Incentive Regulation and Benchmarking

Part I: Endogenous Costs and Carry-over Mechanisms

A report for the ACCC by Darryl Biggar

1. This is the first of two papers on incentive regulation and benchmarking prepared for the ACCC as part of the review of the draft Statement on Regulatory Principles.

2. The key points of this paper are as follows:

- The power of an incentive scheme depends on the responsiveness of future regulated prices (or revenues) to cost out-turns in the past. Lower power schemes provide little incentive for cost-reducing effort but also little risk that regulated prices will deviate from costs in such a way that the regulatory scheme is unsustainable and little risk that the regulated firm will cut quality in order to cut costs.

- The maximum sustainable power of an incentive scheme depends on the quality of the exogenous and endogenous information that the regulator can collect about the expected costs of the regulated firm. The greater the quality of this information, the higher the power of the incentive scheme the regulator can operate in a sustainable and credible way.

- Public discussion and debate in Australia concerning incentive mechanisms seems to suffer from a lack of precision in terminology. A complete specification of an incentive mechanism requires a specification of the length of the regulatory period (or the trigger for a review of regulated prices); the extent to which the regulated prices will depend on endogenous versus exogenous cost factors; and the way in which the observed costs in the past (the endogenous factors) are combined to form the regulated price.

- At present the standard approach in Australia involves a five-year regulatory period and the use of external experts to scrutinise the cost proposals of the regulated firm. The draft statement of regulatory principles does not specify how past cost out-turn information is to be taken into account when scrutinising cost proposals. It is not possible at this stage to come to a view on how the external experts use past cost out-turn information (if at all) in reviewing cost proposals. As a result, it is not possible to come to a view on the power of the incentive mechanism currently in use. Therefore it is not possible to come to a view whether or not the use of a "glide path" or "efficiency carry over mechanism" will improve the incentives under the existing regime.

- The current review of the draft Statement of Regulatory Principles represents an opportunity to clarify, if not the precise mechanism, the properties that the Commission would like to see in an incentive mechanism. This paper proposes three criteria: (a) that the incentive mechanism will yield constant incentives for capex and opex cost savings over time; (b) that the incentive mechanism will yield balanced incentives for capex and opex cost savings; and (c) subject to the other objectives, the Commission would like an incentive mechanism which yields the greatest possible incentives for cost efficiencies.

- The requirement that the incentive mechanism yield constant incentives for cost savings over time restricts the way the future regulated prices can depend on past cost out-turns. Specifically, an incentive mechanism satisfies the criteria if the present value of regulated prices is a function of the present value of the cost out-turn in the previous regulatory period. This class of incentive mechanisms includes the efficiency carry-over mechanism.

- The requirement that the incentive mechanism yield balanced incentives for capex and opex implies that the responsiveness of a change in the present value of the regulated prices to a change in the present value of opex is equal to the responsiveness of a change in the RAB to a change in the capex cost.

- At present it is not possible to state with certainty whether or not the Commission is using an incentive mechanism which has the highest possible power consistent with the other objectives. There may be scope for the Commission to increase the power of its incentive mechanism through greater reliance on exogenous measures of the cost of the TNSPs. This issue is discussed in the next paper.

1. Introduction

1.1 What is incentive regulation?

3. As is well known, the relationship between a regulator and a regulated firm can be viewed as an explicit or implicit contract. The draft Statement of Regulatory Principles refers to this contract as a "regulatory compact".[1] At the broadest level, "incentive regulation" is the use of (usually financial) incentives in this regulatory compact to align the interests of the regulated firm with the objectives of the regulator.

4. There are a number of possible objectives which a regulator might wish to encourage through explicit financial incentives. These include the provision of high quality services, customer responsiveness, nationwide coverage, and so on. In practice, the term incentive regulation is most often used to refer to the use of incentives to induce efficient production by the regulated firm – that is, to induce the firm to choose the combination of inputs, technology and production processes so as to produce a given level of output of a given quality at the least possible cost.

The economic framework

5. In the economic literature, the problem of incentive regulation is usually framed as follows. It is assumed that the costs incurred by the regulated firm depend in part on the level of "cost reducing effort" expended by the managers of the firm.

[1] See chapter 3 in the draft Statement of Regulatory Principles.

This effort is a real social cost but it is not "monetised" in the sense that it does not appear directly in the accounts of the regulated firm.

6. It is assumed that the regulator cannot directly observe the level of cost-reducing effort.[2] Instead, the regulator can only observe the actual costs that the firm actually incurred (ex post). The actual cost out-turn depends, in part, on the level of cost-reducing effort, but it also depends on a number of other factors, such as the quantity and quality of output, the price of inputs, changes in technology, weather and other random events (such as accidents) and the age and quality of the capital stock. The regulator's task is to design an incentive contract which is based only on observable outcomes (such as the costs actually incurred) and which rewards cost-reducing effort.[3]

7. Given an incentive mechanism, the firm will choose to exert effort up to the point where the additional expected profits just matches the cost of an additional unit of effort. Therefore the "power" of an incentive mechanism is determined by the responsiveness of the expected future profits of the regulated firm to changes in the level of cost-reducing effort. An incentive mechanism in which the expected profits of the regulated firm are largely independent of the level of cost reducing effort is a low powered incentive scheme. An incentive mechanism in which the expected profits of the regulated firm increase rapidly with the level of cost-reducing effort is a high-powered incentive scheme.

1.2 The simple one-period case

8. Many of the key issues and principles of incentive regulation can be illustrated in a simple one-period model in which the regulator must set the regulated prices for a firm which produces output in just one period. Let's assume that the firm must produce a known quantity of output.[4] After the output is produced the regulator makes

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[2] In this formulation we are assuming that, if the regulator could observe the level of effort of the regulated firm it would know the expected (but not the actual) cost out-turn with certainty. We are therefore focusing on the "hidden action" or moral hazard problem. In some formulations the regulated firm also has private information about certain parameters (such as the "base" level of costs or the responsiveness of costs to effort) which cannot be observed directly by the regulator. This assumption introduces elements of a "hidden information" or adverse selection problem. In this latter case the regulator can use techniques such as offering a menu of incentive schemes to induce the firm to reveal some of this private information. In the pure hidden action case there is no benefit from offering the regulated firm a menu of choices.

[3] Martin Cave, in 1997 comments to the Department of Treasury and Finance frames the classic regulatory incentive problem as a contract between two agents each of which faces its own incentive or "principal-agent" problem – the regulator (whose principal is the public or consumers of the service) and the regulated firm (whose principal is the shareholders. " As a result, working out how the parties are likely to behave depends upon a range of complex considerations" relating to the objectives of the firm, the objectives of the regulator and the information available to the regulator. In regard to the objectives of the firm, Cave observes that "The firm's shareholders are presumably interested in long-term profits or shareholder value, and possibly the amount of monitoring of the management they have to do. Management behaviour will be determined by the extent of this monitoring, the nature of their contracts for remuneration and the amount of effort they have to put into running the business. The relative importance of these considerations has a major impact on how any system of incentive regulation is likely to operate".

[4] We will assume for simplicity that the regulator can observe demand perfectly so only faces uncertainty about costs. The problem of regulating a monopolist with unknown demand has been

an observation of the firm's costs and determines the amount of revenue the firm is allowed to collect from its customers (or, equivalently, the prices the firm is allowed to charge, which amounts to the same thing if the quantity of output is fixed).

9. In this context, if the regulated revenue is simply set equal to the observed cost out-turn, the profits of the regulated firm are zero, independent of the level of cost reducing effort chosen by the firm. As a result, the firm has very little incentive to exert cost-reducing effort. The firm will exert a low level of cost reducing effort, raising the expected (or average) costs of production. A regulatory mechanism which ties regulated prices or revenues closely to observed costs is a mechanism with relatively weak cost-reducing incentives and is known as a "low-powered" incentive mechanism.

10. If, on the other hand, the regulator sets the regulated prices or revenue in a way which is independent of the firm's observed costs, the profit of the regulated firm will, on average, be higher the higher the level of cost-reducing effort chosen by the regulated firm. As a result the firm will choose a high level of cost-reducing effort and the expected costs of production will be lower. A regulatory mechanism in which regulated prices or revenues are set largely independently of the firm's own observed costs is a mechanism which provides strong incentives for cost reducing effort and is known as a "high-powered" incentive mechanism.

Exogenous and endogenous measures of cost

11. It is useful, at this point, to make a distinction between exogenous and endogenous measures of cost. An exogenous cost measure is an estimate of the costs of the regulated firm which is independent of the actions of the regulated firm. Examples include the average cost out-turns of (a large number of) comparable firms, or a measure of industry-wide productivity growth (assuming a large number of firms in the industry) or the costs of a single comparator firm different from the regulated firm.[5] An endogenous (or "firm-specific") cost factor is a measure of cost which is within the control of the regulated firm, such as the cost out-turn information which is regularly disclosed by the regulated firm itself. The following table provides illustrative examples of different endogenous and exogenous measures of cost.

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addressed by: Lewis, T. and Sappington, D., "Regulating a Monopolist with Unknown Demand", *American Economic Review*, 78 (1988), 986-998 and Lewis, T. and Sappington, D., "Regulating a Monopolist with Unknown Demand and Cost Functions", *Rand Journal of Economics*, 19(3) (Autumn 1988), 438 and Pal, D., "Regulating a monopolist with unknown demand: an alternative approach", *Information Economics and Policy*, 5 (193), 253-267.

[5] The measurement of exogenous costs is discussed in more detail in the companion paper to this paper entitled "Incentive Regulation: Part II: The Use of Exogenous Estimates of Cost: Benchmarking, Yardstick Regulation and Factor Productivity Analysis".

Exogenous Cost Measures	***Endogenous Cost Measures***
• The average of the costs incurred by other firms in the industry; • The costs of a single firm other than the firm being regulated; • The cost estimates produced by an engineering model of a hypothetical efficient network; • An estimate of costs in one period adjusted in subsequent periods by a measure of total factor productivity changes in the industry as a whole;	• The costs incurred by the regulated firm in the past; • An average of industry costs when there are just two or three firms in the industry; • An estimate of costs in one period adjusted in subsequent periods by a measure of TFP changes of the regulated firm; • The costs estimates produced by an engineering model which is re-calibrated each period according to the costs reported by the regulated firm;

12. These exogenous and endogenous cost measures are only of interest to the regulator insofar as they provide a signal of the level of cost-reducing effort of the regulated firm. Since the observed cost out-turn of a regulated firm depends not only on the level of cost-reducing effort but also on a host of other factors (such as the quantity of output produced[6], the price of inputs and the level of various taxes, fees or charges), the regulator can improve the quality of the signal about the level of cost-reducing effort by observing these other factors and taking into account their influence on the observed costs. For example, it might be that the cost out-turn depends strongly on the price of an input which is determined in a market in which the regulated firm is a price-taker (such as the price of oil). By taking into account the effect of the price of oil on the costs of the regulated firm the regulator can more perfectly isolate the component of cost which is due to the cost-reducing effort (or the "controllable efficiencies" of the regulated firm) alone.

13. This is why, for example, in discussions of incentive regulation it is common to make a distinction between "controllable" and "uncontrollable" costs. The "uncontrollable" costs are those costs which can be accounted for by changes in other observable parameters. Ofgem, for example, strips out property taxes and transmission charges from the costs incurred by distributors to come up with a measure of "controllable" costs. However in order to know how to take into account these other observable factors, the regulator must determine a "cost model" which shows how these other factors affect the observed costs of the regulated firm. This raises a new set of issues which are discussed further in the final section of this paper. For the moment we will assume that we are focusing on the controllable component of costs (i.e., that we have correctly and fully accounted for the effects of any cost-influencing factors).

The fundamental trade-off

14. The power of an incentive mechanism clearly depends in part on the responsiveness of regulated prices to the observed costs of a regulated firm (i.e., the

[6] Since the regulated price is outside the control of the regulated firm, the quantity sold is also outside its control.

endogenous cost factors). The more responsive are the regulated prices to the regulated firm's cost out-turn, the lower the power of the incentive scheme. On the other hand, the greater the reliance of the regulated prices on exogenous cost factors, the higher the power of the incentive scheme.[7] What are the pros and cons of high-powered versus low-powered incentive schemes?

15. Since low-powered incentive schemes yield relatively weak incentives for cost-reducing effort, regulators must rely on other mechanisms to ensure a reasonable degree of cost discipline on the regulated firms. In particular, firms subject to low-powered incentives schemes are usually subject to regular and relatively strict cost reviews, accounting disclosure requirements and audits. In effect, the regulator is put in the position of reviewing all the major expenditure decisions of the firm to determine if they were appropriate and were carried out at least cost. These reviews are costly – consuming regulatory resources – and are sometimes viewed as "intrusive", "micromanagement" or a violation of the normal commercial freedom of the regulated firm's managers.[8] High-powered schemes, to the extent that they lead to strong incentives for cost-reducing effort, can reduce or eliminate the need for close scrutiny of the expenditure decisions of the regulated firm.

16. Higher-powered incentive schemes, however, introduce other costs. Significant departures of prices/revenues from costs can render a regulatory scheme unsustainable. For example, if the incentive mechanism allows outcomes in which the regulated prices/revenues are significantly above costs the incentive scheme may be unsustainable in the sense that no matter what regulatory contract is "agreed" ex ante, it may be impossible to prevent intervention to bring prices more closely into line with observed cost out-turns ex post. This might arise either because the regulator fears that its own performance will be negatively assessed as a result of the apparently

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[7] Note that the power of an incentive scheme may vary with the level of cost reducing effort – that is, a scheme might provide strong incentives for low levels of effort but weaker incentives for higher levels of effort or vice versa. The report by EEE Ltd prepared for the Utilities Regulatory Forum, "The Principles and Practices of Regulating Network Charges" distinguishes between "progressive" and "regressive" incentive schemes. Under a progressive arrangement, the sensitivity of regulated prices to observed costs increases in the level of effort of the observed firm. They note: "In principle the easier it is to achieve efficiency improvements, the less should be the reward, while the more difficult it is, the greater should be the reward. This relationship implies that if the regulated company beats the target, then assuming the price control and target return are set carefully, so the share the company keeps should increase. At first sight this may seem politically unappealing from the regulator's perspective, but the schemes for San Diego Gas & Electric (SDG&E) and Southern California Edison (SCE) are "progressive" increasing to 100% for the company as performance increases. In contrast the benefit share scheme for Keyspan Energy's gas is "regressive" with the benefit share to the company reducing as performance increases." (page 101).

[8] The first lesson from experience that EEE Ltd draw is that "the building block methodology and other bottom up cost-based approaches to revenue determination have become very complicated and intrusive and can verge on micro-management" (page 115). In addition, where the regulated firm is simultaneously subject to two or more different regulatory regimes (e.g., if only some of the firm's services are regulated) a low-powered incentive scheme gives rise to strong incentives for the firm to shift costs from the competitive activities to the services covered by the low-powered incentives. See Sappington (2000, 24). Finally, it is common to mention another draw-back of rate-of-return regulation – that, if the regulated rate of return is above the true cost of capital the firm has an incentive to over-invest in capital relative to other inputs. However, it is not clear if this effect is related to the problem underlying incentive regulation.

high profits of the regulated firm or simply because public pressure on the political system demands action to reduce "excess" profits. Laffont and Tirole (2000) write:

> "A case in point is the 1995 breach of the price cap contracts with the UK regional electricity companies, when Professor Stephen Littlechild, a designer of price cap regulation in the 1980s who had become the UK electricity regulator, had to yield to intense political pressure and reduce the caps substantially ahead of the planned review because the companies were making large profits".[9]

17. Conversely, where it appears that regulated prices/revenues will fall significantly short of costs the regulated firm may be able threaten to shutdown or to defer essential maintenance of the capital stock indefinitely. Again, in the context of public utility sectors (such as electricity) this is unsustainable in the long run. If both the regulator and the regulated firm know that the regulated firm will never be allowed to declare bankruptcy, the regulator cannot credibly commit to an incentive scheme in which bankruptcy is a possibility. No matter how high the power of an incentive scheme appears "on the surface", a regulatory mechanism which threatens substantial departures of regulated prices from observed costs is not credible. Sappington (2000, 29) writes:

> "Credibility problems can arise if regulators unilaterally revise the terms of specified regulatory policy before the scheduled date for reviewing the plan. If such premature intervention is expected, then no matter how strong the financial incentives for cost reduction may appear on paper, they will be seriously compromised in practice. Consequently, the potential gains from regulatory policies like price cap regulation may be minimal in settings where regulators cannot credibly promise to abide by the terms of the announced policy. In such settings, regulators are often better served by regulatory regimes that are more congruent with regulators' limited commitment powers".[10]

18. Because higher-powered incentive schemes can lead to prolonged deviation of prices from observed costs it also places greater pressure on the credibility of the regulatory regime. Under a high-powered incentive scheme it is even more important that the regulator be, and be seen to be, genuinely independent of the regulated firm and other interested parties. This is particular of concern in those countries without an established record of independence of regulatory authorities. Laffont and Tirole (2000) write:

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[9] Laffont and Tirole (2000), page 5.

[10] The Supreme Court of Victoria, in one decision, restricted the extent to which the regulator can make use of pure high-powered incentive schemes. NERA summarises the Court's decision as follows: "having regard to external [i.e., exogenous] information would have to be balanced with the obligation of the [Office of the Regulator General] to give consideration to the specific firm's position [i.e., endogenous factors], by reason of its wider regulatory obligations. In keeping with many other jurisdictions, the Victorian regulator is required, for example, to take account of the costs of supplying the relevant services, to maintain the financial viability of the distribution function and to protect customers from monopoly pricing". NERA Energy Regulation Brief, "Re-setting CPI-X Price Caps: Australian Court Endorses Use of Firm-Specific Costs", June 2001.

> “High-powered incentive schemes give regulators substantial discretion over the firm’s profitability. This raises two opposite concerns. In the first scenario, called regulatory capture, the regulator is too soft on the firm and voluntarily inflates its rent. In the second scenario, called regulatory taking, the regulator is too harsh on the firm and does not adequately compensate the firm for its investments and efficiency improvements. The use of price caps reinforces the need for regulatory independence vis-à-vis the regulated firm and other interest groups”.[11]

19. Another problem with high-powered incentive schemes is that, since regulated firms can usually cut costs by cutting quality, higher-powered incentive schemes place greater pressure on other regulatory mechanisms designed to maintain service quality.[12] If maintaining service quality through regulatory mechanisms is difficult and imperfect, overall welfare may be improved by moderating the power of the incentive scheme. This is particularly an issue where reliability is an important component of quality. It may be very difficult for an observer external to the regulated firm to assess the likelihood of failure of a given component or to detect a small increase in the likelihood of failure that would correspond to a small decrease in service quality. Laffont and Tirole (2000) note:

> “High incentives to reduce cost create a concern for quality. Because the firm bears a higher fraction of its expenditures, it is more prone to skimp on services, and so the regulatory reform should be accompanied by increased attention to quality issues. Regulators in the UK learned their lesson in this matter when they were forced to design new quality measures in response to a degradation of BT service quality a few years after the introduction of a price cap. Similarly customers of US West complained of increased delays after it laid off many workers in response to a switch to incentive regulation”.[13]

20. A final drawback of high-powered incentive schemes is that they shift the risk of cost fluctuations from consumers to the regulated firm. To the extent that this risk is systematic, investors will need to be compensated for this risk in the form of a higher cost of capital. This higher cost of capital may offset or eliminate the gains from greater incentives for cost-reducing effort.

The “optimal” incentive mechanism

21. The incentive mechanism which is most appropriate in any given context will depend on a number of factors, such as the quality of the information the regulator can obtain about the level of cost-reducing effort (this, in turn, depends on the nature of the other influences on the firm’s cost out-turns - i.e., the impact of random factors such as weather, changes in the price of inputs and the level of demand, etc.- and the

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[11] Laffont and Tirole (2000), page 5.

[12] “One common way to reduce costs is to reduce service quality. For example, a telecommunications supplier may reduce its repair and customer assistance staffs in order to limit the wages and benefits it pays to employees. Such staff reductions can cause service quality to decline below historic levels. If historic levels of service quality do not exceed ideal levels, then the resulting decline in service quality under incentive regulation can reduce welfare”. Sappington (2000, 32).

[13] Laffont and Tirole (2000), page 5.

extent to which the regulator can observe these other influences), the quality of exogenous measures of the firm's costs, the ability of the regulator to commit to a long-term regulatory contract and the tolerance of the political and regulatory institutions for variations between prices and observed costs.

22. For example, if there were a number of firms producing similar outputs and facing similar input prices and other cost-influencing factors (such as weather), the regulator could use this (exogenous) information about the observed costs of the other firms to reduce the uncertainty regarding the expected cost of the regulated firm. This would permit the regulator to use a higher-powered incentive scheme with little risk of substantial deviation of the regulated prices from the regulated firm's own costs. (This is discussed further in the companion paper on the use of exogenous cost measures).

23. On the other hand, if the cost out-turn of the regulated firm is subject to substantial period-to-period fluctuation (perhaps due to weather) or if the regulator has very little information on how the costs are likely to evolve over time, the use of a higher-powered incentive scheme is unsustainable. A more moderate incentive scheme may be appropriate.

24. Schmalensee (1989) demonstrates that depending on the conditions faced by the regulator lower-powered schemes such as earnings sharing regulation and perhaps even rate of return regulation can be more appropriate than higher-powered schemes such as price cap regulation. "Although earnings sharing regulation and rate of return regulation limit incentives for cost reduction, they keep prices closer to realised cost and better limit the profit that accrues to the regulated firm".[14]

1.3 Incentive regulation over many periods

25. In practice, of course, the relationship between the regulated firm and the regulator is not a one-off or single-period game, but is on-going, lasting many periods (and, in most cases, indefinitely). This adds several important new dimensions to the basic one-period regulation problem explained above. In particular, in this new context:

(a) the regulator may fix the regulated prices at one moment in time for many periods into the future (in the Australian electricity industry, regulators commonly set prices for five years at a time);

(b) the future regulated prices or revenues may depend on observed cost out-turns extending many periods into the past – this leads to a phenomenon known as the "ratchet effect" which is discussed below;

(c) some of the expenditures of the regulated firm will be for long-lived specific assets. Attempts to measure the "cost" of the regulated firm for any period shorter than the life of the sunk assets will therefore require an allocation (or amortisation) of the costs of those assets to the period in consideration. This

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[14] Sappington (2000,31).

allocation is commonly called the "capital costs" or "capital expenditure" to distinguish it from the costs which are not amortised which are known as "operating expenditure".

In principle cost reducing effort could have an effect in reducing both capital expenditure and operating expenditure. In addition a regulated firm may be able to (i) substitute between capital expenditure and operating expenditure; (ii) change the way that the costs of a long-lived asset are amortized over time (by bringing forward or deferring depreciation); or (iii) exercise discretion in the way it classifies expenditure in its reported accounts. In subsequent sections we will discuss the issue of how to ensure that incentives are "balanced" to prevent substitution between capex and opex and between present and future depreciation.

The "ratchet effect"

26. When an incentive mechanism is repeated over time, the regulator naturally has the opportunity to use information about the past performance of the regulated firm when setting the parameters of the incentive mechanism in the future. For example, if the regulated firm successfully reduces its costs in one period, the regulator may "reward" the firm with tougher targets in the future. A rational regulated firm will anticipate this and will take it into account when choosing its level of effort. In other words, in the repeated regulation context, the power of an incentive scheme depends not just on the responsiveness of the current regulated prices to current cost out-turns but, in addition, on how regulated prices in the future will change in response to cost changes today. This is known as the "ratchet effect":

> "The tendency for performance standards to increase after a period of good performance is called the ratchet effect. The term was originally coined by students of the Soviet economic system, who observed that managers of Soviet enterprises were commonly 'punished' for good performance by having higher standards set in the next year's plan or, even worse, in the next quarter's plan. There are widely known instances of Soviet factory managers who responded to newly installed incentives with massive gains in productivity, only to be denounced on the grounds that their improved performance was proof that they had previously been lazy or corrupt".[15]

27. As in the simple one-period case it is still broadly true that the "power" of an incentive scheme depends on the responsiveness of regulated prices or revenues to a change in the level of cost-reducing effort exerted in any one period. However since, due to the ratchet effect, any given change in effort of the regulated firm may change the regulated prices over many periods into the future, we need to compare the responsiveness of the entire stream of future prices to the level of cost reducing effort today. Equivalently, we will compare the responsiveness of the *present value* of future regulated prices to the level of cost-reducing effort.

[15] Milgrom and Roberts (1992), page 233.

The power of an incentive scheme and the lag between cost changes and price changes

28. In the one-period case we saw that the power of an incentive scheme depends on the extent to which regulated prices depend on exogenous relative to endogenous measures of cost. In the context of on-going (multi-period) regulation, the power of an incentive scheme also depends on the lag between a particular cost out-turn and the time at which that cost out-turn is reflected in the regulated prices. If that lag is long, the present value of future regulated prices is less responsive to changes in costs today than if that lag is short. As a result, the power of an incentive scheme increases the greater the extent to which regulated prices today depend on cost out-turns from further in the past relative to cost out-turns from the recent past.

29. One simple way to increase the power of an incentive scheme is therefore simply to fix the regulated prices each year on the basis of cost out-turns from several years earlier. One such approach is to set the regulated prices on the basis of a simple "moving average" of, say, the five most recent years of cost information. This approach is advocated, for example, by Turvey (2002).[16] Envestra (a gas transmission and distribution company), in a submission to the South Australian regulator, also proposed a version of a moving average carry-over mechanism.[17]

30. However, rather than set the regulated prices every period it may be both easier and cheaper (in terms of regulatory resources consumed) for the regulator to commit to a completely "hands-off" strategy for a fixed period. This has become the common practice in Australia, where the regulatory period of five years has become something of a standard.

2 Issues raised by the "standard" approach

31. In this section we explore the concerns that have been expressed about the use of a five-year regulatory period and some of the approaches that have been tried to address those concerns.

The concept of the carryover

32. At the beginning of each five-year regulatory period, the regulator must specify the path of prices or revenues over the next five years[18]. The currently emerging practice is to set the regulated prices in each period as the sum of two components – (a) the underlying "cost benchmarks"; and (b) a "carryover" of any efficiency gains or losses from the previous period (the difference between the cost out-turn and the "cost benchmarks" in the previous period).

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[16] This approach has the advantage that it yields constant incentives for cost-savings over time (unlike the approach which uses a fixed-regulatory period and a "test year" as discussed next).

[17] See ESCOSA, "Electricity Distribution Price Review: Efficiency Carryover Mechanism: Working Conclusions", April 2003, Appendix A.

[18] Or, if not the actual prices or revenues, a formula that will be used to calculate the prices or revenues on the basis of information which will become available later.

33. There seems to be a relatively widespread misunderstanding that the incentive properties of a particular mechanism depend on the "carryover" component alone.[19] This is wrong. The properties of an incentive mechanism depend on the responsiveness of future prices or revenues to current cost-reducing effort. Since the future prices or revenues consist of the sum of the "cost benchmarks" and the "carryover", the properties of an incentive scheme therefore depend on how *both* the "cost benchmarks" and the "carryover" are set.

34. This observation has one important implication: it is not possible to assess the properties of an incentive scheme without a clear mechanism for setting both the carryover and the cost benchmarks. Although several Australian regulators have set out a particular mechanism by which the "carryover" component will be set[20], there remains significant uncertainty about precisely how the underlying "cost benchmarks" are determined. Later in this paper we will argue that the process by which these "cost benchmarks" is set remains largely a "black box". As long as this process is non-transparent, it will not be possible to make concrete statements about the incentive properties of the existing regulatory regime.

The importance of the present value of future prices / revenues

35. Another important point to recognise is that a regulated firm is only concerned about the *present value* of its future stream of revenue. If the regulated prices each period consist (as above) of the sum of the "cost benchmarks" and the "carryover", then the regulated firm is only concerned about the sum of the present value of the cost benchmarks and the present value of the carryover. Given the present value of the sum of these two components, the particular path followed by the cost benchmarks and the carryover in the future is irrelevant for determining the properties of the incentive mechanism today. In particular, whether the carryover is increasing, decreasing or fluctuating over the five-year regulatory period is irrelevant for determining the properties of the incentive mechanism.

36. The most common approach to setting the "cost benchmarks" is to set the prices in the first year of the regulatory period (perhaps on the basis of some measurement of costs) and then to allow the prices over the rest of the regulatory period to trend upwards or downwards from this starting price. The rate at which prices are increasing or decreasing over the regulatory period is typically known as the "X" factor.[21]

37. If the regulated firm cares only about the present value of cost benchmarks over the regulatory period, then, holding constant the present value of the cost benchmarks, the X factor has no impact on the power of the incentive mechanism. Holding the present value of cost benchmarks constant, a high X factor implies a lower starting price and vice versa, but a high X factor does not imply stronger incentives for cost reduction.

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[19] See, for example, ESCOSA (2003).

[20] Such as the "Rolling carry-over mechanism" proposed by ESCOSA and ORG.

[21] Actually, it is more common to define the rate at which prices are increasing or decreasing as "CPI-X", but when the CPI is constant, this can be reduced to simply "X".

38. This is a very common misconception which is reflected, for example, in the statement of regulatory principles when it states “The strength of the incentive effect will depend in part on … the level of X”.[22]

[22] Draft Statement of Regulatory Principles, page 86. A similar statement appears in the paper by EEE Ltd: “A key feature of incentive regulation is that the regulated organisation has an incentive to out perform X (or the cost estimates assumed in setting the price or revenue cap) and thereby increase its profitability” (page 95). It is sometimes argued that if the X factor is fixed for a long enough period, the regulated firm will be forced to achieve at least that level of efficiency – if it does not, it will become insolvent. However, as mentioned earlier, in the case of public utility industries, the government cannot tolerate any interruption in the supply of services. The failure of the firm is therefore not a credible outcome. Anticipating this, the threat of bankruptcy provides little incentive effect on the regulated firm.

It is possible to derive a link between X and the level of incentives but it is indirect and applies only to the effect on prices (i.e., the cost benchmarks and the carryover) in future regulatory periods. Specifically: (a) the level of X in the current regulatory period is relevant only insofar as changes in the cost benchmarks affect the nature and amount of any carryover in the following regulatory period; and (b) the performance of the firm in the current regulatory period may affect the setting of X (in the cost benchmarks) in future regulatory periods.

2.1 Problems arising with a five-year regulatory period

Changing incentives for cost efficiencies over time

39. We have already emphasised that the power of an incentive scheme depends not only on the sensitivity of the regulated prices to exogenous versus endogenous cost factors but also on precisely how the regulated prices depend on the endogenous factors – that is, how the regulated prices depend on the observed cost out-turns in the past.

40. One particular problem which may arise when the regulator uses a fixed-length regulatory period is that the regulator, when setting the prices for the forthcoming regulatory period, may place particular emphasis on the cost out-turn in just one year of the previous regulatory period. This year is called the "test year" and is usually the last year of the previous regulatory period.[23] But if the future regulated prices depend only on the cost out-turn in the test year, the regulated prices are independent of the cost out-turns in other years. As a result, the regulated firm has high-powered incentives for cost reducing effort in years other than the test year and (since test year costs affect prices for the entire forthcoming regulatory period) reduced (or even negative) incentives for cost reducing effort in the test year.

41. There is some evidence of this effect arising in practice. Frontier Economics, in a paper prepared for Ofgem observe that:

> "There is some evidence to suggest that regulated companies in a number of sectors have responded to these signals, delaying savings that could be made in the last few years of a regulatory period and making rapid reductions in costs in the years immediately after a review."[24]

42. In Australia the use of a five-year regulatory period is a relatively recent development and, in most cases, the first full five-year regulatory period has yet to be completed. To date, the only regulated company to complete a full five-year regulatory period is GasNet. In the case of GasNet the operating and maintenance cost out-turn in the first regulatory period exhibit a clear U-shape. This outcome is consistent with (but not conclusive proof of) the hypothesis of weakening incentives for efficiency at the end of the regulatory period.

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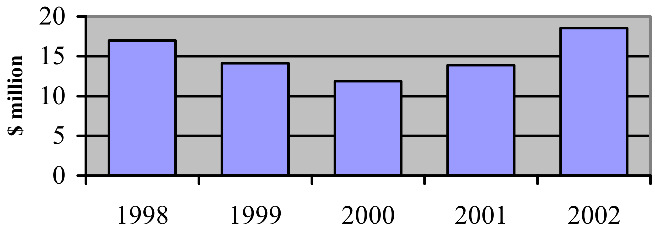
[23] Or, alternatively, the penultimate year of the regulatory period as this is the most recent year for which data is available.

[24] Frontier Economics, "Developing Network Monopoly Price Controls: Workstream B: Balancing Incentives: A Final Report Prepared for Ofgem", March 2003

GasNet actual operating and maintenance costs 1998-2002



Source: ACCC GasNet Final Decision 13 November 2002 Table 6.1

43. Intuitively it is clear that this problem arises from the practice of setting the regulated prices on the basis of the cost out-turn in a single year. If this problem is to be eliminated, therefore, the regulated prices must depend, in some way, on *all* of the cost out-turns in the previous regulatory period.[25]

44. A simple approach is simply to base the regulated prices on the *average* of the costs in the previous regulatory period (in the next section we will discuss a better approach). Pint (1992) shows that even the simple average of past costs exhibits better incentive properties than regulated prices set on the basis of a test year costs alone. Specifically, Pint (1992) compares two incentive mechanisms: (a) a fixed-length regulatory period with regulated prices set on the basis of a test year to (b) the case of a fixed-length regulatory period with regulated prices set on the basis of the average of the costs in the previous regulatory period. She observes:

> "When fixed intervals between hearings are introduced but the price is based on test-year costs, welfare is increased if hearings are not held too frequently, because capital and effort distortions are focused in periods when the firm knows a hearing will occur. However, these welfare gains accrue mainly to the firm in the form of higher profits. A more dramatic change occurs if the price is based on average costs since the previous hearing, when intervals between hearings are fixed. Welfare increases to close to the social optimum, because the firm finds it unprofitable to maintain large enough capital and effort distortions to keep prices high. In this case, gains accrue to consumers and profits fall".[26]

45. In a later section of this paper we will show that it is possible to do even better than using a simple average of the costs of the previous regulatory period.

[25] In the game of golf the handicap of an individual golfer is calculated not on the basis of the results in a single tournament, but on the basis of the golfer's last 20 tournament performances (the average of the ten lowest scores out of the 20 is used).

[26] Pint, Ellen, "Price-cap versus rate-of-return regulation in a stochastic-cost model", *Rand Journal of Economics*, 23(4), Winter 1992

Incentives for capex efficiencies over time

46. As already noted, almost all firms must periodically incur expenses in the purchase or construction of long-lived assets. In order come up with an estimate of the "cost" of the firm in any one year, the regulator must allocate some component of the cost of these sunk assets to the year in consideration. In practice, therefore, the observed "total cost" for any one year consists of the sum of the unamortized costs (better known as operating and maintenance expenditure or opex) and some allocation of the amortized costs (better known as capital expenditure or capex).

47. The previous sections implicitly assumed that the costs incurred by the regulated firm are sufficiently similar from one period to the next that cost out-turns in the past are a good forecast of cost out-turns in the future. While this assumption might be reasonable for operating expenditure (which, by its nature, is on-going and repetitive), it is not likely to be a reasonable assumption for capital expenditure (which tends to be one-off, non-repetitive and lumpy). This raises the question of how the incentives for capex efficiencies might differ from the incentives for opex efficiencies, and how those incentives might vary over time.

48. As the previous discussion made clear, in order to understand the power of the incentives for capex cost efficiency we need to understand the responsiveness of the present value of future regulated prices to the level of capex cost-reducing effort today. As just noted, in a framework in which a distinction is made between capex and opex, the regulated prices are conventionally made up of two components, corresponding to the operating costs and the capital costs. Under an amortizing model such as the building block model, the present value of the capital costs at any point in time is just equal to the level of the regulatory asset base at that time. As a result, the power of the incentives for cost reducing effort on capital expenditure depends on the responsiveness of the regulatory asset base to the capital expenditure out-turn of the regulated firm. If the regulatory asset base is adjusted ex post by an amount equal to the actual capital costs incurred by the regulated firm, the regulated firm will have little incentives to economise on capital expenditure. Conversely, if the regulatory asset base is independent of the actual capital costs incurred by the regulated firm, the firm will have very strong incentives to reduce its capital expenditure to the minimum.

49. The capex out-turn today may affect the regulatory asset base in two ways: the first relates to the direct impact of a project's cost out-turn on the RAB allowed for that project; the second relates to the effect of a project's cost out-turn on the RAB "target" for similar projects in the future:

- First, the regulator may, at the end of the regulatory period, use the observed capex cost out-turn for a particular project to adjust the RAB up or down according to whether the actual cost out-turn for that project was greater or lower than the forecast capital expenditure. This adjustment to the RAB need not be one-for-one in the amount by which the out-turn was above or below the forecast. For example, if the firm spends $10 million less than forecast, the RAB might be adjusted downwards by an amount less than $10 million.

- Second, the regulator may use information on past observed capex cost out-turns in setting the capex forecast for similar projects in future periods. The extent to which past capex cost out-turns provides useful information in setting future capex forecasts obviously depends on the extent to which the capex projects undertaken in the past are similar to those proposed to be undertaken in the future. We can distinguish two cases – in the case of capex projects which are repeated regularly (either because the asset involved has a short life or because the firm has a number of very similar such assets which must be replaced on an on-going and rotating basis) past cost out-turns may be a very good signal of the likely future cost out-turn. Examples might include the upgrading of transformers, or the refurbishment of transmission towers. In contrast, in the case of capex projects which are repeated very infrequently or not at all, the past cost out-turn(s) provide very little information about the cost of capex projects in the future.

50. To summarise, the power of the incentives for cost reducing effort on capital expenditure clearly depends on a number of factors including the extent to which the RAB at the end of the current period is responsive to the cost out-turn; the extent to which the capex project is repeated; and, if so, the extent to which the cost out-turn today affects the RAB at the end of future periods.

Incentives for substitution between capex and opex

51. It appears to be generally accepted that regulated firms can substitute between opex and capex. This might arise, for example, if the maintenance costs of an asset increase with the life of the asset. In this context bringing forward upgrades to the capital stock increases capex but reduces maintenance expenses and therefore opex costs. Conversely, by deferring asset replacement (and thereby increasing the maintenance expenses) a firm may be able to increase opex and reduce capex.[27]

52. An incentive mechanism which gives rise to different "power" of incentives for cost reducing effort for opex and capex creates incentives for the regulated firm to substitute between these two components of cost. For example, if there are high-powered incentives on opex and low-powered incentives on capex, a firm has a strong incentive to substitute capex for opex – any increase in capex has little negative effect on its profit while any decrease in opex has a strong positive effect on its profit. In this case "there are … obvious incentives to capitalise expenses as they add to the asset base and, because operating costs are lower than they otherwise would have been, can project a more efficient management in reducing operating costs".[28] Conversely, a firm facing high-powered incentives for capex efficiencies and low-powered incentives for opex efficiencies has a strong incentive to reduce capex and

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[27] EEE Ltd (2002, 71) note: "There are recognised trade-offs between capital and operating costs; for example more regular inspections and partial replacements can make overhead lines last longer before full replacement".

[28] EEE Ltd (2002, 71). Furthermore: "If efficiency is primarily assessed on the basis of operating costs then companies may have an incentive to substitute capital expenditure for operating expenditure both in terms of their future expenditure plans and in how costs are treated in their accounts because incentives to achieve capital efficiencies are weaker than for operating costs" (page 72).

increase opex. EEE Ltd concludes: "One of the most difficult issues in regulating network charges is to encourage a cost effective trade-off between capex and opex both for transmission and distribution".[29]

53. What is the efficient relative level of incentives for capex and opex cost efficiencies? Ideally, the regulated firm would have an incentive to minimise its total costs. A capex project which has a life of, say, ten years, will have an effect on opex for each of the next ten years. A capex project lowers total cost if and only if the capex increase is smaller than the present value of the opex cost savings over the life of the project. Alternatively, a capex project lowers total cost if and only if the NPV of the project is positive at the margin.

54. In other words, the incentives for cost reducing effort on capex and opex are "balanced" if the change in profits of the regulated firm is proportional to the NPV of the capex project at the margin.

Classification of different types of incentive mechanisms

Before moving to the issues at stake in the ACCC's review of the draft regulatory principles it is worth making the observation that the terminology which is used to discuss various forms of incentive mechanisms is often not precise which can make dialogue and debate difficult.

The previous sections have emphasised that the power of an incentive scheme depends on the following factors:

(a) the length of the regulatory period (i.e., how frequently regulated prices are reset); and

(b) the extent to which the regulated prices depend on observed past cost out-turns ("endogenous" factors) relative to factors outside the control of the firm ("exogenous" factors); and

(c) how the past cost-out-turns are used to set regulated prices over the next regulatory period (i.e., whether past costs are averaged, the weight placed on earlier versus later costs and so on).

In order to be able to evaluate the characteristics of an incentive scheme we therefore need to specify all of the above properties of any given incentive scheme.

In the context of the debate on incentive regulation in Australia it is common to hear discussion of a number of different types of incentive mechanisms including "rate of return" regulation[30]; the "building blocks" approach; and "index based" approaches (with and without so-called "earnings sharing mechanisms" or "off-ramps")[31].

[29] EEE Ltd (2002, 76).
[30] sometimes also called "cost of service" regulation.
[31] Index-based approaches are called by some authors "price cap regulation" although the latter terminology is even less precise.

However, much of the terminology used to describe different types of incentive mechanisms is not precise. For example, does “rate of return” regulation refer to a short or a long regulatory period? If it is a short regulatory period, can regulated prices depend on cost out-turns from several periods earlier? How much can regulated prices depend on exogenous measures of cost while still being called “rate of return” regulation? Because of the ambiguity in terminology, generic comparisons between “rate of return” regulation and, say, “index-based regulation” are difficult.

Arguably, rate of return regulation might be understood to refer to a regulatory mechanism in which the regulator is able to adjust the regulated prices frequently (typically annually). The power of the incentive mechanism under rate of return regulation will therefore depend on how the regulated prices are set – the higher the weight the regulator places on exogenous factors and the less weight the regulator places on recent cost out-turns the higher the power of the incentive mechanism under “rate of return” regulation.

The “building blocks” approach seems, in this context, to be used to denote an approach with a five-year regulatory period (similar to the status quo) with periodic measurement of the (endogenous) cost out-turns. Again, however, the power of an incentive mechanism based on a five-year regulatory period will depend crucially on how the regulated prices are updated each reset – including whether or not the regulator uses a carryover and what form that takes. Again, the higher the weight the regulator places on exogenous factors and the less weight the regulator places on recent cost out-turns the higher the power of the incentive mechanism.

Although there is some variation, the term “index based” (or “price cap”) approaches can be used to refer to incentive mechanisms where regulated prices are primarily set on the basis of factors exogenous to the cost-reducing effort of the regulated firm – such as exogenous estimates of the rate of technological change or an average of the cost out-turns of other comparable firms. This could apply whether the regulatory period is longer (5 or more years) or shorter (such as one year).

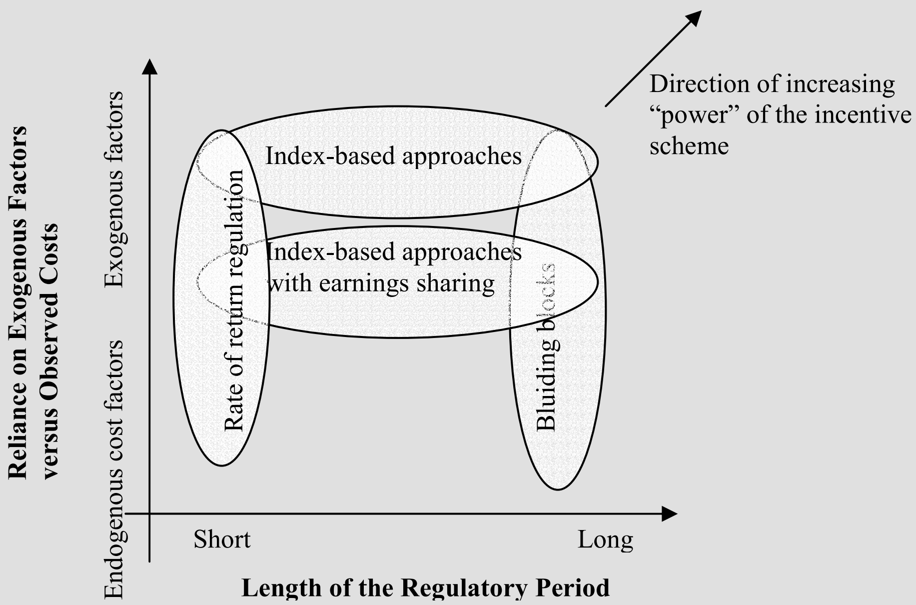
As already emphasised, setting regulated price solely on the basis of exogenous factors is not always sustainable. For this reason, some regulators use a variant of the index-based approach which more closely links the regulated prices to the observed costs of the regulated firm, reducing the power of the incentive mechanism but ensuring that the mechanism is sustainable and therefore credible. One approach is to set the regulated price at the level given by the index-based approach (i.e., independent of the observed costs of the regulated firm) but then, if the observed costs of the regulated firm exceed some threshold[32] (so that the financial viability of the regulated firm is threatened), the regulated price is allowed to increase in proportion to the excess of the observed cost above the threshold. Similarly if the observed cost of the regulated firm falls below some threshold[33], the regulated price is reduced in

[32] Or equivalently, if the observed rate of return of the regulated firm exceeds some threshold.
[33] Or equivalently, if the observed rate of return of the regulated firm falls below some threshold.

proportion to the shortfall of the observed cost below the threshold. These are known as “earnings sharing” or “sliding-scale” mechanisms or “off-ramps”.[34]

These four different approaches can be illustrated as regions on a diagram (see below). As illustrated, rate of return regulation might be taken as implying short regulatory periods, but might include a range of approaches with different reliance on exogenous versus endogenous factors. Similarly, the “building blocks” approach in Australia might be taken as implying longer regulatory periods but, again, the power depends on how regulated prices are reset at the end of a regulatory period. Index based approaches rely (in principle) primarily on exogenous cost factors – but these could be used with either short or long regulatory periods and so on.

This diagram is not intended to provide some clearer definition to the terms that are used. Rather the diagram is intended to emphasise that different terms refer not to specific precise points on this diagram but rather to regions – and, in many cases, these regions overlap. As a result meaningful dialogue using the common terminology is difficult. In this paper we will try to avoid these pitfalls by avoiding terminology and instead specifying each element of the incentive mechanism separately.



2.2 What is the power of the incentive mechanism set out in the draft Statement of Regulatory Principles?

[34] Sappington (2000, 5) describes a typically earnings sharing plan with a target return of 12%. “The firm is authorised to keep all earnings that constitute a rate of return between 10% and 14%. The firm retains half of all incremental earnings between 14% and 16%. The other half of these incremental earnings are awarded to the firm’s customers, usually in the form of direct cash payments or lower prices. The firm is not permitted to retain any earnings that constitute a rate of return in excess of 16%. Any such earnings are awarded entirely to the firm’s customers”.

55. As already mentioned, the power of an incentive mechanism depends on three factors: the length of the regulatory period; the extent to which the regulated prices (i.e., the sum of the "cost benchmarks" and any "carryover") depend on exogenous compared to endogenous measures of cost; and the extent to which the regulated prices depend on recent versus older observations of cost. Does the 1999 draft Statement of Regulatory principles or current ACCC practice specify how each of these factors is calculated in a way which enables us to come to a view on the power of the incentive mechanism set out in the DRP?

The length of the regulatory period

56. On the length of the regulatory period, chapter 6 of the National Electricity Code ("NEC") specifies that the Commission must use a regulatory period of not less than five years. At present the Commission has no plans to adopt a regulatory period for TNSPs longer (or shorter) than five years. Therefore, this aspect of the incentive mechanism is not currently in question.

57. On reliance on exogenous factors, the draft Statement of Regulatory Principles makes no mention of the extent to which the Commission will rely on exogenous versus endogenous factors when it sets the regulated prices for the next regulatory period. (The Electricity Code does express a preference for "CPI-X form or some incentive-based variant of the CPI-X form"[35]. This could be interpreted as a preference for reliance on exogenous factors[36]).

The dependence on endogenous cost factors

58. In keeping with what is now common regulatory practice, the draft Statement of Regulatory Principles specifies that the regulated prices in the next regulatory period are the sum of two components: The underlying "cost benchmarks" and the "carryover". In the draft Statement, the carryover for operating and maintenance expenditures takes the form of a "straight line glide path" over the next regulatory period. As emphasised earlier, since the regulated prices are comprised of both of these components, both are relevant for determining the power of the incentive scheme. In particular, it is incorrect to attempt to attribute the incentive effects to the carryover ("glide path") component alone.

59. The draft Statement of Regulatory Principles specifies in some detail the nature of the carryover ("glide path") component. It explains that "for reasons of simplicity the glide path will be a simple straight line phase out of efficiency gains. That is, for a regulatory period of five years, efficiency gains beyond the X factor would reduce at a rate of 20 per cent per year. Thus, the TNSP will keep 100 per cent of excess efficiency gains for the first year of the next regulatory period, 80 per cent

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[35] NEC 6.2.4 (a)

[36] As this paper argues, there is a significant degree of imprecision in the terminology relating to incentive regulation. There is, therefore, room for debate as to exactly what the Code authors intended. However, it seems likely that they intended a form of "price cap" or "index based" regulation – that is, a regulatory regime based primarily on exogenous indicators of cost. This may be some distance from the current arrangements.

of the excess efficiency gains for the second year, and so on, until all of the excess efficiency gains are phased out by the end of the regulatory period."

60. The "cost benchmarks" are determined by a process which involves inviting the regulated firm to provide estimates of its future costs for the next regulatory period and then seeking the opinion of external experts on the appropriateness of those submitted costs. To the extent that the external experts act as a check on the announced costs of the regulated firms, the question arises as to how those experts arrive at their estimate of the appropriate level of costs. In forming their view do they take into account cost out-turns in the past? If so, do they place more weight on more recent cost out-turns, or older cost out-turns? If cost out-turns were U-shaped (say) would they determine that the most appropriate cost estimate for the next regulatory period is the highest cost out-turn, the lowest cost out-turn or the average cost out-turn? If the external experts do not base their cost estimates on cost out-turns in the past, what other information do they use? How reliable is that information?

61. These questions are, at the present stage, difficult to answer. The process by which the external experts arrive at a view as to the appropriate level of costs is largely a "black box". To the extent that the scrutiny of the external experts acts as a control on the costs of the regulated firms, the precise manner in which the experts determine the appropriate level of cost is of primary importance for assessing the power of the incentive scheme set out in the DRP. To the extent that this process is uncertain or unspecified, the power of the incentives for cost savings will be indeterminate (and possibly varying over time).

62. Furthermore, it seems likely that any attempt to clarify the process by which experts approve the cost estimates of the regulated firm will inevitably involve restricting the discretion of these experts and, to an extent, replacing this discretionary process with a more mechanistic process.

Incentives for capex versus opex efficiencies

63. What does the draft statement of regulatory principles say about the relative power of incentives for capex and opex efficiencies? The draft states that normally the regulatory asset base at the end of a regulatory period will be adjusted to reflect the actual capital expenditure incurred by the regulated firm. "However, the regulated TNSP is invited to demonstrate at each regulatory review that any capital expenditure below forecast levels has arisen because of management induced efficiency gains. Where it is clearly demonstrated by the TNSP that capital expenditure shortfalls have resulted because of management efficiencies or innovations, the capital expenditure efficiency gains may be subject to a glide path, similar to the operations and maintenance expenditure".[37] The details of how the glide path is intended to be applied to capital expenditure are not given.

64. Since any change in the revenue stream of the regulated firm is equivalent to an adjustment to the regulatory asset base we can summarise the position of the draft as stating that the RAB will be adjusted to reflect the actual capital cost out-turn

[37] Draft Statement of Regulatory Principles, page 95.

unless the TNSP can demonstrate that the realized cost savings were due to management efficiencies in which case the RAB will be adjusted by an amount somewhere between the forecast and the actual capital cost out-turn.

65. Without further information on the power of the opex incentives under the present regime, it is impossible to make a definite statement on the relative power of opex and capex incentives. At this stage, it would seem that if the relative power of the incentives for capex and opex were, in fact, roughly equal this would be purely fortuitous.

3 Moving Forward

3.1 The Commission's objectives

66. The current review of the draft Statement of Regulatory Principles is an opportunity for the Commission to determine if it wishes to clarify the current arrangements (so as to enable a better understanding of the incentive properties of the current regime) and, if so, to choose a rule or mechanism which specifies more precisely how past information on costs will be used to determine regulated prices.

67. In assessing the alternatives, the Commission must take into account the objectives set out in the Code. The Code specifies that the regulatory regime chosen by the ACCC must seek to achieve: "an incentive based regulatory regime which (1) provides an equitable allocation between Transmission Network Users and Transmission Network Owners … of efficiency gains reasonably expected by the ACCC to be achievable… and (2) provides for … a sustainable commercial revenue stream which includes a fair and reasonable rate of return … on efficient investment given efficient operating and maintenance practices".[38] In addition, the regulatory regime must seek to achieve "an efficient and cost-effective regulatory environment" and "prevention of monopoly rent extraction by Transmission Network Owners"[39].

3.2 What criteria should the Commission use?

68. Given these objectives, if the Commission were to clarify the incentive properties of its regulation by specifying a more mechanistic incentive mechanism, what criteria should that incentive mechanism satisfy?

69. In the light of the problems identified in the first section and the objectives set out above, we propose that the Commission should choose an incentive mechanism which satisfies the following criteria:

(1) The incentive mechanism *should lead to incentives for cost-reducing effort on both opex and capex which are constant over time*;[40]

(2) The incentive mechanism *should give rise to roughly equal incentives for cost-reducing effort on operating costs and on capital (i.e., investment) costs*; and

(3) Provided the incentive mechanism satisfies the two criteria above, is sustainable, and ensures adequate incentives for maintaining service quality the incentive mechanism *should yield the highest power of incentives for cost reduction*.

[38] NEC 6.2.2. (b)
[39] NEC 6.2.2. (a) and (c).
[40] The South Australian regulator is explicitly required to choose an incentive mechanism which leads to constant incentives for efficiency. Clause 7.2(h) of the Electricity Pricing Order requires that ESCOSA must have regard to "the need to offer ETSA Utilities a continuous incentive (equal in each year of the regulatory period) to improve efficiency in operations, capital expenditure, the utilisation of existing capital assets and the acquisition of prescribed transmission service".

70. In other words, the regulated firm should have no greater incentive to exert effort to reduce expected costs in the current period whether at the beginning or at the end of the regulatory period; no greater incentive to exert effort to reduce capital costs relative to operating costs; and no incentive to "shift costs" across short time periods by, for example, accelerating or deferring depreciation. Subject to these conditions (and other regulatory objectives) the Commission should choose an incentive mechanism of the highest possible power.

3.3 Incentive mechanisms which meet the Commission's criteria

71. This first criterion set out in the previous section was that the Commission should focus on incentive mechanisms which provide constant incentives for opex and capex efficiencies over time. What does this criterion imply about the types of incentive mechanisms that the Commission will consider?

Constant incentives for opex efficiencies

72. Let's focus first on opex cost incentives. It turns out that an incentive mechanism meets this criterion for opex cost incentives if *the endogenous component of the regulated prices (that part which is dependent on the observed cost out-turns in the past) is such that the present value of the regulated prices over the next regulatory period is a function of the present discounted value of the observed costs in the previous regulatory period.* This result is demonstrated in Appendix A.

73. In other words, if the cost out-turns in the previous regulatory period are C_1, C_2, C_3, C_4, C_5, an incentive mechanism produces constant incentives for temporary cost reductions over time if the present value of the regulated prices over the next regulatory period is a function of $\sum_{i=1}^{5} \frac{C_i}{(1+r)^i}$.

74. This result holds, for example, for the carryover mechanism known as the "Rolling Carry-Over Mechanism" provided the cost benchmarks are set equal to the cost out-turn in the last year of the previous regulatory period (see Appendix B).

75. But this is not the only incentive mechanism which has this property. In fact, as already emphasised, any incentive mechanism for which the endogenous component is a function of the present discounted value of the observed costs in the previous regulatory period will have the property that the incentives for temporary cost efficiencies are constant over time.

76. Appendix II shows that this property also holds for a form of carryover based on a "glide path" under certain assumptions about the cost benchmarks (specifically, provided the cost benchmarks are set in a manner which is independent of the past cost out-turns). This property also holds for a form of "moving average carryover mechanism" under certain assumptions about the cost benchmarks

77. Finally, for completeness, it is worth noting that there may be simpler approaches to achieving the objective of constant incentives for cost efficiencies over time. In particular, a simple approach is just to abandon the five-year regulatory period and return to a one-year regulatory period (the "moving average" carryover is an illustration of this approach). If the regulatory period were one year and the regulator used a fixed, mechanistic approach to setting regulated prices the incentives for opex cost efficiencies would be constant over time, independent of the precise mechanism used.

Constant incentives for capex efficiencies

78. Let's turn now to incentives for capex efficiencies. Recall from the earlier discussion that the power of the incentives for capex efficiencies depends on the responsiveness of future RAB adjustments to the cost out-turn from a specific capex project in the current regulatory period. Earlier we distinguished two classes of capex projects – those which were one-off or infrequent. For both classes the power of the incentive scheme depends on how the cost out-turn is incorporated into the RAB. In the case of capex projects which are on-going or repetitive the power of the incentive scheme depends on both how the cost out-turn is incorporated into the RAB at the end of the present period *and* on how the cost out-turn affects RAB adjustments at the end of future periods.

79. Let's look first at the case of on-going repetitive capex projects where the primary influence on incentives is the extent to which cost out-turns today affect cost forecasts in the future. This case is very similar to the opex case discussed above and the same result applies – if there are to be constant incentives for cost reducing effort, the future cost forecasts should depend on past cost out-turns in one particular way – namely, the future cost forecasts should be a function of the present value of past cost out-turns.

80. Now consider the case of one-off or infrequent capex projects. For these projects the primary influence on the incentives for cost savings is the extent to which the cost out-turn will be factored into the RAB at the end of the regulatory period. It turns out that the same principle as stated above applies – namely that the adjustment to the RAB at the end of the current regulatory period should be a function of the present value of the capex cost out-turns during the regulatory period. This result is shown in Appendix I.

Incentives for substitution of capex for opex

81. The second criterion set out earlier was that the Commission should use an incentive mechanism for which the incentives for capex and opex cost efficiencies were balanced. What constraints does this impose on the range of incentive mechanisms that the Commission should consider?

82. Our analysis suggests that an incentive mechanism yields balanced incentives for capex and opex cost efficiencies if *the responsiveness of the present value of regulated prices to the present value of the opex cost out-turn is the same as the*

responsiveness of the RAB to the capex cost out-turn. This result is demonstrated in Appendix I.

Relationship with the Regulatory Test

83. Earlier we observed that the process by which the "cost benchmarks" are set is something of a "black box". It is unclear at this stage which factors determine how those benchmarks are set.

84. The same problem arises with capital expenditure. It is currently unclear how estimates of the forecast cost of a particular project are determined.

85. There is clearly a link here with the "regulatory test". The regulatory test is a test of the prudency of capital expenditure projects which expand or enhance the network. The regulatory test involves a cost-benefit analysis of the project and a selection of alternative projects. In particular, the regulatory test requires that the cost of a particular project be accurately forecast in advance. For the purposes of this paper, this raises two issues:

(a) First, how are those forecast costs determined? Is it on the basis of the cost of similar projects in the past? Or are past projects irrelevant?

(b) Second, if a project passes the regulatory test, is the Commission obliged to allow the TNSP to "roll in" to the asset base the full forecast cost of the project? Or, can the Commission take into account the actual capital cost out-turn when deciding how much to roll into the RAB?

4 Enhancing the power of incentives

86. The third criterion set out above was that, subject to the other objectives being met, the Commission should seek an incentive mechanism which yields the highest possible power.

87. As this criterion implies, increasing the power of an incentive scheme will likely involve a trade-off with other objectives. For example, increasing the power of an incentive scheme may lead to an inefficient reduction in service quality or an inefficient substitution of capex for opex. As already noted, a high powered incentive scheme may give rise to unacceptable deviations of regulated prices from observed costs. For all these reasons, the incentive mechanism which yields the highest possible power consistent with the other objectives may not be a very high-powered incentive mechanism at all. As already noted, Schmalensee (1989) demonstrates that depending on the conditions faced by the regulator earnings sharing regulation and perhaps even rate of return regulation can be more appropriate than price cap regulation.

88. Nevertheless, it is not at present possible to state that the Commission is currently using an incentive mechanism with the highest possible power consistent with the other objectives.

89. There are two ways in which the Commission could increase the power of its incentive regulation. The first is to increase the lag between observations of endogenous costs and the time that information is reflected in regulated prices or revenues. The second is to increase the dependence of the regulated prices on exogenous measures of cost.

90. The use of exogenous cost measures is discussed in detail in the companion paper to this paper and will not be discussed more here. However, some of the themes in that paper also relate to the use of lagged endogenous cost observations and are worth introducing here, in anticipation of the fuller discussion in the next paper.

91. As already noted, the power of an incentive scheme increases with the lag between cost out-turns and the time when those cost out-turns are reflected in regulated prices. However, the longer that lag the more likely it is that the "true" costs of the regulated firm will be affected by a large number of cost-influencing factors (such as changes in demand or changes in the prices of inputs and so on – a fuller list is in the next paper). The longer the lag the greater the likelihood of a substantial deviation between the firms regulated revenue (which depends on the cost out-turn several periods earlier) and the costs incurred by the firm today.

92. Let's suppose, therefore, that the regulator develops a "cost model" which shows how the cost out-turn of the regulated firm vary with these cost-influencing factors. Ideally, this cost model would isolate and identify the controllable component of cost (that component due to the level of cost-reducing effort). However, no cost model is perfect. In practice, however, even a sophisticated model is unlikely to be able to fully and completely take into account all possible cost-influencing factors. As a consequence, there remains a risk that the regulated firm will be systematically undercompensated. For example, if the price of a key input is rising over time and the effect of this increase is not fully accounted for in the cost model, there is a risk that the firm will not be adequately compensated.

93. If the firm is to be adequately compensated, the regulator must take this risk into account when it sets the regulated revenues. In particular, it must increase the level of revenues above the "average" required level forecast by the cost model to the point where the regulator can be very sure that the regulated firm is adequately compensated. This will inevitably imply over-compensating the regulated firm on average. The inevitability of this over-compensation in the presence of asymmetric information is a well-established result in the economic theory of incentive regulation. The additional rent to the firm that results from this over-compensation is known as "information rent".

94. The size of the information rent will depend on the precision of the cost model which will depend, amongst other things, on the length of the regulator lag and the amount of information available to the regulator. In the next paper we discuss ways in which the regulator can reduce this information rent.

Appendix I:

This appendix seeks to demonstrate some of the main mathematical claims in the body of the paper.

Constant Incentives for Opex Efficiency

One of the main claims of this paper is that, when using a five-year regulatory period, the regulated firm will have a constant incentive to make temporary cost savings over time if the endogenous component of the regulated prices is proportional to the present value of the cost out-turn over the past regulatory period.

To see this, suppose that regulated prices in the years 6-10 of the regulatory period depend on the cost out-turn in years 1-5. Let $P(C_1, C_2, C_3, C_4, C_5)$ be the present value of the regulated prices for the next regulatory period as a function of the cost out-turn in years 1-5 of the previous regulatory period.

Suppose that the regulated firm exerts effort to lower costs in year *i* by a small amount – say, \$1. This will increase profits today by \$1 but will reduce the present value of prices in the next regulatory period by the amount $\frac{\partial P}{\partial C_i}$. As a result, the net gain to the regulated firm from exerting effort to lower costs in year *i* is: $-1 + \frac{1}{(1+r)^{5-i}} \frac{\partial P}{\partial C_i}$. If the regulated firm is to have constant incentive to lower costs over time we must have $\frac{\partial P}{\partial C_i} \propto \frac{1}{(1+r)^i}$.

It is easy to check that this is satisfied if *P* is proportional to the present value of the cost out-turn in the previous period.

$$P = \alpha \frac{C_1}{(1+r)} + \alpha \frac{C_2}{(1+r)^2} + \alpha \frac{C_3}{(1+r)^3} + \alpha \frac{C_4}{(1+r)^4} + \alpha \frac{C_5}{(1+r)^5}$$

Constant Incentives for Capex Efficiency

In the paper it is claimed that incentives for (one-off) capex are constant over time if and only if the responsiveness of the RAB to the capital cost out-turn is proportional to the present value of capex cost out-turn.

Let's focus on the case of a one-off capex project (or a project which must be undertaken sufficiently infrequently that information about past cost out-turns is of little use for the future). In this case the incentive for efficiency is primarily determined by the responsiveness of the RAB to the capex cost out-turn. Suppose the $I_1, I_2, ..., I_5$ is the capex cost out-turn in each year of the present regulatory period and suppose that the RAB at the end of the present regulatory period is a function of these cost out-turns - $K = K(I_1, I_2, ..., I_5)$. The responsiveness of the future adjustment to the RAB viewed in period *t* is then $\frac{1}{(1+r)^{6-t}}\frac{\partial K}{\partial I_t}$. If this is to be constant over time we must have that $\frac{\partial K}{\partial I_t} \propto \frac{1}{(1+r)^t}$ which proves the result.

Balanced Incentives for Capex and Opex Efficiency

In the paper it is claimed that the incentives for capex and opex efficiency are "balanced" if the responsiveness of the regulated opex revenue stream to a change in a cost out-turn is equal to the responsiveness of the regulatory asset base to a change in a capex cost out-turn.

Suppose that the regulated firm has an incentive to substitute capex for opex – specifically, suppose that the regulated firm has an opportunity to make an investment in a project which lasts N years. This project raises the capital costs by a small amount ΔI and lowers the operating costs by a small amount ΔC in each of the next N years. This project should be carried out if and only if it lowers total costs – i.e., if and only if it has a positive NPV – i.e.,. if $-\Delta I + \sum_{t=1}^{N}\frac{\Delta C}{(1+r)^t} > 0$. Let's examine the effect of this project on the revenue stream of the regulated firm. Let $P_6, P_{11},..., P_{N+1}$ be the present value of the opex revenue stream in the regulatory periods 6-10, 11-15 and so on up to $N+1-N+6$ (we are assuming that N is a multiple of 5 for simplicity). Assume that the present value of the opex in any one regulatory period is proportional to the present discounted value of costs in the previous regulatory period (i.e., $\frac{\partial P}{\partial C_t} = \frac{\alpha}{(1+r)^t}$) as required by the previous condition. Then the effect of the project on the opex revenue stream is:

$$\sum_{t=5,10,...}^{N}\frac{1}{(1+r)^t}(\Delta C\frac{\partial P_{t+1}}{\partial C_{t+1}} + \Delta C\frac{\partial P_{t+1}}{\partial C_{t+2}} + \Delta C\frac{\partial P_{t+1}}{\partial C_{t+3}} + \Delta C\frac{\partial P_{t+1}}{\partial C_{t+4}} + \Delta C\frac{\partial P_{t+1}}{\partial C_{t+5}})$$

$$= \sum_{t=5,10,...}^{N}\frac{1}{(1+r)^t}\Delta C(\frac{\alpha}{(1+r)} + \frac{\alpha}{(1+r)^2} + \frac{\alpha}{(1+r)^3} + \frac{\alpha}{(1+r)^4} + \frac{\alpha}{(1+r)^5})$$

$$= \frac{\alpha}{(1+r)^5}\sum_{t=1}^{N}\frac{\Delta C}{(1+r)^t}$$

Similarly the effect on the regulatory asset base is:

$$\frac{\Delta K}{(1+r)^5}\frac{\partial K}{\partial I}$$

So the incentives for capex and opex expenditure are balanced if $\frac{\partial K}{\partial I} = \alpha$ which proves the result.

Appendix II: The properties of carryovers – the rolling carry-over mechanism, the glide path and the moving-average carryover mechanism

In this Appendix we will look at different possible carryover mechanisms. In each case we will assume that we are in period 5. The regulated prices for the next 5 periods (i.e., $P_6,...,P_{10}$) are assumed to be the sum of two components: the cost benchmarks ($\overline{C}_6,...,\overline{C}_{10}$) and the "carryover" ($B_6,...,B_{10}$). Both the cost benchmarks and the carryover may depend on the cost out-turns in the previous regulatory period.

The Rolling (or "Efficiency") Carryover Mechanism

Under the rolling carryover mechanism the carryover is defined as follows for some constant α : (see the table below):

$$B_t = \alpha((C_{t-5} - \overline{C}_{t-5}) - (C_5 - \overline{C}_5))$$

With this definition of the carryover, it is straightforward to prove the following result:

The rolling carryover mechanism yields constant incentives for cost-reducing effort over time if and only if the (a) the cost benchmarks ($\overline{C}_6,...,\overline{C}_{10}$) depend only on the cost out-turn in the last year of the last regulatory period (i.e., $\overline{C}_t = \overline{C}_t(C_5)$) and (b) the responsiveness of the cost benchmarks to a change in the cost out-turn in the last year of the last regulatory period is constant and equal to α (i.e., $\frac{\partial \overline{C}_t}{\partial C_5} = \alpha$).

To prove this, let $PV(P)$ be the present value of the regulated prices over the years 6-10 (and similarly for $PV(\overline{C})$ and $PV(B)$). We know from Appendix A that an incentive mechanism yields constant incentives for efficiency if $\frac{\partial PV(P)}{\partial C_i} = \frac{\beta}{(1+r)^i}$ for some constant β.

Now, observe that $\frac{\partial PV(B)}{\partial C_i} = \frac{\alpha}{(1+r)^i}$ for $i = 1,...,4$ and:

$$\frac{\partial PV(B)}{\partial C_5} = -\alpha(\frac{1}{(1+r)} + \frac{1}{(1+r)^2} + \frac{1}{(1+r)^3} + \frac{1}{(1+r)^4})$$

So, $\frac{\partial PV(P)}{\partial C_i} = \frac{\partial PV(\overline{C})}{\partial C_i} + \frac{\alpha}{(1+r)^i}$ for $i = 1,...,4$ and:

$$\frac{\partial PV(P)}{\partial C_5} = \frac{\partial PV(\overline{C})}{\partial C_5} - \alpha(\frac{1}{(1+r)} + \frac{1}{(1+r)^2} + \frac{1}{(1+r)^3} + \frac{1}{(1+r)^4})$$

It is clear from these equations that if we are to have $\frac{\partial PV(P)}{\partial C_i} = \frac{\beta}{(1+r)^i}$ for i=1,…5, we must have $\frac{\partial PV(\overline{C})}{\partial C_i} = 0$ for i=1,..4 (which implies that $\overline{C}_t$ can depend on only the cost out-turn in the last year of the last regulatory period C_5) and $\frac{\partial \overline{C}_t}{\partial C_5} = \alpha$ (i.e., all of the cost benchmarks must have the same responsiveness to a change in C_5 and this must be equal to α). This proves the result.

A somewhat interesting corollary of this result is that when the cost benchmark is simply set equal to the cost out-turn in the last year of the last regulatory period (i.e., when $\overline{C}_t = C_5$ for t=6,…,10) then the carryover for period *t* is just equal to $B_t = C_{t-5} - C_5$. In this context *the rolling carry-over mechanism has exactly the same effect as if the regulator simply set the regulated price in year t equal to the cost out-turn five years earlier*.

To see this, recall that the regulated price in period t is $P_t = \overline{C}_t + B_t$. But, given that $\overline{C}_t = C_5$ and $B_t = C_{t-5} - C_5$ then we have that $P_t = C_{t-5}$.

	Cost bench-mark	Cost out-turn	Effici-ency	Carry-over Year 1:	Efficiency Year 2:	Efficiency Year 3:	Efficiency Year 4:	Efficie ncy Year 5:	Total Carry-Over (Sum of previous columns)
1	$\overline{C}_1$	C_1	$C_1 - \overline{C}_1$						
2	$\overline{C}_2$	C_2	$C_2 - \overline{C}_2$	$C_2 - \overline{C}_2$ - $(C_1 - \overline{C}_1)$					
3	$\overline{C}_3$	C_3	$C_3 - \overline{C}_3$	$C_2 - \overline{C}_2$ - $(C_1 - \overline{C}_1)$	$C_3 - \overline{C}_3$ - $(C_2 - \overline{C}_2)$				
4	$\overline{C}_4$	C_4	$C_4 - \overline{C}_4$	$C_2 - \overline{C}_2$ - $(C_1 - \overline{C}_1)$	$C_3 - \overline{C}_3$ - $(C_2 - \overline{C}_2)$	$C_4 - \overline{C}_4$ - $(C_3 - \overline{C}_3)$			
5	$\overline{C}_5$	C_5	$C_5 - \overline{C}_5$	$C_2 - \overline{C}_2$ - $(C_1 - \overline{C}_1)$	$C_3 - \overline{C}_3$ - $(C_2 - \overline{C}_2)$	$C_4 - \overline{C}_4$ - $(C_3 - \overline{C}_3)$	$C_5 - \overline{C}_5$ - $(C_4 - \overline{C}_4)$		
6		…		$C_2 - \overline{C}_2$ - $(C_1 - \overline{C}_1)$	$C_3 - \overline{C}_3$ - $(C_2 - \overline{C}_2)$	$C_4 - \overline{C}_4$ - $(C_3 - \overline{C}_3)$	$C_5 - \overline{C}_5$ - $(C_4 - \overline{C}_4)$	$C_5 - \overline{C}$ - $(C_5 - C$	$C_5 - \overline{C}_5$ - $(C_1 - \overline{C}_1)$
7		…			$C_3 - \overline{C}_3$ - $(C_2 - \overline{C}_2)$	$C_4 - \overline{C}_4$ - $(C_3 - \overline{C}_3)$	$C_5 - \overline{C}_5$ - $(C_4 - \overline{C}_4)$	$C_5 - \overline{C}$ - $(C_5 - C$	$C_5 - \overline{C}_5$ - $(C_2 - \overline{C}_2)$
8		…				$C_4 - \overline{C}_4$ - $(C_3 - \overline{C}_3)$	$C_5 - \overline{C}_5$ - $(C_4 - \overline{C}_4)$	$C_5 - \overline{C}$ - $(C_5 - C$	$C_5 - \overline{C}_5$ - $(C_3 - \overline{C}_3)$
9		…					$C_5 - \overline{C}_5$ - $(C_4 - \overline{C}_4)$	$C_5 - \overline{C}$ - $(C_5 - C$	$C_5 - \overline{C}_5$ - $(C_4 - \overline{C}_4)$
10		…						$C_5 - \overline{C}$ - $(C_5 - C$	$C_5 - \overline{C}_5$ - $(C_5 - \overline{C}_5)$ =0

A “Glide Path” carryover mechanism

Having observed that the rolling carryover mechanism can, under certain circumstances, yield constant incentives for efficiency, it is worth exploring whether other forms of carryover, such as the "glide path" can also achieve the same outcome.

Consider a "glide path" defined as follows. The total "efficiency savings" for a regulatory period is defined as the present value of the difference between the cost benchmarks and the cost out-turn. i.e., $A = -\sum_{i=1}^{5} \frac{\overline{C}_i - C_i}{(1+r)^i}$. The carryover in the subsequent period is then defined as a declining proportion of this efficiency savings. We will use the proportions set out in the DRP – i.e., in the first period the carryover is 80% of the efficiency, savings; in the next period the carryover is 60% of the efficiency savings and so on. i.e., $B_6 = 0.8A$, $B_7 = 0.6A$, $B_8 = 0.4A$, $B_9 = 0.2A$ and $B_{10} = 0$.

This definition of a glide-path yields constant incentives for efficiency over time provided that the cost benchmarks (without the carryover) yield constant incentives for efficiency over time – for example, if the cost benchmarks are set independent of the firm's own cost out-turns (i.e., set purely on the basis of the exogenous costs).

To see this, observe that:

$$\frac{\partial PV(P)}{\partial C_i} = \frac{\partial PV(\overline{C})}{\partial C_i} + \frac{X}{(1+r)^i} \text{ where } X = \frac{0.8}{(1+r)} + \frac{0.6}{(1+r)^2} + \frac{0.4}{(1+r)^3} + \frac{0.2}{(1+r)^4}.$$

It s clear that the desired outcome ($\frac{\partial PV(P)}{\partial C_i} = \frac{\beta}{(1+r)^i}$ for i=1,…5) can be achieved if $\frac{\partial PV(\overline{C})}{\partial C_i} = 0$ for i=1,..5 – i.e., if the cost benchmarks are independent of the firm's cost out-turn. More generally, the desired outcome can be achieved if $\frac{\partial PV(\overline{C})}{\partial C_i} = \frac{\delta}{(1+r)^i}$ - i.e., if the cost benchmarks (without the carryover) are set in such a way that they yield constant incentives for efficiency over time.

A "Moving Average" carryover mechanism

Envestra, in a submission to ESCOSA, propose a "moving average" carryover mechanism. Under this mechanism, the carryover is not calculated in advance, at the start of each regulatory period, but is calculated each period, using information about cost out-turns in the most recent period.

Under this approach, the responsiveness of the present value of the carryover to a change in costs in a given period is automatically independent of the period (assuming that the formula for calculating the carryover is constant over time). As a result, the moving average carryover yields constant incentives for efficiencies over time provided the cost benchmarks (without the carryover) are calculated in a way which yields constant incentives for efficiency over time.

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Part II: The Use of Exogenous Estimates of Cost:

Benchmarking, Yardstick Regulation and Factor Productivity Analysis

A report for the ACCC by Darryl Biggar

95. This paper is the second of two papers dealing with issues in incentive regulation and benchmarking. In the previous paper I pointed out that the "power" of an incentive scheme depends, amongst other things, on the extent to which the regulated revenues or prices of the regulated firm depend on "exogenous" versus "endogenous" measures of cost. Exogenous measures of cost are estimates of the cost of the regulated firm which are out of the control of the regulated firm itself.

96. This paper explores how those exogenous measures of cost are obtained, how they should be used, and how they have been used in practice in the regulation of electricity transmission and distribution companies.

97. The key points of this paper are as follows:

- Just as endogenous cost measures come from observations of the cost of the regulated firm, exogenous cost measures derive from observations of the costs of *other* comparable firms. Ideally, the regulator would be able to isolate and identify the component of cost which arises solely from differences in the level of cost-reducing effort. But costs may differ across firms for a very large number of reasons including differences in the quantity and quality of services provided and differences in the costs of inputs. Nearly all of the regulatory difficulty relating to the use of exogenous cost measures arises from this problem of distinguishing "legitimate" cost differences from differences due to controllable efficiency differences alone.

- Broadly speaking, estimating an exogenous cost measures involves the following steps: First observations of the costs of a set of comparable firms are collected, together with information on the various factors which influence those costs. Second, using this data, and specific assumptions about the nature of the "cost function", a "cost model" is estimated which takes as an input different values of the cost-influencing factors and yields as an output an estimate of the costs. Finally, information on the cost factors affecting the regulated firm are obtained and fed into the cost model to yield an exogenous estimate of the costs of the regulated firm.

- A primary requirement of any regulatory regime is the requirement that the regulated firm be adequately compensated for prudently-incurred investment. A fundamental question that arises is the following: can the regulator credibly demonstrate to a court that its cost model has fully and correctly captured all of the various factors which influence cost differences between firms, so that any remaining cost differences are solely due to differences in cost reducing effort (or transient measurement error)?

- This is unlikely to be the case. As a result, the regulator must not set the regulated prices/revenues equal to the output of the cost model alone. Instead, the regulator must increase the regulated revenue/prices to the point where there is only a very small probability that the "true" cost of the regulated firm falls below the regulated revenue. Of course, this approach will imply that most firms are able to earn excess returns. This extra return is known as "information rent" and is an inevitable consequence of information asymmetry between the regulator and the regulated firm.

- The size of the information rent depends on the size of the estimated error in the cost model. Some cost models – such as econometric models – allow this error to be estimated (under certain assumptions). Whether or not the model itself allows the error of the estimate to be calculated, there always remains a risk that the assumptions of the model itself might be wrong or that the cost model estimated using historical data might not apply to a situation in the future. This additional risk has an impact on the estimated error of the cost model and therefore on the information rent.

- The larger the information rent, the less likely it is that reliance on exogenous cost measures will be sustainable. However, rather than simply falling back on exclusive reliance on endogenous cost measures (i.e., which tend to be low-powered incentive schemes) the regulator can reduce the information rent required by giving the regulated firm the *option* of choosing a low-powered scheme such as rate of return regulation. More generally, the regulator can (and should) offer a menu of tariff options. Economic theory shows that the theoretically optimal regulatory regime involves a (possibly large) menu of tariff options. Under the theoretically optimal approach the particular tariff a firm will choose depends on the relative level of the firm's true cost and the exogenous cost measure from the cost model. The lower the level of the firm's true cost relative to the exogenous cost measure the higher the power of the incentive scheme the firm will choose and the higher the level of cost-reducing effort.

- Rather than focus on estimating the *level* of the exogenous cost measure, some regulators focus instead on estimating the *rate of change* of this measure. This approach can be justified on the following basis: Although it may not be possible to develop a cost model which fully accounts for inter-firm differences in the level of costs, it might be widely accepted (and, in particular, accepted by the courts) that all firms face the same potential for reducing their costs over time. If this is the case, the regulator could set the rate of change of the regulated prices/revenues equal to the estimated rate of change of the exogenous cost measure.

- In the context of the electricity industry, benchmarking studies have more often been carried out for distribution than for transmission. This may be because the role of transmission is more heterogenous across countries. Transmission plays a significantly different role in different countries and regions due to differences in fuel mix and relative location of fuel sources and major loads. In contrast, although there remain substantial differences in the services provided by distribution companies, there are a large number of such companies (especially if international companies are admitted) and it is possible to make certain meaningful statements about the cost drivers of distribution companies.

- Overall, provided care is taken to offer of menu of contracts it appears that there is significant scope for greater reliance on exogenous measures of cost in the context of the regulation of Australian electricity transmission and distribution businesses.

Introduction

Exogenous Estimates of Cost

98. In the previous paper I distinguished two different types of estimates of cost – endogenous measures of cost which depend on the cost out-turn of the regulated firm itself and exogenous measures of cost, which are independent of the cost out-turn of the regulated firm itself. In this paper we are focussing on the use of these exogenous estimates of cost. Just as endogenous measures of cost derive primarily from observations of the regulated firm, exogenous measures of cost are derived from observations of the cost out-turns of *other* comparable firms perhaps over several time periods.

99. As emphasised in the earlier paper, these cost measures are useful insofar as they allow the regulator to identify that component of cost which is due to the level of cost-reducing effort of the regulated firm. However, a substantial component of the differences in cost observations between firms are due to "legitimate" differences in a number of factors which affect the level of costs incurred by the firms such as the level of output that the different firms produce, differences in the prices they must pay for inputs and differences in the business conditions to which each firm is exposed.

100. More specifically, the costs of electricity transmission or distribution businesses may be expected to differ due to differences in:

- The *nature of the services* provided by each firm (for example, if transmission services were measured by volume and/or distance of electricity transmitted, a transmission company which primarily provided reliability services – which are only called on in the event of a contingency – might appear as high cost even though those reliability services were justified and procured at least cost);

- The *range of services* provided by the firm (a distribution business might appear as high cost if it is required to provide additional services, such as street lighting or heating, which are not provided by the comparator firms);

- The *volume of services* provided (a transmission or distribution business carrying smaller volumes might appear as high cost if there are economies of scale);

- The *quality of services* provided (a firm which offers *n-2* reliability might appear as higher cost than a firm which offers *n-1* reliability);

- The *price of inputs* (a primarily urban firm might have to pay more to acquire easements; firms in rural areas might have to pay more to attract particular labour skills; construction costs will differ between mountainous and flat areas);

- *Governmental regulations* (companies which must underground their wires or control noise emissions may face higher costs than those which do not);

- The *number, density, load factor and size distribution of the customers they serve* (companies which have a higher load factor may appear as more efficient those companies which do not; other things equal the higher the number of customers the higher will tend to be the costs and so on);

- *Environmental factors* (such as terrain, temperature and precipitation – e.g., companies in regions with high temperatures or a greater propensity to electrical storms may have to take more precautions than those in more temperate areas);

- The *age and quality of the capital stock*;

101. This list is not exhaustive. There may be numerous other factors which can explain differences in costs between two firms.

102. Just as important, the "total cost" of a regulated firm consists of both (a) costs which can be attributed to a single time period (usually called "operating and maintenance" costs) and (b) the costs of sunk long-lived assets. Strictly speaking, therefore, it is only possible to accurately compare the costs of firms on a long time horizon when the life of all the sunk assets has expired. In practice, this is infeasible. Instead, an estimation of the "cost" of a regulated firm is usually made over a very short timeframe – as short as one year. An estimation of the "cost" of a regulated firm in any one regulatory period requires an allocation or amortisation of the costs of the sunk, long-lived asset to that one period. In the case of regulated firms, the regulator usually has a substantial amount of discretion as to how that allocation is carried out[41]. In industries with high fixed costs (such as electricity transmission and distribution) the proportion of the capital costs which are allocated to any one regulatory period will have a substantial impact on the resulting cost observation. The handling of capital costs is, therefore, yet another factor which can have a substantial influence on observed cost differences across firms.

[41] The regulated firm is broadly indifferent between different approaches to recovering its capital costs provided that the present value of the future revenue stream is sufficient to cover the costs of its investment.

Cost models

103. Having collected information on cost out-turns and cost-influencing factors of other comparable firms, the regulator must use that information to obtain an exogenous cost estimate for the regulated firm. This is done by estimating or calculating "cost model" which relates the various cost-influencing factors to an exogenous estimate of costs. There are a variety of techniques for calculating or estimating a cost model. One such approach is illustrated in the example below.

104. A cost model takes as inputs information on costs and cost-influencing factors for a number of other firms. This information is combined with information on cost-influencing factors for the regulated firm to come up with the exogenous cost measure.

Example: Calculating an exogenous cost measure

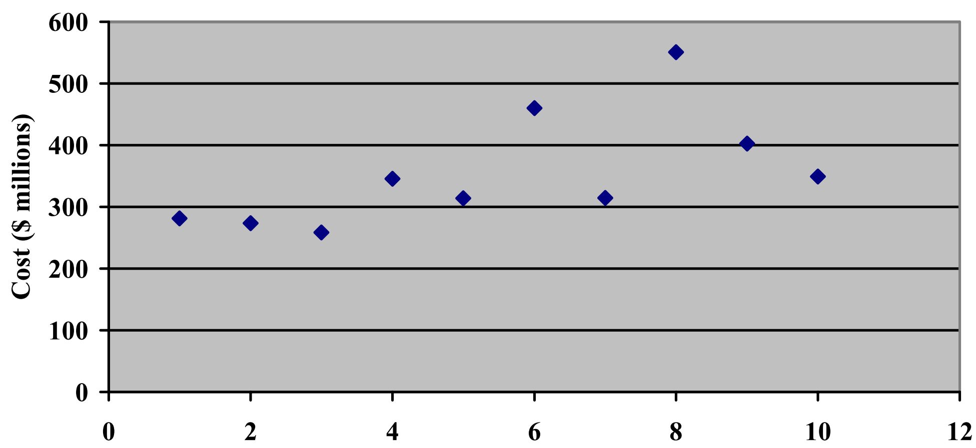
105. Although there are various approaches to estimating a cost model, perhaps the approach which is the simplest and easiest to understand is to assume that the cost function takes a particular structural form and then to use standard statistical techniques (such as ordinary least squares) to estimate the parameters of that cost function. The example below illustrates the estimation of a simple one-parameter cost model and a simple linear two-parameter cost model.

106. Suppose that there are ten comparable firms in the industry. The regulator starts by simply observing the costs incurred by each of these ten firms. These costs (in millions) are as indicated below:

Table 1: The observed costs of ten hypothetical electricity distribution companies

Firm:	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Cost	281.4	273.6	258.4	345.4	314	460	314.4	551	402.6	349

Figure 1: The observed costs of the ten firms in table 1.



107. Suppose that the regulator's first attempt at finding an exogenous cost estimator is to calculate the simple average of this information.[42] The average of these cost observations is $355 million. The standard error of this estimate is $92.2 million (i.e., we can be around 95% confident that the true cost lies between $170.5 and $539.4).

108. Suppose now that the regulator believes that the length of the transmission lines owned by a transmission company influence the level of its costs. The regulator might then seek to collect information on the length of the transmission lines in each network (in kilometres), as set out below:

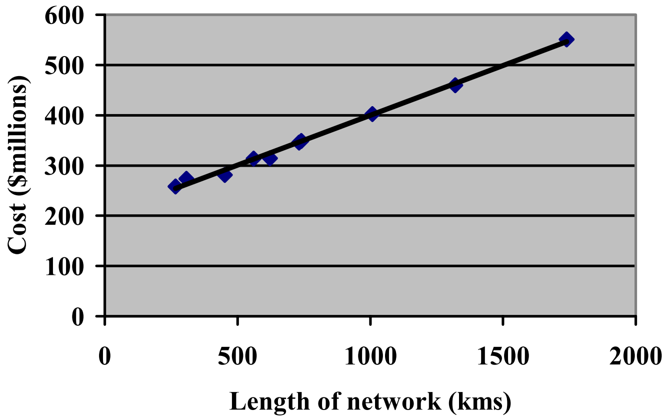
Table 2: Observed cost and network length information for ten hypothetical distribution companies

Firm:	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Cost	281.4	273.6	258.4	345.4	314	460	314.4	551	402.6	349
Length	452	308	267	732	560	1320	622	1740	1008	740

[42] An approach where the cost estimate is the simple average of observed costs is sometimes referred to as "yardstick regulation" although there is no need to restrict the term to just the approach of using an average.

The following graph illustrates this data:

Figure 2 Linear regression of cost against network length for the companies in table 2



109. The regulator might now seek to estimate a cost function with two parameters of the form $Cost = A + B \times Length$. (In the previous example, the regulator estimated a simple cost function with one parameter. The value which minimises the sum of the squares of the "error" terms in that case was just the sample average. In this case, the value of the two parameters which minimise the sum of the squares of the error terms are just the conventional equations for a simple linear regression). The estimated cost function is then $Cost = 201.3 + 0.1984 \times Length$ (illustrated as a line in **Error! Reference source not found.**).

110. If the regulated firm has a network length of, say, 500 kilometres the cost model gives an estimated exogenous cost of $300.5 million with a standard error of just $0.686. The addition of just one additional parameter has (in this simple example) significantly enhanced the precision of the estimate.

More general functional forms

111. In the simple example above, the use of a simple linear model with two parameters was sufficient to estimate the cost with a high degree of accuracy. A more general approach involves estimating a generalised cost function of the kind $C = f(y, w, z)$ where *y* is a vector of output measures, *w* is a vector of input prices (to the extent these differ between firms) and *z* is a vector of exogenous factors (e.g., climate)[43].

112. A form must be chosen for the cost function. As EEE Ltd note, various forms have been used, ranging from simple ones such as the Cobb-Douglas form: $C = aw^b y^c$ (which is usually estimated in the linearised form: $\ln C = \ln a + b \ln w + c \ln y$) or more complex forms, such as the translog form:

[43] See EEE Ltd (2003), page 21.

$$\ln C = b_0 + b_1 \ln w + b_2 \ln y + b_{11}(\ln w)^2 + b_{22}(\ln y)^2 + b_{12} \ln w \ln y$$

113. EEE Ltd Note:

> "The Cobb-Douglas form has fewer data requirements but is restrictive in the properties it imposes upon the production structure. The translog does not impose these restrictions …, but this comes at the cost of having a form which requires more data and can suffer from degrees of freedom and multicollinearity problems. These drawbacks have, however, not proven significant in the context of data sets of the size available in the US. There are a number of functional forms which lie between these two extremes. For example, it is common to limit translogging to the price and quantity variables so as to facilitate the inclusion of as many additional business conditions as possible".[44]

114. The accuracy of the cost model (i.e., the size of the error in the cost estimate) will depend on a variety of factors. Kaufmann et al (2000) observe that:

> "An important advantage of the econometric approach to benchmarking is that results can assess the *precision* of such "point" predictions. Precision is greater as the variance of the prediction error declines. The formula for our estimate prediction error shows that, generally speaking, the precision of the cost model will increase as:
>
> - The size of the sample increases;
> - The number of business condition variables required in the model declines;
> - The business conditions of sample companies become more heterogenous;
> - The business conditions of the company in question become closer to those of the typical firm in the sample; and
> - The model is more successful in predicting the costs of the sampled companies."[45]

115. Although we have focussed here on one approach (using econometric techniques to estimate the parameters of a cost function) other approaches are common. Another statistical technique is "stochastic frontier analysis" which seeks to estimate not an "average" cost function but rather the cost function of the hypothetical efficient frontier. There are also non-statistical techniques of which the best-known is data envelope analysis. The details of the methodology of each of these approaches is not relevant for the rest of this paper. Interested readers are referred to the papers by EEE Ltd (2003) and Abbott (1999) and the references therein.

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[44] EEE Ltd (2003), page 22.

[45] Kaufmann et al (2000), page 9

The Use of Exogenous Cost Estimates

116. Having collected information on the cost out-turn of different firms and the factors which might affect those costs (perhaps over several time periods), the regulator can use this information in one of two ways. First, the regulator can attempt to form an exogenous estimate of the *level* of the costs of the regulated firm or, second, the regulator can attempt to form an estimate of the *rate of change* of the costs of the regulated firm. The reasons for this distinction will become clear below.

117. Regulators do not necessarily make a clear distinction between these two approaches either in practice or in their policy statements. For example, some regulators use an approach in which the regulated prices/revenues are adjusted according to a "CPI-X-Z" approach where the "X" factor is set on the basis of the rate of change of industry-wide productivity changes and the "Z" factor is a firm-specific factor which increases the rate of decline of the prices of those firms which are deemed to have the lowest efficiency. The use of the Z factor in this context implies that the regulator is taking some account of not just the rate of change of industry costs but also the level.

118. We will look first at the case where the regulator seeks to estimate the *level* of the costs of the regulated firm.

Problems with focus on the level of the exogenous cost estimate

119. A primary requirement of any regulatory regime is the requirement that the regulated firm be adequately compensated for prudently-incurred investment.

120. Let's suppose that the regulator seeks to use the cost information from other firms to obtain an exogenous estimate of the costs of the regulated firm. A key issue is the following: "Can the regulator credibly demonstrate to the courts that the model correctly accounts for all inter-firm differences in cost so that any remaining differences between the exogenous cost measure and the regulated firm's observed cost out-turn is solely due to either (a) controllable efficiencies or (b) random, temporary measurement error?"

121. In the (unlikely) event that the answer is yes – that is, in the event that the regulator can credibly demonstrate that it has correctly accounted for all inter-firm differences, any remaining gap between the exogenous cost estimate and the firm's observed cost must be purely due to controllable efficiencies or measurement error. In this case, the regulator can set the regulated revenue directly equal to the exogenous cost estimate knowing that any revenue excess is either temporary and random or the result of the superior efficiency of the regulated firm. Conversely, any revenue shortfall is either temporary and random or the result of inefficiency of the regulated firm, which is within the power of the regulated firm to correct. Either way, the regulator can be sure that the regulated revenue will be sufficient to compensate the firm for its prudent investment. The following box demonstrates this result in the extreme case where there are just two firms in the industry.

Benchmarking When the Regulator Can Isolate the Effort Component

In the text below I emphasise the problems that can arise when the regulator cannot be sure that its cost model correctly and fully controls for inter-firm cost differences. To make this point as stark as possible, this box shows that if regulator can isolate the effort component of costs, benchmarking is both simple and effective – in fact, just one comparable firm is necessary to achieve perfect incentives for cost-reducing effort. (This example is based on an example in Laffont and Tirole (2000), box 2.1)

To see this, suppose that there are two firms in the industry who face the same underlying cost structure so that their costs differ only as a result of differences in the level of cost-reducing effort. (More specifically, the costs of these firms are given by $C_i = \beta - e_i$ where β is a constant and e_i is the level of cost-reducing effort of firm *i*). In addition, both firms face the same disutility of effort.

Suppose that the regulator observes the cost out-turn of firm 2 and uses this to set the revenue for firm 1 (and vice versa for firm 2). This simple regulatory mechanism achieves the first-best outcome: Both firms then choose to set the same, high level of effort and both firms earn zero profit (i.e., earn no information rent). As Laffont and Tirole observe "Thus, benchmarking here allows the government to mimic the full-information outcome even if it does not know the firm's technology".

But the critical issue here is that even though the regulator does not know the firm's technology it must be certain that it can accurately observe and control for all those factors which might affect cost differences between the two firms. This is unlikely to be the case in practice.

122. The more likely event is that the regulator cannot be certain (or cannot credibly demonstrate why it is certain) that it has correctly accounted for all inter-firm differences in cost. No matter how sophisticated the model chosen by the regulator, there is always a chance that the model does not fully account for all inter-firm differences in cost. In this case, the regulator cannot set the regulated revenue directly on the basis of the observed exogenous cost. Doing so runs the risk that the regulated firm will either be systematically undercompensated (or systematically overcompensated - in either case, the incentive mechanism is unsustainable).

123. As already emphasised, a primary requirement of any regulatory regime is the requirement that the regulated firm be adequately compensated for prudently-incurred investment. Therefore, in this context, the regulator *must* set the regulated revenue in such a way that there is (at least) a very high probability that the regulated firm will be properly compensated. This implies, in turn, that the regulated revenue must be such that there is a high probability that the regulated firm will be adequately compensated even if the cost model has systematically underestimated its true costs.

124. In short, this implies that regulated revenue must be set on the basis of an amount which is strictly higher than the observed exogenous cost. But how much higher? The cost model itself may be able to provide the answer to this question. Where the parameters of the model are estimated using statistical techniques, those same techniques can allow us to answer the question: “at what level should the regulated revenue be set to be 99% sure that the regulated revenue exceeds the firm’s true costs?”

125. More generally, it is intuitively clear that the appropriate level of the regulated revenue will depend on the statistical error of the cost model (i.e., the residual or “unexplained” component of observed costs). The higher this statistical error, the higher the regulated revenue will need to be to ensure that the revenue exceeds the true cost with a high probability.

126. Of course, this argument implies that the regulated revenue will on average over-estimate of the “true” costs of the regulated firm. But this should be no surprise. Economic theory demonstrates that over-compensation of a regulated firm is an inevitable consequence of the regulator’s lack of information about cost. This over-compensation is an additional rent earned by the firm as a result of its information advantage and is called “information rent”. The following extended quote from Laffont and Tirole (2000) explains this principle:

> “In the presence of incomplete information about the firm’s technology or opportunity cost, though, the government faces a trade-off between giving good incentives to the firm and capturing its potential rent. Recall that proper incentives for effort are created by a fixed-price contract (or more generally by a high-powered incentive scheme). But a contract that yields $1 to the firm each time the firm endogenously reduces its costs by $1 also gives it $1 whenever its cost is lower by $1 for exogenous reasons; that is, a firm is a residual claimant also for cost factors that are outside its control. This fact generates substantial rents. In contrast, a cost-plus contract (or, more generally, a low-powered incentive scheme), while providing poor incentives to keep cost down, is efficient at capturing the firm’s potential rent. Indeed, the firm does not benefit when it is luck and its cost is exogenously reduced by $1, since this costs is fully borne by the government.
>
> To illustrate this adverse selection problem and the impact of the power of the incentive scheme, suppose that there is no moral hazard problem – that is, that the firm’s cost is exogenously determined. This cost can be either 5 or 10. If the government is constrained to offering a fixed-price contract, and if the public good is socially sufficiently valuable so that the government must supply it, then the government has no choice but offering 10 to the firm. While this offer ensures that the firm is willing to produce the public good, it also leaves a rent equal to 5 if the firm has a low cost. In contrast, a cost-plus contract pays only what is needed to let the firm break even. [Assuming that low effort translates into an excess cost of 3] the realised cost is then, say, 8 or 13 … but the payment matches the cost.

> We thus conclude that *there is a basic trade-off between incentives, which call for a high-powered incentive scheme, and rent extraction, which requires in the presence of adverse selection, low-powered incentives*".[46]

127. We can apply these principles to the simple model estimated earlier. Under the first approach where the cost estimate was the simple average of the observed costs of the other firms the exogenous cost estimate was $355 million with a standard error of $92.2 million. If we assume the sample data above were drawn from a normal distribution, the regulator could be around 97.5% confident that the regulated revenue was above the true cost of the regulated firm by choosing a regulated revenue of $539.4 million. Of course, this yields a high probability that the regulated firm will be overcompensated. The information rent in this example is large because the information available to the regulator is relatively poor.

128. In the second case, the regulator collected additional information on the length of each network and estimated a simple linear two-parameter model. This model gave an exogenous cost estimate (for a network of 500 kms) of $300.5 million with a standard error of 0.686. As a result, if the regulator set the revenue equal to, say, $301.87 million the regulator could be very sure that the regulated firm would be adequately compensated.[47] The information rent has reduced substantially.

129. In general, the size of the information rent will depend on the statistical accuracy of the cost model. If the probable error in the cost estimate is small, the size of the information rent will be small. On the other hand, when the statistical error in the cost estimate is large, the information rent will be large which may not be sustainable. The appropriate response of the regulator in this context is discussed in the next section.

130. Even if the cost model yields a relatively small statistical error (suggesting that the model's cost estimates are relatively accurate) this does not necessarily imply that the information rent is small. The cost model itself depends on certain assumptions (e.g., assumptions about errors being normally distributed) which may not accurately reflect reality. Ideally, these uncertainties should be added to the statistical error predictions of the model itself and should (in principle) be reflected in a higher information rent.

131. Of course, the need to take into account the risk that the model is not correctly formulated applies equally strongly when non-statistical techniques are used to calculate the cost model. One of the drawbacks of non-statistical techniques (such as data envelope analysis) is that the model itself provides no "internal" estimate of the accuracy of the results. This does not mean, of course, that the model provides estimates of perfect accuracy. How are error estimates to be obtained in this circumstance? One approach is to observe the variability of the cost estimates of the model under different formulations. If small changes in the model's assumptions lead to large changes in the cost estimates it seems likely that a much larger allowance

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[46] Laffont and Tirole (2000), page 40-41, emphasis in the original.
[47] Of course, in practice, there still remains some uncertainty about whether the model was specified correctly which is ignored in this example.

would be necessary than that suggested by the model itself to ensure that the regulated firm is adequately compensated.

132. In addition, there is one final source of uncertainty faced by the regulated firm. The cost model is inevitably estimated using historical cost information. Even if there were a very high precision in the estimated model there remains the risk that a change in the environment will change the parameters of the cost function. This possibility increases the risk faced by the regulated firm and should (in principle) be reflected in the information rent.

133. By way of illustration, the next box sets out the experience of the energy regulator in the Netherlands in using DEA to set the regulated revenue of regulated distribution companies. The model actually used was relatively simple, and related costs to a relatively small number of cost drivers. The Dutch regulator made no allowance for uncertainty in the predictions of the model thereby implicitly assuming that *all* of the observed cost differences were due to controllable efficiencies. This assumption was made even though, even though the analysis of the regulator itself showed that cost estimates varied by 20-30% depending on the formulation of the model chosen. Unsurprisingly the regulator has been challenged in the courts.

134. The Dutch regulator is not alone in mis-using the output of benchmarking models. As the following box shows, regulators in the UK and Norway have also attempted to set regulated revenue directly on the basis of the output of cost models (with no attempt to reflect the errors in estimation in the models).

The Experience with DEA in the Netherlands

In the Netherlands, the Dutch energy regulator, DTe, sought to set the regulated revenue stream of 18 electricity distribution companies and one electricity transmission company in part on the basis of the observed cost outcomes of the companies in this industry. In particular, the DTe commissioned Frontier Economies to use Data Envelope Analysis (a non-statistical technique) to determine the “efficient frontier” and then to assess the extent to which each firm departed from the efficient frontier.

The DEA technique was carried out for two different measures of cost: (a) controllable operating expenditure and (b) controllable revenues (operating expenditure plus annualised standardised capital cost). A number of different combinations of seven cost-influencing factors were considered (the seven factors were number of units of electricity distributed, number of small and large customers, length of network, number of transformers, peak demand at low voltage and peak demand at high voltage).

Perhaps not surprisingly, the distribution companies exhibited a wide range of relative efficiency, with the worst performers having an efficiency of around half that of the best performers.

The Dutch regulator used this information on relative efficiency in the following way – the regulator assumed that the model correctly and fully reflected all inter-firm cost differences (so that all remaining cost differences were due to controllable efficiencies). The Dutch regulator assumed that these inefficiencies could be removed in a single regulatory period, which in this case was three years. A firm which was, say, 35% inefficient was therefore required to increase its productivity at a rate of around 10% per annum (in fact DTe placed a cap on the X factor of 8% per annum).

The approach of DTe was subsequently subject to a review by the Dutch competition authority (the NMa). EEE Ltd write: "After improving the quality of the data NMa altered the methodology for standardising the capital charges, and reset the Xs which resulted in modest reductions to many of the Xs proposed by DTe. Significantly the changes in data and methodology between DTe's analysis and NMa's analysis resulted not only in significantly higher efficiency under NMa's methodology, there were also significant changes in relative efficiency between the companies."

Not surprisingly, many distribution companies have sought to appeal this approach to the courts.

In the light of the analysis set out in this paper, we can see that the fault of the DTe and the NMa was to assume that the DEA technique fully and completely adjusted for any differences in the cost-influencing factors between firms, so that any remaining differences can be attributed entirely to controllable differences in efficiencies. This point is echoed by EEE Ltd who note that "DTe and NMa implicitly assumed that after making some small adjustments for exogenous factors a DEA score of less than 1 is entirely due to inefficiency, rather than due to a mix of inefficiency, of differing cost characteristics and modelling error."

As EEE Ltd observe, the fallacy of this assumption can be seen in the both "the variation in both the absolute calculation of efficiencies and the change in relative efficiencies between the analyses by DTe and by NMa".

As the analysis in this paper has argued, given the uncertainty in the accuracy of the model, the DTe should have set the revenue cap in such a way that it could be virtually certain that all firms would receive at least an adequate rate of return. How much would this imply scaling up the revenue? It is difficult to say. Unfortunately, one of the disadvantages of the DEA approach is that it does not yield statistical information on the reliability of the estimates.

Theoretically efficient regulation: the menu of contracts

135. In the previous section we noted that if the regulator is to be certain that the regulated firm will be adequately compensated, the regulator must increase the regulated revenue above the cost estimate yielded by the cost model to the point where the regulator can be almost certain that the revenue will be sufficient to cover the true costs of the regulated firm. As we noted above, if the estimation error in the cost model is large the resulting information rent may be large and therefore reliance on exogenous cost measures will be unsustainable.

136. However, the regulator need not abandon the use of exogenous cost measures entirely. There is an alternative which moves the regulatory scheme closer to the theoretically optimal regulatory mechanism.

137. In particular, the regulator can ensure that the regulated firm does not go undercompensated by allowing the regulated firm the *option* of choosing a low-powered incentive scheme (such as rate of return regulation) if it wishes. Although there is some probability that the regulated firm will choose the low-powered incentive scheme and will have only weak incentives for cost-reducing effort, there remains some probability that the regulated firm will choose the high-powered incentive scheme and will therefore have strong incentives to increase its efficiency. This approach is better than simply abandoning the use of high-powered schemes entirely.

138. To see this more clearly, suppose that the regulator obtains an exogenous measure of cost. If the regulator set the regulated revenue *equal* to this cost measure there would be a strong possibility (usually around 50%) that the regulated firm will be systematically undercompensated. But suppose that the regulator simultaneously offered the regulated firm the option of rate-of-return regulation (i.e., regulation based solely on the firm's own endogenous costs). In this case if the "true" cost of the regulated firm were such that the firm would be undercompensated by the tariff based on the exogenous cost measure, the firm could choose the tariff based on the endogenous costs, which yields a strong assurance of being adequately compensated. At the same time, if the "true" cost of the regulated firm were such that the tariff based on the exogenous cost measure would lead to over compensation of the firm, the firm would choose the higher-powered tariff. Overall, the economy would benefit from the stronger incentives for cost efficiency present under this tariff.

139. The regulator may be able to do even better than the simple two-tariff menu in the example above. In particular, by offering a third "medium"-power tariff, there may be some positive probability that the regulated firm would choose this medium-powered tariff rather than just rate of return regulation.

140. In fact, economic theory shows that the theoretically optimal regulatory regime involves a (possibly large) menu of tariff options from which the regulated firm can choose. If the regulated firm happens to have a "true" cost which is significantly higher than the exogenous cost estimate the regulated firm will choose a low-powered incentive scheme. The lower the "true" cost of the regulated firm, the higher the power of the incentive scheme it will choose. Under the optimal regulatory regime, if the regulated firm happens to have the lowest possible "true" cost it will always choose the highest powered incentive scheme and will therefore choose the efficient level of cost-reducing effort.

Focus on calculating the rate of change of the exogenous cost estimate

141. In the previous section the regulator sought to come up with an exogenous estimate of the costs of the regulated firm. But, as we saw in the last section, this approach has certain drawbacks. If the regulator cannot credibly demonstrate that it has incorporated all the relevant cost-influencing factors, the regulator must either (a)

scale up the exogenous estimate to the point where there is a high probability that the regulated firm is, on average, over-compensated or (b) make use of a menu of tariff options.

142. An alternative approach is to focus not on the level of the exogenous cost estimate but on its rate of change. The usefulness of this approach depends on the assumption that the rate of change of costs is largely independent of inter-firm cost-influencing factors – in other words, the assumption that all the comparable firms, no matter what their individual situation, can reduce their costs at the same rate. (Or, more generally, that the regulator's model completely and fully captures all of the factors which influence the rate of change of costs)

143. To the extent that this assumption will be accepted by the courts, the regulator can base the (rate of change of) the regulated revenue on the exogenous measure of the rate of change of costs. Any increase in the apparent profitability of the regulated firm is therefore due to an increase in the efficiency of the regulated firm, for which it should be rewarded. Conversely any reduction in the apparent profitability of the regulated firm must be due to a reduction in the efficiency of the regulated firm.

144. Note that the current rate of change of an exogenous measure of costs is not something which is observable at the time the regulator must make its decision on (the rate of change of) the regulated revenue. As a result, the regulator must make a forecast of the likely rate of change of the exogenous measure of costs in the future. This introduces the risk that the future rate of improvement in cost efficiency might be different than the past (perhaps due to a slow down in technological developments).

145. In practice, when regulators control the rate of change of revenue or prices, they almost always use a "CPI-X" approach – that is, they allow the regulated revenues or prices to increase at a rate equal to the consumer price index less an "X factor". This raises the question as to how the regulator should set the X factor.

146. Let's suppose that the regulated firm has a cost function of the form $C = C(q, r, w, t)$ where *q* is the quantity of output of the regulated firm, *r* and *w* are the cost of inputs capital and labour respectively, and *t* is a time variable – reflecting the fact that the regulated firm may become more (or less) efficient over time. Let's suppose that the regulator regulates prices equal to average cost (i.e., $p = \frac{C}{q}$). Then the percentage rate of change in the regulated prices are given by:

$$\frac{\dot{p}}{p} = \frac{\dot{C}}{C} - \frac{\dot{q}}{q} = \frac{1}{C}(C_q \dot{q} + C_w \dot{w} + C_r \dot{r} + C_t) - \frac{\dot{q}}{q}$$
$$= \frac{wC_w}{C}\frac{\dot{w}}{w} + \frac{rC_r}{C}\frac{\dot{r}}{r} + (\frac{qC_q}{C} - 1)\frac{\dot{q}}{q} + \frac{C_t}{C}$$
$$= \varepsilon_w \frac{\dot{w}}{w} + \varepsilon_r \frac{\dot{r}}{r} + (\varepsilon_q - 1)\frac{\dot{q}}{q} + \frac{C_t}{C}$$

where $\varepsilon_w = \frac{wC_w}{C}$ is the elasticity of a change in cost with respect to a change in the price of labour inputs, $\varepsilon_r = \frac{rC_r}{C}$ is the elasticity of a change in cost with respect to a change in the price of capital inputs, and $\varepsilon_q = \frac{qC_q}{C}$ is the elasticity of a change in cost with respect to a change in the quantity of output (or, equivalently, the ratio of marginal cost to average cost). Note that $\varepsilon_q < 1$ signifies increasing returns to scale.[48]

147. In other words the percentage rate of change of regulated prices is a linear function of the percentage rate of change of input prices, the percentage rate of change of output and the rate of change of overall productivity.

148. The final step is to place this analysis in a general equilibrium context. In a general equilibrium context only relative price levels matter (absolute price levels have no meaning). If the average cost of two industries are reducing at the same rate their relative prices do not change. The percentage rate of change of a relative price is just the difference in the percentage rate of change in the individual prices (i.e., $\frac{p_2}{p_1}\frac{d}{dt}(\frac{p_1}{p_2}) = \frac{\dot{p}_1}{p_1} - \frac{\dot{p}_2}{p_2}$). So let's consider the rate of change of the ratio of the price of the output of the regulated industry and a hypothetical good consisting of "all other goods and services in the economy". If we assume that the economy as a whole exhibits constant returns to scale, we can conclude that the percentage rate of change of the regulated price is equal (a) to the percentage rate of change of all goods and services in the economy plus (b) a term related to the rate of increase in input prices in the regulated industry less a term related to the rate of increase in input prices in the rest of the economy; plus (c) a term related to the rate of increase in productivity in the regulated industry relative to the rate of increase in productivity in the rest of the economy; plus (d) a term related to the effect of increasing returns to scale in the regulated industry.

149. In practice, this approach is usually simplified further. In particular, the last term (which relates to the effect of increasing returns to scale) is usually subsumed within the third term (the general productivity increase in the industry). In addition, the regulated industry is often assumed to experience the same rate of input price inflation as the rest of the economy. As a result we have derived that the percentage rate of change of regulated prices should be equal to the percentage rate of change of all goods and services in the economy less a term reflecting the difference in productivity growth between the regulated industry and the rest of the economy.

150. This approach can be illustrated using a simple example drawn from Bernstein and Sappington (2001). In this example "the expected annual rate of productivity growth in the regulated industry is 2%, and the corresponding growth rate elsewhere in the competitive economy is 1%. Input prices in the regulated industry are expected to increase 0.5% annually, and the corresponding growth rate of input prices

[48] This analysis is similar to analysis in Bernstein and Sappington (1999).

elsewhere in the economy is 1.5%. In this setting, the X factor should be 2% (=(2-1)+(1.5-0.5)%)".[49]

151. In practice, the rate of change of an exogenous cost measure can be estimated by calculating a cost estimate using any one of the models used to estimate the level of exogenous costs mentioned in the previous section. In addition to those methods, a measure of the rate of change of exogenous costs is often estimated by looking at the change in total factor productivity for an industry over time. Of course, there is always a risk that the historic rate of change of exogenous costs will not continue into the future. To an extent this could be controlled by estimating a function which yields the "rate of change of costs" as a function of certain factors.

Application to Benchmarking Transmission and Distribution Companies

152. The analysis in the previous section highlighted certain theoretical issues with benchmarking. It is clear that the sustainability of an incentive mechanism based on benchmarking will depend (amongst other things) on the precision of the cost estimates. An important question, therefore, is whether or not it is in practice feasible to accurately estimate exogenous costs for electricity transmission and distribution companies.

153. In this section we look briefly at the experience with attempts to obtain exogenous cost estimates of electricity transmission and distribution companies.

Benchmarking Distribution Companies

154. Is it possible to come up with a reasonably accurate cost model for electricity distribution companies in Australia?

155. There are several reasons why it might be possible to use benchmarking in the regulation of distribution companies: distribution companies provide services which are somewhat more comparable than those of transmission companies; there are more typically a reasonable number of distribution companies in any one country; and data is available for a large number of companies in other countries (especially the US).

156. There is, in fact, a long history of benchmarking electricity distribution companies. Jamasb and Pollitt (2000) provide a list of about 25 such studies (reproduced here as a table in the appendix to this paper). The table on the next page sets out the key features of those studies which have been directly used to determine the regulated revenues for distribution companies.

157. As a case-study, I focus here on one such study, carried out by Pacific Economics Group ("PEG") for CitiPower (an electricity distribution company in Victoria). The Pacific Economics Group are acknowledged experts on benchmarking and are regularly commissioned to provide relative efficiency studies for regulated

[49] Bernstein and Sappington (2001), page 3.

and non-regulated firms. Their study of CitiPower yields some insights on the extent to which these techniques might be useful in Australia.[50]

158. Broadly speaking, this study involved the following steps:

- First, a simple econometric model was estimated. This model sought to explain the observed total cost of the utility based on several cost-influencing variables referred to in the study as "business conditions" variables.

- Second, the parameters of this model were estimated using a database of 103 distribution companies in the US.

- Third, the estimated model was then applied to the business conditions affecting CitiPower to determine an exogenous cost estimate. This cost estimate was then adjusted in various ways to enhance comparability with the actual costs incurred by CitiPower.

159. The measure of total cost which the model sought to estimate was defined as the sum of operating expenses, customer service costs, a share of "administrative and general" expenses and the "capital cost". The capital cost was estimated using a straight-line depreciation technique.

160. The model estimated the total cost based on six "business conditions" variables – the quantity of electricity delivered (in MWh), the price of labour services, the price of capital services, the number of total customers, miles of distribution line, and the percentage of distribution plant which is for electricity (to account for the fact that many distribution companies provide both gas and electricity which may share economies of scope).

161. PEG note that many other variables were considered but were "ultimately excluded due to data quality problems or the lack of statistical significance of their parameter estimates". These included: peak load; load factor; area of territory served; percent of line miles underground; a measure of the severity of cold weather; a measure of the severity of hot weather; rainfall; number of tariff options; and the poverty rate.

162. The estimated cost function was as follows (the t-statistic for each of the parameters is indicated in brackets):

$$\log Cost = \underset{(482.45)}{15.045} + \underset{(32.25)}{0.160} \log Price\_Labour + \underset{(89.67)}{0.592} \log Price\_Capital + \underset{(1.72)}{0.123} \log Volume$$

$$+ \underset{(10.97)}{0.729} \log Num\_Customers + \underset{(2.37)}{0.099} \log Miles\_Lines + \underset{(1.72)}{0.325} \log Percent\_Electric$$

[50] See Kaufmann et al (2000).

163. A number of adjustments were made to allow CitiPower's cost estimate to be compared with CitiPower's actual costs. In particular, Citipower's costs exclude the cost of substations which bring the power down to distribution voltage levels. In the US, such substations are usually included in the distribution assets. In addition, the costs of connection to the distribution system are sometimes recovered from customers. In the US, in the FERC dataset, distribution companies report total connection costs (whether customers have paid a contribution or not). Other differences relate to the provision of street lighting (which CitiPower provides, whereas on average "US utilities provide less street lighting than CitiPower") and the allocation of common costs (most US utilities are integrated into generation and transmission allowing the common costs to be spread over a larger cost base). CitiPower's costs were converted into a US dollar equivalent using purchasing power parity rather than the actual exchange rate applying at any point in time.

164. Using this equation, PEG estimate a cost for CitiPower of around $104,000 for 1997 and $102,000 for 1998. PEG do not directly report the error bounds on these estimates, however they do report that the cost which is around $21,000 lower is only 1.66 standard deviations away from the mean. This suggests that we can only be around 95% sure that the "true" cost falls in the range $80,000-120,000. Put another way, the regulated revenue would have to be at least $120,000 to be reasonably sure that the firm would not go undercompensated.

165. This is a reasonably large error term. Using this information to regulate CitiPower might prove to be unsustainable. Given that CitiPower's actual cost out-turn in 1998 was around $80,000, if CitiPower was regulated on this basis, it might expect to earn rather substantial excess returns which might not be tolerated indefinitely. Of course, an alternative is to use a menu of tariff options.

Table 3: Benchmarking and incentive regulation of distribution utilities in selected countries

Country	Benchmarking/regulation method	Benchmarking sample	Inputs and outputs	From benchmarking to X-factor/reward
Great Britain	COLS analysis of OPEX Revenue cap	14 RECs in Great Britain	Input: OPEX Output: Composite variable (50% no. of customers, 25% electricity distributed, 25% network length)	High-cost utilities must move 75% of the distance to the efficient frontier by 2001/02
Netherlands	DEA: total controllable costs Revenue cap	19 Dutch utilities	Input: OPEX Output: units, peak demand high voltage, peak demand low voltage, network length, customers small, customers large	Benchmarking analysis and analysis of OPEX. X=8 to -2 for individual companies. Assume all inefficiency for companies below the maximum cap of 8 eliminated by year 3 and a frontier shift of 2% per annum (some companies could have been given up to X=17)
Norway	DEA: total controllable costs Revenue cap	~180 national, regional networks and distribution utilities	Inputs: Capital (book value and replacement cost), goods/services, losses, labour Outputs: No. of customers, energy delivered, length of lines & sea cables	Utility's revenue cap for the 1998-2001 is reduced with 38.2% of the distance of utility's efficiency score from the frontier: a 70% score means 11.5% revenue cap reduction or 3.5% p.a. plus a 1.5% p.a. general efficiency requirement
Australia - New South Wales	DEA, SFA, TFP Revenue cap	219 utilities – NSW, other Australia, New Zealand, England & Wales and US	Inputs: Total O&M costs, transformer capacity, network size Output: Electricity sold, no. of customers, peak demand	Various forms of benchmarking are used but there is not a single 'preferred' benchmarking technique or an automatic translation of the results of quantitative benchmarking into the pricing determinations.
California - Southern California Edison	ROR-based profit sharing Price cap	-	-	$P_0 = P_{1996}$, $X_{1997=1.2\%}$, $X_{1998} = 1.4\%$, $X_{1999-2001} = 1.6\%$ +/- 50 bps – shareholders receive all gains/losses +/- 50-300 bps – shareholders marginal share is 25-100% +/- 300-600 bps – shareholders receive all the gains/losses > +/- 600 bps – triggers rate review
Chile	Efficient theoretical reference / model firm Yardstick regulation	-	Input: CAPEX, O&M, losses and customer related costs (low, medium and high voltage) Output: Added distribution value (ADV) for efficient model firms	The estimated ADV (tariffs) for the model firms are applied to comparable real distribution utilities

Source: Jamasb and Pollitt (2000), table 5.

Benchmarking Transmission Companies

166. There have been significantly fewer studies which use benchmarking techniques to obtain cost estimates for transmission companies. There could be a variety of reasons for this. For example, there tend to be fewer transmission companies in any one country than distribution companies. As a result, benchmarking transmission companies almost always requires more difficult and controversial international comparisons. More fundamentally, it may be that the role of transmission is more heterogenous from one country to another.

167. Electricity transmission networks provide two services: the transportation of electricity from one point to another; and reliability benefits (i.e., enhancing the security of supply at different locations).

168. Focussing on the transportation function of transmission networks, the extent to which transmission services are required will clearly depend on the nature and location of the major fuel sources and major centres of demand. It is usually cheaper to transport electrical energy than coal – as a result, many coal-fired generators are located at mine-mouths, with reliance on electricity transmission networks to carry that electricity to the major load centres.[51] Conversely, it appears cheaper to transport gas through a pipeline than to transport electricity. As a result, gas-fired generators are generally located closer to major load centres. A country which has primary reliance on gas-fired generators will therefore tend to have a lower proportion of transmission cost in the total cost of the electricity industry.

169. It is also not clear that the quantity of electricity transported is a useful cost-influencing factor. As already noted, electricity transmission networks also provide a reliability service. A transmission line may be economically justifiable even though it carries no electricity in the normal state of the network – the line may only be required when a contingency actually occurs. Such a transmission line would appear to be highly inefficient on a measure of cost per unit of electricity actually transported. Furthermore, even if we focus on transportation services alone, a transmission line may be economically justifiable for the potential transportation services it provides – the ability to carry electricity may act as a control on market power even though no electricity is actually transported.

170. More generally, load factors are clearly also important. Electricity demand is highly variable (as can be generation – in the case of hydro, solar or wind generation). A country with highly variable demand (due to weather patterns) or highly variable generation patterns (perhaps due to fluctuating hydro production due to weather patterns) might have higher average costs than a network with a high load factor..

171. Finally, economies of scale may be more important in transmission than distribution. If there are substantial economies of scale a transmission network might

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[51] Similarly, hydro generators tend to be located in mountainous regions which are not necessarily located close to major load centres.

appear as higher cost simply because its total volume (however that is measured) is lower.

172. In any case, the table on the next page summarises the approach taken by the Netherlands and Norway in benchmarking their electricity transmission companies.

Table 4: Benchmarking and incentive regulation of transmission utilities in selected countries

Country	Benchmarking/regulation method	Benchmarking sample	Inputs and outputs	
Netherlands	DEA Revenue Cap	40 international utilities (Sweden, Spain, UK, Germany, US, Norway, Finland)	<u>Input</u>: Total Cost <u>Output</u>: Units Transmitted (kWh); Maximum Simultaneous Demand (MW); +220kV Circuit Lines (km); and Transformers (number) Efficiency: 70% (2000)	X 2
Norway	Value Chain Method (VCM) Revenue Cap	One-to-one benchmarking against the Swedish transmission company – Svenska Kraftnät	<u>Input</u>: CAPEX & OPEX costs (C), Units/No. of cost drivers (net length, transformers, connectors, stations) multiplied by assigned weights (CD) <u>Output</u>: C/CD used to compare relative efficiency • CAPEX eff. = 71.6% • OPEX eff. = 79.2% • Total eff. = 74.0%	U p. th in G 1

Conclusion

173. In theory, by placing greater reliance on exogenous cost estimates, a regulator can increase the power of an incentive mechanism. This has led to a great deal of interest in techniques for obtaining exogenous estimates of cost – often known as "benchmarking".

174. In fact, there is a relatively large literature in the techniques and practices of measuring the relative efficiency of different firms. These techniques have often been applied to electricity distribution companies (and, on occasion, to electricity transmission companies).

175. A few countries have used the output of these techniques to directly set the regulated revenues/prices of regulated transmission and distribution companies. Here, however, the output of these techniques have been misapplied. Regulators (especially in the Netherlands and Norway) have assumed that their models fully and correctly account for all inter-firm differences in cost and have therefore set the regulated revenue in a way which assumes that all firms can move to the hypothetical "efficient frontier" in a short period of time. This had led to inevitable disputes and legal challenges.

176. It seems unlikely that the regulators in these cases will be able to credible demonstrate that the remaining cost differences in their models are solely due to

differences in controllable efficiencies. In this context the regulator should set the regulated revenue in such a way that there is a very high probability that the regulated firm will be adequately compensated. This will imply over-compensating the regulated firm on average. The extent of that over-compensation will depend on the remaining degree of uncertainty about the regulated firm's true costs (i.e., the size of the error in the forecast of the model).

177. If the estimation error of the model is large the information rent may be sizeable and therefore sole reliance on exogenous cost estimates may prove unsustainable. Instead, the regulator could (and should) move to offering a menu of tariff options. By allowing the regulated firm to choose to be regulated under rate of return regulation the regulator can ensure that the regulated firm is adequately compensated with a lower overall level of information rent.

178. Although benchmarking techniques are inevitably imperfect (especially in the way they handle capital costs), when combined with a "menu of options" approach there appears to be significant scope for further reliance on benchmarking techniques to enhance the incentives on regulated firms to increase cost efficiency.

Appendix

Table 5: Electricity Benchmarking Studies

Author	Sample	Method of Analysis
IPART (1999)	219 Australian, New Zealand, England and Wales and US distribution utilities	DEA
Whiteman (1999)	7 Australian and international sample of 32 utilities	DEA, SFA
Filippini (1998)	39 Swiss municipal electricity distribution utilities 1988-91	Translog cost function
Førsund and Kittelsen (1998)	1983-89 data on 150 Norwegian distribution utilities	Malmquist DEA
Goto and Tsutsui (1998)	9 Japanese and 14 US electric utilities 1983-93	DEA
Kumbhakar and Hjalmarsson (1998)	Swedish electricity distribution 1970-1990	Translog input requirement function, stochastic frontier framework, DEA
Meibodi (1998)	Panel data of 26 LDCs (2 years). Panel data of 30 Iranian plants (6 years) and 1 cross-section of 30 dist. organisations.	SFA, DEA
Zhang and Bartels (1998)	32 power supply authorities in Australia, 51 power boards in New Zealand and 173 distributors in Sweden	DEA, Monte Carlo simulation, bivariate lognormal input distribution
Lawrence, Houghton et al. (1997)	8 Australian infrastructure industries incl. electricity 1991-96	Performance indicators, TFP, DEA
Yunos and Hawdon (1997)	Malaysian, 27 LDCs and the UK utilities	DEA
Bagdadioglu, Price et al. (1996)	76 Turkish distribution organisations (72 public, 2 private, 2 integ. Private) 1991	DEA
Burns and Weyman-Jones (1996)	12 RECs in England 1980/81 to 1992/93	SFA using cross-sectional and panel data
Claggett et al. (1995)	74 municipals, 45 co-operatives under Tennessee Valley Authority 1985-89	Profit function mode, Cobb-Douglas model
Whiteman (1995)	Electricity systems of 85 LDCs	DEA
Berry (1994)	US rural electric co-operatives and investor-owned utilities 1988 (Gen., Trans, and Dist.)	Translog cost functions for IOUs and co-operatives
Burns and Weyman-Jones (1994)	RECs 1973-93	Non-parametric programming of relative efficiency, Malmquist productive indices
Claggett (1994)	157 TVA distributors 1982-89 (108 municipals and 49 co-operatives)	Standard translog cost function
Hougaard (1994)	82 Danish distribution utilities	DEA
Pollitt (1994)	129 US transmission utilities (23 public, 106 private), 145 distribution utilities (136 US, 9 UK; 119 private, 26 public)	DEA and OLS
Giles and Wyatt (1993)	60 regional Electricity Supply Authorities for New Zealand 1986/897	Translog cost model
Miliotis (1992)	45 electricity distribution districts of the Greek Public Power Corporation	DEA
Weyman-Jones (1991)	12 UK Area Electricity Boards (AEBs) for the period 1986/87	Non-parametric linear programming efficiency measurement
Charnes et al. (1989)	75 Texas electric co-operatives	DEA compared with existing ratios and regressions based systems

Source: Jamasb and Pollitt (2000) and the references therein.

In addition to the sources in the table above, Abbott (1999) mentions several other studies of benchmarking and productivity in the Australian electricity industry including:

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