised by confusion over the distinction between costs, prices and quantities (eg Kaufmann 2009, pp.11–12). Economic Insights (2009a) has developed a robust and comprehensive approach to measuring the quantity and annual cost of capital inputs for use in TFP–based regulation which is fully consistent with the important regulatory principle of ex ante financial capital maintenance and which allows for the recovery of efficient costs ex ante.

Capital input quantities

Provided the quantities used in calculating TFP reflect actual quantities, then rolling the price cap forward using an X factor based on industry TFP growth and input prices will allow the DB to continue to recover efficient costs. Furthermore, it will provide the DB with an incentive to outperform industry TFP growth and achieve revenue in excess of actual costs. However, this will only occur if the quantities used in calculating TFP accurately reflect actual output and input quantities. That is, TFP needs to accurately reflect the change in the quantity of output produced per unit of the quantity of input used. It is thus critical to have accurate measures of prices and quantities. It is likely to be desirable to use direct quantity measures wherever possible and minimise reliance on 'indirect' quantities derived by deflating values by a price index. This is because price indexes are formed at a more aggregated sectoral level (eg the Electricity, gas and water sector) and may not accurately reflect the prices of energy distribution capital goods.

The second and most important consideration is ensuring that the quantity of annual capital input used in calculating TFP accurately reflects the production characteristics of the industry. Energy network industry assets are typically subject to little physical deterioration over their lifetime and continue to supply a relatively steady stream of annual services over their lifetime. Consequently, their true depreciation profile is more likely to reflect the 'one hoss shay' or 'light bulb' assumption than that of either declining balance or straight–line depreciation. That is, they produce roughly the same service for each year of their life up to the end of their specified life rather than producing a given percentage or absolute amount less service every year. In these circumstances the most appropriate proxy for the quantity of capital input is likely to be the physical quantity of the principal assets (since alternative proxies such as the constant price gross capital stock will be less accurate). In the case of energy distribution it is feasible to use this proxy as there are relatively few asset types and readily available means of aggregating asset capacities (eg Lawrence 2003 and Economic Insights 2009b use MVA–kilometres to sum power line capacities and kVAs to sum transformer capacities).

The reason it is important to use an accurate physical depreciation profile to reflect changes in capital quantities (or capital service potential) is that TFP provides information on the change in output quantity each year relative to the change in input quantity. That is, we need to look at the change in output quantity per unit of annual capital input quantity from these assets when forming the TFP measure. If the decay in the annual capital input quantity available to the production process is overestimated then the rate of TFP growth will be correspondingly overestimated and the DB will be placed under financial pressure because achievable productivity gains will have been significantly overestimated. Because capital inputs in these industries are long–lived, this issue assumes particular importance.

Using a physical depreciation profile in these circumstances that involves either declining balance or straight–line depreciation will overstate the decay in annual capital inputs and, hence, overstate TFP growth thus compromising the EDB's ability to recover efficient costs.

The potential impact of the different capital input quantity proxies was clearly illustrated in Economic Insights (2009c). Using data for the Victorian electricity DBs the rate of TFP growth was nearly 1 per cent per annum higher over the period 2002 to 2007 using the constant price depreciated asset value capital input quantity proxy compared to the physical capital input quantity proxy. The corresponding overstatement of TFP growth for the Victorian gas DBs using the constant price depreciated asset value capital input quantity proxy was nearly 1.8 per cent per annum.

The overstatement of TFP growth using the constant depreciated asset value proxy advocated by PEG (2004) and Kaufmann (2009) is increased in this case by the use of regulatory depreciation. The regulatory depreciation rates afforded some EDBs increased rapidly over recent years. This has not been a critical issue under building blocks regulation since the depreciation rate used simply affects the timing of receipts. One EDB's regulatory depreciation rate increased from 4.54 per cent in 2000 to 7.53 per cent in 2005 – an increase in the depreciation rate of around two thirds. Simply using this regulatory depreciation rate as the basis of forming the capital input quantity using the depreciated asset value approach will, needless to say, lead to major distortions.

In appendix C of this report we present an illustrative quantitative example which further highlights the large distortions which can be introduced by using geometric depreciation in forming the capital input quantity when the underlying physical depreciation profile is in fact one hoss shay. In this case we also require ex ante FCM and examine the distortions which flow through to resulting output price and input price measures.

Appendix 2 of Kaufmann (2009) reproduces earlier PEG arguments for using geometric depreciation rates in forming the capital input quantity measure and the use of a 'monetary' (ie constant price depreciated asset value proxy measure) approach. This material was addressed in detail in Economic Insights (2009b) which demonstrated that 'one hoss shay' depreciation has been found by seminal articles to be a better representation of depreciation than the geometric profile and is advocated for utility studies by the World Bank. Furthermore, the US Bureau of Labor Statistics (the statistical agencies in the US responsible for measuring multifactor productivity growth), the Australian Bureau of Statistics and Statistics New Zealand have all recognised that structures capital input quantities remain at relatively high levels for most of the asset's life. In all three cases the multifactor productivity estimates incorporate this assumption.

The statistical agencies form a 'productive' capital stock using 'age–efficiency' profiles which is then used as the quantity of capital input. Age–efficiency profiles are commonly assumed to be either hyperbolic in shape (ie little deterioration in the early stages of the asset's life but more in the later years) or geometric (ie rapid deterioration in the early years and little deterioration in the later years). The US, Australian and New Zealand agencies have adopted the hyperbolic age–efficiency profile in their productivity studies. A key parameter in the hyperbolic age–efficiency profile can be set to influence the degree of curvature. A value of one for this parameter leads to a flat or one hoss shay profile while a value of zero would give equal deterioration each year (ie approximate straight line deterioration). All have set this parameter at 0.5 for equipment and 0.75 for structures. That is, they are assuming closer to one hoss shay deterioration for structures. This is the opposite of the geometric deterioration profile advocated by PEG.

The Economic Insights (2009b) material presenting the case for one hoss shay depreciation in forming energy network TFP capital input quantities is reproduced in appendix D to this report. We note that this material has not been challenged by Kaufmann (2009) although a new issue has been raised which is addressed below.

An issue of some concern in electricity distribution is how so–called 'wall–of–wire' effects might be allowed for in the regulatory regime. This refers to the fact that much of the existing networks were rolled out over a relatively short time period compared to their asset life and so the need to replace network assets will be similarly concentrated over a short period leading to a rapid increase in replacement capex compared to current levels. Kaufmann (2009) suggests that measuring capital input quantities by proxies reflecting so–called 'one hoss shay' depreciation would not directly allow for the recovery of efficient costs if there was a 'wall–of–wire' effect. Dr Kaufmann suggested that using a 'monetary' based proxy for capital input quantities would allow for wall of wire effects by increasing the capital input quantity and reducing measured TFP growth and hence allow the application of a less onerous X factor. However, this approach does not recognise the underlying production characteristics of the industry and is likely to introduce significant distortions as illustrated above.

If we take the case of an EDB that simply replaces old lines with new lines of the same length and capacity then the quantity of capital input used by this EDB has changed little (as the carrying capacity of lines remains relatively constant over their lifetime). What has changed, however, is the annual cost of this capital input as the new capex has to be recognised in calculating the FCM–consistent amortisation charge. This will have two impacts on the X factor. Firstly, there will be a change in the relative weighting of capital and opex input quantities in forming the TFP measure. Secondly, the EDB's input price will have increased and so there will be an increase in the input price differential between the industry and the economy. The latter effect will lead to a reduction in the X factor, all else equal. If the industry input price increase was sufficiently large due to a sudden large increase in replacement capex then the X factor may in fact become negative (ie lead to price increases in excess of CPI growth). Applied properly TFP–based regulation will allow recovery of efficient costs in this case provided the replacement profile of the firm is similar to that of the industry or peer group used in setting the X factor.

In summary, the physical proxy approach to measuring capital input quantity (or service potential) is consistent with underlying engineering and economic logic and day–to–day experience. It fully recognises the cost of capital inputs and, unlike the PEG approach, is consistent with ex ante financial capital maintenance. It is also consistent with the bulk of empirical evidence on depreciation patterns and current Australian, US and New Zealand statistical agency practice.

Capital annual user costs

It is important to distinguish the quantity of capital input used (or service potential) and the annual cost of using capital (or amortisation charge) used in TFP calculations. As noted above, because network assets exhibit 'one hoss shay' depreciation in physical terms, the quantity of capital input will be quite different from the (constant price) regulatory asset base (RAB). Rather, the quantity of capital input is likely to be better proxied by either the physical stock of assets or the (constant price) undepreciated asset value (ie gross capital stock rather than net capital stock which is what the RAB is).

However, in determining the annual cost of capital used in TFP–based regulation, it is important to ensure that, on an ex ante basis, capital amortisation charges (the sum of charges for a return on and a return of capital) lead to full recovery of efficient expenditure. In TFP–based regulation the amortisation charge is used in both setting the P_0 (ie aligning opening period revenue with opening period costs) and in forming the weight applied to capital input quantities in the TFP calculation. Thus, if financial capital maintenance is accepted as a key regulatory requirement, then the capital charge should be based on the RAB (assuming this is a reasonable proxy for opening historic cost). Furthermore, the amortisation charge should be based on an exogenous weighted average cost of capital (WACC) reflecting true opportunity costs rather than an endogenous rate of return reflecting past pricing practices.

If the alternative approach of using an endogenous rate of return is used, there is a risk the resulting TFP estimate will be biased as the weighted average of the opex and capital partial productivities will be using inappropriate weights. That is, if the opex and capital partial productivities are growing at different rates, then the resulting TFP measure will be biased when the weighted average is taken using inappropriate weights. Furthermore, the endogenous rate of return approach will not achieve ex ante FCM, except by accident.

The overall amortisation charge should be built up as the sum of the amortisation charge for the initial capital base (or opening RAB) and for capex in each subsequent period. Annual depreciation can be allowed for in both cases. For the initial capital base component depreciation should be calculated based on the weighted average remaining asset life while for subsequent capex depreciation should be calculated based on the overall weighted average asset life.

This means that the approach to calculating annual capital costs (both for calculating opening P_0 adjustments and for weighting purposes in calculating the TFP growth rate used in setting the X factor) is effectively the same under TFP–based and building blocks regulation if financial capital maintenance is to form a key element of both approaches.

It is important to recognise that although network assets undergo little physical depreciation over their lifetime, their asset value progressively falls over their lifetime since, as each year passes, they have one less year left they can contribute to the production process.

It should also be recognised that there are an infinite number of amortisation charge profiles that can satisfy FCM requirements. The only requirements are that the net present value of the amortisation charges less final scrap value equals the initial purchase cost. The amortisation charges typically derived under building blocks regulation that involve return on and return of capital elements are one such profile. Since these charges are currently widely used and they satisfy FCM it makes sense to continue to use these charges as the annual cost of capital inputs (or amortisation charge) under TFP–based regulation. Note, however, that these calculations are applied to historical data under TFP–based regulation rather than forecast data as would be the case with building blocks regulation.

There are also a number of welfare implications of the profile of amortisation charges. Generally, a front end loaded profile will not be consistent with encouraging efficient utilisation of the asset although it may be favoured by DBs who might be concerned about regulatory risk. Ideally, the depreciation profile should reflect the asset's actual length of life and be as consistent as possible with its service potential profile.

It is worth restating that under both building blocks and TFP–based regulation DBs are given the opportunity ex–ante to recover efficient costs. In practice changes over the course of the regulatory period will lead to both upside and downside effects which will mean that actual costs may be somewhat lower or higher than anticipated and so actual returns will be somewhat higher or lower than anticipated at the outset. However, the ex ante requirement for FCM should be the guiding principle to provide the opportunity to recover efficient costs.

In summary, if ex ante FCM is regarded as an important regulatory requirement then the approach to forming the annual user cost of capital is clear-cut – it should be broadly the same as that used in building blocks. A practical example of this can be found in Economic Insights (2009b). The endogenous rate of return approach to forming the user cost of capital will not be suitable for use in TFP–based regulation if ex ante FCM is considered important.

4.3 Boundary issues

Another difficult but important issue is the one of transmission/EDB 'boundaries'. The productivity specification implicitly assumes that all EDBs have the same system boundary and system structure. But some EDBs take their power at lower voltage from the transmission business and have relatively simple systems while others take their power at higher voltages and may have subtransmission and/or multiple transformation steps. Examples of the former are Tasmania and Victoria while NSW and Queensland are examples of the latter. But output is measured in the same way for all EDBs, irrespective of their system boundary or structure. The EDB that has the narrower boundary and simpler structure will appear more efficient, all else equal, as it will use less input per unit of measured output. While this will mainly be of relevance to efficiency (or productivity level) comparisons, it may also have an impact of comparative TFP growth rates if technical change varies across the different parts of the network. That is, if technical change is higher at the distribution network end of the overall system than it is at the subtransmission and zone substation stage then those EDBs that have more complicated structures and take their power at higher voltage from the transmission system will be disadvantaged. To put EDBs on a like–with–like footing, a way of adjusting for differences in system boundaries and historic system structures may be required.

4.4 Issues to be resolved

This section has demonstrated that the specification of opex inputs is relatively straight–forward although a number of implementation issues do remain. It has also demonstrated that, after a period of debate, the appropriate specification of capital inputs now appears to be clear. Since network assets approach the physical characteristic of one hoss shay depreciation, the service potential or input quantity of capital inputs should reflect this pattern. Using physical quantity proxies is a relatively robust way of doing this although other options such as the use of hyperbolic age efficiency profiles (as are widely used in National Accounts multifactor productivity) are also available. Using constant price depreciated asset value proxies (which do not reflect the true physical service potential of assets) will introduce significant biases and compromise the ability of the regulated DBs to recover efficient costs. If ex ante FCM is regarded as an important regulatory requirement then the approach to forming the annual user cost of capital should be broadly similar to that used in building blocks.

Some issues remain to be resolved in practice and these are listed below:

- What should be the specified constant opex activity coverage?
- Should this be the same across all DBs?

- Is there common treatment of expenditure on isolated asset refurbishment both over time and across DBs?
- Are cost allocation practices comparable and consistent across multi–utilities?
- What is the most appropriate way of handling pass–through costs?
- What refinements need to be made to the opex price index?
- Should labour prices be proxied by sectoral AWOTE or the sectoral LPI?
- Do the water industry and the generation/production and transmission parts of the electricity and gas industries unduly influence Electricity, gas and water sector price indexes?
- What combination of Producer Price Indexes best captures the price of the non–labour components of opex?
- Which method best proxies in practice the physical depreciation of network assets: physical measures, constant price gross capital stocks or the use of a hyperbolic age–efficiency profile to form a productive capital stock measure?
- What MVA–kilometre conversion factors are most appropriate for Australian EDBs?
- Should these vary across EDBs?
- How should the quantity of non–system fixed assets be proxied?
- What WACC value should be used in forming the capital amortisation charge?
- What profile of amortisation charges should be used?
- Should one WACC value be applied to all assets (ie both sunk and new) or should there be different rates of return allowed on sunk and new assets as argued by Dieter Helm (2009)?
- Should allowance be made for transmission/distribution boundary differences across DBs?

5 INDEXING METHOD

A TFP index is generally defined as the ratio of an index of output growth divided by an index of input growth. Growth rates for individual outputs and inputs are weighted together using revenue or output cost shares and input cost shares, respectively. In other words, the TFP index is essentially a weighted average of changes in output quantities relative to a weighted average of changes in input quantities. TFP indexes have a number of advantages including:

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

To operationalise the index number concept we need a way to combine changes in diverse outputs and inputs into measures of change in total outputs and total inputs. Different index number methods take this weighted average change in different ways.

Diewert (1993) reviewed alternate index number formulations to determine which index was best suited to TFP calculations. Alternative index number methods were evaluated by assessing their performance relative to a number of axiomatic tests. These included:

- the constant quantities test: if quantities are the same in two periods, then the output index should be the same in both periods irrespective of the price of the goods in both periods;
- the constant basket test: this states that if prices are constant over two periods, then the level of output in period 1 compared to period 0 is equal to the value of output in period 1 divided by the value of output in period 0;
- the proportional increase in outputs test: this states that if all outputs in period t are multiplied by a common factor, λ, then the output index in period t compared to period 0 should increase by λ also; and,
- the time reversal test: this states that if the prices and quantities in period 0 and t are interchanged, then the resulting output index should be the reciprocal of the original index.

The four most popular index formulations were evaluated against these tests. The indexes evaluated included:

- the Laspeyres base period weight index;
- the Paasche current period weight index;

- the Fisher ideal index which is the square root of the product of the Paasche and Laspeyres index and which has been used extensively in previous TFP work, including that of Lawrence (2003, 2007a) and Economic Insights (2009); and
- the Törnqvist index which has also been used extensively in previous TFP work, including that of PEG (2004, 2008a).

When evaluated against the tests listed above, only the Fisher ideal index passed all four tests. The Laspeyres and Paasche index fail the time reversal test while the Törnqvist index fails the constant basket test.

On the basis of his analysis, Diewert recommended that the Fisher ideal index be used for TFP work although he indicated that the Törnqvist index could also be used as it closely approximates the Fisher ideal index.

AEMC (2009, p.23) recommended that the regulator be permitted to choose the index number method it considers appropriate, provided the method chosen satisfies the important technical requirement of being ‘superlative’ (that is, it can provide a close approximation to an arbitrary smooth function). Both the Fisher and Törnqvist indexes are superlative.

The Fisher index technique is increasingly favoured by statistical agencies because it satisfies all the desirable axiomatic properties for price and productivity indexes. It has been our experience that the Fisher and Törnqvist index methods produce very similar results provided the indexes are both used in chained form.

The issue remaining to be resolved is as follows:

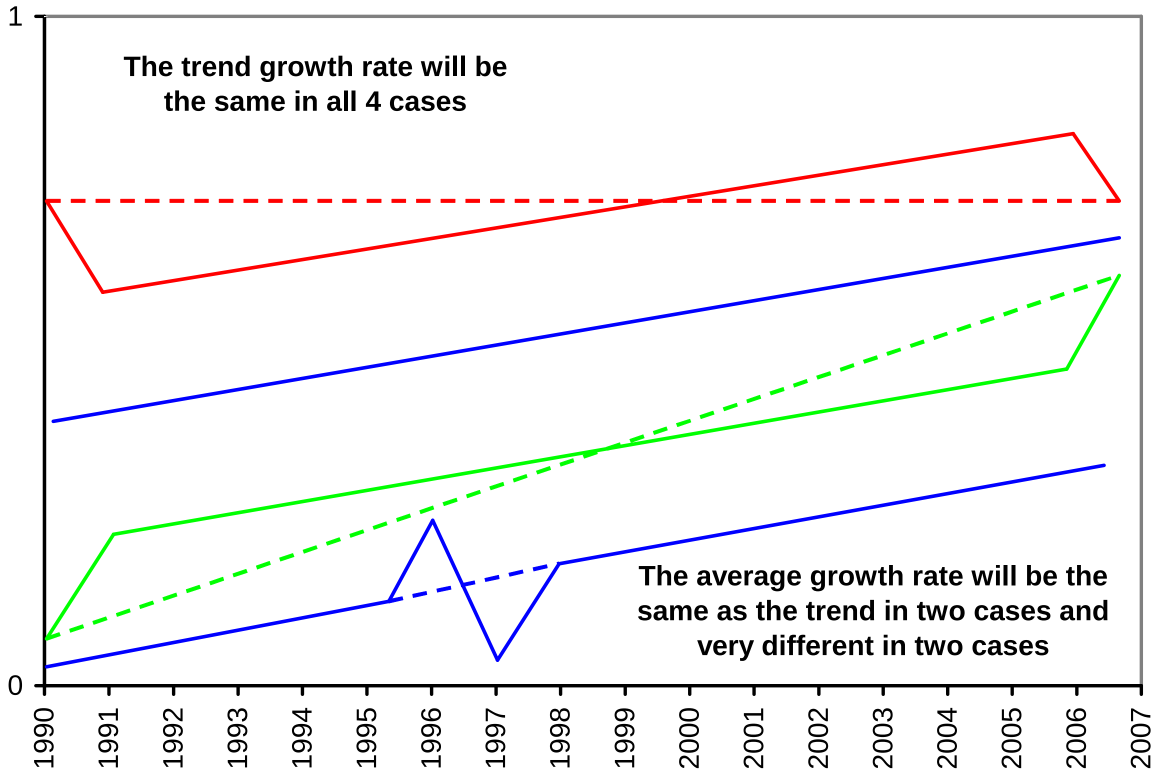
- Should the Fisher index be nominated as the preferred index to be used because of its superior axiomatic properties and because it is increasingly the index of choice of statistical agencies?

6 CALCULATING TFP GROWTH RATES

Two different approaches have been used to calculate the TFP growth rate used in TFP–based regulation. PEG (2004, 2008a,b) has used the average annual growth rate between the first and last observations calculated using the logarithm of the ratio of the index values divided by the number of annual changes between the first and last years. Lawrence (2003, 2007b) and Economic Insights (2009b), on the other hand, have used a regression–based trend method which regresses the logarithm of the relevant variable against a constant and a linear time trend. The time trend regression coefficient is then the logarithm of (one plus) the relevant growth rate.

Economic Insights (2009c) showed that whether the difference between the two methods is material depends on whether the relevant series is stable or volatile and whether the first and last observations are relative outliers from the trend of the intervening years. The sensitivity analysis showed that the PEG output index for gas distribution was relatively volatile with the first year above trend and the last year below trend. This meant that calculating an average growth rate based on these two observations would, in that case, give a significantly lower growth rate than the regression–based method which fits a line of best fit to all the observations. In this case the growth rate from using the endpoints method was only just over half that obtained by the regression method.

Figure 1: **Trend and average growth rates – four scenarios**



The first thing to note when considering which method is best in the context of TFP–based regulation is that any growth rate measure is, by definition, a summary measure and will not show the full picture. Different methods will, therefore, have pros and cons and will be better suited to some circumstances but not others. What is required here is the best means of predicting future growth based on an extrapolation of past experience.

In figure 1 we present four different stylised scenarios. In all cases the underlying trend growth rate is the same but in three of the scenarios there are two observations away from the trend. In the second scenario where there are no observations away from the trend and the average and trend growth rates will be the same. Similarly, in the fourth scenario where the observations away from the trend are in the middle of the series, the average and trend growth rates will be the same.

But in the first and third scenarios where the observations away from the trend occur at the end points then the average and trend growth rates will be very different. The trend growth rates will be the same as in the second and fourth cases but in the first case the average growth rate will show no growth (whereas the trend growth rate is positive) because the first observation is above trend and the last observation is below trend. And in the third case the average growth rate will be considerably higher than the trend because the first observation is below trend while the last observation is above trend.

This illustrates that the average growth rate method is sensitive to outlier observations which occur at either endpoint of the series (but much less so to outliers that occur away from the endpoints).

The example provided in Kaufmann (2009, p.10) is essentially similar to the first scenario in figure 1 except that the series finishes one year earlier (ie there is only an outlier observation at the start of the series for Company Two in the example). Kaufmann argues that the trend method leads to a biased result but it should be noted that if the series started one year later then the average growth rate would be very different (and the same as the trend rate). This highlights that the average method can lead to relatively volatile results depending on the time period chosen. All else equal, stability and avoidance of erratic changes are preferred in price cap setting.

The question is which method is better for setting the TFP growth rate to be used in TFP–based regulation? The Essential Services Commission (2006) argued that one of the advantages of TFP–based regulation compared to building blocks regulation was that it deemphasised the role of ‘test’ years at the end of the preceding regulatory period. That is, because prices are rolled forward based on TFP growth over an extended period and there is less or no reliance on test years for setting future prices then there is less incentive for DBs to manipulate their performance in those test years. However, setting the growth rate based on average TFP growth places more emphasis on the end point year and could provide an incentive for DBs to manipulate their performance in those years. More generally, because the average method places more weight on the end point years (as shown in figure 1) then it increases instability and risk. But the trend method may not track exactly from the start point to the end point which some regard as a disadvantage.

Forming the industry TFP index

Two different approaches have been used to form the industry (or group) TFP index. One is to sum all relevant variables across all DBs to form an industry aggregate for each variable used in the analysis and to then calculate TFP growth for the industry directly based on these aggregates. This is the approach adopted in Lawrence (2003) and Economic Insights (2009b).

The alternative approach is to take a weighted average of individual DB TFP growth rates. For example, PEG (2009) formed TFP indexes for each EDB and then formed an industry TFP growth rate by taking a weighted average of the individual EDB TFP growth rates using each EDB's share in total industry 'costs' for that year.

The weighted average approach used by PEG (2009) is applying the weights for the chosen variable to all variables used in the analysis whereas the summing all variables directly approach does not impose this restriction.

The weighted average approach becomes problematic when the variable chosen to form the weighted average is itself distorted as is the case with the PEG (2009) choice of 'costs' as the relevant weight. This is because PEG (2009) set 'costs' for each EDB equal to its revenue (ie an endogenous user cost approach was used). There is a very wide range of realised rates of return among New Zealand EDBs and so EDBs earning very low rates of return will have their TFP growth underweighted in forming the industry weighted average growth rate while those earning very high realised rates of return will have their TFP growth overweighted given the TFP specification adopted. This means the weighted average approach to forming the industry TFP growth rate can lead to a distorted estimate of the industry TFP growth rate.

6.1 Issues to be resolved

The growth rate issues remaining to be resolved are as follows:

- In the context of predicting future productivity or price growth based on an extrapolation of past experience, is the trend or average method the most appropriate?
- Is calculating the growth rate by the trend method the most appropriate because it reduces the importance of endpoint outliers and thus reduces volatility and reduces the incentive to manipulate performance at the end of the regulatory period?
- Is calculating the growth rate by the average method the most appropriate because it tracks exactly from the start point to the endpoint in all circumstances?
- Should the industry or group TFP growth rate be formed based on a TFP index using data for all variables summed directly to the industry level rather than by taking a weighted average of individual DB growth rates since the latter can lead to distortions?

7 ASSESSMENT AND CONCLUSIONS

AEMC (2009, pp.26–27) set five criteria for the assessment of TFP specifications for use in TFP–based regulation. These criteria are that the specification:

- results in a stable index over time;
- creates no systematic bias in the TFP growth estimate;
- is consistent with promoting economic efficiency and does not result in any perverse incentives;
- is consistent with the service provider's regulatory asset base; and
- results in reporting requirements which are proportionate and not onerous.

We now assess the various specification elements discussed in the preceding sections against these criteria.

Stability

Output specifications that use volatile proxies such as non–coincident peak demand will result in relatively volatile output and TFP indexes. These proxies are unlikely to accurately reflect the actual variable (contracted reserved capacity in this instance) and should be avoided. Similarly, specifications that place a high weight on throughput output variables will also generally be more volatile. Currently non–billed functional outputs such as system capacity will, on the other hand, tend to be more stable.

On the input side, consistent measurement and coverage of opex activities is important in ensuring stability of the TFP index. Since network assets are subject to relatively little physical deterioration – or loss of carrying capacity – over their lifetimes, the quantity of annual capital input to the production process will tend to be relatively stable through time. It is important that this fundamental characteristic of network capital be recognised in the TFP specification. Attempts to proxy capital input quantities by so–called 'monetary' proxies such as the constant price depreciated asset value (which do not reflect the true service potential of assets) will overestimate the deterioration in network capacity and lead to series which 'cycle' unrealistically over asset lifetimes. One hoss shay based capital input quantity proxies such as physical network capacity will provide a more accurate proxy which is also much more stable over time.

No systematic bias

Recognising both billed and non–billed functional outputs and the divergence of prices from marginal costs will avoid biases that may arise from setting an X factor based solely on traditional (ie revenue weighted) industry or group wide TFP growth. That is, to avoid the resulting bias it is necessary to recognise the differences in DB pricing structures and the divergence of each from underlying cost structures. This is because while technical change may be relatively common across DBs, both observed and achievable TFP growth across DBs will also depend critically on the divergence of prices from costs on both the output and input sides.

As noted above, to avoid systematic bias in TFP from the input side, it is necessary to use capital input quantity proxies that accurately recognise the characteristics of network assets. Since network assets are long–lived, relatively sunk in nature and subject to little deterioration in carrying capacity over their lifetimes, the capital input quantity proxy must recognise the one hoss shay nature of their service potential over time. Proxying capital input quantities by constant price depreciated asset values will lead to biased TFP growth estimates as the decay in capital inputs over time will be significantly overstated. This would be further exacerbated by using regulatory depreciation to form this proxy since many Australian DBs have dramatically increased their depreciation allowances under building block regulation to advance the timing of the return of capital. This would be likely to further overstate the decay in capital and, hence, the rate of TFP growth.

Further systematic biases in TFP growth estimates can arise from the use of an endogenous user cost of capital rather than an exogenous user cost based on explicit incorporation of financial capital maintenance. Use of an endogenous approach can produce biased TFP growth rates if the firm has not been earning its specified WACC. This is because inappropriate weights will be used when forming the TFP measure (which is essentially a weighted average of the opex and capital partial productivities). Furthermore, it may not accurately allow for increased capex over time, particularly if capital prices have been increasing rapidly. Forming an exogenous FCM–consistent user cost taking account of both the initial capital base and subsequent capex will avoid this source of bias.

Economic efficiency

The fundamental objective of economic regulation of energy networks is to improve economic efficiency. The criterion of consistency with economic efficiency is considered to be the single most important criterion when assessing alternative TFP specifications. To ensure that economic efficiency is being advanced it is important to look at all aspects of economic efficiency and the impact of regulation on consumers as well as producers. The specification advocated in Kaufmann (2009) relies on a set of axiomatic ‘accounting identities’ rather than being firmly grounded in economic analysis. It largely ignores the linkage between regulation and consumer welfare. Furthermore, by not satisfying the important regulatory principle of ex ante financial capital maintenance it compromises the ability of suppliers to recover efficient costs.

The link between economic regulation and economic efficiency has been recognised in building block regulation but only included as an afterthought by way of regulatory pricing principles (and not all of these have addressed the structure of prices). To ensure regulation is contributing to overall economic efficiency it is necessary to look not only at the overall price level but also at the structure of output prices. It is only by recognising the full range of functional outputs – billed and non–billed – and the deviation of prices of each of these from their underlying costs that we can be sure that economic efficiency is being advanced. A full explanation of these issues is provided in Economic Insights (2009a).

On the input side failure to explicitly incorporate the important principle of ex ante FCM will lead to biased TFP estimates and price paths and compromise DBs’ chance to recover their efficient costs. Failure to recognise the actual characteristics of networks such as the relatively constant carrying capacity of network assets over their lifetime will also lead to inappropriate price paths being set with consequential detrimental impacts on economic efficiency and ability to recover efficient costs.

It is recognised that advancing economic efficiency involves undertaking quite complex analysis and may lead to a slightly more complex TFP and price cap specification. However, without this analysis and recognising these realities, there is a risk that resorting to simplified 'practical' approaches which do not take account of the requirements for efficiency improvement will be counterproductive.

Consistency with RAB

To be consistent with the DB's RAB, TFP–based regulation needs to use annual capital user costs or amortisation charges that recognise the RAB as the initial capital base and roll the RAB forward using the important regulatory principle of ex ante FCM. The annual capital user cost is fundamental to setting both initial prices (ie P_0s) and in measuring TFP that will form the basis for setting the X factor.

To be fully consistent with the DB's RAB, the method used to calculate the capital amortisation charges needs to be FCM–consistent seeing that that is the basis for rolling the RAB forward in current building blocks regulation. The endogenous user cost approach will not be fully consistent with the RAB, except by accident.

Reporting requirements

Economic Insights (2009e) highlighted that current DB reporting requirements are inadequate to support TFP analysis to the robustness required for use in being the primary basis for price cap setting. This is because of lack of thorough specification of the basis on which data should be reported, lack of consistency across jurisdictions and over time and the failure to collect adequate physical data. Addressing these data reporting deficiencies was identified by regulators as being critical to continued application of the building blocks method as well as to facilitating potential application of a TFP–based method.

None of the TFP specifications discussed in this report involve onerous reporting requirements. Furthermore, improvements to current reporting requirements and processes will have to be made regardless of which specification is used.

Including non–billed as well as billed functional outputs would require some additional data compared to simply including billed outputs but the likely candidate measures of system capacity are easily assembled from current physical asset data. Similarly, using physical proxies for capital input quantities may require DBs to report slightly more than the mainly financial data currently reported. However, these data are all readily accessible from DB information systems. Forming estimates of output costs may require some development but this information is already used in regulatory pricing principles reporting in many cases and in internal DB processes.

Economic Insights (2009b) has recently undertaken an FCM–consistent TFP analysis using current regulatory reporting data (known as the Information Disclosure Data) in New Zealand thus demonstrating that more accurate and appropriate TFP analysis for price cap setting can be undertaken without increasing reporting burdens.

Conclusion

Based on the above assessment of the various aspects of TFP specification against the AEMC's criteria we conclude that the key features of the TFP specification should be as follows:

- both billed and non–billed functional outputs should be included
- key outputs covered should include throughput, customer numbers, contracted reserved capacity and overall system capacity
- a better measure of contracted reserved capacity is required
- more work is required to develop a system security output
- the difference between output component revenue and underlying costs should be taken account of
- more disaggregation of throughput and customer numbers should be included if possible
- a consistent specification of opex activity coverage needs to be developed along with consistent application of capitalisation and cost allocation methods
- capital input quantity proxies need to reflect the key characteristics of network assets including their relative lack of deterioration in carrying capacity over their lifetime – physical measures of capacity represent a robust and easily implementable proxy
- capital amortisation charges need to explicitly incorporate the principle of financial capital maintenance and be consistent with the RAB

The appropriate TFP specification for use in TFP–based regulation has been the subject of ongoing debate over the last several years. Recent developments including the development of the Economic Insights (2009a) analytical framework have provided a clear way forward. Implementation of a TFP specification along the lines outlined above would make a clear and demonstrable contribution to improving economic efficiency while ensuring DBs are given the opportunity to recover efficient costs.

APPENDIX A: RESPONSE TO KAUFMANN SUBMISSION

Dr Lawrence Kaufmann (2009) has made a personal submission to the AEMC which has an extensive discussion of TFP specification and related issues. This submission misinterprets and, consequently, mischaracterises many aspects of the Economic Insights (2009a) framework. It also makes many incorrect claims regarding the framework advanced by Dr Kaufmann. We respond to this submission in detail in this appendix.

Before addressing Dr Kaufmann's specific criticisms and claims in turn, we start off by noting that Kaufmann (2009) attempts to draw a distinction between 'academic' TFP studies and frameworks and a 'practical' approach he claims is required for setting utility prices. This distinction is misleading because the Economic Insights (2009a) approach is technically robust and key parts have been made operational in Economic Insights (2009b). In contrast the relevant economic framework underlying the approach advocated by Kaufman (2009) is inadequate or absent and the approach also has numerous operational problems.

The Kaufmann framework is based purely on an axiomatic approach which appeals to one accounting identity, namely that the growth in industry revenue should equal the growth in industry costs. This identity can only hold in general if the ex post rate of return on invested capital is treated as an endogenous variable which is determined by setting costs equal to revenues. Dr Kaufmann's methodology does not properly account for the opportunity cost of capital for firms in the distribution industry and takes no account of the sunk cost nature of network assets. It fails to satisfy ex ante financial capital maintenance (except by accident) and fails to provide DBs with an opportunity to recover their efficient costs. The Kaufmann methodology further compounds problems by adopting an approach to measuring the quantity of capital which is divorced from the characteristics of the industry. And it fails to link the pricing outcome to consumer preferences and welfare – something that is clearly essential for robust and sustainable economic regulation.

If the energy distribution industry had the same characteristics as a perfectly competitive industry then the above shortcomings in the Kaufmann (2009) framework would not be problematic. In fact, under such circumstances the Kaufmann and Economic Insights frameworks would produce relatively similar results. However, the energy distribution industry is not a perfectly competitive industry – rather, it is a classic natural monopoly industry and failure to allow for the non–competitive features of the industry can lead to a flawed outcomes. The Economic Insights (2009a) framework was developed to overcome the shortcomings in the simplified framework advocated by Dr Kaufmann. Correctly allowing for the characteristics and complexities of the industry has important implications for both the specification of TFP used and the structure of the TFP–based price cap.

We turn now to the specific issues raised in Kaufmann (2009).

Billed and other functional outputs

Kaufmann (2009, p.6) quotes an earlier submission to the Commerce Commission by PwC (2009) that claimed that the use of functional outputs in isolation may compromise the ability of DBs to recover efficient costs. Kaufmann (2009, p.7) goes on to incorrectly state that Economic Insights 'favor "functional" outputs that are not actually billed to customers'. The

Economic Insights approach does not entail the exclusive use of an 'abstract' output measure with no market price. Rather, it involves recognising a fuller range of network outputs of which billed outputs are a subset.

The Economic Insights methodology incorporates an adjustment to the X factor which takes account of the difference between prices and marginal costs for each output. This adjustment and others reflect the underlying economic welfare foundations of the Economic Insights methodology. For non–billed functional outputs market prices would be treated as zero in deriving the X factor but the input costs associated with those outputs would be captured. For billed outputs the differences between marginal costs and market prices are included. Thus, the appropriate measure of output in our approach is one that includes all relevant functional outputs irrespective of whether they are explicitly billed for or not. However, all outputs that are priced would also need to be included (ie these would, by definition, be a subset of functional outputs), along with terms to reflect operating cost and capital cost increases in order to ensure financial capital maintenance.

The main reason that it is necessary to include all functional outputs is that they are cost determining. Hence, as these functional outputs change from period to period, there are cost implications. These cost implications are missed in a framework where only billed outputs are included in the list of outputs.

An empirical example from Economic Insights (2009b) which addresses the PwC (2009) example is reproduced in appendix B of this report. Rather than the PwC example being 'unrebutted' as Kaufmann (2009, p.7) claims, the example in appendix B demonstrates the actual Economic Insights output framework and how it allows recovery of efficient costs. We note that PwC did not subsequently challenge the Economic Insights example. We note also that the importance of allowing for divergences between current pricing structures and actual outputs delivered and the costs of those outputs has been recognised by DBs in submissions to the AEMC (eg Energex 2009, Jemena 2009).

Kaufmann (2009, p.6) also claims that derivation of output cost data would involve the use of econometrics. We note that econometric methods are only one means of deriving information on output costs. Many DBs have already had to assemble output cost information as part of demonstrating compliance with regulatory pricing principles under building blocks regulation.

Dr Kaufmann's preference for revenue weights only is explained by his interpretation of allocative efficiency. On page 6 of his submission he states 'the allocative efficiency criterion used by the ESC in this context does not refer to the efficiency of pricing structures, but rather to the broader allocative concern that industry revenues change at the same rate as the growth in industry costs'. However, rather than being a 'broader' concern, this reflects a relatively narrow focus as it ignores the link between regulation and economic welfare – something that is essential if regulation is to achieve its fundamental objective. The Economic Insights framework provides a way of explicitly incorporating the impact of pricing structures in setting the price cap. This is something that is recognised as important in building blocks regulation in many jurisdictions but has been tacked on as an afterthought in requiring compliance with designated regulatory pricing principles.

But the need to recognise the divergence of prices from marginal costs is also critical to ensuring that X factors are set which allow DBs to recover their efficient costs. Economic Insights (2009a) demonstrated that DB TFP growth is made up of three components (a pure technical change term, a term showing the divergence between price and marginal cost and a term showing the divergence between capital prices and the marginal saving in operating costs from capital investment). An important implication of this is that while technical change may be relatively similar across DBs (or at least those with similar operating environment conditions), the second and third terms are likely to vary widely across DBs depending on the pricing practices adopted.

The Kaufmann (2009) approach is predicated on the assumption that achievable TFP growth should be relatively similar across all DBs. However, while technical change may be relatively similar across DBs (with similar operating environments), the pricing structures adopted may be quite different and hence the second term involving the deviation of prices from marginal costs may be quite different. This will lead to the DBs' achievable TFP growth rates being different. Failure to recognise this in either setting the structure of the regulatory regime or the composition of peer groups in setting a group–wide X factor is likely to cause difficulties. This was the point of the Victorian and Queensland example given in Economic Insights (2009b) and quoted in Kaufmann (2009, p.7).

Finally, Kaufmann (2009, p.8) claims that the proposal to allow DB–specific X factor adjustments and to (potentially) include a capital module negates the need to include non–billed functional outputs which he claims is predicated on there being one X factor applied to the entire industry. This is incorrect on both counts. Firstly, allowance for both billed and non–billed functional outputs is necessary to provide a basis for any tailoring of X factors that may occur and, secondly, recognition of the divergence between prices and marginal costs of all outputs is necessary regardless of whether one DB is regulated in isolation or whether a common X is applied across multiple DBs if regulation is to be consistent with improving economic welfare.

Index stability

Kaufmann (2009, p.8) claims that his index specification is stable since it leads to revenue changes that track industry cost changes. However, his specification's compliance with this requirement is illusory since it uses an endogenous approach to quantifying the annual cost of capital (ie the annual cost of capital is taken to be simply the difference between revenue and opex). This specification fails to recognise the importance of FCM since the implied rate of return is whatever it happens to have been historically rather than being based on parameters reflecting true opportunity costs. Dr Kaufmann's approach runs the risk of being circular since costs are effectively set to reflect past revenues which then form the basis for setting future revenues and so on. This contrasts with the Economic Insights (2009a) approach where the capital amortisation charge is set exogenously to be FCM–consistent and revenues are set to reflect actual opportunity costs.

Since the Kaufmann (2009) specification does not satisfy FCM (except by accident) and has the potential for revenues to become increasingly misaligned with true opportunity costs, it is likely that larger price review adjustments will have to be made when true opportunity costs are recognised. This contrasts with the Economic Insights (2009a) specification where DBs are given the opportunity to recover their true opportunity costs from the outset.

No systematic bias

Contrary to the claim in Kaufmann (2009, p.9), the Economic Insights specification does not introduce any systematic biases since it recognises the actual characteristics of network assets in specifying the capital input quantity and explicitly recognises ex ante FCM in setting the amortisation charge. This contrasts with the Kaufmann specification where capital input quantities decay much faster than in reality given the nature of network assets (ie the assets display physical depreciation more akin to one hoss shay rather than straight–line) and capital charges do not reflect true opportunity costs (except by accident). This bias is exacerbated by Dr Kaufmann's preference for using regulatory depreciation in forming his capital input quantity given that many Australian DBs' depreciation allowances have increased rapidly under building blocks regulation as some DBs have chosen to 'front–end load' allowances.

Kaufmann (2009, pp.10–11) goes on to claim that using the trend rather than average (or endpoint–to–endpoint) index growth rate can introduce a degree of bias. As noted in section 6 of this paper, no summary measure will, by definition, present all the information contained in an index series. But a potential problem with the average growth rate method is that it is unduly susceptible to endpoint outliers. This also leaves it susceptible to manipulation by DB actions at the end of the regulatory period. The average growth rate method is also likely to be relatively volatile. This is demonstrated by considering the example Dr Kaufmann gives of Company Two. If the time period was shortened by one year by dropping the first observation then the average growth rate changes from 1.8 per cent to 3.4 per cent. The corresponding trend growth rate, on the other hand, changes by the much smaller amount from 2.6 per cent to 3.4 per cent. In contrast to the trend growth method, the average growth rate method is relatively sensitive to the time period chosen.

Consistency with economic efficiency

Kaufmann (2009, p.11) again claims that his specification allows revenue to track costs better for the industry and so there will be less need for resets at price reviews. However, as noted above, the compliance of the Kaufmann (2009) specification with the requirement that revenue tracks costs is illusory and potentially circular because of the use of an endogenous user cost of capital. This contrasts with the Economic Insights (2009a) framework where revenues track costs based on true opportunity costs and explicit allowance is made for ex ante FCM.

The Kaufmann (2009) specification further fails to allow for the non–competitive characteristics of energy networks and so will not promote economic efficiency as well as the Economic Insights specification where these characteristics are explicitly recognised and allowed for.

Consistency with RAB

The discussion in Kaufmann (2009, pp.11–12) reflects considerable confusion over the distinction between capital prices and quantities. It claims that the Economic Insights (2009a) specification uses capital quantities that are not consistent with the regulatory data used to set initial prices. However, TFP measures the change in output quantity relative to the change in input quantity. An accurate measure of TFP needs to recognise the actual production characteristics of the industry, and hence the actual input quantities used each year including the service potential of capital. The Economic Insights framework recognises the one hoss shay nature of the service potential of network assets. The Kaufmann specification, on the other hand, assumes decay in capital service potential that far exceeds what occurs in reality and will, all else equal, lead to an overestimation of TFP growth. This will compromise the ability of DBs to recover their efficient costs.

A practical illustration of this overestimation of measured TFP growth resulting from the Kaufmann specification was given in Economic Insights (2009c). Using data for the Victorian electricity DBs the rate of TFP growth was nearly 1 per cent per annum higher over the period 2002 to 2007 using the constant price depreciated asset value capital input quantity proxy compared to the physical capital input quantity proxy. The corresponding overstatement of TFP growth for the Victorian gas DBs using the constant price depreciated asset value capital input quantity proxy was nearly 1.8 per cent per annum.

Where the annual cost of capital or amortisation charge enters TFP–based regulation is in setting the initial price and in weighting capital quantities in forming the total input quantity index. And the Economic Insights framework recognises the RAB, regulatory depreciation and FCM in setting this amortisation charge. In fact, the amortisation charge is essentially similar to the return on and return of capital used in building blocks regulation. This allows capital quantities to be aggregated with opex quantities in an unbiased way. The Kaufmann specification, on the other hand, not only introduces a biased measure of capital input quantities but is also likely to lead to biases in aggregation through the use of the endogenous approach to measuring the cost of capital which is not FCM consistent (except by accident).

Kaufmann (2009, p.12) makes another incorrect claim when he suggests that the use of physical capital quantity proxies 'will not reflect the impact of capital replacement expenditures on utility's unit cost as directly as monetary capital values'. In appendix 3 Kaufmann (2009) suggests that using a 'monetary' based proxy for capital input quantities would allow for wall–of–wire effects by increasing the capital input quantity and reducing measured TFP growth and hence allow the application of a less onerous X factor. However, this approach does not recognise the underlying production characteristics of the industry and is likely to introduce significant distortions as illustrated above.

If we take the case of an EDB that simply replaces old lines with new lines of the same length and capacity then the quantity of capital input used by this EDB has changed little (as the carrying capacity of lines remains relatively constant over their lifetime). What has changed, however, is the annual cost of this capital input as the new capex has to be recognised in calculating the FCM–consistent amortisation charge. This will have two impacts on the X factor. Firstly, we would expect to see a change in the relative weighting of capital and opex input quantities in forming the TFP measure. Secondly, the EDB's input price will probably have increased and so there will be an increase in the input price differential between the industry and the economy. The latter effect will lead to a reduction in the X factor, all else equal, and was clearly recognised in PwC (2009).

Reporting requirements

Kaufmann (2009, pp.12–13) claims that the TFP specification he advocates could be implemented 'immediately' using currently available data. However, Economic Insights (2009e) showed that current DB reporting requirements are inadequate to support TFP analysis to the robustness required for use as the primary basis for price cap setting. This is because of the lack of thorough specifications of the basis on which data should be reported, lack of consistency across jurisdictions and over time and the failure to collect adequate physical data.

It is noteworthy that the ESC indicated to Economic Insights that it viewed the relative lack of physical data in current regulatory reporting as a major shortcoming for building blocks analysis as well as it being a constraint on TFP. This was because regulators were unable to use this source of information as a cross check on financial data and as a basis for better understanding the DBs' operations. Improved specification and consistency of regulatory reporting is therefore important no matter what regulatory regime is adopted going forward. The additional data requirements of the Economic Insights specification over the Kaufmann specification are not onerous.

Economic Insights (2009b) has recently undertaken an FCM–consistent TFP analysis using current regulatory reporting data in New Zealand thus demonstrating that more accurate and appropriate TFP analysis for price cap setting can be undertaken without increasing reporting burdens.

Design Issues

Kaufmann (2009, p.14) argues that it is not necessary to divide the industry into subgroups for X factor setting purposes since it is not necessary to reflect the conditions faced by individual DBs, it would 'dramatically' increase complexity and is not justified on the basis of current evidence on relative DB TFP growth. Economic Insights (2009a) demonstrated that while technical change may be relatively common across DBs, differences between prices and underlying costs on both the output and input side mean that achievable TFP growth is likely to vary significantly across DBs. This means that it is likely to be necessary to divide DBs into at least a small number of peer groups. This should not greatly increase the complexity of TFP–based regulation. And the current evidence referred to relates to the PEG (2004, 2008a) study which estimated TFP growth for the Victorian EDBs. More robust and more extensive evidence is required before a call can be made on this issue.

Kaufmann (2009, p.15) claims that price reviews would be relatively light–handed.. But, as outlined above, under Dr Kaufmann's specification industry revenue only tracks industry 'costs' because costs are defined to equal revenue rather than being calculated on the basis of true opportunity costs and explicit ex ante FCM. We therefore believe the need for significant periodic price resets would be higher under the Kaufmann (2009) specification as revenues are more likely to diverge from actual costs.

Kaufmann (2009, p.17) argues that off–ramps do 'not materially impact incentives'. However, it needs to be recognised that while it would be prudent to have at least one 'insurance' mechanism in a TFP–based regulatory regime, these will come at a cost to incentives. Of more concern is the cumulative adverse impact of having multiple insurance mechanisms on incentives. For instance, including both off–ramps and a capital module would considerably weaken incentives for prudent management and improved efficiency.

Miscellaneous issues

Kaufmann (2009, p.19) argues that earlier research on Victorian DB TFP was based on the premise that 'the TFP methodology should determine the required data rather than the existing data–set dictating the design of the TFP methodology'. We concur with this principle but note that the use of non–coincident peak demand in the earlier Victorian studies represents the peak energy entering the network at the bulk supply points and is likely to be a particularly poor proxy for the contracted reserved capacity that large customers pay for. This is because diversification of demand within the network means that the total peak energy entering the network at any one time will be less than the sum of maximum demands at the final customer level (which will all occur at different times). The relative volatility of peak demand also makes it a poor proxy for contracted reserved capacity which could be expected to be much more stable. Non–coincident peak demand appears to have been used because it was available, not because it was a good proxy. Lawrence (2005b,c) noted other problems with the opex series used which appeared to have been constructed by the regulator and could not be replicated by the DBs.

Kaufmann (2009, p.21) questions the analytical basis for the Economic Insights (2009a) analytical framework and refers to his appendix 4 which claims the framework is based on unrealistic assumptions. We have already demonstrated in this report that the Economic Insights (2009a) framework is necessary to address the complexity of the task faced by regulators and to ensure that economic regulation achieves its fundamental objective of improving economic welfare. By contrast, the framework advocated by Dr Kaufmann fails to adequately take account of the non–competitive characteristics of energy networks and is likely to compromise the ability of DBs to recover efficient costs while not recognising the importance of DB pricing structures. Kaufmann (2009, appendix 4) will be responded to below.

Kaufmann (2009) appendix 1 on output specification

Kaufmann (2009, appendix 1) sets out the 'indexing logic' claimed to support Dr Kaufmann's preferred TFP specification and his output specification in particular. As noted at the start of this appendix, the Kaufmann framework is based purely on an axiomatic approach which appeals to one accounting identity, namely that the growth in industry revenue should equal the growth in industry costs. This identity can only hold in general if the ex post rate of return on invested capital is treated as an endogenous variable which is determined by setting revenues equal to costs. This methodology does not properly account for the opportunity cost of capital for firms in the distribution industry and it fails to link the pricing outcome to consumer preferences and welfare – something that is clearly essential for robust and sustainable economic regulation.

Kaufmann (2009, p.23) notes that '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'. But the energy distribution industry is not a competitive industry – rather, it is a classic natural monopoly industry and failure to allow for the non–competitive features of the industry will lead to a flawed outcome. The Economic Insights (2009a) framework, on the other hand, recognises the non–competitive characteristics of the industry and the implications of these for both TFP specification and the form of the price cap.

Furthermore, Kaufmann (2009, p.25) restates his emphasis on 'allocative efficiency' as being that changes in revenue track changes in costs and downplays the role of price structure in determining allocative efficiency. But Economic Insights (2009a) demonstrates that price structure – and the relationship between prices and underlying costs in particular – is a critical determinant of allocative efficiency and ensuring that regulation improves economic welfare. The relationship between prices and underlying costs also plays a key role in determining the rate of TFP growth that is achievable by a particular DB. The Kaufmann framework is, therefore, too overly simplistic to adequately address the complexities that regulators have to address.

Finally, Kaufmann (2009, p.27) again claims that only the use of 'billing determinants' weighted by revenue shares will allow DBs to recover efficient costs. As demonstrated at length in Economic Insights (2009a,b) and in this report, it is necessary to include all functional outputs (of which billed outputs are a subset) and to weight them by the difference between prices and underlying costs to allow DBs to recover efficient costs while adequately addressing efficiency and welfare objectives.

Kaufmann (2009) appendix 2 on measurement of capital

Kaufmann (2009, appendix 2) repeats an earlier PEG appendix which claimed that capital quantities should be measured by the 'monetary' (ie constant price depreciated asset value proxy) approach. This appendix was responded to in Economic Insights (2009b) and we note that the subsequent PEG submission (repeated as appendix 3 in Kaufmann 2009) did not take issue with any of the substantive arguments made. The Economic Insights response is repeated as appendix D to this report. Appendix C to this report presents an empirical example of the distortions that can arise in output prices when the TFP specification uses geometric depreciation in forming the capital quantity when the actual depreciation profile is one hoss shay.

Kaufmann (2009) appendix 3 – PEG submission to the Commerce Commission

The recent PEG submission to the Commerce Commission reproduced as appendix 3 of Kaufmann (2009) contains a number of misinterpretations of the Economic Insights (2009a) framework and of comments made in Economic Insights (2009b). It also contains a number of inaccurate claims regarding the simple framework advocated in Kaufmann (2009). Many of the issues have already been addressed in this report and will not be repeated at length here. However, below we do briefly address the key points made in the PEG submission for completeness.

Kaufmann (2009, appendix 3) starts off with a lengthy discussion of whether or not the framework advocated by Dr Kaufmann relies on the assumption of competitive markets. The Kaufmann framework is based purely on an axiomatic approach which appeals to one accounting identity, namely that the growth in industry revenue should equal the growth in industry costs. Kaufmann (2009, p.23) earlier noted the following:

> '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'

This may be a reasonable approach in a stylised perfectly competitive industry where firms earn a normal rate of return. However, this identity can only hold in general if the ex post rate of return on invested capital is treated as an endogenous variable which is determined by setting costs equal to revenues and this is the way Dr Kaufmann proposes to implement his framework. But this methodology does not properly account for the non–competitive nature of network industries, the true opportunity cost of capital for DBs or the sunk cost nature of network assets. Furthermore, it fails to link the pricing outcome to consumer preferences and welfare – something that is clearly essential for robust and sustainable economic regulation of natural monopolies.

If the energy distribution industry had the same characteristics as a perfectly competitive industry, then the above shortcomings in the Kaufmann (2009) framework would not be problematic. In fact, as noted earlier, under such circumstances the Kaufmann and Economic Insights frameworks would produce relatively similar results (biases introduced by Dr Kaufmann's approach to measuring the quantity of capital aside). This is because there would be no unbilled functional outputs, prices would equal marginal costs, all firms would earn a normal rate of return and FCM would be achieved. However, the energy distribution industry is not a perfectly competitive industry – rather, it is a classic natural monopoly industry and failure to allow for the non–competitive features of the industry can lead to flawed outcomes. The Economic Insights (2009a) framework was developed precisely to overcome these major shortcomings in the simple framework advocated by Dr Kaufmann.

Kaufmann (2009, pp.42–44) explicitly introduces margins ('M') or excess profits into his analysis for the first time. We note that this term was included in the Lawrence (2003) framework and formed the basis of one of the X factor components in the New Zealand thresholds regulatory regime. Dr Kaufmann argues that it is acceptable to ignore the change in margins term in his TFP specification because the Commerce Commission intends to reset prices at the start of the regulatory period so that revenues equal (exogenous) costs (ie there would be a P_0 reset as well as a productivity–based X factor). However, this fails to recognise the significant distortions that can be introduced by the use of an endogenous approach to measuring the annual cost of capital in a natural monopoly industry as advocated by Dr Kaufmann. This is particularly the case in New Zealand where DB residual rates of return (formed as revenue less opex less depreciation, all divided by the RAB) ranged from –1.25 per cent to 15.8 per cent for the average of the years 2004 to 2006 (Lawrence 2007b). If opex and capital quantities are growing at different rates then the Kaufmann approach will introduce significant biases for nearly all DBs. This bias can only be avoided by using an exogenous approach to specifying capital amortisation charges as done in Economic Insights (2009a,b).

Kaufmann (2009, p.44) goes on to make the somewhat extraordinary claim that:

> 'The assumption that ΔM = 0 is also compatible with ex ante FCM. The TFP specification above is focused on satisfying the objective that the expected change in industry revenue over the term of the DPP [default price path] equals the change in industry costs. This objective is furthered by the fact that PEG employs an ex post approach to capital measurement, which ensures that industry costs will equal revenues over the period for which TFP is measured.'

The statement appears to confuse the fact that a price reset process is to be undertaken to align revenues and costs at the start of the next regulatory period with the fact that historical returns are used in Dr Kaufmann's endogenous approach to measure the cost of capital in his TFP model. As noted above, there is a very wide range of realised rates of return observed for the New Zealand DBs and this will likely introduce significant biases in TFP growth rates measured this way. The use of an endogenous (or ex post) approach to measuring the annual cost of capital is in no way compatible with FCM except by accident (ie if the residual rate of return happens to coincide with the true opportunity cost). Rather, the only way to ensure ex ante FCM is achieved is to adopt an exogenous (or ex ante) approach to specifying the capital amortisation charges to be used in the TFP analysis (and these should be the same as those used in the P_0 reset process). Furthermore, as noted earlier, the claim above that the endogenous approach to measuring the annual cost of capital 'ensures that industry costs will equal revenues' is illusory as it defines the problem away by setting costs equal to revenue.

Kaufmann (2009) next presents a rather lengthy discussion of the distinction between TFP growth and technical change. Dr Kaufmann's confusion on what Economic Insights (2009b) was saying about the framework he advocates was likely influenced by inadequate wording in our earlier report. The point being made in Economic Insights (2009b) was that the traditional approach (and the one advocated by Dr Kaufmann) implicitly assumes that achievable TFP growth is the same for all firms. However, actual TFP growth in a natural monopoly industry is influenced by factors other than technical change. These mainly relate to the divergence of prices from marginal costs. While technical change may be relatively similar across DBs (or at least those with similar operating environments), the large differences in pricing structures adopted by DBs and the relative extent of unbilled functional outputs will mean that achievable TFP growth will be different across DBs. Because the framework advocated by Dr Kaufmann does not distinguish these factors, it effectively assumes that achievable TFP growth is the same across all DBs.

Kaufmann (2009, p.53) goes on to argue that 'a more complex analytical framework that decomposed TFP growth into different components' was not necessary since the current New Zealand regime (generally) mandates a common X factor for all DBs (although DB–specific P_0s are permitted). However, a key implication of the analysis in Economic Insights (2009a) is that imposing a common X factor across all DBs may not reflect achievable TFP growth in all cases if DB pricing structures diverge from underlying costs. One way of allowing for any resulting differences in achievable TFP growth under these circumstances might be to make relevant adjustments to the P_0s. But even if this was not done, it would still be important to be aware of the influences of factors beyond DB control on achievable TFP growth.

We note that the current AEMC design proposal does allow scope for DB–specific X factors and this proposal was supported by Kaufmann (2009, p.18). A more sophisticated framework than that advocated by Dr Kaufmann is clearly required to address the range of issues that is likely to arise and to ensure that network regulation is contributing to improved economic welfare.

Kaufmann (2009) next proceeds to a lengthy discussion of whether the issue of 'capital fungibility' is important in determining the appropriate TFP specification. Having assets that are not sunk in nature is an important assumption of the Jorgensonian user cost formula advocated by PEG (2009). The ability to freely trade capital assets is an important prerequisite for calculating the opportunity cost of capital based on current market prices for the relevant capital, a specified rate of return and the observed rate of capital gains as all are explicitly included in the standard user cost formula (although the capital gains term is incorrectly omitted from the PEG 2009 formula). If assets are in fact sunk and, therefore, not freely tradable then the application of the standard user cost formula is no longer valid. Rather, we then need to calculate a shadow price for the sunk capital and allow for the deviations of regulator approved amortisation charges from these underlying shadow prices. The appropriate shadow price will be given by the net present value of the savings in opex that an additional unit of sunk capital would generate.

Kaufmann (2009, p.57) states that Economic Insights' (2009a) 'entire discussion of capital fungibility applies to puzzles that exist only at the theoretical level but have no practical implications for TFP measurement'. This statement is incorrect. If network assets are in fact sunk (which they clearly are) then calculating user costs as if the assets were freely tradeable will likely produce biased TFP growth estimates. The importance of this issue is reflected in ongoing regulatory proceeding debates over the appropriate value of network assets. Since the assets are sunk and not freely tradeable, it is difficult to establish their current value. A workable way forward on this issue is the application of a fully FCM consistent amortisation charge based as closely as possible on original asset cost as implemented in Economic Insights (2009b).

It should be noted that the approach to measuring the actual annual cost of capital that PEG (2009) adopt and which Kaufmann (2009) advocates departs from the traditional Jorgensonian formula referred to above. As noted elsewhere in this report, the use of an endogenous cost of capital equal to the difference between revenue and opex will not necessarily entail use of an objective and realistic opportunity cost for capital and is not consistent with ex ante FCM. In some situations (eg for competitive industries or networks that have been regulated for long periods using building blocks) it may provide an approximation to a reasonable opportunity cost but it will not be suitable where there is a wide range of current rates of return (as among New Zealand DBs) or where the TFP study is being used to set the actual price path.

Kaufmann (2009, p.59) next argues that a benefit of using 'monetary values rather than physical metrics to measure capital is that they reflect the impact of capital replacement expenditure on industry unit costs more directly and transparently than physical capital metrics'. But the problem with the approach advocated by Dr Kaufmann is that his depreciated asset values incorporate regulatory depreciation (which is largely straight–line based but has often been front–end loaded). Hence the depreciation profile used to form the capital quantity proxy does not reflect the actual service potential characteristics of network assets which are largely one hoss shay in nature[1]. The decay in the capital quantity proxy will be too high in this case and TFP growth will be generally overstated.

As noted in section 4.2 above, so–called 'wall–of–wire' effects are most accurately captured in the price differential term in the X factor. The approach Dr Kaufmann advocates indirectly picks these effects up as a decline in measured TFP (even though the service potential of network assets – and hence TFP – is unlikely to have changed). The one hoss shay capital quantity proxy and FCM–consistent amortisation charge approach used in Economic Insights (2009b) is a more direct and accurate representation which allows DBs to recover efficient costs while providing an undistorted measure of TFP growth.

Kaufmann (2009, pp.61–63) again raises the issue of a discussion of alternative approaches to measuring capital quantities in Ontario Energy Board (OEB) proceedings in 2008. Dr Kaufmann's appendix 2 contains a claim that these issues were debated 'extensively and transparently' in the OEB proceedings. This claim was challenged in Economic Insights (2009b) which noted that the main issue in Ontario was a lack of relevant capital data to implement either the 'monetary' or the physical quantity proxy approach. Indeed, the lack of Ontario data was so problematic that US TFP results ended up being used by the OEB instead.

Economic Insights is of the view that these issues were not independently reviewed in the Ontario proceedings. Dr Kaufmann, clearly an advocate of the so–called 'monetary' approach, was the advisor to the OEB. Furthermore, the topic received coverage of only one paragraph in the OEB (2008b) report. As noted in appendix D to this report, many key analysts and leading statistical agencies have recognised that the service potential of structure assets remains at relatively high levels for most of these assets' lives and that this should be recognised when forming the capital input quantity for use in TFP studies. This is the opposite of the depreciation profile typically included in the so–called 'monetary' proxy for the quantity of network capital.

Kaufmann (2009, p.63) observes that 'some [Economic Insights] personnel apparently were part of the team advising the OEB for the first generation incentive regulation plan'. This is incorrect. Dr Frank Cronin and a team from PHB Hagler Bailly Consulting advised the OEB on its first generation incentive regulation plan and the OEB decision drew directly on this work. It is noteworthy that the OEB (2008a, p.14) made the following observations regarding Dr Cronin's views on the PEG methodology:

> 'Dr. Cronin did not support PEG's recommended approach for developing a productivity factor for three main reasons: the belief that the U.S. industry was too dissimilar to that in Ontario to provide a basis for a productivity factor; the belief that PEG's measure of capital was flawed; and concern that PEG's output measure was incorrectly specified.'

The final issue Kaufmann (2009, appendix 3) raises is whether the use of functional outputs allows DBs to recover their efficient costs. The response to this issue has already been covered on the second page of this appendix.

[1] In principle a monetary approach could be used provided the depreciation profile that is adopted reflected the physical depreciation that actually occurs.

Kaufmann (2009) appendix 4 on Economic Insights' (2009a) assumptions

Kaufmann (2009, appendix 4) questions a number of the assumptions used in developing the Economic Insights (2009a) framework.

Dr Kaufmann starts off by questioning whether electricity network assets are in fact sunk in nature. He notes that DBs have the flexibility to add to capacity as required and hence the networks are somewhat dynamic in nature. We agree that DBs can add capacity and modify network configuration somewhat as required. However, the added assets are still sunk in nature. We do not see DBs routinely (if ever) removing lines and relocating them to new areas where demand may have grown. Rather, new assets may be added but they are then largely left in situ for the remainder of their lives. They certainly cannot be readily traded. Our framework allows for the addition of new capital and the removal of expired capital but capital is still sunk in nature.

Kaufmann (2009, p.73) makes a clear error and fundamental misinterpretation in the following statement:

> 'These investments are an indispensable part of what EDBs do, and the [Economic Insights] Theoretical Report essentially assumes them away. … [Economic Insights'] recommended X factor formula draws a sharp distinction between opex inputs and fixed, sunk capital costs, but makes no explicit provision for input price changes on new capital expenditures.

The Economic Insights framework treats the initial capital base as sunk and calculates FCM consistent amortisation charges on that sunk capital based on the remaining average asset life. It then allows each year's capex to be added as new sunk assets and FCM consistent amortisation charges are calculated for that capex based on the total average asset life. As noted above, the Economic Insights (2009a,b) framework further includes a direct allowance for increases in the price of new assets such as might be encountered in a 'wall–of–wire' situation.

Dr Kaufmann's clear misinterpretation of this issue was covered in Economic Insights (2009b, p.71) as follows:

> 'PEG (2009b) appears to be under the impression that investment is not allowed for in the FCM discussion in Economic Insights (2009a,b). For clarity, new capital investment of a sunk nature is included in allowable costs and reflected in price increases by the inclusion of an appropriate amortisation schedule as such capital expenditure is incurred.'

The remainder of the points raised in Kaufmann (2009, appendix 4) are all relatively inconsequential. The first of the remaining points questions the assumption in Economic Insights (2009a) that the regulator requires proportional changes in all output prices. This is a standard simplifying assumption in this type of technical analysis. It could readily be relaxed but would lead to a more complicated X factor formula without significant benefit.

Dr Kaufmann next questions the assumption that regulators have a target rate of change in profits for the regulated firm linked to the change in revenues. He argues that regulators in practice tend to target a rate of return rather than a change in profits per se. This could, of course, be readily incorporated in the model but, again, at the expense of more detail and with no significant benefit.

Finally, Dr Kaufmann questions our simplification in the technical report's equation (279) by assuming two terms at the end of the preceding equation can be neglected as they are likely to be close to zero. Again, it is standard practice to simplify equations by removing terms that are likely to be close to zero. These terms could readily be left in but at the expense of a more complicated X factor formula. The benefits from doing so would, in our view, be far less than the costs.

In conclusion, it can be seen that first of the objections Dr Kaufmann raises in his appendix 4 is incorrect and the remaining three are all inconsequential. It should be noted that throughout this appendix we have highlighted the very significant assumptions Dr Kaufmann makes in arriving at his preferred simple formula. Not the least of these is that using the endogenous user cost of capital approach will allow DBs to recover their efficient costs. And the implementation assumption that non–coincident peak demand can be used as a proxy for contracted reserved capacity is clearly problematic. Any model will, by definition, require many simplifying assumptions to be made. We have highlighted the major assumptions Dr Kaufmann makes. The assumptions in Economic Insights (2009a) that Dr Kaufmann's appendix 4 criticises are, by comparison, all relatively minor.

APPENDIX B: FUNCTIONAL OUTPUTS AND THE RECOVERY OF EFFICIENT COSTS

There has been some misinterpretation of the Economic Insights (2009a) framework regarding the inclusion of other functional outputs besides those that are directly billed for. In a submission to the New Zealand Commerce Commission PwC (2009) included a worked example that purported to show that using functional outputs would not allow the recovery of efficient costs. However, the PwC example did not reflect the Economic Insights (2009a) framework and this was responded to in Economic Insights (2009b). Since a similar misinterpretation is made in the Kaufmann (2009) submission, the explanation and counterexample provided in Economic Insights (2009b) is repeated below.

PwC (2009, p.8) states:

> 'It is submitted that the question of what definition of output is 'right' for regulatory purposes is not the definition that reflects 'exactly what service does an energy distribution business provide' or the service that reflects best the utility gained by customers. Rather the right definition of output is the one that is most likely to generate a price path that aligns an EDB's revenue stream with its costs (that is, achieves ex ante financial capital maintenance). Assessed against this objective, it seems self evident that using a measure of output that does not reflect how prices are set can lead to obvious errors (that is even if there is only one regulated firm). This argument is explained most simply by providing a simple example, which is set out in Box 1 below.'

In the Box 1 referred to, PwC presents a simple example where they define output exclusively in terms of an 'abstract' measure such as capacity that is not charged for and that measure of output is used exclusively relative to an input measure to define TFP. PwC claim that if this measure of TFP is to be the X factor and used in conjunction with unit cost increases to define allowable price increases, then revenue would not be sufficient to recover cost.

This example does not, however, reflect the proposal in the Economic Insights (2009a) report. The PwC example is an interpretation of the way that TFP has been traditionally implemented to date but with the substitution of an output measure that does not have a billed price. But the Economic Insights approach does not entail the exclusive use of an 'abstract' output measure with no billed price. Thus, the simple PwC example is neither relevant nor reflective of the Economic Insights approach.

To demonstrate that the PwC example does not interpret our approach correctly, an example is presented below to show that the Economic Insights methodology does derive a price increase which ensures revenue aligns with cost. We do this in a simplified framework that uses the same basic data as presented in the PwC example[2]. The point is that although some outputs included in the calculation of TFP may not be priced, the price of those outputs that

[2] The PwC example uses logarithmic derivatives of prices and quantities but for convenience we use a discrete time framework here. As is the case for the PwC example, the example presented here abstracts from problems associated with sunk costs, in order to focus on the non-priced output issue raised by PwC.

do have a billed price must increase sufficiently to ensure revenues align with costs.

Consider a two period situation for a single firm producing two outputs, where one output has a billed price and the other output does not have a billed price for two periods, t=0,1. Denote the prices of the two outputs in period t by P_1^t and P_2^t and the quantities of the two outputs in period t by Q_1^t and Q_2^t. Assume the first output is electricity sales or throughput and the second output is a capacity measure. Due to institutional constraints, only the first output is priced so that P_2^0 and P_2^1 are both zero. Set P_1^0 equal to 1.

Assume that in period 0, the volumes of the two outputs were both equal to 100 units. Based on these assumptions and the growth rates in the PwC example, the following output assumptions apply:

(B1) $Q_1^0 = 100$; $Q_2^0 = 100$; $Q_1^1 = 105$; $Q_2^1 = 120$.

Note that $Q_1^1/Q_1^0 = 1.05$ and $Q_2^1/Q_2^0 = 1.20$.

Let the amount of input used in periods 0 and 1 be Z^0 and Z^1, respectively, and let the corresponding input prices be W^0 and W^1.

Assume that there are zero profits in period 0 so that the value of input, W^0Z^0, is equal to the value of billed output, $P_1^0Q_1^0 = 1\times100 = 100$. Set $W^0 = 1$ and since P_1^0 is also equal to 1, this means that Z^0 must be equal to 100 as well. Based on these assumptions and the growth rates in the PwC example, the following input assumptions apply:

(B2) $W^0 = 1$; $W^1 = 1.04$; $Z^0 = 100$; $Z^1 = 115$.

Now assume, following PwC's example, that the regulator sets billed prices in period 1 so that the firm makes zero profits in period 1. P_1^1 is then the solution to the following equation:

(B3) $P_1^1\times105 = W^1Z^1 = 1.04\times115 = 119.6$

or $P_1^1 = 119.6/105 = 1.1390$. Thus, to ensure revenues align with costs the price cap must allow for a 13.9 per cent increase in the billed price of Q_1, which is very close to PwC's 14 per cent increase[3].

The basic price and quantity data for the two outputs can be summarised as follows:

(B4) $P_1^0 = 1$; $P_2^0 = 0$; $P_1^1 = 1.139$; $P_2^1 = 0$.

With all of the price and quantity data determined, define (one plus) the TFP growth factor (TFPGF) as the billed output index, Q_1^1/Q_1^0, divided by the input quantity index, Z^1/Z^0:

(B5) $\text{TFPGF} \equiv [Q_1^1/Q_1^0]/[Z^1/Z^0] = 1.05/1.15 = 0.913$.

Conventionally measured TFP growth is TFPG minus 1, which is −8.70 per cent. PwC find that conventional TFP growth is −10 per cent – this difference is due to applying the conventions used in index number theory with TFPGF defined as an output index divided by an input index, whereas PwC used a difference approach to measuring TFP growth.

Now, equate cost to revenue in each period so that:

(B6) $P_1^0Q_1^0 = W^0Z^0$;

[3] The difference is due to PwC's use of continuous time compared to the discrete time presentation above.

(B7) $P_1^1 Q_1^1 = W^1 Z^1$.

Taking the ratio of (B7) to (B6) and using definition (B5), the following very simple price cap formula is derived:

(B8) $P_1^1/P_1^0 = [W^1/W^0]/TFPGF$.

One plus the rate of increase in capped prices is set equal to (one plus) the rate of increase in input prices divided by (one plus) the rate of growth in TFP.

To show the consistency of the Economic Insights methodology in arriving at the estimated price increase of 13.9 per cent it is necessary to develop the counterpart to equation (278) in the Economic Insights (2009a) technical report. This equation requires estimates of the rate of technical progress and estimates of marginal costs and this information was not presented in the PwC example.

Assume that some econometric estimation has been undertaken and the parameters of the period t cost function, $C(W,Q_1,Q_2,t)$, have been determined where:

(B9) $C(W,Q_1,Q_2,t) = W[\alpha + \mu_1 Q_1 + \mu_2 Q_2][1 - \tau t]$; $\qquad t = 0,1$

where α, μ_1, μ_2 and τ are the estimated parameters. These parameters have the following interpretations: α can be interpreted as a fixed cost parameter, μ_1 and μ_2 are the marginal costs of outputs 1 and 2 in period 0 and τ is the rate of technical progress (or of exogenous cost reduction). Period t total cost is equal to $W^t Z^t$ so if observed period 0 and 1 total costs were given by the right hand side of (B9) for t = 0,1, the following equations will hold:

(B10) $W^0 Z^0 = W^0[\alpha + \mu_1 Q_1^0 + \mu_2 Q_2^0]$;

(B11) $W^1 Z^1 = W^1[\alpha + \mu_1 Q_1^1 + \mu_2 Q_2^1][1 - \tau]$.

Also, assume that the fixed cost α is equal to 10, the two marginal costs μ_1 and μ_2 are equal to 0.1 and 0.8 respectively and $1 - \tau$ is equal to 115/116.5 so that τ is equal to 0.0129 and hence the rate of technical progress is approximately 1.3% per year:

(B12) $\alpha = 10$; $\mu_1 = 0.1$; $\mu_2 = 0.8$; $\tau = 0.0129$.

It can be verified that if the data for periods 0 and 1 satisfy (B1), (B2) and (B4) and the parameters of the cost function satisfy (B12), then equations (B10) and (B11) hold exactly. Thus, the assumed parameters are perfectly consistent with PwC's basic assumptions.

Now equate cost to revenue in each period so that equations (B6) and (B7) hold. Using equations (B10) and (B11) and equating them to (B6) and (B7) respectively and taking ratios, the following equation for the allowed rate of increase in the price of billed outputs that will ensure zero profits in each period is obtained :

(B13) $P_1^1/P_1^0 = [W^1/W^0][1 - \tau][(\alpha + \mu_1 Q_1^1 + \mu_2 Q_2^1)/(\alpha + \mu_1 Q_1^0 + \mu_2 Q_2^0)]/[Q_1^1/Q_1^0]$.

Substituting the data and parameter assumptions (B1), (B2), (B4) and (B9) into the right hand side of (B13) produces $P_1^1/P_1^0 = 119.6/105 = 1.1390$ and thus the price cap must allow for a 13.9% increase in the billed price of Q_1 to keep pure profits at a zero level. This is the same answer as that in using the conventional TFP growth methodology; see (B3) and (B8) above.

To provide further clarification, in the interpretation of the Economic Insights proposal, consider the measure of TFP defined by the last three terms of equation (278) from the

Economic Insights (2009a) technical report which PwC also considers in Box 2 (p.10) of their report:

$$(278)\ \alpha'(t) = \beta + \{w'(t)\cdot z(t) + P_k'(t)\cdot k(t) - \tau(t)C_z(t) - [p(t)-\mu(t)]\cdot y'(t) + [P_k(t)-\pi(t)]\cdot k'(t)\}/R(t).$$

where:

$\alpha'(t)$ = the regulated allowable rate of change of prices;

β = a profit adjustment term;

$w'(t)\cdot z(t)$ = the rate of change in opex input prices weighted by opex input quantities;

$P_k'(t)\cdot k(t)$ = the rate of change in capital input prices weighted by sunk capital input quantities;

$\tau(t)C_z(t)$ = the rate of technical progress with respect to operating expenses weighted by operating costs;

$[p(t)-\mu(t)]\cdot y'(t)$ = the gap between price and marginal cost for all outputs weighted by the rates of change for all outputs;

$[P_k(t)-\pi(t)]\cdot k'(t)\}$ = the gap between the price of sunk capital and the marginal saving in operating costs from using additional capital weighted by the rate of change of sunk capital inputs;

$R(t)$ = total revenue; and

t = time period.

Note that equation (B13) above is the exact discrete time counterpart to three components of the continuous time equation (278) in the Economic Insights (2009a) technical report. The discrete time term W^1/W^0 is the counterpart to the continuous time term $w'(t)\cdot z(t)$, the term $1 - \tau$ is the counterpart to the term $-\tau(t)C(t)$ and the term $[(\alpha + \mu_1Q_1^1 + \mu_2Q_2^1)/(\alpha + \mu_1Q_1^0 + \mu_2Q_2^0)]/[Q_1^1/Q_1^0]$ is the counterpart to the term $[\mu(t) - p(t)]\cdot y'(t)$. The other terms in (278) – a profit adjustment term and a term taking account of sunk costs do not appear in (B13) because no profit adjustment is required and the example presented here does not incorporate sunk costs, in order to focus on the output issue raised by PwC.

Returning to PwC's simple example in their Box 1, note that their proposed 'correct' measure of TFP growth is deducted from the weighted change in input prices to determine the allowable change in output prices. The same 'correct' measure of TFP growth that PwC defines can be decomposed as explained in the example presented above. However, ideally our measure requires an estimate of pure technical change available to all firms, marginal cost and billed prices, amortisation charges and user benefits. As an approximation, some of the terms may be ignored but it is noted that the inclusion of the divergence between marginal cost and prices is important in terms of addressing underlying economic welfare considerations and is likely to be important in practice where the divergences across firms may be very significant.

It may be helpful to consider the intuition for the last two terms in (278) as follows. Consider the term $[p(t)-\mu(t)]\cdot y'(t)$. Suppose demand for regulated output m is increasing so that $y_m'(t)$

is positive. If $p_m(t)$ is greater than $\mu_m(t)$, then the extra revenue that is generated by the increase in demand will be greater than the incremental cost of producing the increased amount of output m and profits will increase. To keep profits at zero, capped prices have to decrease. Now consider the term $[P_k(t)-\pi(t)]\cdot k'(t)$. Suppose $k'(t)$ is positive and assume that k is a scalar. To maintain financial capital, the firm needs extra revenues to recover the incremental capital charges, $P_k(t)k'(t)$. However, opex will fall incrementally by $\pi(t)k'(t)$ due to the extra capital that has been added. Thus, the net amount of extra revenues that are needed are $[P_k(t)-\pi(t)]k'(t)$ and capped prices will have to adjust to generate this net charge.

As noted earlier, for 'abstract' outputs – or, to be more accurate, economic or functional outputs – where billed prices do not exist those billed prices would be treated as zero in (278) but the input costs associated with those outputs would be captured. This is because the weight is the difference between marginal cost and billed prices, which in this case is simply marginal cost. For billed outputs changes would be weighted by the differences between marginal costs and billed prices. Thus, the appropriate measure of output in our approach is one that includes all relevant economic outputs irrespective of whether they are explicitly billed for or not. However, all outputs that are priced would also need to be included (ie these would, by definition, be a subset of economic outputs), along with terms to reflect operating cost and capital cost increases in order to ensure financial capital maintenance.

Our approach recognises that TFP growth is not the same for all firms and, importantly and consistent with underlying economic logic, specifies that prices should increase more than on average if marginal costs exceed prices and more than on average if the price of capital (based on amortisation charges) exceeds the marginal benefit. Although there may be legislative restrictions on taking account of differences in price–marginal cost differences for individual firms in setting an X factor, it may be possible to make adjustments in other ways and it may also be relevant to make an industry–wide adjustment.

APPENDIX C: GEOMETRIC AND ONE HOSS SHAY DEPRECIATION

PEG (2009a, appendix 2) and Kaufmann (2009, appendix 2) prefer to measure capital input quantities in 'monetary' terms, to adopt a geometric depreciation profile for EDBs and to calculate the rate of return based on an ex post concept. PEG also seems to prefer indexation of historic costs using an investment deflator rather than the CPI, although they use the ex post approach to form the cost of capital in practice.

Economic Insights (2009a) prefers to measure capital in physical units, to adopt a one hoss shay profile for the capital input service potential, to calculate the rate of return on an ex ante basis and to index capital charges with the consumer price index.

Economic Insights (2009b) provided a response to the capital measurement issues raised by PEG and particularly the claim that 'indexing logic' requires a 'monetary' measure of capital which is not true. This appendix provides further material based on some simple examples highlighting the bias in the estimation of TFP growth and output and input price growth that arises from using geometric depreciation when the assets actually exhibit one–hoss shay depreciation. The examples also clarify the implications of using an investment deflator to index capital charges, while still ensuring ex ante FCM in real CPI–adjusted terms.

Set out below are the results from comparing the following four models of capital charges and TFP based on stylised data and parameters.

The Models

1. Indexed historic cost using the CPI as the inflation index with FCM maintained in real CPI adjusted terms and depreciation calculated on a one–hoss shay basis.
2. Indexed historic cost using an investment deflator as the inflation index but with FCM maintained in real CPI adjusted terms (by choice of an appropriate discount factor) and depreciation calculated on a one–hoss shay basis.
3. A Jorgenson user cost model with FCM maintained in real CPI adjusted terms and depreciation calculated on a geometric basis.
4. The PEG approach to determining a residual cost of capital that (in contrast to PEG) achieves FCM in real CPI–adjusted terms and with depreciation calculated on a geometric basis.

Assumptions

Real cost of capital = 6 per cent.

CPI inflation rate = 2.22 per cent

Investment inflation rate = 4.06 per cent

Opex inflation rate = 3.55 per cent

Rate of growth of opex inputs = –0.5 per cent

Asset life = 20 years.

Cost of investment = $100 million.

Initial value of opex inputs = $10 million.

Zero excess profits in every year by specification of appropriate output prices.

Output growth of 0.25 per cent per year corresponding to better utilisation of fixed capital.

TFP growth is conventionally defined as output growth divided by input growth where there is only one output and the input aggregate is constructed using chained Fisher indexes with user charge weights for the capital input.

Model 1

Model 1 corresponds to Case 2 of the Economic Insights (2009a) technical report that specifies constant real user charges, in CPI–adjusted terms, while ensuring ex ante financial capital maintenance is exactly achieved.

In Model 1, the period–by–period amortisation charges are specified so that when indexed by the consumer price index and discounted by a nominal discount rate based on an expected nominal cost of capital (that embodies expected nominal consumer price inflation) and summed will exactly equal the present value of the capital expenditure.

One hoss–shay depreciation is assumed.

Model 2

Model 2 corresponds to Case 3 of the Economic Insights (2009a) technical report.

In Model 2, the period–by–period amortisation charges are specified so that when indexed by an investment price index and when discounted by a nominal discount rate based on an expected nominal cost of capital (that embodies expected nominal consumer price inflation) and summed will exactly equal the present value of the capital expenditure.

One hoss–shay depreciation is assumed.

Model 3

Model 3 uses the standard definition of Jorgenson user costs that comprises an opportunity cost of capital rate, a physical geometric depreciation rate and a capital gains rate (where nominal capital gains are deducted from the nominal opportunity cost of capital) all applied to the relevant investment deflator.

In Model 3, the period by period charges are estimated using the Jorgenson user cost of capital formula and discounted by a nominal discount rate based on an expected nominal cost of capital (that embodies expected nominal consumer price inflation). This ensures the present financial capital is maintained exactly in real CPI–adjusted terms.

In Model 3 the geometric depreciation rate is defined so that after 20 years of life only 5 per cent of the asset is left, implying a geometric depreciation rate of 13.9 per cent. It is assumed that the residual capital stock is sold at the end of year 20 at the prevailing market price as reflected in the investment price series estimate.

Model 4

Model 4 is based on the PEG approach of measuring the annual user charge as a residual as well as the adoption of a geometric depreciation rate as in Model 3. However, in this example, financial capital maintenance is maintained by construction since the same output and opex input data as used in Model 1 are also used in Model 4. The main differences compared with model 1 are depicted in terms of radically different patterns of prices and quantities for capital services and TFP growth, thereby highlighting the impact of assuming a geometric rather than a one–hoss shay measure of depreciation.

Table 1 presents the results for TFP growth, output price growth and input price growth for each of the models over the 20 year time frame. Models 1 and 2 have a very similar estimate for TFP growth but as model 2 assumes that charges will be indexed by an investment price deflator which exhibits faster growth than the CPI, then input price growth is higher for Model 2 than for Model 1. To maintain zero profits this in turn implies output price growth is higher for Model 2 than for Model 1. Thus, if Model 2 (asset price indexation of user charges) is used in place of Model 1 (CPI indexation of user charges), then early year Model 1 customers will pay lower prices for the utility's output as compared to early year Model 2 customers but then later year Model 2 customers will pay higher prices than later year Model 1 customers.

Table 1: **Growth of TFP, output and input prices with different cost of capital depreciation and indexation, per cent per annum**

	Model 1	*Model 2*	*Model 3*	*Model 4*
TFP growth	0.53	0.52	6.03	7.57
Output price growth	2.41	3.25	–2.12	2.41
Input price growth	2.95	3.78	3.73	10.16

Note: By construction all models incorporate financial capital maintenance. Model 1 assumes one–hoss shay depreciation and indexation of charges with the consumer price index. Model 2 assumes one–hoss shay depreciation and indexation of charges with an investment price index. Model 3 assumes geometric depreciation and Jorgenson definition of user cost of capital (which uses investment price index). Model 4 assumes geometric depreciation but capital charges as in model 1.

Compared with models 1 and 2, models 3 and 4 show very large growth rates of TFP of 6.03 and 7.57 per cent, respectively. This arises because of the assumption, in models 3 and 4, of geometric depreciation which implies a period by period reduction in capital input services over the 20–year period compared with no reduction in capital input services in Models 1 and 2 until the end of the 20–year period. If physical depreciation is more akin to a one–hoss shay characterisation than a geometric pattern, the above comparisons show the significant bias that is potentially introduced into measures of TFP growth.

Models 3 and 4 also differ significantly in terms of the growth rates for output and input prices. In Model 3 output average price growth is negative over the whole time frame but this implies high prices in the early years of the investment and declining over time. By construction model 4 assumes the same profile of total user charges as for model 1 (consistent with achieving financial capital maintenance). However, this implies very rapid input price growth reflecting the reduction in capital inputs over time.

APPENDIX D: CAPITAL INPUT QUANTITIES

This appendix reproduces section B4 of Economic Insights (2009b) which responded to issues raised in PEG (2009, appendix 2). The PEG appendix is reproduced in Kaufmann (2009). Note that page numbers referred to here relate to the original PEG appendix.

PEG (2009, appendix 2) and PwC (2009) have raised the issue of the most appropriate way to measure capital input quantities in TFP studies.

TFP is the ratio of total output quantity to total input quantity. Individual input quantities are aggregated into a measure of total input quantity using indexing methods with shares in total cost as weights. We thus require a quantity and price for each individual input, including capital inputs. Given the long–lived nature of capital inputs we require a measure of the annual 'service potential' quantity for capital inputs. This represents the quantity of service it could potentially provide each year. This will in turn be influenced by the pattern of physical deterioration in the asset.

Two commonly used physical deterioration profiles are 'one hoss shay' depreciation where the service potential quantity remains relatively constant over the asset's life and declining balance or 'geometric' depreciation where the service potential quantity declines by a given percentage each year. In the latter case the decline in service potential quantity is rapid in the early years of the asset's life. A simple proxy for a pattern of one hoss shay service potential quantity is the physical quantity of the capital input available while a simple proxy for a pattern of geometric deterioration of service potential is the constant price depreciated asset value formed using the declining balance method.

PEG (2009, p.43) makes the statement that 'with extremely rare exceptions, PEG believes that only monetary measures of capital stocks should be used to measure capital in energy utility TFP studies'. PEG claims that this is 'overwhelmingly' supported by economic theory and empirical evidence. However, the evidence PEG presents in support of this claim is extremely selective and ignores both the characteristics of the industry and current statistical agency practice.

Before addressing PEG's points in turn, it is worth noting that the primary data required for TFP studies are output and input *quantities*. The PEG statement that only monetary measures of capital should be used in energy utility TFP studies is hard to reconcile with this basic requirement of TFP studies. We assume PEG means that it prefers that values deflated by a price index are used as a proxy for the required quantity measure. It is worth noting at the outset, however, that this indirect method of deriving the required quantity measure will always be a second best method compared to direct quantity information, if the latter is available. This is because the price indexes used to deflate values to arrive at proxy quantities will never accurately reflect the prices paid by an individual firm or industry. If direct quantity information is available, along with the corresponding prices, then this source of error can be eliminated.

PEG (2009, p.44) commence by arguing that capital input quantities will only be consistent with total cost and opex quantities if a monetary capital value approach is used. PEG goes on to argue that setting an X factor using a physical method for measuring capital input quantities will be 'inconsistent' with using the capital cost to set starting prices. This argument is incorrect. Economic Insights (2009a) demonstrates at length how amortisation charges can be set taking account of the desirable regulatory principle of ex ante financial capital maintenance and these charges – which are analogous to those used in building blocks regulation – are then divided by the quantity of capital input to derive the price of annual capital input which is in turn used in the X factor formula. This is the approach adopted in this report and is fully internally consistent – a fact that is recognised by PwC (2009). Furthermore, as demonstrated by the empirical application in this report, the Economic Insights method does not exacerbate price volatility and is fully transparent.

Rather, the user cost formula adopted by PEG (2009) is not consistent with the sunk cost characteristics of the energy distribution industry and, as will be shown in the following section, is likely to be biased upwards as it does not accurately reproduce the Jorgenson (1963) user cost formula.

Returning to the issue of the most appropriate proxy for the pattern of deterioration in the quantity of the service potential of network assets over time, it may be useful to consider a simple example. Suppose an EDB installs 100 MVA–kilometres of line with a 50 year life. In the first year of the asset's life it will have a service potential of 100 MVA–kilometres. The question is how does this change over time? The one hoss shay approach would say that it remains at 100 MVA–kilometres for the next 49 years. The geometric approach advocated by PEG (2009) would say that this progressively declines – in fact relatively rapidly – so that by the 49th year the service potential of the line might only be, say, 2 MVA–kilometres.

While any simple proxy will be an approximation to the true underlying pattern of change in the service potential, those familiar with the operational characteristics of the electricity distribution industry agree that the service potential of the 100 MVA–kilometre line will change little over its lifetime. It may deteriorate to, say, 95 MVA–kilometres towards the end of its life but it will certainly not deteriorate rapidly and end up near zero at the end of its life. The geometric profile advocated by PEG (2009) thus has little to recommend it for measuring the productivity of energy distribution industries and the one hoss shay proxy will be far more appropriate.

It should be noted, for the avoidance of doubt, that Economic Insights is not saying that the geometric profile has no role to play in any TFP study. There will be some industries that have too many types of capital items to make the application of a physical quantity proxy approach implementable. The issue may also be less critical in industries with relatively short–lived capital. But in energy distribution there are relatively few types of capital, they are all relatively long–lived and all exhibit relatively little physical deterioration over their lifetime. In this case it is possible to provide a far more accurate proxy to the pattern of change in the quantity of annual service potential by use of a physical quantity proxy. PEG (2009) goes on to quote a number of academics and agencies in an attempt to discredit the one hoss shay approach. However, it is important to recognise that this depreciation profile has a long history, has been found to be a good proxy by many studies and is closer to the approach used by leading statistical agencies than the geometric approach advocated by PEG.

In a seminal article on depreciation published in the *American Economic Review*, Coen (1975, p.73) found the following:

> ‘Geometric decay of productive capacity – a commonly employed assumption in recent studies of investment behavior – does not appear to underlie actual capital spending decisions. Equipment generally evidences losses in productive capacity as it ages, though not necessarily at a geometric rate, but structures in the majority of industries suffer no loss in productive capacity over their lives (they resemble one–hoss shays).’

Major energy distribution assets are more akin to structures than equipment and so one hoss shay proxies will be appropriate.

With regard to capital inputs for utilities and transport, a major World Bank primer for regulators has observed the following:

> ‘The quantity of capital should reflect the potential service flow that can be derived from the capital equipment in each year. Expecting the potential service flow to be quite similar in each of the 20 years is reasonable, though more down time could be required in the latter years of the asset's life as more maintenance is required. Hence the potential service flow in year 20 could be 5 or 10 percent below that in year 1 (an engineer could provide advice on this matter). In any case, it is often reasonable to assume that the potential service flow will be quite similar from one year to the next … Note that when we use physical proxies as our capital measures, such as network length and transformer capacity, we are also implicitly assuming that the service flow of the asset is not affected by its age.’ (Coelli, Estache, Perelman and Trujillo 2003, pp.109–110)

This illustrates that the practice of using physical quantities to proxy capital input quantities has considerable international support.

The US Bureau of Labor Statistics (BLS) (which is the statistical agency in the US responsible for multifactor productivity analysis) has recognised the role of physical deterioration as opposed to financial depreciation in productivity studies as follows:

> ‘It is not possible to describe some plausible age/efficiency profiles in terms of a constant pattern of deterioration. A good illustrative example is that of a light bulb. It deteriorates very little (if any) through most of its lifetime, That is, its services (converting electricity into light) remain nearly constant. Then, one day, it burns out, after which it has no value whatsoever. While the light bulb is an extreme example (and often too short–lived to be considered capital), many assets appear to provide nearly constant service flows during their initial years. Automobiles are one example. Even though automobile resale values decline rapidly (depreciate) during the first three years of their service lives, two and three year old autos are often as nice looking and reliable as new ones. In other words, their services do not deteriorate very rapidly. Why, then, do their values depreciate? The depreciation reflects the buyers expectations of the future services the auto will provide. Buyers and sellers are evidently quite aware that a three year old auto will become unreliable much sooner than a new one, even if it is presently in ‘good condition’.

> 'The distinction between depreciation and deterioration corresponds to the distinction between the value of a capital good and its service flow. The fundamental neoclassical assumption, that the value of an asset equals the discounted value of future services (rents), addresses precisely this issue. At BLS, what we have concluded from this is that, for productivity measurement, we want the specification … to reflect an asset's efficiency profile and not its price profile. To emphasize that our measures are constructed with productivity measurement in mind, we have dubbed them 'productive capital stocks'. We sometimes refer to capital stocks constructed from age/price profiles as 'wealth stocks'.' (Harper 1997, pp.9–10)

The key component used in forming the productive capital stocks used for productivity analysis is the age–efficiency profile described by the OECD (2001, p.53) as follows:

> 'The loss in productive capacity of a capital good over time is shown in its age–efficiency profile or the rate at which the physical contributions of a capital good to production decline over time, as a result of wear and tear. … A one–year old truck may have lost 20% of its market value but it has not necessarily lost 20% of its capacity to ship goods from one place to another. Indeed, the trucking services of a one–year old vehicle are probably nearly identical to those of a new one.'

Age–efficiency profiles are commonly assumed to be either hyperbolic in shape (ie little deterioration in the early stages of the asset's life but more in the later years) or geometric (ie rapid deterioration in the early years and little deterioration in the later years). PEG (2009) argues in favour of a geometric age–efficiency profile. One of the smaller US research agencies quoted by PEG – the Bureau of Economic Analysis (BEA) – has used a geometric age–efficiency profile in productivity studies but the major US statistical agency responsible for multifactor productivity studies, the BLS, has rejected the geometric profile in favour of the hyperbolic profile.

Importantly, both Statistics New Zealand and the Australian Bureau of Statistics have adopted the hyperbolic age–efficiency profile in their productivity studies. A key parameter in the hyperbolic age–efficiency profile can be set to influence the degree of curvature. A value of one for this parameter leads to a flat or one hoss shay profile while a value of zero would give equal deterioration each year (ie approximate straight line deterioration). Both SNZ and the ABS set this parameter at 0.5 for equipment and 0.75 for structures. That is, they are assuming closer to one hoss shay deterioration for structures. This is the complete opposite of the geometric deterioration profile advocated by PEG.

PEG (2009, p.48) also raises the issue of whether a 'portfolio effect' might apply whereby even if individual assets exhibit one hoss shay depreciation, the aggregate of those assets may still exhibit geometric depreciation. This proposition may have some traction if there was a large number of firms with a wide spread of asset ages. By definition it does not apply for the case of a single firm. In the case of the New Zealand EDBs there are relatively few firms and the age characteristics of the assets are likely to be similar. Indeed, the EDBs have previously highlighted the 'bunched' nature of previous network rollouts and the likelihood of an impending 'wall of wire' as assets all of similar age require replacement. These characteristics mean that this 'portfolio effect' argument in favour of geometric depreciation in aggregate does not apply in this case.

PEG (2009, p.49) quote an earlier paper by Diewert (2001) where alternative depreciation methods were assessed using aggregate Canadian National Accounts data covering the period 1965 to 1999. Only two types of capital were included in the study – equipment and non–residential construction – and Diewert (2001, p.73) specifically noted that infrastructure capital was not included in the study. The study was not designed to determine which method was appropriate but rather to show the differences in the various methods and leave open which method was best but the study showed that it is perfectly feasible to implement a one hoss shay model of capital accumulation with National Accounts data.

PEG (2009, p.50) also quotes an early report by Lawrence (1999) which criticised the use of simple total route kilometres as a measure of capital in an early Australian benchmarking study. It should be noted that these criticisms cannot be levelled against the approach adopted in this report as PEG appear to imply. Firstly, the current report uses a measure of line capacity rather than simple route kilometres which allows the aggregation of lines of differing sizes – the kilometres travelled by the Boeing 747 versus the Cessna example contained in the quote is thus not relevant in this case. Furthermore, the current study distinguishes between overhead lines and underground cables and thus the substantially different level of resources required to install each.

Finally, PEG (2009, pp.50–51) makes a number of claims regarding regulatory proceedings in Ontario in 2008 which are incorrect. PEG claims that the issue of 'physical versus monetary capital values' (sic) was debated 'extensively and transparently'. However, there were very few data items available for the Ontario EDBs. There was some detail on opex and there were data on a few physical items, including overall line length. But there were no data on capital expenditure and recent data only existed for the period 2002 to 2006. There were thus inadequate data available for Ontario to construct a TFP measure using PEG's 'monetary' approach. Instead, PEG (as advisor to the regulator) advocated using its US database instead which showed ongoing TFP growth.

London Economics International which was representing some of the Ontario EDBs produced alternative estimates for the short period 2002 to 2006 using the very limited data on line length as a measure of capital quantity. This allowed at least some information on TFP for Ontario for recent years to be entered. However, the major problem with the Ontario estimates was that there were no data for the period 1998 to 2002 and data prior to 1998 was not available on the same basis as the recent data. The regulator was concerned that a 'patchwork' approach would have to be adopted that involved different approaches to capital measurement (given that the original Ontario study covering the period up to 1997 had used a 'monetary' approach). There was thus no 'extensive' or independent evaluation of the merits of the two approaches in this proceeding.

It should be noted that the Ontario regulator also rejected some aspects of its own advisor's analysis (Ontario Energy Board 2008b, p.12).

In conclusion, it can be seen that the physical proxy approach to measuring capital input quantity adopted in this study is consistent with underlying engineering and economic logic and day–to–day experience. It fully recognises the cost of capital inputs and, unlike the PEG approach, is consistent with ex ante financial capital maintenance. It is also consistent with the bulk of empirical evidence on depreciation patterns and current New Zealand, US and Australian statistical agency practice. It represents a more accurate and improved way forward for regulatory proceedings.

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