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THIRD SUPPLEMENTAL SUBMISSION TO THE AEMC REVIEW INTO THE USE OF TOTAL FACTOR PRODUCTIVITY FOR THE DETERMINATION OF PRICES AND REVENUES

ESC RESPONSE TO JEMENA'S SUPPLEMENTAL SUBMISSION AND A REPORT BY NETWORK ADVISORY SERVICES

SEPTEMBER 2009

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In August 2009, two new documents were submitted to the AEMC in conjunction with its ongoing Review Into the Use of Total Factor Productivity for the Determination of Prices and Revenues. The first (received 11 August 2009) was a supplemental submission by Jemena Ltd. in response to earlier reports by Economic Insights and Brattle Group. Much of Jemena's supplemental submission referenced and responded to the Essential Services Commission (ESC) of Victoria's supplemental submission submitted in June 2009. The second document was a report (released 21 August 2009) by Network Advisory Services titled *Issues in Relation to the Availability and Use of Asset, Expenditure and Related Information for Australian Electricity and Gas Distribution Businesses.* This paper will briefly respond to some issues raised in those documents.

The Jemena submission makes several comments regarding the incentive power report prepared by Pacific Economics Group (PEG) in 2005, which the ESC discussed in our supplemental submission. Jemena wrote that "There has been no substantive public discussion of the PEG report, and the model upon which it is based remains a "black box"—the model has not been made public and its formulation and input assumptions have not been tested independently" (p. 2). On the following page, however, it notes that PEG has written two technical appendices that present key mathematical details underlying the specification and solution of the model, and those appendices are available to readers upon request to the ESC.

The ESC notes that, in our opinion, a standing offer to make a document available to any interested party is equivalent to a publicly available document. Moreover, we have made these appendices available to several people in the industry, including at least one employee at Jemena.[1] Dr. Kaufmann of PEG reports that he has engaged in a series of e-mail exchanges with this employee, and these exchanges involved a certain amount of "testing" of the model's assumptions but were, in any event, designed to educate and make the operation of the model as transparent as possible.

We therefore believe that there is no foundation for Jemena's criticisms but, in order to avoid any confusion on this point, we are attaching the two incentive power appendices to this paper. Both the ESC and PEG would also welcome further discussion of the details of the model, as well as on the detailed spreadsheet model prepared by PEG which was also included in our June 2009 supplemental submission. This spreadsheet model demonstrates the operation and financial implications of TFP-based and building block approaches towards index-based regulation for two hypothetical companies. We believe this spreadsheet can be very instructive for stakeholders that wish to gain a "hands on" understanding of how a TFP-based regulatory option would work in practice, and how it would compare to a building block model applied to the same data. The spreadsheet model is also flexible, and interested parties can experiment with a variety of expenditure, economic growth and related scenarios and trace their

1 This employee is Warwick Tudehope, Manager of Network Regulation and Compliance for Jemena.

implications for the alternative TFP-based and building block regulatory approaches.

Throughout this consultation, the ESC has endeavoured to make the bases for our conclusions as transparent as possible. Towards that end we have presented a wealth of information that can help inform stakeholders on the merits of the alternative approaches. We welcome full public consultation on all the documents that we have submitted and strongly encourage Jemena and other stakeholders to investigate this material.[2]

Jemena also takes exception with the notion that billing determinants should serve as outputs in a TFP study, as demonstrated in the ESC's various submissions during this consultation. Jemena writes (p. 4):

> *…from a practical standpoint, it is clear to us that a network business's principal functions are to provide connections and ensure that there is sufficient capacity to meet network users' requirements (whatever they are) in all but extreme "1 in X" circumstances. Capacity is installed in increments where the size of the increment is determined by forecast maximum peak demand at some time in the future. At any time, installed capacity will almost always exceed actual peak demand which can vary significantly and is outside the distributor's control. The distributor is compensated for the prudently incurred cost of providing that capacity notwithstanding the fact that actual peak demand may reach the capacity limit only rarely. 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.*

The ESC does not dispute any of this, but we note that the entire discussion above refers to the *inputs* that firms need to manage to meet customers' demands. Inputs are not outputs, which are (essentially by definition) the goods and services that customers are actually demanding. This is true in *any* industry. Moreover, in all industries, firms need to manage their inputs in order to provide the outputs that their customers are demanding. Jemena's discussion of its need to add capacity in increments that often exceed their customers peak demands' is no different than the situation facing many capital-intensive firms (*e.g.* steel mills and airlines), yet the outputs of these industries are clearly not defined by the capital that those firms are purchasing but rather by the goods or services that they are providing to their customers through the use of that capital. It is absolutely critical that stakeholders

2 Another criticism that Jemena makes regarding the incentive power model is that its finding that consumer welfare can be lower under building block regulation than traditional cost of service regulation is "implausible." This opinion appears to be based simply on an assumption that incentive regulation must necessarily produce better outcomes than cost of service regulation. It does not consider that, in principle, linking prices to forecast costs (as under building blocks) can unambiguously lead to higher prices than under cost of service regulation (where prices are linked to historical costs) if the approved forecasts are in excess of the utilities' actual costs. Further review of the incentive power model can illustrate this point.

distinguish between inputs and outputs when undertaking TFP studies and the ESC's recommended output specification is consistent with that distinction.[3]

Regarding the Network Advisory Services' (NAS's) paper, the ESC believes that much of this report confirms what many observers already know. It is clear that Australian states and territories do not have detailed, historical time series data of capital expenditures which would ideally be used to construct capital stocks. We cannot change the past, but the fact that the ideal data are not available does not mean that we cannot construct TFP indexes that are consistent with how utility prices are in fact being calculated right now. In fact, since TFP would be used to calculate index-based changes in those prices, TFP calculations would need to use current RAB values so that price levels and price changes would be computed from an internally consistent dataset.

On the other hand, the NAS report does contain a good discussion of issues that should be addressed to ensure that appropriate and comparable data series are calculated going forward. The ESC believes that these discussions are valuable and can help inform future data collection efforts. The development of a practical TFP-based regulatory model should not be directed towards trying to reconstruct the past, but rather in defining and collecting the information that network industries need for effective regulation in the future. Developing higher-quality and more comparable data is equally important for building block and TFP-based approaches to CPI-X regulation

3 In addition, if peak demand is a more significant driver of costs than kWh, then Jemena and other distributors should attempt to design their rates to reflect this reality. Such cost-reflective rate designs would likely contribute to additional TFP growth and consumer welfare more generally. The fact that they have not done so has no bearing on what weights are effectively associated with the outputs that customers are demanding: the output's prices.

Incentive Power and Regulatory Options in Victoria: Technical Appendix

Pacific Economics Group, LLC
Economic and Litigation Consulting

Incentive Power and Regulatory Options in Victoria: Technical Appendix

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TECHNICAL APPENDIX ONE: MATHEMATICAL DETAILS OF INCENTIVE POWER MODEL

A1.1 Cost Assumptions

A1.1.1 Cost Basics

In each year *t*, a utility's total cost (c_t) is the sum of operating and maintenance expenses (co_t) and capital cost (ck_t).

$$c_t = co_t + ck_t \tag{A1.1}$$

The value of a firm's capital stock at the end of each year depreciates in the following year at a constant annual rate *d*. The value of the capital stock is increased each year by the amount of new capital investment $(capex_t)$. Therefore, the value of the capital stock at the end of the year (vk_t) is given by

$$vk_t = (1-d)\cdot vk_{t-1} + capex_t . \tag{A1.2}$$

Capital cost in each year *t* is the sum of the depreciation of the capital stock and the opportunity cost of capital

$$ck_t = (d+r)\cdot vk_{t-1} . \tag{A1.3}$$

A1.1.2 Firm Inefficiency

The minimum cost of service is denoted by $c_t^{\min}$. This is the lowest cost that is achievable given available technology. The firm's actual cost may be higher than the minimum and is given by the equation

$$c_t = c_t^{\min} n_t . \tag{A1.4}$$

Here n_t is the inefficiency factor. It lies in the range $[1,\infty]$. Also, because of demand growth and the need for new investment, we assume that each year both the *minimum* capex and opex increase at rates given by

$$capex_{t+1}^{\min} = \gamma_1 capex_t^{\min} . \tag{A1.5}$$

$$co_{t+1}^{\min} = \gamma_2 co_t^{\min} . \tag{A1.6}$$

A1.1.3 The Technology of Cost Reduction

We assume that cost can be reduced through the firm's "efforts", or pursuit of specific cost reduction initiatives. Suppose that there are F kinds of initiatives available to reduce capex and G kinds of initiatives available to reduce opex. The amounts of each cost reduction initiative undertaken in each period *t* are denoted by $x_{f,t}$ and $y_{g,t}$.

$$\mathbf{x} = x_{1,t}, x_{2,t}, \ldots x_{F,t} \text{ and } \mathbf{y} = y_{1,t}, y_{2,t}, \ldots y_{G,t}. \qquad \text{[A1.7]}$$

If the utility manager is pursuing a given capex reduction initiative *f* in a period $s \leq t$, the impact of the effort on capex is given by

$$\begin{aligned} &\sum capex_{t-1} - capex_t = \sum p_x x_{f,s} + \alpha_x x_{f,s} - \alpha_{xx} x_{f,s}^2 + \delta_x \; x_{f,s} \ln\left(\frac{capex_t}{capex_t^{\min}}\right) \\ &s.t.\, vki_t \geqq vki_t^{\min} \end{aligned} \qquad \text{[A1.8a]}$$

Similarly, when pursuing opex reducing initiative *g* in a period $s \leq t$, the impact of the effort on cost is given by

$$\begin{aligned} &\sum co_{t-1} - co_t = \sum p_y y_{g,s} + \alpha_y y_{g,s} - \alpha_{yy} y_{g,s}^2 + \delta_y \; y_{g,s} \ln\left(\frac{co_t}{co_t^{\min}}\right) \\ &s.t.\, co_t \geqq co_t^{\min} \end{aligned} \qquad \text{[A1.8b]}$$

In each case, there may be certain implementation costs at the start of the project. The terms, p_x and p_y determine these "up-front" costs. These are monetary costs that affect profits and are observed by the regulator and, therefore, can be considered at price reviews. The square term in each effort function implies that there are decreasing returns from cost cutting effort in a given year. The parameters α_{xx} and α_{yy} determine the magnitude of these effects.

The final term in each equation reflects the assumption that cost reduction becomes more difficult as firms approach minimum cost. Thus, the further a firm is from minimum cost the easier it is to achieve cost reductions. The parameters δ_x and δ_y determine the magnitude of these "catch up" effects.

In addition to these monetary costs, the firm also bears implicit "psychic" costs associated with cost reduction activities. This assumption reflects the view that efficiency-boosting activities often impose costs in excess of observed monetary costs (*e.g.* the human costs to both workers and managers when payrolls are reduced).

We assume that these costs are captured in effort functions given by

$$\varphi_t^{\ x} = \sigma_x x_t \quad \text{[A1.9a]}$$

$$\varphi_t^{\ y} = \sigma_y y_t \quad \text{[A1.9b]}$$

We restrict the firm's chosen values of *x* and *y* to be non-negative. This assumption rules out scenarios where firms can engage in wasteful spending to raise their costs in the hope of raising prices at the next regulatory review.

Our specification of the cost reduction process is very flexible. For both opex and capex reduction activities, we can change the values of the parameters α, σ, p, the period when the up front costs are incurred, and the years in which resultant cost reductions occur. Opex and capex reductions can be modeled separately (by setting some parameters to zero) or considered together.

A1.2 Revenue Assumptions

A1.2.1 Revenue Basics

The firm is assumed for simplicity to provide a single service. The quantity of service provided is assumed to be constant. The expected revenue from the service (R_t) is established by the regulator and depends on an approved regulatory plan. Each plan is a combination of the following rules:

- what portion of its earnings the firm is allowed to keep every year through the operation of an earnings-sharing mechanism (ESM)
- how often allowed prices are updated (every 1-10 years)
- how allowed prices are updated when the plan expires. The following options have been modeled.
  - total cost in the last year before the review (a traditional historical test year)
  - a “partial” true up of prices to cost in the last year of the plan: formally this occurs by picking a value $\gamma < 1$ and setting R_t according to the following formula

$$R_t = (1-\gamma)c_t + \gamma c_o \,. \quad \text{[A1.10]}$$

  - a building block adjustment of prices to reflect *projected* costs over the term of the next plan

- a basic building block adjustment plus an efficiency carry over mechanism that phases out efficiency gains that were achieved in the previous plan

A1.2.2 Building Block Forecasts and Allowed Costs

In the building block approach, at the beginning of each plan tern the firm's allowed revenue is set according to

$$\text{allowed revenue}_t = opex_t^{allow} + (r+d)(k_T + capex_t^{allow}) \quad for \quad t = T+1,\ldots,T+N \text{ .[A1.11]}$$

where T is the beginning of the plan tern, N, is the length of the plan term, k_T is the capital entering the beginning of the plan term, and $opex_t^{allow}$ and $capex_t^{allow}$ are allowed operations and maintenance spending and capital spending, respectively, in each year t. In the basic building block formulation, these allowed spending levels are equal to the respective observed cost at the end of the expired plan, plus allowed spending changes, or

$$opex_t^{allow} = opex_T + \Delta opex_t^{allow} . \quad \text{[A1.12a]}$$

$$capex_t^{allow} = capex_T + \Delta capex_t^{allow} . \quad \text{[A1.12b]}$$

Allowed changes in opex and capex depend on the firm's projected changes in opex and capex and the regulator's evaluation of those spending projections. The firm's problem in this case is to choose a sequence of efforts in capex and opex reduction, given by $\{x_t\}$ and $\{y_t\}$, in addition to choosing a sequence of forecasts for capex and opex costs at the beginning of each plan term. These are denoted by $\{FC_t\}_{t=T}^{T+N}$ for capex and $\{FO_t\}_{t=T}^{T+N}$ for opex. Under the "UK parameterization," the regulator determines the sequence of $\{\Delta opex_t^{allow}\}_{t=T+1}^{T+N}$ and $\{\Delta capex_t^{allow}\}_{t=T+1}^{T+N}$ according to the following formulas:

$$\Delta opex_t^{allow} = opex_T \left\{ \frac{FO_t - opex_T \gamma_1^t}{4 opex_T} - .08 \left(\frac{FO_t}{opex_T} \right)^{\frac{FO_t}{opex_T}} \left(\frac{FO_t - opex_T \gamma_1^t}{opex_T} \right) \right\} \text{.[A1.13a]}$$

$$\Delta capex_t^{allow} = capex_T \left\{ .075 + \frac{FO_t - capex_T \gamma_2^t}{4 capex_T} - .08 \left(\frac{FC_t}{capex_T} \right)^{\frac{FC_t}{capex_T}} \left(\frac{FC_t - capex_T \gamma_2^t}{capex_T} \right) \right\} \text{.[A1.13b]}$$

However, as discussed in Chapter Two, the UK parameterization implies that the regulator allows a much lower level of a company's forecast costs to be reflected in prices than was the case in Victoria's first EDPR. We have accordingly developed a

"Victorian Parameterization" of the building block model that generates predictions for forecast and allowed cost levels that are similar to what was observed in the first EDPR. This parameterization retains the same basic mathematical structure as A1.13a and A1.13b but alters the numerical parameters. The specific formulas for the sequence of $\{\Delta opex_t^{allow}\}_{t=T+1}^{T+N}$ and $\{\Delta capex_t^{allow}\}_{t=T+1}^{T+N}$ allowed under the Victorian parameterization are:

$$\Delta opex_t^{allow} = opex_T \left\{ .015 + \frac{FO_t - opex_T \gamma_1^t}{4 opex_T} - .12 \left(\frac{FO_t}{opex_T} \right)^{\frac{FO_t}{opex_T}} \left(\frac{FO_t - opex_T \gamma_1^t}{opex_T} \right) \right\} \quad \text{[A1.14a]}$$

$$\Delta capexx_t^{allow} = capex_T \left\{ .25 + \frac{FC_t - capex_T \gamma_2^t}{4 capex_T} - .12 \left(\frac{FC_t}{capex_T} \right)^{\frac{FC_t}{capex_T}} \left(\frac{FC_t - capex_T \gamma_1^t}{capex_T} \right) \right\} \quad \text{[A1.14b]}$$

The regulator can also undertake "partial" building block true-ups for $opex_t^{allow}$ and $capex_t^{allow}$ as given by the formulas below

$$opex_t^{allow} = opex_T + \varepsilon(opex_{T-N} \gamma_1^N - opex_{T)} + \Delta opex_t^{allow} . \quad \text{[A1.15a]}$$

$$capex_t^{allow} = capex_T + \varepsilon(capex_{T-N} \gamma_2^N - capex_{T)} + \Delta capex_t^{allow} . \quad \text{[A1.15b]}$$

Here T is the last year of the expired plan, N is the length of the plan term, and $opex_{T-N}$ is the opex level in the first year of the expired plan. The parameter $\varepsilon < 1$ and represents the fraction, or the "true up," of allowed opex or capex to actual observed opex and capex, respectively. The changes in allowed opex and capex in [14a] and [14b] are still given by equations [13a] and [13b], respectively.

A1.2.3 Efficiency Carry Over Mechanisms

We explored a number of efficiency carry over mechanisms (ECMs) that begin with the calculation of the net present value (NPV) of the difference between allowed levels of opex and capex and actual spending over the previous plan term. For the first regulatory plan, there is no carry over mechanism. However, at the beginning of each following plan term we calculate the following NPV expressions:

$$NPV_{T+1} = EC_t^{capex} + EC_t^{opex}, \text{ where} \quad \text{[A1.16a]}$$

$$EC_t^{capex} = \sum_{j=T+1-N}^{T} r\beta^{T-j+1}(capex_j^{allow} - capex_j) + \beta(opex_T^{allow} - opex_T) \quad \text{[A1.16b]}$$

$$EC_t^{opex} = \sum_{j=T+2-N}^{T} \{(opex_j^{allow} - opex_j) - (opex_{j-1}^{allow} - opex_{j-1})\} \qquad \text{[A1.16c]}$$

Here, it should be noted that cost savings made in earlier years of the expired plan are worth more in present value terms than those made toward the end of the expired plan.

Given these calculations, a number of alternative ECMs can be added to the firm's allowed revenues. We explored three different ECM formulas.

1. No ECM: This option simply means there is no efficiency carry-over mechanism.
2. Current ECM: If $NPV_{T+1} > 0$ then the firm gets $\max\{EC_t^{opex} + EC_t^{capex}, 0\}$ added onto their allowed revenue.
3. Preferred ECM: The firm gets $EC_t^{opex} + EC_t^{capex}$ added on to their allowed revenue *regardless* of whether NPV_{T+1} is positive or not.

A1.2.4 "Polar" Regulatory Regimes

In addition to the variants of the building block regulatory regimes, we explored three other "polar" regulatory applications. The first is "pure" cost of service regulation, where the regulator is assumed to re-set prices each year based on observed costs at the end of the previous year. We also examined two "pure" external regulatory regimes. One is a pure external benchmark, where revenue is set at the value of an external benchmark at the beginning of the first regulatory plan and never adjusted. Revenue in this case is given by

$$\text{allowed revenue}_t = opex_0 + (r+d)k_0 \quad for \quad t = 1,2,3\ldots \qquad \text{[A1.17]}$$

"Endogenous TFP" is another external regulatory mechanism. Here, prices are external to any given firm, but are adjusted each year by subtracting the total cost savings achieved by a representative firm (*i.e.* a firm with average inefficiency). Since our model assumes no output growth or input price inflation, these cost savings are equal to TFP growth, so allowed prices (revenues) decline at the rate of the industry's TFP growth. This is represented by the formulas below

$$\text{allowed revenue}_1 = opex_0 + (r+d)k_0 \quad for \quad t = 1 \qquad \text{[A1.18a]}$$

$$\text{allowed revenue}_t = (1 - TFP)\text{allowed revenue}_{t-1} \quad for \quad t = 2,3,\ldots \qquad \text{[A1.18b]}$$

A1.3 The Decision Problem

In all regulatory scenarios, the objective of utility management is to choose levels of effort in each period of a lengthy time horizon to maximize the expected net present value of revenues minus both monetary and "psychic" costs. The decision problem can be stated formally as

$$\max_{\mathbf{x}_t\,\mathbf{y}_t} \sum_{t=1}^{\infty} \beta^{t} (\pi_t - \varphi_t) . \qquad [A1.19]$$

Here, β is a discount factor where $\beta = \dfrac{1}{1-r}$ and π_t is the amount of profit where

$$\pi_t = R_t - c_t . \qquad [A1.20]$$

C_t is defined as in [1] and includes all cost reduction efforts. The NPV of total cost savings can be computed by [21] below.

$$\text{cost savings} = \sum_{t=0}^{T} \beta^{t} (c_0 - c_t + \text{cost growth}) . \qquad [A1.21]$$

The cost growth term in [21] comes from [5] and [6]. For example, if we are pursuing an opex reduction initiative and there is opex growth, then the cost growth up to time *t* would be given by $opex_0(\gamma_1^t - 1)$. The same would apply if we are pursuing a project to reduce capex.

Given this definition of cost savings, customer benefits is given by

$$\text{customer benefits} = \text{cost savings - profits} . \qquad [A1.22]$$

In the building block regulatory scenarios, the firm also chooses a path of opex and capex forecasts before the start of a new regulatory plan. The firm's choices for these variables are given by its solution to the problem previously captured in equations [13a] and [13b]. Given these forecasts and subsequent allowed prices, the firm optimizes the objective function given by [19] – [20] in the same manner as a utility that is not subject to a building block regime.

A1.4 Model Solution

Since the model is hard to handle analytically, we wrote a computer procedure that searches over possible values of *x* and *y* to maximize the value of the objective function under a given plan and computes and reports the resulting value of capital, costs, and eventually the present values of profits, cost savings, and total social benefits. This procedure is run for all regulatory plans of interest, and the results for each plan are saved automatically into a text file.

Each plan is a quadratic optimization problem numerically programmed in C++ with non-negative choice variables $\{x_t\}_{t=1}^{T}$ and/or $\{y_t\}_{t=1}^{T}$. We implement an objective function that takes values $x_1, x_2, \ldots x_T$ and returns the value specified by [19] given the regulatory constraints that apply to the given regulatory regime. The sum [19] is computed up to T=120 (instead of infinity), and the price is updated according to the plan rules at the end of each plan term.

The objective function specified above has a unique maximum because it is a quadratic optimization problem. The optimum values of x_i can be either zero or positive. To search for optimal sequence of efforts, we first make 300 random guesses and choose the one that gives the maximum value of the objective function. This first step gives us initial approximated values close to the optimum ones.

In the second step, we implement an iterative converging procedure similar to the "steepest gradient descent" method. The iteration process ends when the next iteration of all x_i differs from the current one insignificantly (by 0.0001).

A1.5 Model Calibration

The following constants were chosen to set initial values for the model:

Parameter	*Value*
R (capital rate)	.078
d (depreciation rate)	.05
β	(discount rate) .93
co_0 (initial opex)	$400,000,000
vki_0 (initial capex)	$234,375,000
vk_0 (initial capital cost)	$600,000,000
n^{ave}	1.25

The initial cost figures are calibrated to the realities of a typical large “wire” or “pipe” business. Assuming an initial total annual cost of $1 billion, 60% takes the form of capital cost while 40% takes the form of opex. Assuming a 5% annual depreciation rate, and a 7.8% cost of funds, the initial value of plant, $4,687,500,000, is the solution to the equation

$$\$600{,}000{,}000 = (.05 + .078) \cdot vk \qquad \text{[A1.23]}$$

Initial capex is assumed to equal the initial depreciation of $.05 \cdot vka = \$234{,}375$. Here are the other important model calibration assumptions:

- We consider two types of opex or capex reduction projects: (1) initiatives that reduce costs permanently, and (2) one-off initiatives in a particular year.
- For permanent cost reduction initiatives we consider cases with payback periods of 1,3, and 5 years. The payback period is defined here as the number of years needed for the company to break even, *i.e.* the time when total cost reductions to date will recoup the up-front costs related to the project.
- The catch up parameters, δ_x and δ_y, are chosen to fit the assumption that a firm that commences a regime of full rate externalization with inefficiencies will eliminate the inefficiencies in 10 years.
- The implicit (regulatory/nuisance) costs φ comprise 20% of the explicit monetary up-front costs UFC (*i.e.* $\sigma = .2p$).

TECHNICAL APPENDIX TWO: MATHEMATICAL CHARACTERIZATION OF UK SLIDING SCALE MECHANISM AND APPLICATION TO VICTORIA

This appendix discusses the "sliding scale mechanism" developed by the Office of Gas and Electricity Markets (Ofgem) in the UK and PEG's adaptation of some key elements of this mechanism to analyzing regulatory options in Victoria. Ofgem's sliding scale mechanism applies to the UK distribution companies' capital expenditures. This mechanism was motivated by Ofgem's view that the distributors have incentives to inflate their planned capex during the next price control period but then "underspend" once an allowed capex is used to set the value of X. Ofgem believes some utilities have actually behaved in this way, although others have not. The aims of the sliding scale mechanism are to:[1]

- retain incentives for efficient capital spending during all years of the control
- reduce the emphasis on Ofgem's or its consultant's view of the appropriate level of capex
- reduce the perceived risk that the price control causes under-investment
- allow but not encourage expenditure in excess of the allowance
- reduce the possibility that companies submitting high capex projections will make very high returns from underspending
- reward companies making "low" capex forecasts
- avoid incentives to underspend in ways that reduce service quality or create service quality problems in subsequent years

The sliding scale mechanism essentially gives companies a choice between:

- a lower allowance for capex reflected in the controls, but with a higher-powered incentive that allows them to retain a greater share of "underspend" relative to the allowance and collect a greater share of "overspend"; or

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[1] Much of the text on this and the following page comes from the Office of Gas and Electricity Markets, *Electricity Distribution Price Control Review: Initial Proposals*, June 2004 pp. 89-94.

- a higher allowance for capex in the controls, but with a lower-powered incentive that lets companies keep a lower share of "underspend" and collect a lower share of "overspend."

Companies also get an additional reward if they do choose the lower allowed capex option, but do not receive this reward if they select higher allowed capex. If the sliding scale mechanism is designed correctly, it is "incentive compatible" and removes incentives for the company to inflate its projected capex. The mechanics of Ofgem's proposed sliding scale mechanism are as follows:

- Ofgem determines a benchmark level of projected capex over the price control period for each REC; in the distribution price review, these benchmarks were determined by the engineering consulting firm PB Power
- Each REC presents its actual capex projections over the price control period
- Ofgem determines a capex *allowance rate*, *additional income* and a capex *incentive rate* depending on the relationship between benchmark and forecast capex. The allowance rate is the total amount of capex that will be allowed in the controls; this number is specified as a multiple over the benchmark level. The additional income term is an addition to the distributor's allowed revenue that also depends on the relationship between benchmark and forecast capex. The incentive rate is equal to the portion of capital "underspend" the company is allowed to retain. The allowance rate, additional income and incentive rate each increase as the company's forecast gets closer to the benchmark level, and vice versa. This approach therefore rewards companies for keeping their capex forecasts low.

For example, if a company's projects its capex to be 140% of the PB Power benchmark, their capex allowance rate is 115% of the PB Power forecast value. If they over- or underspend relative to this forecast, they get to keep or bear 20% of the difference *i.e.* the marginal incentive rate is 20%. Alternatively, for companies whose capex forecasts are equal to or less than the PB Power benchmarks, their allowance is set at 105% of the PB Power capex forecast. If they over- or under-spend relative to the allowed capex level, they keep or bear 40% of the difference, so their marginal incentive rate is 40%.

Ofgem established the sliding scale mechanism as a matrix which displays the values of the key parameters and how they vary with the forecast/benchmark relationship. The table below captures the main features of the sliding scale matrix.[2]

Forecast (F)/ Bench (B)	Δ	Allowance Rate (AR)	Δ	Incentive Rate (IR)	Δ	Additional Income (AI)	Δ
100		105.00		.40		2.5	
105	5	106.25	1.25	.38	-.02	2.1	-0.4
110	5	107.50	1.25	.35	-.03	1.6	-0.5
115	5	108.75	1.25	.33	-.02	1.1	-0.5
120	5	110.00	1.25	.30	-.03	.06	-0.5
125	5	111.25	1.25	.28	-.02	-0.1	-0.7
130	5	112.75	1.25	.25	-.03	-0.8	-0.7
135	5	113.75	1.25	.23	-.02	-1.6	-0.8
140	5	115.00	1.25	.20	-.03	-2.4	-0.8

The first column shows the ratio between forecast and benchmark capex (in percentage terms). The second column (the "delta") presents the change in the forecast/benchmark ratio from the row above. The third column presents the allowance rate (AR, also in percentage terms) associated with a given forecast/benchmark ratio; this allowance rate is multiplied by the benchmark capex value, and the product determines allowed capex. The fourth column presents the change in the AR from the row above. The fifth column presents the incentive rate (IR) for a given forecast/benchmark ratio; this incentive rate is multiplied by the difference between allowed and actual capex value. The sixth column presents the change in the IR from the row above. The seventh column presents the additional income (AI) associated with a given forecast/benchmark ratio. The eighth column presents the change in the AI from the row above.

To make the insights of the sliding scale mechanism more generally applicable, PEG attempted to distill the relationships inherent in the sliding scale matrix and present

[2] This table is not identical to Table 3 presented in Ofgem, *op cit*, but it does contain all the essential features of that table, and this specification is more useful for our purposes.

them in mathematical formulas. For some relationships, it was possible to do this exactly; for other relationships, there probably is no exact mathematical representation, but we came up with close approximations. We express everything in terms of monetary values (*e.g.* total value of allowed capex). In the formulas below, F refers to the value of the forecast capex, and B refers to the value of the benchmark capex.

The expression below presents the monetary value of allowed capex as it relates to the forecast/benchmark ratio.

$$\text{Allowed capex} = \begin{cases} 1.05B & F < B \\ \left(1.05 + \dfrac{F-B}{4B}\right)B & F \geq B \end{cases} \qquad \text{[A2.1]}$$

The expression below shows the incentive rate as a function of the forecast/benchmark relationship.

$$\text{Incentive Rate (IR)} = \begin{cases} .4 & F < B \\ \left(.4 - \dfrac{F-B}{2B}\right) & F \geq B \end{cases} \qquad \text{[A2.2]}$$

This is not an exact match to the sliding scale matrix, but it does “split the difference” between the deltas in this incentive rate as it varies with the forecast/benchmark ratio. That is, it can be seen that the deltas in the IR alternate between -.02 and -.03; the formula above computes a delta IR of -.025 for any given change in the relationship between forecast and benchmark capex.

The expression below presents the additional income as a function of the forecast/benchmark relationship.

$$\text{Additional Income (AI)} \approx \begin{cases} .025\text{B} & F < B \\ \left(.025 - .08\left(\dfrac{F}{B}\right)^{F/B}\left(\dfrac{F-B}{B}\right)\right)B & F \geq B \end{cases} \qquad \text{[A2.3]}$$

Again, this is not an exact match with what is in the sliding scale matrix, but it can be shown that is a very close approximation for values of this relationship within the bounds indicated by the sliding scale matrix.

To apply this to Victoria, PEG used the allowed capex and AI formulas derived above to characterize allowed capex as a function of a distributor's forecasts. The "incentive rate" is not applicable in Victoria since the Commission applies an efficiency carry-over mechanism to differences between allowed and actual spending (for both opex and capex). Ofgem's incentive rate is essentially an alternative to the efficiency carry over mechanism with regard to the treatment of differences between allowed and actual expenditures. We therefore determined the allowed value of capital spending as the sum of the allowed capex and AI formulas above.

In addition, Victoria has espoused a fairly specific means of establishing capex and opex "benchmarks." The "benchmark" for capex in Victoria will be given by the trend growth in capex, and a distribution business's (DB's) forecasts are evaluated relative to the observed growth trend. The "benchmark" for opex is the "revealed" spending level observed at the end of a regulatory plan; a DB's projected opex changes over the next regulatory plan are evaluated relative to this benchmark. We incorporate these "benchmark" assumptions into our incentive power model.

Recall that in the incentive power model, allowed opex and capex spending in each period *t* are given by equations [12a] and [12b] presented in Technical Appendix One. These equations are reproduced below.

$$opex_t^{allow} = opex_T + \Delta opex_t^{allow} \qquad \text{[A2.4]}$$

$$capex_t = capex_T + \Delta capex_t^{allow} \qquad \text{[A2.5]}$$

Here, period *T* is the last observed year in the expired regulatory plan. We need expressions for allowed changes in opex and capex. We begin by summing the allowed capex and AI formulas above and dividing each by the value of *B*, which expresses spending in percentage change terms.

$$0.75 + \frac{F-B}{4B} - .08\left(\frac{F}{B}\right)^{F/B}\left(\frac{F-B}{B}\right) \qquad \text{[A2.6]}$$

Next, for capex, we incorporate the growth trend assumptions reflected in equation [5] in Technical Appendix One.

$$0.75+\frac{FC_t-capex_T\gamma_2^t}{4capex_T}-.08\left(\frac{FC_t}{capex_T}\right)^{\frac{FC_t}{capex_T}}\left(\frac{FC_t-capex_T\gamma_2^t}{capex_T}\right) \qquad [A2.7]$$

This expression is then multiplied by the last observed capex value in the expired regulatory plan, which expresses the allowed change in capex in monetary terms. This is given by

$$capex_T\left(0.75+\frac{FC_t-capex_T\gamma_2^t}{4capex_T}-.08\left(\frac{FC_t}{capex_T}\right)^{\frac{FC_t}{capex_T}}\left(\frac{FC_t-capex_T\gamma_2^t}{capex_T}\right)\right) \qquad [A2.8]$$

This is equivalent to equation [13b] in Technical Appendix One. For opex, we perform similar calculations, but note that the "benchmark" is the last observed value of opex rather than the opex trend. This leads to the following formula.

$$opex_T\left(\frac{FO_t-capex_T\gamma_1^t}{4capex_T}-.08\left(\frac{FO_t}{capex_T}\right)^{\frac{FO_t}{capex_T}}\left(\frac{FO_t-capex_T\gamma_2^t}{capex_T}\right)\right) \qquad [A2.9]$$

This is equivalent to equation [13a] in Technical Appendix One.