

Submission to Initial Reset of the  
Default Price Path for Electricity  
Distribution Businesses:  
Draft Decisions Paper



**Pacific Economics Group, LLC**  
Economic and Litigation Consulting

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Default Price Path for Electricity  
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# 1. INTRODUCTION

In September 2009, the New Zealand Commerce Commission (the Commission) released its *Draft Decisions Paper: Initial Reset of the Default Price Quality Path for Electricity Distribution Businesses* (the Draft Decisions Paper). At the same time the Commission released the Economic Insights (EI) report *Electricity Distribution Industry Productivity Analysis: 1996-2008* (the EI Report). Both papers are primarily focused on developing draft recommendations for empirical values of the parameters used to reset the default price-quality path (DPP) for the electricity distribution businesses (EDBs). In doing so, both papers present some comments on the methodology that Pacific Economics Group (PEG) has recommended for estimating the EDBs' total factor productivity (TFP) growth.

The Electricity Networks Association (ENA) asked me to respond to these comments on PEG's TFP methodology. The ENA believes that any potential misunderstandings of PEG's TFP study should be addressed, even if there are no immediate implications for the DPP. A better understanding of the application of TFP to utility regulation should put the foundation for resetting the DPP on a more firm conceptual foundation and thereby promote regulatory stability. PEG's TFP research has been misinterpreted and mischaracterized in this proceeding, but addressing these misconceptions provides an opportunity to clarify the relationship between changes in regulated prices, unit costs and TFP for utility industries.

I begin by addressing the claims regarding the "indexing logic" and assumptions that underpin PEG's TFP specification. I then briefly discuss the theoretical framework which motivates EI's analysis and explain how EI's analysis is focused entirely on theoretical issues rather than practical TFP measurement. Next, I consider the extent to which the PEG and EI TFP methodologies address two very concrete regulatory concerns (reflecting capital replacement expenditures, and enabling industry-wide revenues to track changes in industry costs). The final section provides brief concluding remarks, and a technical appendix presents details on the decomposition of TFP.

## 2. PEG'S TFP SPECIFICATION

The EI Report makes some startling claims about PEG's TFP specification. Most importantly, they say that

...much of the PEG (2009a,b) analysis is not appropriate because it attempts to treat energy distribution as if it were a competitive industry. The PEG analysis does not recognise the increasing returns to scale nature of the industry and the presence of sunk costs which means the 'indexing logic' PEG uses is inappropriate. It is precisely because of these features that the industry is being regulated.

Large parts of the PEG reports on Economic Insights (2009a,b) are thus based on assessing the Economic Insights framework and key conclusions using the PEG framework which does not take proper account of important economic characteristics of energy distribution businesses. If one were to accept the PEG competitive industry framework as a starting point this may give the impression that many of the criticisms that are raised have some credibility but this is based on assuming a framework that does not take explicit or adequate account of the underlying economic characteristics of the industry under consideration.

Furthermore, even if the PEG framework were accepted there are numerous problems in its interpretation and implementation (although many of these problems are not considered specifically here). In particular, the PEG TFP framework assumes that all capital invested in electricity distribution businesses is not sunk, ie it is variable and can be readily bought and sold in a competitive market and switched to alternative uses. The PEG TFP framework also does not make any explicit allowance for the scope for prices to reflect monopoly or market power related mark ups, ie output prices are assumed to be competitive.

It is well recognised by Economic Insights that a focus of the approach to regulation in New Zealand and in many other jurisdictions is to try to regulate natural monopoly industries to mimic the outcomes that would arise in a 'workably' competitive market. However, there is a big difference in assuming a framework that relies on assumptions that a competitive market exists, as PEG does, and developing a framework that takes account of relevant characteristics not consistent with a competitive market in order to provide guidance on appropriate regulatory decisions to help achieve conditions consistent with a competitive market outcome, which is what Economic Insights (2009a,b) does.<sup>1</sup>

The Commission has apparently accepted these claims, and applied them more broadly to the "traditional" X factor formula. In the Draft Decisions Paper, the

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<sup>1</sup> Economic Insights (2009), *Electricity Distribution Productivity Analysis: 1996-2008*, p. 48.

Commission wrote that “the traditional formula is underpinned by a number of assumptions that are not relevant to EDBs – notably that the relevant markets are perfectly competitive and that capital is perfectly fungible.”<sup>2</sup> EI advanced the claim about capital fungibility in its earlier reports, but its new claim that the traditional approach to TFP estimation for regulated industries (ironically) assumes that these industries are competitive was presented for the first time in this proceeding in the most recent EI Report.

These claims by EI are entirely incorrect. PEG’s TFP specification relies on accounting *identities* which are true by definition. The ‘indexing logic’ results by applying straightforward algebra (and just a little calculus) to these accounting identities. Since the identities are true by definition, they are completely general and apply to an industry regardless of the degree of competition or whether it is characterized by constant or increasing returns to scale. PEG’s derivation relies on just a single assumption, but this assumption applies to a *regulatory* objective, not the cost characteristics or state of competition in the industry. Moreover, this assumption is consistent with the Framework established in the Draft Decisions Report, and one which I believe the Commission will support.

It is easy to show mathematically that PEG’s specification does not assume the industry is characterized by constant returns to scale or perfect competition in factor or product markets. I addressed the capital fungibility issue in my previous submission but will deal with it again in the following section. The analysis below simply reprises the indexing logic presented in PEG’s earlier report, although it provides a bit more detail and rearranges the order of the equations to elucidate the relationships more clearly. However, it is mathematically equivalent to the “indexing logic” presented in my earlier reports.

I begin by noting that the cost of any industry (or enterprise) can be expressed as the product of an index of input prices ( $W$ ) and an index of input quantities ( $X$ ), as summarized in equation [1]:

$$C = W * X \quad [1]$$

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<sup>2</sup> Commerce Commission, *Draft Decisions Paper: Initial Reset of the Default Price Quality Path for Electricity Distribution Businesses*, p. 79.

It should be recognized that this expression applies to *any* industry, regardless of the degree of scale economies inherent in that industry's production technology. If we take logarithms of both sides of (1) and differentiate, we obtain the following expression

$$\Delta C = \Delta W + \Delta X \quad [2]$$

Here the 'delta' symbol ( $\Delta$ ) refers to the rate of change of the variable in question with respect to time. Equation (2) has a straightforward and intuitive interpretation. It says that the rate of change in an industry's cost can be decomposed into two pieces: the change in the industry's input prices; plus the change in input quantities purchased by the industry.

We can also specify an index of output quantity  $Y$  for the industry. The rate of change of industry output quantity is therefore given by  $\Delta Y$ . If we subtract  $\Delta Y$  from both sides of [2] it is not changed. Doing so yields

$$\Delta C - \Delta Y = \Delta W + \Delta X - \Delta Y \quad [3]$$

Dividing industry cost by the index of output quantity for the industry (*i.e.*  $C/Y$ ) is defined as the industry's *unit cost* ( $UC$ ). The change in industry unit cost is therefore given by<sup>3</sup>

$$\Delta C - \Delta Y = \Delta UC \quad [4]$$

Similarly, industry TFP is defined as the index of industry output quantity divided by an index of industry input quantity ( $TFP = Y/X$ ). The change in industry TFP is therefore given by

$$\Delta Y - \Delta X = \Delta TFP \quad [5]$$

If we substitute [4] in the left hand side of [3], and [5] in the right hand side of [3] and rearrange terms, we have

$$\Delta UC = \Delta W - \Delta TFP \quad [6]$$

Equation [6] is simple but powerful result. It says that the rate of change in unit cost for an industry depends on the growth rate in industry input prices minus the growth rate of industry TFP. In other words, TFP is a *comprehensive* measure of *all* the factors that will lead the unit cost trend for an industry to differ from the trend in prices paid for

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<sup>3</sup> Formally, this expression for the change in industry unit cost can also be obtained by taking logs and differentiating the expression  $(C/Y) = UC$ , as was done in moving from equation (1) to (2).

the inputs used in production. When TFP growth is positive, the TFP trend can therefore be interpreted as the amount by which the industry's unit cost trend has been kept below the trend in input prices confronting the industry.

Equation [6] has several important implications. First, it establishes a direct link between changes in TFP and changes in unit cost for an industry. Second, it shows that TFP is a comprehensive measure of all the factors that lead unit cost growth to differ from input price growth. It should also be recognized that this relationship is entirely general, and will therefore apply to industries that operate under increasing returns to scale technologies (which for utilities typically prevail over a large range of potential output).<sup>4</sup> If input prices and all other variables are equal, a realization of scale economies in an industry will by definition cause that industry's unit cost to decline. Equation [6] says that, when input prices are unchanged, a reduction in unit cost will be reflected in greater measured TFP growth. Thus under this basic indexing logic – which again leads directly to PEG's TFP specification – increasing returns are possible and, when they are realized, they will be captured in the TFP growth rate.

We now turn from cost to revenue. The revenue of any industry (or enterprise) can be expressed as the product of an index of output prices ( $P$ ) and an index of output quantities ( $Y$ ). Below we apply this identity to the regulated EDB industry.

$$R = P * Y \quad [7]$$

Taking logarithms of both sides of (7) and differentiating yields

$$\Delta R = \Delta P + \Delta Y \quad [8]$$

We can also define the change in margin in the EDB industry  $\Delta M$  as follows

$$\Delta M = \Delta R - \Delta C \quad [9]$$

Equation [9] is also entirely consistent with how EI has defined  $\Delta M$  and how this term has been used in its indexing expressions. Since equation [9] applies to the regulated EDB industry, the  $\Delta C$  term in [9] naturally applies to the regulated EDB industry as well. This is consistent with the analysis above which applies to all industries, and we can accordingly apply equations [1] – [6] into any further analysis that follows from [9].<sup>5</sup>

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<sup>4</sup> The degree of scale economies in utility industries often varies depending on the amount of output, with relatively greater scale economies at lower output levels.

<sup>5</sup> More formally, the analysis that follows [9] is specific to the EDB industry and uses the EDB industry equivalents of [1]-[6], but the industry superscripts on variables are suppressed.

Now we come to the one and only assumption in our analysis. We assume that, in productivity-based regulation where a single X factor applies to the entire industry, the regulator wants to set allowed prices so that there is no change in margins for the EDB industry on average *i.e.*  $\Delta M = 0$ . From equation [9], it is clear that if  $\Delta M = 0$  then

$$\Delta R = \Delta C \quad [10]$$

If we subtract  $\Delta Y$  from both sides of [10] it is unchanged and yields

$$\Delta R - \Delta Y = \Delta C - \Delta Y \quad [11]$$

From [8], we can see that  $\Delta R - \Delta Y = \Delta P$ ; we substitute this in the left-hand side of [11].

We also substitute  $\Delta UC = \Delta C - \Delta Y$  from [4] on the right-hand side of [11], and also substitute for  $\Delta UC$  from [8] into the right-hand side of [11], which yields

$$\begin{aligned} \Delta P &= \Delta UC \\ &= \Delta W - \Delta TFP \end{aligned} \quad [12]$$

This is of course the equation that links changes in output prices for the EDB industry to changes in industry input prices minus changes in industry TFP. If we assume that inflation will be measured by the CPI instead of directly by an industry input price index, further manipulation will lead to the “traditional” B factor formula that was used in the TFP thresholds regime. These further manipulations will have no impact on the appropriate industry TFP specification, which is the focus of the current exercise.

This simple analysis has some powerful implications (in addition to those discussed above). First, it focuses specifically on how TFP should be specified in a *regulatory* application for setting the rate of change in utility prices. The regulatory nature of this analysis is apparent in the assumption  $\Delta M = 0$ , or the regulatory objective that the rate of change formula should be calibrated to keep margins for the industry as a whole unchanged. This is the only assumption that appears anywhere in our analysis.<sup>6</sup>

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<sup>6</sup> It may, however, be argued that there are two other implicit assumptions in our analysis. The first is that we are focusing on the industry TFP specification, and not TFP specifications for individual utilities. The second is that we are using historical observed trends to set allowed prices so that  $\Delta M = 0$  rather than projected data on costs and outputs. However, both of these assumptions are explicit in the focus of the Commission’s review, which sets a single X factor in the rate of change formula based on (but not necessarily equal to) achieved productivity growth. These assumptions in PEG’s analysis are therefore clearly compatible with the Draft Decisions Paper.

*This is also the only assumption that underlies the “competitive market paradigm” that was discussed in the earlier PEG papers.* This is evident from the fact that when  $\Delta M = 0$ , the change in industry revenues equals the change in industry costs. The latter was assumed in the earlier papers, but since it is mathematically equivalent to  $\Delta M = 0$  these assumptions are two sides of the same coin. Clearly, this assumption is motivated by the objective of deriving a rate of change formula that mimics the long-run outcome of competitive markets, where the change in industry margins is in fact equal to zero. Our analysis in no way “relies on assumptions that a competitive market exists,” as EI asserts. It is no more valid to say that PEG’s analysis assumes that the regulated industry is competitive than it would be to say that a regulator, acting as a surrogate for competitive market forces which are absent for regulated monopolies, transforms utilities into competitive industries. Such an argument confuses the analogy with reality.

I also believe the assumption that  $\Delta M = 0$  is compatible with the Draft Decisions Report. In my opinion, this is evident in section 6.41, where the Commission says that it will undertake initial price adjustments on a business-specific basis so that costs are equal to revenues for all EDBs. The Commission notes that these price adjustments “would also mean that the final term (in Formula 6 of the Draft Decisions Report) relating to profits is not included (in the rate of change formula), just as the monopolistic mark-up term was not included in the Thresholds B-factor because profitability adjustments were implemented through the separate  $C_2$  factor.”<sup>7</sup> Thus, since the Commission will reset initial prices so that revenues equal costs for each EDB, the DPP will not target margins. Rather, the Commission will set the DPP so that the expected change in margins for the industry overall will be unchanged over the term of the DPP *i.e.*  $\Delta M = 0$ .

The assumption that  $\Delta M = 0$  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 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.

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<sup>7</sup> Commerce Commission, *op cit*, p. 75.

EI agrees that this is a feature of PEG’s TFP specification, but not that it will lead to allocative efficiency or FCM. It writes “...PEG’s (TFP) approach does ensure that industry revenues track costs but the industry costs may include excessive or deficient profits and would not therefore represent real opportunity costs. This feature of PEG’s methodology...is not generally consistent with ensuring the principle of ex ante financial capital maintenance nor with achieving allocative efficiency in increasing returns industries.”<sup>8</sup> In other words, EI agrees that our TFP specification ensures that industry revenues grow at the same rate as industry costs on an *ex ante* basis, but claims that this does not ensure FCM or allocative efficiency because there may be excessive or deficient profits at the outset. Since our rate of change formula fails to include terms that target such excess/deficient profits, EI claims they can be “locked in” under our approach.

This conclusion is flatly incompatible with the framework that the Commission adopted in the Draft Decision. Section 6.41 clearly states that the Commission will make initial price adjustments on a business specific basis to address any concerns it has in relation to individual profit levels. This process will ensure that any concerns in relation to profit levels are reflected in initial prices and therefore cannot be “locked in” by a rate of change formula where industry revenues necessarily track industry costs on an *ex ante* basis.<sup>9</sup> Moreover, throughout my work I assumed that the Commission would undertake such initial price adjustments before the rate of change formula took effect, since this occurs in nearly all productivity-based regulatory application for energy utilities and was expected here as well.

It should also be recognized that all features of PEG’s TFP specification support the objective of having industry revenues track industry costs. This aim underpins my recommendation to use billing determinants as outputs and the use of (deflated) monetary rather than physical capital metrics. PEG’s earlier reports provide an extensive

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<sup>8</sup> Economic Insights, *op cit*, p. 51.

<sup>9</sup> However, this rate of change formula will not ensure that margins are unchanged for every EDB over the term of the controls. This is not desirable public policy (*i.e.* such an approach will effectively destroy incentives to improve cost efficiency) and, even more fundamentally, cannot be achieved (except by chance) with a single X factor, which will be used for this initial Reset of the price controls.

discussion of why these features of our TFP specification are necessary for satisfying this goal, as well as how they flow logically from the indexing logic that is detailed above.

It bears repeating that PEG's TFP specification does not assume that the utility industry is competitive, nor that it is characterized by constant returns to scale, nor that the markets for the factors of production or the utility output is competitive. Equations [1] through [6] above capture the cost conditions of the industry and establish the link between changes in industry TFP and changes in industry unit cost. These equations are general identities that apply for any industry, regulated or competitive. The lion's share of EI's critique rests on the assertion that PEG assumes regulated industries exhibit the characteristics of competitive markets, and this claim is clearly and indisputably false. This does raise a question, however: how can a group of highly competent (even distinguished) regulatory economists come to such a fundamentally erroneous conclusion? The answer is revealing, since it helps to explain the entire analytical approach that EI has taken for this review.

### 3. THE FRAMEWORK FOR THE ECONOMIC INSIGHTS APPROACH

The EI analysis has attempted to embed TFP measurement for CPI-X regulation into economic theory. They are quite forthright about this approach, as the first paragraph of the EI report *The Theory of Network Regulation in the Presence of Sunk Costs* says “(t)he Commerce Commission has engaged Economic Insights Pty Ltd (‘Economic Insights’) to prepare a report which considers the interrelationship between the choice of asset valuation method and CPI–X price paths set using productivity analysis. To adequately address this topic it has been necessary to revisit the theory of regulation and fill in some important gaps which have existed to date.”<sup>10</sup>

Readers familiar with this theory will recognize much of the EI analysis. Indeed, a key point of departure for EI is a literature of more than 50 years that focuses on integrating productivity into a more formal economic theory of production. Undoubtedly, few if any participants in this proceeding are familiar with this history (in fact, most Ph.D. economists are not familiar with this literature either; it is a specialized field within the profession). There would also be no reason to review this highly arcane topic except for two factors. One is that it has led EI to adopt a frame of reference that leads to significant errors, particularly the erroneous claims about PEG’s TFP specification. Second, it leads EI to investigate theoretical puzzles that have no practical implications for regulatory applications of TFP measures.

Although the theoretical debates go back even further, the best starting point for understanding EI’s approach is a Nobel Prize-winning paper published by Robert Solow in 1957.<sup>11</sup> This paper was titled “Technical Change and the Aggregate Production Function.”<sup>12</sup> The purpose of the paper was “to isolate shifts of the aggregate production function from movements along it” (which, given the framework he developed and its application to macroeconomic data from the US, was equivalent to “segregating

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<sup>10</sup> Economic Insights, *The Theory of Network Regulation in the Presence of Sunk Costs*, Report prepared for Commerce Commission, p. 1.

<sup>11</sup> A good discussion of the research before the Solow paper, and Solow’s contribution in integrating much of this work, is Z. Griliches (1996), “The Discovery of the Residual: A Historical Note,” *Journal of Economic Literature*, Vol. 34, 1324-1330.

<sup>12</sup> Solow, R., (1957) “Technical Change and the Aggregate Production Function,” *The Review of Economics and Statistics*, Vol. 39, 312-320.

variations in output per head due to technical change from those due to changes in the availability of capital per head.”) In economic theory, “movements along the production function” correspond to changes in output that are associated with changes in input. “Shifts in the production function” are equivalent to technical change.

Solow’s paper developed three different equations that can be used to isolate shifts in the production function from movements along the function. In retrospect, these equations are simple and straightforward, but regardless of their elegance Solow’s paper represented an intellectual breakthrough. However, Solow was only able to derive these equations by making certain assumptions. In particular, he assumed that there were competitive markets for labor and capital services and, for two of the equations, he assumed a constant returns to scale technology.<sup>13</sup>

Solow showed that, when these conditions are satisfied, then a shift in the production function (*i.e.* technical change) will be equivalent to TFP growth (change in outputs in excess of change in inputs). Solow then applied his model to data on US economic output growth from 1909 to 1949. He estimated that only 12% of this growth in real output per man-hour was due to increased capital intensity, or greater capital inputs (per man-hour). The remaining 88% of real output growth was due to technical change.

Solow’s paper inspired a large amount of subsequent work. Researchers noted that the technical change identified as being the main driver of real per capita output growth was in reality an unexplained “residual.” Many therefore referred to technical change as the “Solow residual” and some even called it “the measure of our ignorance.” Accordingly, there were efforts to undertake more accurate and detailed “growth accounting” in an effort to better explain the sources of economic and productivity growth which, under Solow’s assumptions, was equivalent to technical change.

One of the seminal papers in this literature is “The Explanation of Productivity Change” by Dale Jorgensen and Zvi Griliches.<sup>14</sup> EI also references this paper, and states that this paper underpins our TFP specification. This reference also details some of EI’s

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<sup>13</sup> Solow also assumed what economists refer to as “neutral” technical change, which is an assumption that does not touch on the current debates and will not be discussed further.

<sup>14</sup> Jorgensen, D.W. and Z. Griliches, (1967) “The Explanation of Productivity Growth,” *Review of Economic Studies*, Vol. 34., 249-283.

erroneous reasoning on why PEG's TFP specification assumes that the industry in question must operate under competitive market conditions. They write:

Equation (4) on page 38 of PEG (2009a) is essentially based on the seminal work of Jorgenson and Griliches (1967) which shows that the primal and dual methods for calculating TFP growth coincide under certain conditions. In other words  $Trend P - Trend W = -(Trend Y - Trend X) = -Trend TFP$  is by definition only true when there is competitive price taking behaviour (where prices are equal to marginal cost) and constant returns to scale. For example, if there is not competitive price taking behaviour then equation (1) in PEG (2009a) which equates revenues and costs does not apply so one cannot arrive at (4). Similarly, if there are economies of scale equation (3) need not apply. In addition, the derivation of (3) requires competitive conditions to hold in the factor markets for all the firm's inputs: for example, the marginal cost of each input (including all capital inputs) is assumed to equal its market price in a competitive market in order to arrive at the share terms assumed in the equation. But clearly there is not a competitive market (nor a 'workably' competitive market) for sunk capital in the electricity distribution industry in New Zealand.<sup>15</sup>

However, it is very instructive to review what Jorgensen and Griliches actually say about the relationship between changes in measured TFP growth and the assumptions that EI identifies. Jorgensen and Griliches write:

Our definition of changes in total factor productivity is the conventional one. The rate of growth of total factor productivity is defined as the difference between the rate of growth of real output and the rate of growth of real factor input. The rates of growth of real product and real factor input are defined, in turn, as the weighted averages of the rates of growth of individual products and factors. The weights are relative shares of each product in the value of total output and of each factor in the value of total input. *If a production function has constant returns to scale and if all marginal rates of substitution are equal to the corresponding price ratios, a change in total factor productivity may be identified with a shift in the production function. Changes in real product and real factor input not accompanied by a change in total factor productivity may be identified with movements along a production function.*<sup>16</sup> (emphasis added)

PEG's TFP specification is *identical* to what Jorgensen and Griliches call "the conventional one" [note that this conventional TFP specification includes relative shares of revenue (*i.e.* relative shares of each product in the value of total output) as output

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<sup>15</sup> Economic Insights, *op cit*, p. 49.

weights]. Moreover, Jorgensen and Griliches do **not** say that this conventional TFP specification requires competitive price taking behavior or constant returns to scale. On the contrary, the italicized text makes it clear that these assumptions are necessary **only** if the conventional TFP growth measure is to be identified with and equivalent to a shift in a theoretical production function.

This result is what EI refer to above when they say the “primal and dual methods for calculating TFP growth coincide (only) under certain conditions.” A similar result was also evident in Solow’s work, which was devoted to the specific purpose of distinguishing a shift in the production function from movements along the production function, which Jorgensen and Griliches clearly echo in the italicized text. But whether the “primal and dual methods for calculating TFP growth coincide” has no practical implications on estimating TFP growth to be used in a rate of change formula.<sup>17</sup> As Solow’s work demonstrates, these assumptions come into play **only** when research goes beyond practical TFP measurement and embeds productivity in a formal economic theory of production. This theory can be useful for peeling back the layers of the onion and identifying more disaggregated sources of TFP growth, but it is entirely beside the point if the objective of the analysis is to develop a comprehensive estimate that necessarily reflects all sources of TFP growth.

This is in fact the measure of TFP growth that is required for CPI-X regulation. Recall the implications of the indexing logic that were discussed in the previous section. This logic showed that the TFP measure to be used in productivity-based regulation must be comprehensive and reflect all the factors that lead industry unit cost growth to differ from the growth in input prices facing the industry. The “conventional” TFP approach will produce this estimate of TFP growth and is therefore the appropriate method to use in practical regulatory applications.

The EI report is replete with references to the fact that the PEG TFP specification will not measure technical change because the assumptions necessary for TFP growth to

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<sup>16</sup> Jorgensen and Griliches, *op cit*, p. 250.

<sup>17</sup> There are limited exceptions to this rule, almost always pertaining to the case when X factors are to be “tailored” to the circumstances of individual utilities, but they do not apply in the current proceeding. This point is discussed further below.

be equivalent to a shift in the production function (for the “primary and dual methods for calculating TFP growth to coincide”) are violated for regulated industries. For example:

If there is marginal cost pricing, then  $T^*(t) = \tau(t)C(t)$ ; ie TFP growth is equal to technical change. This is just the dual expression of the usual Solow residual which is identified with technical change (an upward shift in the production function due to improving technology or equivalently, a downward shift in the cost function) and ***under the assumptions of competitive pricing and constant returns to scale, TFP growth is equal to technical change.*** However, if marginal cost pricing does not hold and there are not constant returns to scale, then conventionally defined TFP growth as defined by PEG (2009a) and PwC (2009) is not equal to technical change (pp. 58-59; bold in the original)

...the new (*i.e.* EI) approach highlights important factors that contribute to TFP other than technical progress whereas the traditional (*i.e.* PEG) approach effectively defines TFP as technical progress which is incorrect for natural monopoly industries. The Economic Insights approach identifies those components of TFP growth other than technical progress. (p. 60)

Hopefully it is clear that EI’s belief that PEG has defined TFP as being equivalent to technical change is not only incorrect, but the inverse of what we have done. PEG has intentionally used a TFP measure that includes all contributions to industry TFP growth. Restricting the industry “productivity” measure in productivity-based regulation to the industry’s rate of technical change is not appropriate since this is only one component of TFP growth. EI’s suggestion that “the traditional approach effectively defines TFP growth as technical progress” is also factually incorrect as a statement of how productivity-based regulation has been implemented. I am aware of more than 40 instances where information on TFP trends was used to set the terms of rate of change formulas, and in every one the “productivity” measure was not restricted to technical change.

The last quote from EI also emphasizes that there are components of TFP growth other than technical progress and says that one of benefits of its proposed “new” approach is that it identifies these components.<sup>18</sup> While I certainly concur with the view

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<sup>18</sup> This is evident from the sentences proceeding the statement quoted above, which was presented in the context of supposedly demonstrating that measured TFP growth under EI’s methodology would be equivalent to TFP growth under PwC’s proposed approach. EI wrote that “(h)owever, a question that may arise in the context of interpreting the algebraic example is that if the numerical estimate of TFP is the same under both approaches then why bother with the new

that TFP includes more than technical change, EI's identification of other contributions is not nearly as "new" as they suggest. Other papers in the economics literature have presented similar, although not identical, analyses which provide a framework for decomposing TFP into a variety of components. Indeed, PEG has undertaken such decompositions in our work for utility industries. We have also gone beyond these theoretical exercises and *estimated* the extent to which various factors contribute to TFP growth.

One of these studies was our 2004 analysis of TFP growth for the EDBs in Victoria, Australia, conducted on behalf of the Essential Services Commission of Victoria. The appendix to this submission presents the exact language in that report where we undertook a theoretical decomposition of TFP growth into six separate components. In addition to technical change (termed technological change in that report), these components include the realization of scale economies and the departure of prices from marginal costs, both of which EI explicitly says are neglected in our TFP estimates. PEG applied this equation to data from the Victorian EDBs, and we were able to obtain empirical estimates of some but not all of these factors to TFP growth in Victoria's electricity distribution industry.<sup>19</sup>

This Victorian study provides definitive proof that PEG's measured TFP growth is not equivalent to technical change (either conceptually or empirically). If the data were available, PEG could have implemented this same decomposition formula for the New Zealand EDBs and provided more information on the sources of industry TFP growth. However, there was no reason to do so since it was known that only a single X factor was to be applied to all EDBs. As we stated in our Victorian report (and in the appendix), TFP decompositions are typically desirable in productivity-based regulation only if X factors are to be "tailored to utility circumstances that differ materially from industry norms (either historically or at a given point in time). This can be done by

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approach. There are two answers to this. The first is that the new approach highlights important factors that contribute to TFP other than technical progress whereas the traditional approach effectively defines TFP as technical progress which is incorrect for natural monopoly industries. The Economic Insights approach identifies those components of TFP growth other than technical progress."<sup>19</sup>

<sup>19</sup> In particular, it was not possible to distinguish the inefficiency factor from technological change, or quantify the impact of non-marginal cost pricing, due to lack of data.

developing information on the sources of TFP growth and adjusting the X factor to reflect the impact on TFP resulting from differences between a utility's particular circumstances and what is reflected in historical TFP trends." Since a single X factor was to be applied for the rate of change formula, there was no reason to use econometric methods to decompose TFP growth into different components in order to develop company-specific, "tailored" X factors. Ironically, even though EI claims that its TFP framework is superior to PEG's, its decomposition of TFP growth (unlike PEG's) is entirely theoretical and was not practically implemented. Thus EI's analysis would not lead to any practical benefit in this review even if the Commission was interested in developing multiple, tailored X factors.<sup>20</sup>

In sum, EI's belief that PEG's TFP specification assumes that the EDB industry is competitive and characterized by constant returns to scale is entirely a strawman of its own construction. EI was apparently driven to this erroneous conclusion because the frame of reference it adopted for its work was entirely theoretical rather than practical. EI's analysis is firmly rooted in the "growth accounting" theoretical literature which (going back to Solow's 1957 paper) *begins* by making the assumptions necessary for TFP growth to be equivalent to technical change, then progressively relaxes those assumptions in order to identify the various contributors to TFP (and in macroeconomic applications, economic) growth. EI apparently believed that PEG adopted the same perspective, but in fact we began from the opposite vantage point and developed a TFP specification that necessarily includes all potential contributions to TFP growth. We could have adopted a more complex analytical framework that decomposed TFP growth into different components, as EI did, but there was absolutely no reason to do so since a single X factor was to be applied to all the EDBs and this X factor should reflect all the contributions to industry TFP growth.

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<sup>20</sup> Another irony is that at least some EI personnel were very familiar with PEG's TFP work in Victoria and the decomposition of TFP undertaken there. In fact, a similar decomposition of partial factor productivity growth for operating inputs into an identical set of contributors (plus an additional factor reflecting the impact of capital stock) was described by EI personnel as "well grounded in economic theory;" see Meyrick and Associates (2007), *Gas Distribution Opex Rate of Change*, Report to the Victorian Gas Distribution Businesses, p. 3. It should therefore have been clear that PEG neither assumes that TFP is equivalent to technical change, nor that PEG's TFP estimates include only technical change.

Finally, I believe this historical overview may shed light on the discussion of EI's views on capital fungibility that appeared in my previous submission. This discussion appears in section 4.2.1.4 of the submission, and below I replicate the sections that pertain most directly to this issue (note: this quote is lengthy, but it is difficult to excerpt this discussion without losing valuable context):

.... Christensen and Jorgensen are drawing a *distinction* between two different options for measuring capital inputs and service prices. One uses direct, market-based rental rates that result from transactions when capital is freely tradable. The other is the ex ante cost of capital measure, which results from an imputation based on the discounted value of the capital services. The authors pose these as *different* approaches towards estimating capital cost; clearly, the ex ante second option does not depend on, or otherwise assume, that assets are freely variable as in the first approach. The Christensen and Jorgensen discussion of the ex ante approach therefore contrasts sharply with the EI exposition, which claims that only “in this freely variable case, the purchase price can be decomposed into a sum of discounted period by period rental prices or user costs...in the case of irreversible or sunk cost investments, the argument in the previous sentence does not work.” Christensen and Jorgensen say otherwise; they note that “factor outlay on capital may be separated (i.e. decomposed) into price and quantity components” in their approach, which they must undertake because capital is *not* freely tradable, not because it is.

This discussion shows that we do not need to assume that capital is freely variable for practical measurement (using the ex ante, Jorgensen measure) of the costs of sunk assets. These capital cost measures can, in turn, be used as components of TFP studies, including TFP studies for electricity distribution networks. While we do not agree with EI's statements regarding the need to assume freely variable capital to measure sunk costs, we do believe they are making a more valid point in another context. That context, however, is one of almost pure economic theory rather than practical utility regulation.

This can be seen by considering two equations that appear in the Theoretical Report. The first is equation (157), which is obtained in the freely variable capital case when the cost function is differentiated with respect to capital.

$$(157) P_k = -\partial c(y,w,k)/\partial k$$

The right hand side is the differential of the cost function with respect to capital; the left hand side is the price of (imported) capital. Compare this with equation (219) where capital is sunk and cannot be varied.

$$(219) P_k = -\partial c^1(y^1, w^1, k^1)/\partial k - \partial c^2(y^2, w^2, k^2)/\partial k ;$$

EI compares these equations, and considers their implications, in an illuminating discussion on page 55:

Recall equation (219) in the previous section, which set  $P_k$ , the purchase price of a new unit of capital, which when installed or built cannot be varied for its useful life, equal to  $-\partial c_1(y_1, w_1, k)/\partial k \geq 0$  (which is the marginal user benefit that this fixed capital stock will generate in period 1) plus  $-\partial c_2(y_2, w_2, k)/\partial k \geq 0$  (which is the marginal user benefit that this capital stock will generate in period 2). These partial derivatives of the opex cost functions play a crucial role in the determination of the rate of opex technical progress as we saw in section 5.4 above; ie recall equation (157) in section 5.4. However, in section 5.4, because we assumed that the capital input was variable, we could argue that the derivative  $-\partial c_1(y_1, w_1, k)/\partial k$  could be closely approximated by its observable user cost. In the present context, we cannot make the same argument due to the fixity of the capital. This fact creates problems for the measurement of technical progress.<sup>21</sup>

The entire focus of EI's discussion here is on the *interpretation* of a derivative. When capital is freely variable, the derivative of cost with respect to capital can be interpreted as, and “closely approximated by, its observable user cost.” However, when capital is sunk, “we cannot make the same argument due to the fixity of capital.” In this circumstance, “the purchase price of a new unit of capital, which when installed or built cannot be varied for its useful life” will be equal to the sum of its marginal user benefits (*i.e.* the sum of opex cost savings in periods one and two that result from this fixed cost investment). The issue of freely variable vs. sunk capital costs is therefore not, in a practical sense, whether their capital service prices and service flows can be measured using “standard” techniques; in both cases, they can. EI is instead investigating how these different capital assumptions relate to the theoretical cost function; the implications for how to define and categorize firms' optimizing behavior with respect to capital inputs; and the corresponding decomposition of TFP growth into distinct components.

If this seems like an exceptionally arcane topic, it has actually received a fair amount of attention in the economics literature. Ever since Solow's pioneering work in the late 1950s, economists have debated the extent to which TFP growth can be interpreted as a shift in the cost function. This is equivalent to evaluating the extent to which measured TFP growth is equivalent to technical progress. It has been established that technical change is only one component of TFP growth, and TFP growth will be equivalent to technical change only when certain assumptions are satisfied. As the passage above indicates, measuring

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<sup>21</sup> Economic Insights (2009a), p. 55.

technical progress is also central to EI's analysis.

However, the extent to which TFP can be interpreted as technical progress, and the degree to which this divergence depends on the fixity of the capital stock, are not issues that have any practical relevance for setting the terms of the DPP. Capital costs can be and have been estimated in multiple TFP studies for energy networks, as well as other industries (such as telecom, railroads and oil pipelines) that have "sunk" assets. The sunk nature of many EDB assets is therefore not a barrier to practical TFP measurement in this proceeding (even using the "standard" ex ante cost of capital approach that PEG is not recommending). EI's Theoretical Report may have much to offer the academic specializing in productivity measurement, but it should be seen as a contribution to a long line of theoretical literature rather than an identification and potential remedy for problems inherent in using "standard" measures of TFP growth in CPI – X regulation.<sup>22</sup>

Perhaps this discussion would have been clarified by explicitly referencing the theoretical literature, beginning with Solow's 1957 paper, that EI was building on and responding to. I was trying to avoid unnecessary digressions into purely theoretical or historical topics, but EI's latest claims have made it necessary to understand how this theory has led to misinterpretations of PEG's TFP specification. This theoretical review has also made it possible to distill the essence of the argument above, hopefully more clearly.

To simplify just a bit, EI's concerns regarding capital fungibility essentially stem from the fact that Solow's 1957 paper (and some subsequent work) assumes perfectly competitive markets for capital services.<sup>23</sup> A perfectly competitive market cannot exist for the *entire* capital stock of an enterprise because some capital assets are 'sunk' and therefore cannot be varied in response to changes in capital user prices. EI therefore contends that "conventional" TFP measures assume that capital markets are perfectly fungible or, in their words, "the PEG TFP framework assumes that all capital invested in electricity distribution businesses is not sunk, ie it is variable and can be readily bought and sold in a competitive market and switched to alternative uses" (p. 48).

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<sup>22</sup> PEG submission , pp. 46-48.

<sup>23</sup> This assumption is necessary for capital to be paid its marginal product, which in turn is necessary to simplify Solow's initial differentiation of the production function. An equation that is very similar to equation (157), referenced in the preceding quotation from EI's Theoretical report, is therefore implicit in Solow's original analysis.

However, this claim is incorrect. The reason is that the assumption that EI finds objectionable is only invoked in *theoretical* work that attempts to embed productivity into formal economic models. More precisely, when EI says (p. 49) “the marginal cost of each input (including all capital inputs) is assumed to equal its market price in a competitive market in order to arrive at the share terms assumed in the (cost) equation,” this statement is not true with reference to developing index-based measures of input quantity, which are the metrics used directly in empirical TFP studies and, hence, the X factor in the rate of change formula. These index-based metrics are computed using data that do not depend either implicitly or explicitly on marginal costs, so there is no need to invoke the price = marginal cost assumption. This assumption is only necessary when researchers attempt to link productivity measures to the *theoretical* cost function. This relationship assumes optimizing behavior by firms, which in a theoretical context will mathematically take effect by differentiating the cost function with respect to individual inputs. The optimal choice for each input (including capital) is then determined by solving for the value where this derivative is equal to zero. The derivative of cost with respect to an input is the marginal cost that EI refers to above. But again, the derivation of this marginal cost occurs only in the theoretical realm of the production function; it plays no role either explicitly or implicitly in the index-based measurement of capital costs or input quantities developed by PEG in this proceeding. Since this assumption plays no role whatsoever in measuring the price or quantity of capital services in “conventional” TFP estimation, EI’s entire discussion of capital fungibility applies to puzzles that exist only at the theoretical level but have no practical implications for TFP measurement.<sup>24</sup>

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<sup>24</sup> An analogy from the field of physics might be the relationship between quantum mechanics, which describe the behavior of very small particles, and general relativity, which describes the relationship between time, space and gravity. Some theoretical implications of quantum mechanics contradict the implications of general relativity, yet physicists agree that both are true when applied to the realms for which they were developed. If a group of scientists – say those working at NASA in 1961 – were given the task of putting a man on the moon before the decade was over, their time would be better spent by addressing the practical challenges that confront them, using the appropriate tools and models, rather than attempting to resolve the theoretical discrepancies that exist below the surface and at a very deep level with the field. Indeed, physicists have attempted to develop such a “unified field theory” for about 80 years and still have not agreed on one. EI has attempted a variant of a unified field theory of regulation in this proceeding, but this effort was focused on theoretical puzzles rather than issues that play any concrete, practical role in TFP measurement.

In closing this section, I should emphasize that none of these remarks are meant to disparage EI's work. This work is impressive on a theoretical level and intriguing for a productivity specialist. Unfortunately, it is motivated by theoretical concerns rather than practical TFP measurement issues that need to be addressed. This approach was not fit for the purpose of this review. In fact, the EI framework has fostered confusion and led to significant misinterpretations rather than enhanced clarity and understanding of the relationship between unit costs, TFP and the rate of change in utility prices. EI may disagree with our TFP specification for other reasons, but they cannot in good faith continue to maintain that PEG's TFP specification assumes that the EDB industry exhibits the characteristics of a competitive market. This is such a serious and fundamental error that, in the interests of developing a full, accurate and transparent record for future proceedings, I believe it should be acknowledged and rectified in the Final Decision.

## **4. IMPLICATIONS OF ECONOMIC INSIGHTS SPECIFICATION**

There has already been extensive debate on the extent to which the EI and PEG TFP specifications satisfy the criteria that the Commission established for this review. I do not want to rehash this debate but do believe it is important to respond to claims that EI has made about two specific issues. The first is alternative capital measures and their ability to reflect capital replacement expenditures. The second is the relationship between changes in revenues and outputs choices in the TFP specification. I deal with each of these issues in turn.

### **4.1 Capital Replacement and the Choice of Capital Measures**

Both the Commission and the EDBs largely agree that capital replacement expenditures are accelerating in the industry (although they differ on the magnitude). Compared with the observed past, if there are greater capital replacement expenditures in the industry, there will be greater growth in the real (*i.e.* inflation-adjusted) unit cost of distribution service. This should be reflected in greater increases in allowed, real distribution prices to recover these higher unit costs. Real price increases are equivalent to a reduction in the X factor (again, compared with what was approved in the past). Furthermore, because these unit cost pressures stem from industry pressures, they should be reflected in either the industry TFP trend or industry input price trend components of the X factor (*i.e.* the impact of increased replacement of EDB assets on economy-wide TFP or input price growth will be negligible or nil).

One of the practical benefits of using (deflated) 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. Since the change in unit cost is equal to the change input prices minus the growth in TFP, a higher volume of capital replacement expenditures (as opposed to an increase in capital asset prices) will necessarily be reflected in a lower measured TFP growth rate. This will, in turn, lead to a lower X factor and greater allowed changes in prices to recover these higher unit costs.

The reason that monetary values reflect the impact of capital replacement expenditures on unit cost growth, and measured TFP growth, more directly than physical metrics is intuitive. When capital is measured by physical counts, the replacement of one asset by another does not impact the physical amount of assets in the system. The change in measured input quantity is therefore zero. All else equal, capital replacement therefore has no impact on measured input quantity growth, measured TFP growth or the X factor.

This is not the case when monetary values are used to measure capital. The monetary value of the replacement capital added to the system almost always exceeds the value of the asset being replaced. Some of this extra cost will no doubt be due to the inflation in capital asset prices that has occurred over the replacement cycle. In addition, new assets can also be more expensive because they are of higher quality. Improvements in asset quality should be reflected in changes in the quantity of assets that are employed, since the utility now effectively has “more” of an asset available for production. Because the costs of replacement assets are greater, a monetary valuation of capital will typically lead to an increase in the amount of measured capital input, which all else equal leads to a reduction in TFP growth and a higher X factor. This contrasts with the use of physical metrics where, as in the example above, replacement expenditures have no impact on the X factor. A higher X factor is appropriate to recover the increase in the EDB’s unit cost.

There is also evidence of this phenomenon in the TFP studies presented by PEG and EI in this proceeding. Below I present data on growth in capital inputs for 2004-2008. This is the period over which capital replacement is widely believed to be accelerating (such an acceleration is also supported by empirical evidence from PEG’s study). EI does not present any data on comprehensive capital input, but it does present information on PFP growth for overhead lines, underground cables, and transformers (Table 1 in the EI Report). I use these PFP estimates, along with the reported growth in EI’s output quantity index, to compute growth in input quantity for overhead (OH), underground (UG) and transformer (Transf) assets over the 2004-2008 period, using the identity that capital input quantity growth = output quantity growth – capital PFP growth. I also develop an estimate of total capital input quantity growth using cost share weights based on information on the user cost of OH, UG, and Transf assets presented in EI’s Table A1 in Appendix A. The results are presented below.

**NZ EDBs' Growth in Capital Input, 2004-2008**

	<u>Total Capital Quantity</u>	<u>OH</u>	<u>UG</u>	<u>Transf</u>
PEG	3.10%			
EI	1.95%	0.66%	2.51%	2.50%

I also computed alternative quantity estimates using the direct capital measures reported for OH, UG and Transf assets in Appendix A. The latter OH and Transf quantity estimates were the same as those reported above, but for some reason the growth in UG assets was smaller in the latter approach (1.96% versus 2.51%); if the latter value is correct, then EI's average increase in total capital input quantity over the 2004-2008 would be 1.76%. In either case, it can be seen that PEG's monetary value of the EDBs capital stock grows more rapidly than EI's physical measure of this capital stock. This is consistent with the fact that PEG's measure is capturing the additional capital input, and upward pressure on EDB unit costs, stemming from accelerated capital replacement expenditures, but EI is not. If all of the differential estimated above was due to capital replacement, and capital accounted for about 60% of costs, then an appropriate adjustment of the X factor for the EDBS developed with physical capital metrics would be approximately -0.7% (*i.e.*  $(1.95\% - 3.10\%) \cdot 0.6 = -0.69\%$ ).

Finally, it should be reiterated that the issue of physical versus monetary capital metrics was debated extensively in the 2008 Ontario incentive regulation proceeding, and the regulator strongly rejected the use of physical capital metrics. EI says that this claim is "incorrect" and contends that

"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 2008, p.12)."<sup>25</sup>

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<sup>25</sup> Economic Insights, *op cit*, p. 67.

This characterization of the Ontario proceeding is plainly incompatible with the Ontario Energy Board's final decision, which states:

The Board accepts the use of U.S. data for the purposes of the derivation of the TFP trend for 3<sup>rd</sup> Generation IR. Use of this data set was supported by PEG and Prof. Yatchew. Ms. Frayer (representing the team that included EI personnel) sought to circumvent the problem through a patchwork of studies that, in the Board's view, are not adequately demonstrated to be based on a series of consistent principles. *Of greatest concern with Ms. Frayer's approach is the measurement of capital, which is inconsistent with the prior Ontario TFP studies and does not appear to have been adopted in any jurisdiction other than New Zealand* (italics added)<sup>26</sup>

It can be seen that the Board does express concern with the "patchwork" approach that London Economics and EI personnel promoted, but contrary to EI's claim it did not conclude that this was "the major problem" with the study. Instead, the Board's "greatest concern" was with the proposed *measurement* of capital, which they explicitly linked to how capital was measured in the TFP study presented in New Zealand. The Board also noted that this approach to capital measurement has not been adopted in any other productivity-based regulation plan, a clear reference to the use of physical capital measures which have, in fact, apparently been adopted only a single time in TFP studies for regulatory applications. EI may disagree with the Board's reasoning, but they cannot dispute that the Board singled out the proposed physical capital measures as their "greatest concern" which led to the rejection of the TFP study supported by EI personnel.

EI also mischaracterizes the nature of the review process in Ontario. The Board members evaluate all proposals before them on an equal, objective basis. This includes the proposal I put forward as an advisor to the Staff of the OEB. There were five days of debate before Board members on a wide variety of incentive regulation topics, and it is clear from the transcripts from that most questions were directed towards me. This is appropriate and not surprising, since the Staff's proposal was the first presented in the proceeding and proposals from other stakeholders were offered in response to the Staff's position. It is also clear from the transcripts that the issue of how to measure capital in TFP studies received a significant amount of attention in the proceedings.<sup>27</sup>

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<sup>26</sup> Ontario Energy Board, *Supplemental Report of the Board*, September 17, 2008, p. 12.

<sup>27</sup> For example, see pp. 55-61 and 67-75 of the transcripts from the March 27, 2008 stakeholder meeting; pp. 76-92 of the transcripts from the August 5, 2008 meetings; and pp. 17-20 and 31-33 in the August 6, 2008 meetings.

Board members consider all the evidence and proposals before them impartially. Indeed, in the first incentive regulation plan that was approved by the OEB in January 2000, they rejected the proposal of the Staff’s advisors and crafted their own plan.<sup>28</sup> In 2008, however, the Board adopted every aspect of my output quantity specification, input quantity specification and TFP estimates for the rate of change formula; the *only* aspect of my TFP recommendation that the OEB “rejected” was the period for which TFP was to be measured. I recommended an 11-year sample period (1995-2006), but the Board selected an 18-year sample period (1988-2006).

#### **4.2 Changes in Revenues and the Choice of the Output Measures**

Another issue that was discussed in the EI Report and the Draft Decisions Paper was the choice of output measures and how these choices impacted the subsequent alignment of changes in revenues with changes in costs during the term of the price controls. PwC supported and expanded on the position put forward in my submission, that the correct outputs for this purpose are the billing determinants. PwC wrote:

‘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.’<sup>29</sup>

EI responded to PwC’s numerical example by saying (p. 53)

“(t)his example does not, however, reflect the proposal in the Economic Insights (2009a,b) reports. 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 market price. But the Economic Insights approach does not entail the exclusive use of an ‘abstract’ output measure with no market price. Thus, the simple PwC example is neither relevant nor reflective of the Economic Insights approach.

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<sup>28</sup> Some EI personnel apparently were part of the team advising the OEB for the first generation incentive regulation plan.

<sup>29</sup> Economic Insights, *op cit*, pp. 52-53.

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 examples. The point is that although some outputs included in the calculation of TFP may not be priced, the price of those outputs that do have a market price must increase sufficiently to ensure revenues align with costs.

EI then re-expresses the PwC example using their notation and shows that it leads to a 13.9% increase in the price of  $Q_1$ , which is very similar to PwC's estimated 14 per cent increase. EI then writes (p. 54) "(t)o 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 (2009b) 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."

However, not only were "estimates of the rate of technical progress and estimates of marginal costs...not presented in the PwC example," this information was never presented or used to develop EI's output quantity index either. EI's "demonstration" of the equivalence of their method and the PwC result is similarly unmoored from the actual methodology that EI used to estimate output growth. This demonstration first assumes an econometric cost function that never appeared in their TFP work, followed by an assumed number of quantitative values of cost function parameters that were never estimated, followed by a series of algebraic manipulations that were never undertaken. The end result of this process demonstrates nothing about EI's method, because the demonstration does not replicate the approach that EI used to estimate output growth. It is also not sufficient to say that EI's example could have been implemented, or represents an equivalent representation of their index-based approach. An econometric approach to estimating TFP would require far more data than index-based methods, would have dramatically increased the complexity of the process, and certainly may not have yielded the parameter estimates that EI assumes. PwC's example therefore stands un rebutted, and the intuition underlying their analysis and ultimate conclusion are both correct.

EI also provides what it calls "a concrete example" of the implications of using PEG's proposed output specification. They write (p. 59):

It may be helpful to provide a concrete example of the distortions that can arise from using simple revenue weights and billable outputs to form an estimate of TFP growth that could be used in setting an X factor. The Australian states of Victoria and Queensland have diametrically opposed charging practices. In Victoria the EDBs place the majority of their charges on the variable components of throughput and, to a lesser extent, peak demand. In Queensland, on the other hand, EDBs place nearly all their charges on fixed components, ie there are negligible throughput and peak demand charges. Throughput has been growing faster than customer numbers in recent years. If billable outputs and revenue weights were used to form the average TFP growth rate across these two states and a common price cap applied based on this then the resulting estimate would be appropriate for none of the EDBs. This is because the output weights used to form the average industry TFP estimate would reflect to any meaningful extent neither the pricing nor the underlying costs of any of the EDBs given the diametrically opposed charging practices of the two states. If the alternative approach of using functional (or economic) outputs (of which billable outputs are a subset) and allowing for both costs and prices in forming output weights is used, then all EDBs are put on an even footing and the resulting TFP estimate will be more appropriate for use in setting a common X factor across all the EDBs

I agree that if two companies differ in terms of the relative revenues collected from two outputs, and those outputs grow at different rates, the revenues for these companies will grow at different rates. PEG's specification would lead to average revenue (and margin) growth that therefore differs from the revenue (and margin) growth for either of the companies. But this result stems entirely from the fact that a single X factor is being applied to the entire industry, so it is impossible to tailor the value of X to be specific to individual company circumstances (which would be a difficult and contentious exercise to attempt).

EI's "functional output" does not solve this problem any more effectively than PEG's. Companies would still start with differences in rate designs and experience different rates of output growth, which would lead to the same outcome of having different rates of revenue and margin growth. If a non-priced "functional" output is added to the TFP specification, the only effect will be to drive a wedge between revenue and cost growth for the industry as a whole (unlike PEG's approach, where industry revenues and costs grow at the same rate), while doing nothing to correct the "problem" for individual companies.

EI's analysis therefore never demonstrates that including unbilled outputs in the output specification ensures that "all EDBs are put on an even footing." This can only be achieved in theory through a more complex, tailored set of X factors, including X factors

that includes company-specific adjustments for the differences between prices and marginal costs by output. EI's approach clearly does not include these adjustments, and developing the required marginal cost information would prove costly, contentious and (almost certainly) unsuccessful given the complexity and data requirements of the exercise.

## 5. CONCLUDING COMMENTS

In conclusion, I remark briefly on the issues of complexity and relevance. It is true that any estimation of industry TFP and input prices will involve a certain “irreducible” level of complexity, but there is no reason to make this exercise more complex than necessary. I believe EI’s approach, while interesting to the specialist, simply was not necessary or appropriate for this review. It was motivated by a desire to burrow into the finer points of the economic theory of production and its potential application to utility regulation. However, the “sunk cost” issues that occupy so much of EI’s analysis are puzzles that exist only at the theoretical level and not on the more practical plane of TFP measurement. This theoretical frame of reference also led EI to misinterpret and mischaracterize PEG’s TFP specification.

I also believe that, if the Commission continues down this path, the EDBs and customer groups will literally never understand the rationale for how their prices are adjusted under the rate of change formula. Frankly, it’s not reasonable to ask them to try. The EI analysis presupposes a level of expertise that will limit the accessibility of their work to a relatively small number of specialists.

Time constraints probably prevent an immediate resolution of these debates. Nevertheless, I urge the Commission to carefully consider the logic and implications of the TFP specification that I have recommended on behalf of the ENA. I believe that close inspection will satisfy the Commission that it does not suffer from the defects that EI claims, for if it did it would never have been approved by regulators of a diverse set of network industries. I also believe it represents a more transparent and sustainable foundation for effective incentive regulation of New Zealand EDBs, which is why I have recommended that it be adopted in this proceeding.

## APPENDIX: THE SOURCES OF TFP GROWTH

*(Note: this decomposition of TFP growth into various components first appeared on pp. 99-102 of the December 2004 PEG report “TFP Research for Victoria’s Power Distribution Industry,” prepared for the Essential Services Commission of Victoria Australia. A full copy of this report is available at the ESC website or by request from the author).*

There are rigorous ways to set X factors so that they are tailored to utility circumstances that differ materially from industry norms (either historically or at a given point in time). This can be done by developing information on the sources of TFP growth and adjusting the X factor to reflect the impact on TFP resulting from differences between a utility’s particular circumstances and what is reflected in historical TFP trends. To provide a conceptual foundation for such adjustments, below we consider how the broad TFP aggregate discussed above can be decomposed into various sources of productivity change.

Our analysis begins by assuming a firm’s cost level is the product of the minimum attainable cost level  $C^*$  and a term  $\eta$  that may be called the inefficiency factor.

$$C = C^* \cdot \eta . \quad [9]$$

The inefficiency factor takes a value greater than or equal to 1 and indicates how high the firm’s actual costs are above the minimum attainable level.<sup>30</sup>

Minimum attainable cost is a function of the firm’s output levels, the prices paid for production inputs, and business conditions beyond the control of management. Let the vectors of input prices facing a utility, output quantities and business conditions be given by  $\mathbf{W}$  ( $= W_1, W_2 \dots W_J$ ),  $\mathbf{Y}$  ( $= Y_1, Y_2 \dots Y_I$ ), and  $\mathbf{Z}$  ( $= Z_1, Z_2 \dots Z_N$ ), respectively. We also

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<sup>30</sup> A firm that has attained the minimum possible cost has no inefficiency and an inefficiency factor equal to 1. The natural logarithm of 1 is zero, so if a firm is operating at minimum cost, the inefficiency factor drops out of the analysis that follows.

include a trend variable ( $T$ ) that allows the cost function to shift over time due to technological change. The cost function can then be represented mathematically as

$$C^* = g(\mathbf{W}, \mathbf{Y}, \mathbf{Z}, T). \quad [10]$$

Taking logarithms and totally differentiating Equation [2] with respect to time yields

$$\dot{C} = \left( \sum_i \varepsilon_{Y_i} \cdot \dot{Y} + \sum_j \varepsilon_{W_j} \cdot \dot{W} + \sum_n \varepsilon_{Z_n} \cdot \dot{Z} \right) + \dot{g}. \quad [11]$$

Equations [9] and [11] imply that the growth rate of *actual* (not minimum) cost is given by

$$\dot{C} = \left( \sum_i \varepsilon_{Y_i} \cdot \dot{Y} + \sum_j \varepsilon_{W_j} \cdot \dot{W} + \sum_n \varepsilon_{Z_n} \cdot \dot{Z} \right) + \dot{g} + \dot{\eta}. \quad [12]$$

The term  $\varepsilon_{Y_i}$  in equation [4] is the elasticity of cost with respect to output  $i$ . It measures the percentage change in cost due to a small percentage change in the output. The other  $\varepsilon$  terms have analogous definitions. The growth rate of each output quantity  $i$  is denoted by  $\dot{Y}$ . The growth rates of input prices and the other business condition variables are denoted analogously.

Shephard's lemma holds that the derivative of minimum cost with respect to the price of an input is the optimal input quantity. The elasticity of minimum cost with respect to the price of each input  $j$  can then be shown to equal the optimal share of that input in minimum cost ( $SC_j^*$ ). Equation [11] may therefore be rewritten as

$$\begin{aligned} \dot{C} &= \sum_i \varepsilon_{Y_i} \cdot \dot{Y} + \sum_j SC_j^* \cdot \dot{W} + \sum_n \varepsilon_{Z_n} \cdot \dot{Z} + \dot{g} + \dot{\eta}. \\ &= \sum_i \varepsilon_{Y_i} \cdot \dot{Y} + \dot{W}^* + \sum_n \varepsilon_{Z_n} \cdot \dot{Z} + \dot{g} + \dot{\eta}. \end{aligned} \quad [13]$$

The  $W^*$  term above is the growth rate of an input price index, computed as a weighted average of the growth rates in the price subindexes for each input category. The *optimal* (cost-minimizing) cost shares serve as weights. We will call  $W^*$  the optimal input price index.

Recall from the indexing logic presented earlier that

$$TFP = \dot{Y} - \dot{X} \quad [14]$$

And

$$\dot{X} = \dot{C} - \dot{W} \quad [15]$$

The input price index above is weighted using actual rather than optimal cost shares. Substituting equations [14] and [15] into [13], it follows that

$$\begin{aligned} TFP &= \dot{Y} - (\dot{C} - \dot{W}) \\ &= \dot{Y} - \left[ \left( \sum_i \varepsilon_{Y_i} \cdot \dot{Y}_i + \sum_n \varepsilon_{Z_n} \cdot \dot{Z}_n + W^* + \dot{g} + \dot{\eta} \right) - \dot{W} \right] \\ &= \dot{Y} - \left\{ \left[ \left( 1 - \frac{1}{\sum \varepsilon_{Y_i}} \right) \cdot \sum \varepsilon_{Y_i} \cdot \dot{Y}_i + \sum_i \frac{\varepsilon_{Y_i}}{\sum \varepsilon_{Y_i}} \cdot \dot{Y}_i \right] + \sum_n \varepsilon_{Z_n} \cdot \dot{Z}_n + W^* + \dot{g} + \dot{\eta} \right\} - \dot{W} \\ &= \dot{Y} - \left\{ \left[ \left( \frac{1}{\sum \varepsilon_{Y_i}} - 1 \right) \cdot \sum \varepsilon_{Y_i} \cdot \dot{Y}_i + \dot{Y}^\varepsilon + \sum_n \varepsilon_{Z_n} \cdot \dot{Z}_n + W^* + \dot{g} + \dot{\eta} \right] - \dot{W} \right\} \\ &= \left( 1 - \sum \varepsilon_{Y_i} \right) \cdot \dot{Y}_i + (\dot{Y} - \dot{Y}^\varepsilon) - (W^* - \dot{W}) - \sum_n \varepsilon_{Z_n} \cdot \dot{Z}_n - \dot{g} - \dot{\eta} \end{aligned} \quad [16]$$

The expression above shows that growth rate in TFP has been decomposed into six terms. The first is the **scale economy effect**. Economies of scale are realized if, when all other variables are held constant, changes in output quantities lead to reductions in the unit cost of production. This will be the case if the sum of the cost elasticities with respect to the output variables is less than one.

The second term is the **nonmarginal cost pricing effect**. This is equal to the difference between the growth rates of two output quantity indexes. One is the index used to compute TFP growth. The other output quantity index, denoted by  $\dot{Y}^\varepsilon$ , is constructed using cost elasticity weights. The Tornqvist index that we use to measure TFP should theoretically be constructed by weighting outputs by their shares of revenues. It can be shown that using cost elasticities to weight outputs is appropriate if the firm's output prices are proportional to its marginal costs, but revenue-based weights will differ from cost elasticity shares if prices are not proportional to marginal costs. Accordingly,

this term is interpreted as the effect on TFP growth resulting from departures from marginal cost pricing.<sup>31</sup>

The third term is the **cost share effect**. This measures the impact on TFP growth of differences in the growth of input price indexes based on optimal and actual cost shares. This term will have a non-zero value if the firm utilizes inputs in non-optimal proportions.

The fourth term is the **Z variable effect**. It reflects the impact on TFP growth of changes in the values of the Z variables that are beyond management control.

The fifth term is **technological change**. It measures the effect on productivity growth of a proportional shift in the cost function. A downward shift in the cost function due to technological change will increase TFP growth.

The sixth term is the **inefficiency effect**. This measures the effect on productivity growth of a change in the firm's inefficiency factor. A decrease in a firm's inefficiency will reduce cost and accelerate TFP growth. Firms decrease their inefficiency as they approach the cost frontier, which represents the lowest cost attainable for given values of output quantities, input prices, and other business conditions.

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<sup>31</sup> See Denny, Fuss and Waverman *op cit*, p. 197.