Report prepared for Vector

Setting the WACC percentile for Vector's price-quality path

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1. Introduction

1.1 Commission's notice of intent

On 31 March 2014, the Commerce Commission (Commission) issued a notice of intention to do further work on the cost of capital Input Methodologies (IMs) for electricity distribution and other businesses regulated under Part 4 of the Commerce Act 1986. The Commission invited submissions providing:[1]

- Empirical or analytical evidence regarding the appropriate WACC percentile.
- Any additional considerations (supported by evidence) that differ between sectors, which might affect the appropriate WACC percentile.

The questions posed by the Commission are narrowly focused and this report is prepared within that context. In particular, we take as accepted that the IM for determining the regulated WACC is intended to form part of a set of IMs which ensure investors retain incentives to invest when investing would increase the long-term benefit to consumers consistent with outcomes produced in competitive markets.

1.2 Approach and findings

The Commission echoes the High Court in asking whether empirical evidence and theoretical results support the Commission's decision to set the determined WACC at the 75th percentile of its estimated range.[2] We perceive this question as comprising four component parts:

- Is an estimate of WACC prone to error and if so might those errors be material?
- Are the economic effects from an error in WACC asymmetrical and if so of what order of magnitude?
- What does a given asymmetry of effect imply for determining a margin on estimated WACC?
- What is currently known, and what can be deduced or approximated, about the asymmetry of effects, and does this analysis support the Commission's decision to set the regulated WACC at the 75th percentile of its estimated range?

We arrive at the following answers to these questions:

- We show that the Commission's estimation of WACC is subject to considerable error due to model and parameter error. Hence, the Commission cannot be sure that an estimate of WACC made according to its approach (without a margin) achieves for investors an expectation of a normal return.

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1 The Commerce Commission, 'Further work on the cost of capital input methodologies: process update and invitation to provide evidence of the WACC percentile', 31 March 2014

2 The Commerce Commission, 'Further work on the cost of capital input methodologies: process update and invitation to provide evidence of the WACC percentile', ibid, paragraph 4.

- Economic theory seems unambiguous; the economic loss to society of making incorrect decisions based on the WACC estimate are higher if WACC is under estimated than if it is over estimated.
- A mixed loss function, where the loss is small for low over or underestimation but is exponential for significant underestimation, would appear to best model the loss from under or over estimation of WACC.
- Using publically disclosed information, we provide an order of magnitude estimate of the size of the potential welfare loss from a WACC that is set too high, and show that only a comparatively small amount of investment need be cancelled to produce a much larger economic loss were WACC understated by the same amount.

We conclude that the available analytical evidence, and inferences from investment decisions, certainly support the Commission adopting at least the 75th percentile, if not higher, to account for the risks of parameter error. This evidence also suggests that the Commission should, in addition, allow for model error in its estimate of WACC.

The findings in this report reflect the work that it was possible to complete to a reasonable level of rigour within the timeframes set by the Commission. Were more time available, it should be feasible to refine the analysis to help the Commission identify the degree of margin above the 75th percentile that would be necessary to achieve, on an expected basis, a welfare enhancing trade-off between the risk of understating WACC and the risk of overstating WACC.

1.3 Structure of paper

We have structured the body of our paper into four sections:

- *Section two* discusses the uncertainty inherent in estimating WACC for regulatory purposes. The 'true' WACC is not observable and its estimation is subject to two types of error: model error and parameter error.
- *Section three* shows the degree of uncertainty in the CAPM based estimate of WACC resulting from parameter error. This section also gives examples of piece-wise linear and LINEX loss functions where the loss from estimation error is asymmetric (that is, the loss from underestimation of WACC is greater than the loss from an equal degree of overestimation).
- *Section four* reviews briefly the analytical foundation for why the long-term loss to consumers would be greater from underestimation of WACC than from overestimation, and concludes that a mixed loss function, where the loss is small for low over or underestimation but is exponential for significant underestimation, would appear to best model the loss from under or overestimation of WACC.
- *Section five* reviews some analytical and quantitative evidence for guidance as to the asymmetry of loss. These approximations illustrate the point, firmly established in the theoretical literature, that only a comparatively small amount of investment need be cancelled to produce a much larger loss of benefit to consumers than they would incur if WACC were overstated.

2. A regulated firm's WACC is not known

2.1 Capital markets determine the WACC

Every business entity has a WACC, which to use the language of the High Court, is the entity's "normal expected rate of return". As the Court explained:[3]

> *The cost of capital a firm faces is the financial return that investors require from an investment in the firm, given the risk. Investors have choices, and will not invest in an asset unless the expected return is at least as good as that they might expect from a different investment of similar risk.*

The Court's observation - that investors have choices and will not invest unless the expected return is at least as good as they might expect from a different investment of similar risk – is not in dispute; the concept that investors require a risk adjusted return consistent with opportunity cost lies at the core of the IMs adopted by the Commission and upheld by the High Court.

The difficulty, however, is that the financial return required by investors, the 'true WACC', is not observable. It can be estimated but there is no way of knowing how that estimate compares with the true WACC.

2.2 WACC estimates are subject to error

2.2.1 Model error

Estimates of WACC may vary from the true WACC for a regulated entity due to the inadequacy of the CAPM as a description of the investment world that it attempts to describe; that is, from model error.

The CAPM is an abstraction from reality which is intended to be analytically tractable and yet capture the key features of the real investment world. While the CAPM is accepted as being the best available model for estimating the cost of equity, there is growing evidence in the finance literature that the CAPM does not fully capture the true costs facing a company when making investment decisions. That is, in the real world there are significant departures from the assumptions of the CAPM, with the result that an estimate of WACC obtained using the CAPM is likely to understate the true cost.

The sources of model error include the following:

- optimisation and stranding risk
- market frictions

[3] Wellington International Airport Ltd and others v Commerce Commission [2013] NZHC 3289, paragraph 1069.

- timing flexibilities
- firm resource constraints.

Optimisation risk

Optimisation risk arises from the possibility that a regulator may optimise out for regulatory valuation purposes some portion of assets that a company has invested in but which are no longer considered necessary to deliver the required service. Stranding is an extreme form of optimisation which occurs where complete assets are removed from the regulatory asset base. The effect of optimised or stranded assets in a regulated environment is to reduce the allowable revenue base of the regulated firm.

Market frictions

Market frictions can take a variety of forms including funding constraints, financial distress costs, information asymmetries, and regulation. Market frictions impose additional costs and constraints on raising capital not accounted for in the assumptions underlying the CAPM, and thus are not accounted for in a regulator's estimate of WACC.

Market frictions may impact on the overall cost of capital for the company. When a firm raises capital to invest in a project, especially if the quantum is large relative to the size of the firm, or the risk of the investment is high, this tends to influence the opportunities and cost of capital for the rest of the firm. One example of this is a firm's debt rating may fall due to the adoption of a particular project and thereby increase the cost of debt for other future projects that the firm may undertake.

Timing flexibilities

Timing flexibilities introduce a further source of error. When a project commences the firm incurs an additional opportunity cost: the sacrifice of the opportunity (or option) to begin the project at some date in the future. However, the CAPM/WACC framework implicitly assumes that projects are either fully reversible or unable to be delayed. When commencing a project the opportunity cost of the option which is sacrificed is assumed to be zero.

However, many projects are at least partly irreversible (i.e., have sunk costs) and most can be delayed. For irreversible investments, the ability to delay is valuable because it allows the firm to gather more information about the project's viability, thereby minimizing the potential for losses and maximizing the potential for maximum profits. This opportunity for further delay disappears when a project begins. This loss of flexibility is an additional capital cost of the project, the size of which increases with the specific risk of the project.

This additional capital cost manifests itself not through additional capital expenditure on the project, but rather as a reduction in the value of the firm (through loss of the option). Investors require compensation to offset this loss.

Firm resource constraints

The CAPM/WACC framework assumes that firms have unlimited resources and have no constraints on growth. Firms frequently face rationing of managerial talent and organisational capital, simply because they have more desirable projects in the pipeline than they have resources available to execute them. Consequently, commencing a project today may entail sacrificing the option of another project in the future, and this foregone opportunity is an additional capital cost of the current project. Again, the more uncertainty there is about the future project's prospects, the more valuable is the firm's option on it, and hence the greater is this additional cost.

The issues summarized above have been addressed on many occasions in the expert reports submitted to the Commission for consideration in its deliberations on setting WACC. The Commission has agreed that at least some of these issues impact on WACC but it has adopted the view that until the companies can provide estimates of the impact it will not make any adjustment to the allowed WACC. This is unsatisfactory. If a cost is greater than zero, zero is not the best estimate of that cost. Nor would it seem to be consistent with the Commission's charge to promote outcomes consistent with outcomes produced in workably competitive markets.

2.2.2 Parameter error

WACC is a weighted average of the cost of debt and the cost of equity. Neither can be observed and therefore must be estimated:

- The cost of debt is estimated as the sum of the risk free rate and the debt premium.
- The cost of equity is estimated by use of the Capital Asset Pricing Model (CAPM).

Thus, in estimating a WACC for regulatory purposes, a regulator must estimate a number of parameters – leverage, the risk free rate, the debt premium, beta and the market risk premium. While leverage can be regarded as a decision variable, the other parameters are unobservable and must be estimated. Estimates of these input parameters are subject to considerable uncertainty; the estimates of beta and the market risk premium are particularly uncertain.

The Commission to date has recognised the problem of parameter error. To reduce the probability of it setting, in error, an allowed WACC for regulated firms less than the true WACC, and hence to reduce the probability of under investment, the Commission adds a margin to its estimate of WACC. We discuss this margin further in Section three below.

2.3 Real world setting of hurdle rates

Extensive survey literature on capital budgeting decisions show that in workably competitive markets firms employ hurdle rates well in excess of WACC. The literature also shows that firms use sophisticated capital budgeting techniques, including using the CAPM to estimate the cost of equity and WACC to discount unlevered cash flows. However, there is very significant variation across firms in terms in the estimates of the inputs to the CAPM calculation.[4] Furthermore, firms adjust discount rates for additional factors such as new

[4] Brotherson, W., Eades, K., Harris, R. and R. Higgins, 2013, ""*Best Practices" in Estimating the Cost of capital: An Update*", Journal of Applied Finance, 15-33.

business, project size, planning uncertainty, changes in market conditions and international investment.[5]

Summers (1987)[6] finds that the average hurdle rate used by Fortune 500 firms in the mid-1980s was approximately double the maximum WACC possible for the average firm. Poterba and Summers (1995)[7] report similar findings for Fortune 1000 firms: an average real hurdle rate of 12.2% versus a maximum possible WACC of 7%. The results reported in Arnold and Hatzopoulos (2000)[8] for a 1997 UK survey suggest an average nominal hurdle rate of 14.6%. Jagannathan, Matsa, Meier and Tarhan (2014)[9] report that in their 2003 study the hurdle rates used by their sample firms are on average twice the CAPM based WACC rates. The recent study by Sharpe and Suarez (2014)[10] shows that while interest rates dropped by 8% between 1985 and 2012, reported hurdle rates have remained relatively constant.

It is possible that that the gap reflects an internal mechanism for controlling the asymmetries in the distribution of cash flows around the forecasts by managers. Such asymmetries may be caused by the risk of low probability but high impact negative shocks that are difficult to model explicitly in cash-flows (such as natural disasters, technological stranding and/or transaction costs resulting from future periods of financial distress).

That is, the higher reported hurdle rate may, in part, be a reflection of the fact that the project must pay off above the true WACC in the normal state of affairs in order to compensate for the fact that asymmetric risks to cash-flows cause the mean expected return to be lower than this. Of course, to the extent that companies face such asymmetric risks to cash flows the same logic suggests that the Commission should provide a margin above its CAPM based estimate of WACC.

Alternatively, high hurdle rates might reflect a policy of firm's tending to appraise projects riskier than the average of its existing assets. This seems unlikely to be important for at least two reasons.

First, direct evidence suggests otherwise. These hurdle rates are obviously ex ante rates of return and may be higher than average realised rates but the margin points to the fact that firms seek compensation for investing that exceeds the CAPM-based estimate of WACC. The margin is likely to be in response to the factors discussed above in relation to

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5 See for example, Association for Financial Professionals, 2013, "*Estimating and Applying Coast of Capital: Report of Survey Results*", 22pp.

6 Summers, L., 1987, *Investment incentives and the discounting of depreciation allowances, in The Effects of Taxation on Capital Accumulation*, ed. Martin Feldstein, Chicago: University of Chicago Press.

7 Poterba, J. and L. Summers, 1995, *A CEO survey of US companies' time horizons and hurdle rates*, Sloan Management Review, 43-53.

8 Arnold, G. and P. Hatzopoulos, 2000, "*The Theory-Practice Gap in Capital Budgeting: Evidence from the United Kingdom*, Journal of Business Accounting & Finance, 603-626.

9 Jagannathan, R., Matsa, D., Meier, I. and V. Tarhan, 2014, *"Why do firms use high discount rates?"*, working paper (available from SSRN), March, 77pp.

10 Sharpe, S. and G. Suarez, 2014, "*The insensitivity of investment to interest rates: Evidence from a survey of CFOs*", Federal Reserve Board, Washington, DC, 40pp.

incompleteness of the CAPM-based estimate of WACC. There are a number of studies that support that view. Mukherjee and Hingorani (1999)[11] report that the most common reasons for senior management to employ high discount rates are high unsystematic risk, project irreversibility, and valuable future investment opportunities. The first and third of these are consistent with concern about market frictions and future financing costs; the second is consistent with the recognition of timing options.

Similarly, Graham and Harvey (2001)[12] find that more than a third of firms adjust their discount rate upwards in response to project-specific risks, and also to non-market macro risks such as interest rates, GDP and unexpected inflation. Graham and Harvey (2011 and 2012)[13] report mean discount rates of 14.7% in 2007, 14.8% in 2011 and 13.5% in 2012, close to the numbers reported by Jagannathan et al (2014). Keck, Levengood and Longfield (1998)[14] report that such behaviour is even more prevalent in the firms of smaller countries that are less integrated into global capital markets. Bruner et al[15] find that firms adjust their hurdle rates for investment-specific risks. Over half of the respondent firms in their survey do, or sometimes do, make adjustments to reflect the risk of individual investment opportunities in their hurdle rates.[16] Froot (1999)[17] examined eight possible reasons for the high implicit discount rates used in the catastrophe insurance industry and concluded that capital market frictions were the most likely reasons. Finally, Jagannathan et al (2014) suggest that organisational and managerial resource constraints may explain the margin over WACC.

Second, internal control procedures cannot explain other common firm responses to project-specific risks, the most notable of which is hedging. There is clear evidence that firms hedge a great deal. They hedge currency risk, interest rate risk, price risk, demand risk and most other risks to which they have significant exposure. But hedging cannot be rationalised in a pure CAPM world. If the risks being hedged are project-specific, then the firm is expending resources on activities that investors could undertake themselves. If the hedged risks contribute to a firm's market risk, then hedging simply moves the firm along the capital market line and its value remains unchanged. Thus, in a CAPM world, hedging is a zero net-present-value project at best. The ubiquity of hedging, therefore, is a strong indicator that project-specific risk is important for competitive firms.

11 Mukherjee, T. and V. Hingorani, 1999, Capital-rationing decisions of Fortune 500 Firms, Financial Practice and Education, 7-15.

12 Graham, J. and C. Harvey, 2001, "The theory and practice of corporate finance: evidence from the field", Journal of Financial Economics, 187-243.

13 Graham J. and C. Harvey, September 2011 and June 2012, Duke/CFO Magazine Global Business Outlook, US topline tables.

14 Keck,T., Levengood, E. and A. Longfield, 1998, Using discounted cash flow analysis in an international setting: A survey of issues in modelling the cost of capital, Journal of Applied Corporate Finance, 82-99

15 Bruner, R., Eades, K., Harris, R. and R. Higgins, 1998, Best practices in Estimating the Cost of Capital: Survey and Synthesis, Financial Practice and Education, 13-28.

16 Bruner *et al*, p.18.

17 Froot, K., Ed., 1999. *The financing of catastrophe risk*. University of Chicago Press.

2.4 Conclusion

Error in estimation of WACC arises from two sources: model error and parameter error.

This section has established that model error is likely to be significant. However, while the Commission has to date conceded the existence of model error it has not allowed for model error in establishing its estimate of WACC. This approach reflects the Commission's view that estimation of a margin for model error is difficult. However, if a cost is known to have a value that exceeds zero then zero is certainly not a good estimate of that cost.

The Commission does allow for parameter error and hence the so-called 75th percentile estimate of WACC. However, in section three we show that the Commission's approach does not recognize the high degree of uncertainty arising from parameter error. Section three also gives examples of piece-wise linear and LINEX loss functions where the loss from estimation error is asymmetric.

3. The Commission's 75th percentile estimate

3.1 Allowing for parameter error

The Commission recognises the problem of parameter error by adding a margin to its estimate of WACC. While the Commission calls this adjusted estimate the 75th percentile of the distribution of WACC, that description is incorrect. WACC is a fixed point – it does not have a probability distribution. We show below that the Commission's estimate is subject to considerable sampling error.

Estimation of the cost of equity proceeds by substituting in the CAPM equation point estimates of the parameters. Thus uncertainty surrounding these point estimates of the parameters translates through to the estimate of WACC as there is an algebraic relationship between the parameters and WACC. In addition there is uncertainty in estimation of the margin of the cost of debt over the risk free rate. The processes of generating the estimates of the parameters can be thought of as stochastic processes that throw up a different value each time an estimate is made, and thus the estimator of WACC, denoted by $\hat{W}$, can also be thought of as being stochastic. That is, there is a probability distribution for $\hat{W}$. This probability distribution is called the sampling distribution of $\hat{W}$.

If the properties of the sampling distribution were known then it would be possible to calculate the probability that the estimation process will produce estimates of WACC that fall above or below any specified action limit. The Commission assumes (reasonably) that:

- $\hat{W}$ is unbiased; that is, that the expected value of $\hat{W}$ equals W, the mean value of the sampling distribution for this method of estimation.
- The sampling distribution of $\hat{W}$ is a normal distribution. That is, the sampling distribution of $\hat{W}$ is N(W, $\sigma^2(\hat{W})$) where $\sigma(\hat{W})$ is the standard deviation of the distribution.

Thus, if the Commission sets the WACC equal to $\hat{Y}$, the value of the observed estimate, $\hat{W}$, plus a fixed margin, K, that is:

$$\hat{Y} = \hat{W} + K$$

then $\hat{Y}$ is also a normal distribution, with expected value Y = W+K and, given that K is fixed, also standard deviation $\sigma(\hat{W})$, that is, $\hat{Y}$ is N(W+K, $\sigma^2(\hat{W})$). The relationship between the two normal distributions is shown in Figure 1 below.

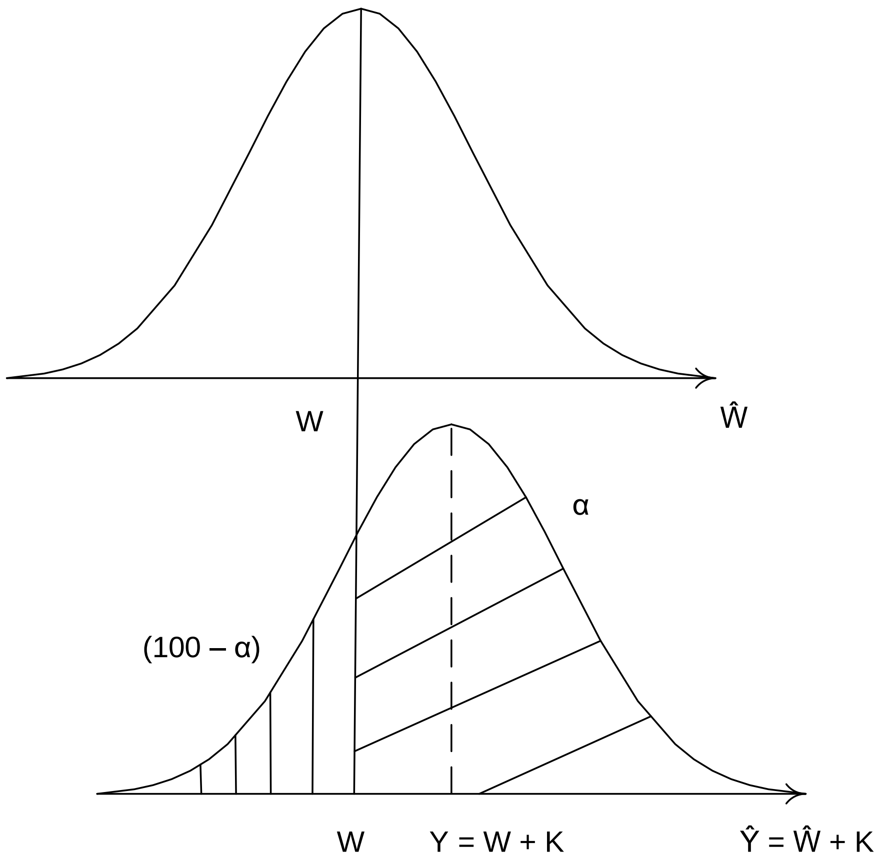

Figure 1: The sampling distributions of $\hat{W}$ and $\hat{Y}$

Figure 1 shows the probability of under estimation of W, that is, $\hat{Y}$ is less than W, as (100 - α)%, or equivalently, the probability of over estimation of W, that is, $\hat{Y}$ is greater than W, as α %. The choice of the value of α determines the size of the margin, K (and vice versa). Expressing K as K = Z $\sigma(\hat{W})$, where Z is the standard normal deviate corresponding to α, then, for example:

if K = 0.6745 $\sigma(\hat{W})$ then α = 75% (1)

or, with a margin twice as large, that is, K = 1.3490 $\sigma(\hat{W})$, then α = 91.1% (2)

This means that for any particular estimation of WACC, the estimate made may be less than or greater than the mean value, W, as W is not known; however, with use of, for example, K = 0.6745 $\sigma(\hat{W})$, the process followed to obtain the estimate will produce an underestimate 25% of the time and an overestimate 75% of the time. With the twice as large margin, the estimate would produce an underestimate 8.9% of the time and an overestimate 91.1% of the time.

The estimator $\hat{W}$ is based on the CAPM and therefore it does not include a margin for model error. Given the case presented in section two above, model error does exist and therefore $\hat{W}$ is a biased estimator of the 'true' WACC and the mean value, W, understates the true WACC by the margin that should be allowed for model error.

The Commission's concept of its "75th percentile estimate" of WACC is evident from Table 7.4 (page 267) of the 2007 Draft Decisions paper[18] on the supply of natural gas. The table shows "percentiles", calculated as follows:

$$\hat{W} + Z\,\hat{\sigma}(\hat{W})$$

where $\hat{\sigma}(\hat{W})$ is an estimator of $\sigma(\hat{W})$. Thus for $\alpha = 75\%$, the percentile is:

$$\hat{W} + 0.6745\,\hat{\sigma}(\hat{W})$$

The Commission describes these percentiles as percentiles of the WACC distribution and the [75th] percentile is explained as being such that "… there is only a [25%] probability that the true value [of WACC] is more than this …". These statements are incorrect. There is no WACC distribution and thus there are no percentiles as per the Commission's description. The WACC is a fixed (but unknown) number. A percentile is a fixed point on a probability distribution. The Commission's 75th percentile is a variable. It makes sense to state the probability of the value of a variable falling above or below a fixed number, but not the converse. The explanation should be that the 75th percentile is such that there is <u>around</u> a 25% probability that the value of the estimator will be less than the mean value W (the mean of the sampling distribution and true WACC exclusive of a margin for modelling error). Equivalently, there is <u>around</u> a 75% probability that the value will be greater than W.

An important difference between the explanations for the 75th percentile (denoted by $\hat{\hat{Y}}$) and $\hat{Y}$ is that in relation to probability, the correct explanation for $\hat{\hat{Y}}$ uses the qualifier "around". This reflects the fact that $\hat{\hat{Y}}$ is based on $\hat{\sigma}(\hat{W})$, the estimator of $\sigma(\hat{W})$. The value of $\hat{\sigma}(\hat{W})$ will vary from one estimation to the next just as $\hat{W}$ does. Therefore the Commission's estimate of WACC is not $\hat{Y}$ equals $\hat{W}$ plus the fixed margin $Z\,\sigma(\hat{W})$ but rather, $\hat{\hat{Y}}$ equals $\hat{W}$ plus the varying margin $Z\,\hat{\sigma}(\hat{W})$. Thus, while an interval estimate for Y at 95% confidence[19] is given by:

$$\hat{Y} \pm 1.96\,\sigma(\hat{W})$$

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18 Commerce Commission, 4 October 2007, *Authorisation for the Control of Supply of Natural Gas Distribution Services by Powerco Limited and Vector Limited: Draft Decisions Paper.*

19 Choice of the 75% probability for the estimator of WACC reflects the greater concern for underestimation than for overestimation. The confidence coefficient of 95% is the conventional minimum level of confidence and applies to estimation of the percentile of the sampling distribution.

a 95% confidence interval for Y based on $\hat{\hat{Y}}$ is given by:

$$\hat{\hat{Y}} \pm 1.96\,\sigma(\hat{\hat{Y}})$$

that is:

$$\hat{W} + Z\,\hat{\sigma}(\hat{W}) \pm 1.96\,\sigma(\hat{\hat{Y}})$$

Given the asymmetric consequences of error in estimation of WACC (considered further in sections 4 and 5 below), it can be argued that the estimate of WACC should be set at the upper end of this interval. The interval can be obtained as follows:

Using the post-tax form of the CAPM, the cost of equity, k_e, is given by:

$$k_e = R_f(1-t_i) + \phi\beta_e$$

where, R_f = risk free rate

$$\beta_e = \beta_a[1 + L/(1-L)]$$

β_e = the equity beta

β_a = asset beta, and

L = leverage ratio

$$\phi = k_m - R_f(1-t_i)$$

k_m = the expected rate of return on the market portfolio

t_i = the personal tax rate on interest

The cost of debt capital, k_d, is calculated as:

$$k_d = R_f + p$$

where, p = debt premium

WACC is given by

$$WACC = k_e(1-L) + k_d(1-t)L$$

where, t = the corporate tax rate

Substituting for k_e and k_d in the equation for WACC gives:

$$WACC = (R_f + pL)(1-t) + \phi\beta_e(1-L)$$

where the personal and corporate tax rates are assumed to be equal.to t.

Given that L is a decision variable and assuming that R_f and t are not stochastic, then $\hat{W}$, the estimator of W, is given by:

$$\hat{W} = (R_f + pL)(1-t) + \hat{\phi}\hat{\beta}_e(1-L)$$

where $\hat{\phi}$ is the estimator of ϕ and $\hat{\beta}_e$ is the estimator of β_e. Then, $E(\hat{W})$, the expected value of $\hat{W}$, is given by:

$$E(\hat{W}) = (R_f + pL)(1-t) + E(\hat{\phi}\hat{\beta}_e)(1-L)$$

If ϕ and β_e are estimated by maximum likelihood from a simple market model regression using T observations (R_i, R_m), then it can be shown that the following results hold to a good level of approximation:

$$\sigma(\hat{\hat{Y}}) = \hat{\sigma}(\hat{W}) + 2Z(\frac{1-L}{T})\frac{\phi\beta\sigma_i^2}{V}$$

where

$$\hat{\sigma}(\hat{W}) = \frac{1-L}{\sqrt{T}}\sqrt{V}$$

$$V = \sigma_i^2\frac{\phi^2}{\sigma_m^2} + \beta_e^2\sigma_m^2$$

To illustrate the order of magnitude in the uncertainty in the estimate of $\hat{\hat{Y}}$, assume the following:

(a) $\hat{\sigma}_m$ = 20%, the common annual estimate[20]

(b) $T = 60$

(c) $\hat{\sigma}_i$ = 30%

(d) ϕ =7%, L=.44, β_e = 0.6

(e) Z = 0.6745

Thus, $V = 0.0254$, $\hat{\sigma}(\hat{W}) = 0.0115$, $\sigma(\hat{\hat{Y}}) = 0.0134$, and therefore the interval estimate is:

$$(\hat{W} + 0.8 \pm 2.6)\%$$

[20] See, for example Penman, S., *Financial Statement Analysis and Security Valuation*, McGaw-Hill Irwin, 2007, p 690; the estimate also accords with the Dimson et al (2004).

Thus if the calculations based on the CAPM had produced an estimate $\hat{W}$ = 8.0% then the 95% interval estimate of the 75th percentile is (8.0 + 0.8 ± 2.6)%, that is 6.2% to 11.4%. The meaning of this interval is that the limits of the interval may or may not enclose the percentile but 95% of the time intervals would be obtained such that the limits do enclose the percentile. The size of the interval in this example shows very clearly the degree of uncertainty in the Commission's CAPM based estimate of WACC resulting from parameter error.

3.2 Loss functions

The process of estimation of WACC should start with consideration of the costs of making incorrect decisions based on the estimation and whether those costs are the same for underestimation (where $\Delta = (\hat{Y} - W) \leq 0$) as for overestimation (where $\Delta > 0$). Consistent with the view that the cost of underestimation is greater than the cost of overestimation, the Commission has chosen the 75% probability level for K but it has not been clear why 75% was chosen and why not some higher probability level such as 90%. This issue can be considered, at least at a conceptual level, by use of loss functions. For example, if the relative loss of welfare from underestimation versus overestimation was modelled by the following asymmetric piece-wise linear loss function:

$$L(\Delta) = \begin{cases} |\Delta|, & \Delta > 0 \\ b|\Delta|, & \Delta \leq 0 \end{cases} \tag{3}$$

It can shown that the expected value of the welfare loss is minimised if:

$$\alpha = b/(1 + b)$$

Thus, the Commission's decision to take $\alpha = 75\%$ is actually consistent with minimising expected loss under the asymmetric piece-wise linear loss function (3) with the loss ratio set at $b = 3$, that is, where the welfare loss from underestimation is regarded as three times greater than the loss from overestimation. If the Commission had instead set $\alpha = 91.1\%$, that would have been consistent with the loss ratio instead set at $b = 9.7$. As noted at (1) and (2) above, this would have the effect of doubling the margin K from 0.6745 $\sigma(\hat{W})$ to 1.3490 $\sigma(\hat{W})$.

There are many alternative forms of loss function. For example, the greater relative loss of welfare for underestimation can be modelled as occurring only where there is significant underestimation. This type of asymmetric linear piece-wise loss function has the form:

$$L(\Delta) = \begin{cases} |\Delta|, & \Delta > -d\,\sigma(\hat{W}) \\ b|\Delta| - c\,\sigma(\hat{W}), & \Delta \leq -d\,\sigma(\hat{W}) \end{cases} \tag{4}$$

This function has a kink at $-d\sigma(\hat{W})$. As with function (3), discussed above, the combination of values for α and K reflect the choice of values for the parameters.

Panel A in Figure 2 below, shows the loss function (3) in blue (for the case $b = 3$, for which $\alpha = 75\%$ and $K = 0.6745\,\sigma(\hat{W})$) and, for comparison, the loss function (4) in red for $b = 5,\ c = 2 \text{ and } d = 0.5,$ for which the minimum loss occurs for $\alpha = 74.6\%$ at $K = 0.6609\,\sigma(\hat{W})$.

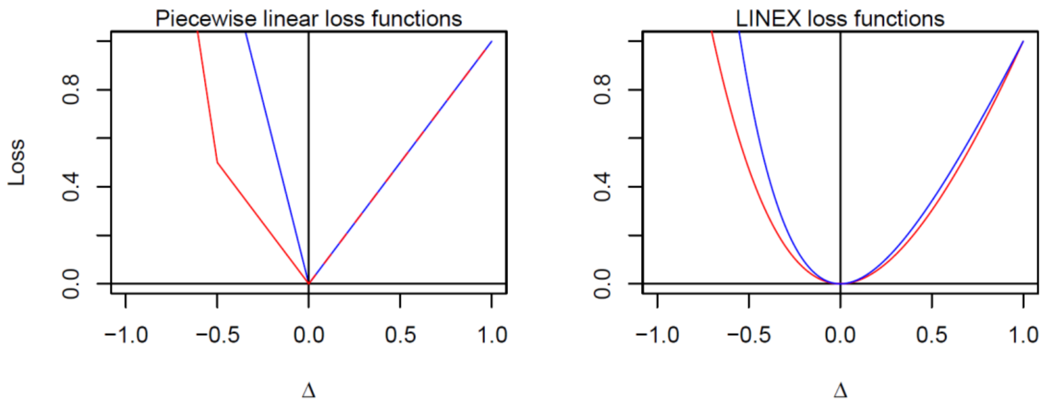
LINEX loss functions are also asymmetric. The general form is:

$$L(\Delta) = e^{-\delta\Delta} + \delta\Delta - 1$$

A particular function is determined by the choice of δ. If $\delta > 0$, the function models loss that increases almost exponentially for underestimation and almost linearly for overestimation. If δ is very small the function is close to a quadratic (symmetric) function.

Panel B of Figure 2 shows two LINEX functions. The function in red is at $\alpha = 75\%$ for $K = 0.675\,\sigma(\hat{W})$ and the function in blue is at $\alpha = 90\%$ for $K = 1.280\,\sigma(\hat{W})$. As with the piece-wise linear loss functions discussed above, the combination of values for α and K reflect the choice of the value for the parameter δ.

Figure 2 Piecewise and LINEX loss functions



Panel A **Panel B**

Panel A in figure 2, shows the two piecewise linear loss functions, the function (3) in blue and the function (4) in red. The function in blue is at $\alpha = 75\%$ for $K = 0.6745\,\sigma(\hat{W})$ and the function in red is at $\alpha = 74.6\%$ for $K = 0.6609\,\sigma(\hat{W})$. Overestimation results in the same loss for both functions. For a low level of estimation error the function in red has symmetric loss (underestimates and overestimates of the same size result in the same loss). Compared to the function in blue, the function in red, shows lower loss for a low degree of underestimation but larger loss for significant underestimation.

Panel B shows two LINEX loss functions. The function in red is at $\alpha = 75\%$ for $K = 0.675\,\sigma(\hat{W})$ and the function in blue is at $\alpha = 90\%$ for $K = 1.280\,\sigma(\hat{W})$.

In both panels A and B the error in estimation has been scaled to units of $\sigma(\hat{W})$.

In addition to these particular types of loss functions considered here, functions can also be formed that are mixtures of particular types. For example, the kinked piece wise linear function considered here could be modified so that for significant underestimation the loss increases exponentially.

3.3 Conclusion

The analysis in this section shows that the Commission's estimate of WACC is subject to considerable sampling error. Hence, the High Court was misinformed when it commented that the expectation of a normal return should be enough; neither the Commission nor the Court can be sure that an estimate made according to the Commission's approach achieves an expectation of a normal return because that estimation is subject to considerable error.

Loss functions provide a conceptual basis for choice of the probability level for the estimator of WACC in terms of the consequences of error in estimation. The Commission's decision to take P(75) as the estimate of WACC is consistent with minimising expected loss under the assumption that a simple asymmetric linear loss function appropriately describes the response to loss and, specifically, that the loss from underestimation would be regarded as three times greater than the loss from overestimation. This section also discusses other types of loss functions. In the case of the particular kinked piece-wise linear loss function considered, the loss from error in estimation is symmetric for low levels of error but for significant underestimation the amount of loss increases by a factor of 5 compared to overestimation. For LINEX loss functions, if the loss parameter is positive, the loss from underestimation increases almost exponentially while the loss from overestimation increases almost linearly. Loss functions can also be mixtures of particular types of functions.

4. Asymmetric risk to long-term consumer benefit WACC errors

4.1 Economic loss if WACC set too high

4.1.1 Welfare loss from prices being too high

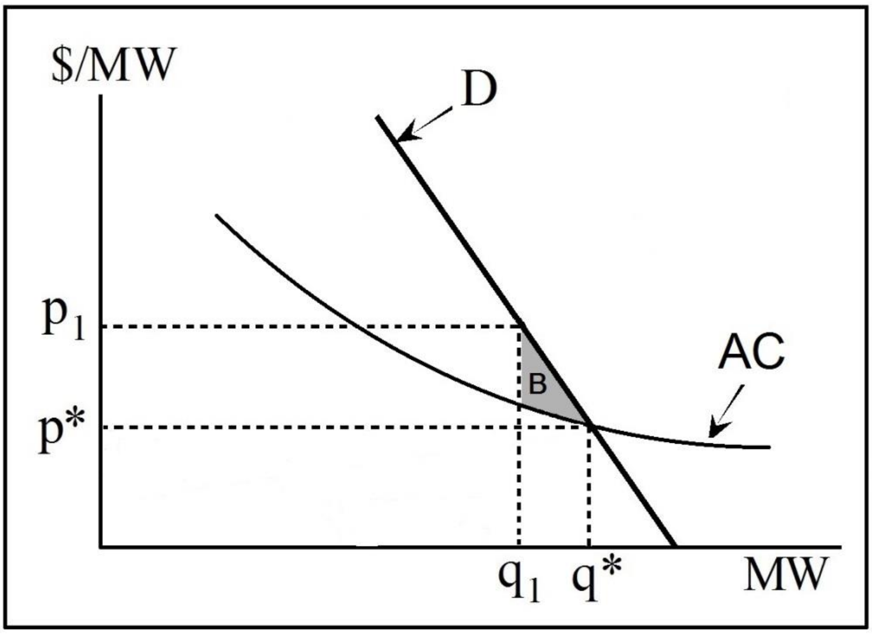
If WACC is set too high (and all other parts of the price control are precisely correct), prices will be higher than they would otherwise be. With higher prices, there would be a corresponding reduction in the quantity demanded for electricity distribution services – the analysis that follows focuses on electricity distribution but similar results would be obtained for gas transmission. Since the reduced demand for electricity distribution has a higher value to consumers than the economic cost of producing it, the reduction in demand would result in an allocative efficiency loss. Figure 1 illustrates the allocative efficiency loss if prices are inefficiently raised above average cost.[21]

In figure 1, p* reflects the price that would be charged were the determined WACC set equal to the true WACC. However, if WACC is set too high, and prices increase to p_1, demand would be reduced to q_1. This level of usage of the distribution network is inefficient, because the usage that has been discouraged would be worth more to the users than it would cost to produce. The loss in economic welfare is shown by the shaded triangle (B). Economists call this loss to economic welfare, the 'dead-weight loss' (because no one benefits from this loss, it is therefore a dead-weight on the economy), it is also referred to as the Harberger triangle.[22]

21 Economic text books typically draw this figure with reference to marginal costs. In an industry, such as electricity networks, with substantial fixed costs and economies of scale, distribution services must recover efficient average costs if services are to be maintained to consumers.

22 Named in honour of Arnold Harberger, see his paper 'Three basic postulates for applied welfare economics: An interpretive essay'. Journal of Economic Literature (1971) 9, 785-97.

Figure 3 Allocative efficiency loss from WACC being set too high



4.1.2 Welfare loss likely less in practice

In practice, the welfare loss would be less than implied by a direct calculation of the deadweight loss. Firstly, the higher WACC gives the regulated entity an incentive to 'over' invest. This problem is referred to in the economics literature as the "Averch-Johnston effect".[23] This over investment would provide some benefit to consumers through higher quality. The investment decision process is discussed briefly below.

Secondly, the welfare loss described above assumes that the monopolist must charge all customers a single, simple price. However, utilities can and do charge multi-part tariffs, with both fixed and variable elements and can exercise some degree of price discrimination. A regulated entity would not have the information to price discriminate perfectly. But it will have good proxies. Property location and value, and quantity consumed, are all good indicators of likely willingness to pay for the service. Optional tariff offerings can also be used to price discriminate. This means that the regulated firm's pricing structure would likely reduce, possibly considerably, the expected welfare loss from setting WACC too high.

23 See Averch, H. A (1988), *The New Palgrave, A Dictionary of Economics*, Macmillan, p. 160.

4.2 Economic loss from setting WACC too low

4.2.1 Welfare loss from prices being too low

If WACC is set below the true WACC (and all other parts of the price control are precisely correct), prices will be lower than they would otherwise be. With lower prices, there would be a corresponding increase in the quantity demanded for electricity distribution services. This increase in demand would be inefficient, as the price charged for these services would be less than the full economic cost of providing the service.[24] Figure 1 could readily be re-drawn to show that the welfare loss arising from mispricing (either pricing too high or pricing too low) tends to be roughly symmetrical.

4.2.2 Investment determines consumer benefit over time

However, it is new investment that delivers the lion's share of consumer benefits over time. If the regulator sets WACC below the return required by investors, regulated firms could be expected to under invest (we discuss the practical realities below). As the High Court commented: "Investors have choices, and will not invest in an asset unless the expected return is at least as good as that they might expect from a different investment of similar risk."

It is this prospect of reduced or deferred investment which determines the asymmetric risk. A marginal project from a firm's perspective may generate substantial economic welfare for consumers, and if such a marginal project is not undertaken, all of this benefit is lost. Wright, Mason and Miles (2003)[25] provide a simple model that illustrates this point and the argument is explained in further detail in Dobbs (2008).[26] Earlier work by Pindyck identified similar issues in considering the losses from regulatory price cap arrangements on irreversible investment choices.[27]

Firms also typically have the option of not only choosing the start date and initial scale, but also the rate of subsequent expansion. This project flexibility gives rise to option value, and gives the firm an incentive to delay investments and reduce the initial scale and pace of roll out of new investment.[28] Allemann and Rappaport made a similar finding.[29] An incentive to

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24 This analysis is made more complex in network industries, with large scale fixed assets, as in the short-term, the marginal cost of meeting additional demand may be low. However, if the long-term benefit to consumers is to be achieved the full economic cost needs to be recovered.

25 Wright S., Mason R., Miles D., 2003, "A study of certain aspects of the cost of capital for regulated utilities in the U.K". 13/2/2003.

26 Dobbs, M, 2008 "Setting the regulatory WACC using Simulation and Loss Functions –The case for standardising procedures" Competition and Regulation in Network Industries, Volume 9, No 3.

27 Pindyck R.S., 1988, "Irreversible investment, capacity choices and the value of the firm", American Economic Review, 78, 969-985.

28 Dobbs, M, "Intertemporal price cap regulation under uncertainty'. Economic Journal 114:421-440.

29 Alleman J. and Rappaport P., 2002, "Modelling regulatory distortions with real options", The Engineering Economist, 47, 390-417.

defer investment because the regulated WACC had been set below the true WACC would compound any adverse incentive for efficient investment from the price cap regulation more generally. One of the conclusions reached by Evans and Guthrie (2012), when looking at price-cap regulation and the scale and timing of investment, is that *"regulated firms invest in smaller, more frequent, increments than social planners, with greater investment distortions the greater the economies of scale."*[30]

4.2.3 Risk of disruption to services

Consumer losses can also arise if a firm does not invest to maintain services or withdraws from providing a particular form of service. If a company withdraws from a market in a competitive environment another company can expand its output or enter into the market to make up the lost supply from the failed company. But in the context of firms regulated under Part 4, there is limited scope for competitors to replace any supply which has ceased to be profitable for the incumbent.

Hence, if the simulation of competitive pressures via a regulatory price cap induces the regulated entity to fail outright (in the extreme case), or to withdraw from the supply of certain services, even if that would be the efficient outcome in a competitive setting, it imposes transitional costs on consumers that lose access to the regulated service whilst a new supplier is identified, or some other transitional arrangement is implemented. The benefits to consumers of avoiding disruption are factors to be accounted for in determining the risks of over and under estimating WACC.

4.2.4 Some realities of investment decision-making

The realities of investment decision-making for utilities means the impact of setting WACC too low is unlikely to be linear, either in terms of investment decision-making or in terms of the impact on consumers.

With regard to investment decision, expenditure in certain core categories of an electricity distribution network would not be immediately curtailed should WACC be set below the true cost of capital. A regulated firm could be expected to continue invest to ensure the safe operation of the network, and to meet legal and technical code compliance requirements. Failure to adequately address these aspects would have severe impacts on the firm's operation which could include suspension of the firm's rights to operate, or prosecution of directors or senior managers.[31]

In addition, at any point in time, a number of investment projects would be committed, with contracts let to suppliers and others etc. At least for small variances in the determined WACC from the true WACC, the least cost option for a firm may be to complete at least some of the committed projects.

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30 Evans, L. and Guthrie, G. "Price-cap regulation and the scale and timing of investment". RAND Journal of Economics, 43 (3), pp 537-561.

31 Statement of Ryno Verster, Manager of Engineering: Asset Investment for Vector Limited, 2010, paragraph 1.18.

At the extreme, were the regulated WACC set so far below the true WACC that all investment were curtailed, an electricity network firm would find itself no longer complying with its technical and safety regulations, which would be reflected through deteriorating power quality measures. It seems likely that in these extreme circumstances, the firm would cease operating the network rather than face the liabilities and penalties associated with breaches.[32]

The impact on consumers of reduced investment in distribution networks is also unlikely to be linear. We understand that the impact of reduced investment on reliability, for instance, would initially be small but that the effect would compound over time.[33] This exponential path would be reinforced as research and investment programmes in innovative technologies would likely be among the first to be terminated. While curtailing this form of investment is likely to have a high cost in the longer-term, network managers are likely to find it difficult to justify expenditure for future benefits when existing asset conditions are deteriorating with immediate impacts on operations as capital expenditure is reduced.[34]

The practicalities of investment decision making for a utility like an electricity distribution business suggest that the loss function from setting WACC too low should reflect large under estimation error as having considerably (disproportionately) larger consequences than a smaller error.

Constraints on investment decision-making also apply if the regulated WACC is set above the true WACC. For example, asset replacement decisions are generally made on condition based assessments which account for factors such as whether the asset:[35]

- would become unsafe to the public or operators
- no longer meet required technical considerations
- performance has an excessive negative impact on network performance
- has failed
- has become obsolete and can no longer be maintained or refurbished.

It is possible that if the regulated WACC were set an increment higher than the true WACC that additional assets may be replaced or upgraded than would otherwise occur, or more likely, replaced or upgraded sooner than would otherwise occur. This over investment would provide benefit to consumers through higher quality, though this quality increment may be economically inefficient.

It seems unlikely that a regulated entity would deliberately build assets that provided no benefit to consumers simply because a regulated WACC for one regulatory period was set at an increment to the true WACC. The regulated entity could not be confident that this increment would be sustained in the next regulatory period (given the uncertainty in setting the CAPM derived WACC), the asset would not enter the regulated RAB until the next

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32 Statement of Ryno Verster, ibid, footnote 12.

33 Statement of Ryno Verster, ibid, paragraph 5.18.

34 Statement of Ryno Verster, ibid, paragraph 6.2.

35 Statement of Ryno Verster, ibid, paragraph 5.2.

regulatory period, and if the expenditure is subsequently recognized by the regulator as inefficient it may be optimized out of the regulated asset base.

4.3 Conclusion

The theoretical research touched on above seems unambiguous; as general propositions:

- Investors have choices, and will not invest in an asset unless the expected return is at least as good as they might expect from a different investment of similar risk.
- The allocative efficiency loss (deadweight loss) from overstating WACC is likely to be small and roughly symmetrical with the allocative efficiency loss from understating WACC.
- New investment delivers the lion's share of consumer benefits over time and hence under investment would cause substantial loss to consumers.

Hence, there seems little room for doubt that the asymmetry risk is real and important; that the costs to society of making incorrect decisions based on the WACC estimation are higher if WACC is under estimated than if it is over estimated. A mixed loss function where the loss is small for low over or underestimation but is exponential for significant underestimation would appear to best model the loss from under or over estimation of WACC.

The following section reviews analytical and some empirical evidence for guidance on the size the asymmetry of the economic welfare loss and hence the adjustment required to ensure that, on an expected basis, the determined WACC promotes the long-term benefit of consumers.

5. Analytical and empirical guidance on asymmetry of loss

5.1.1 Analytical evidence

Dobbs (2011) studied (conceptually) the overall welfare outcomes from setting the allowed rate of return at different levels within an estimated WACC range, given the uncertainty about the regulated entity's 'true' WACC.[36] The Commission cited this paper in its consultation paper 'Invitation to have your say on whether the Commerce Commission should review or amend the cost of capital input methodologies', dated 20 February 2014. As the Commission is aware of this literature, we summarise only key conclusions.

Dobbs specifies a conceptual model in which a regulator sets an allowed rate of return when it cannot know the supplier's true WACC. If the allowed rate of return exceeds the supplier's hurdle rate, the supplier invests, but because the price is higher than the efficient level the result is a reduction in total welfare (that is, a deadweight loss). If the allowed rate of return is set below the supplier's hurdle rate, the supplier does not invest and total welfare is reduced because welfare-enhancing investment does not proceed. Dobbs assumes that the regulator sets the allowed rate of return and corresponding price cap for electricity network suppliers, and those suppliers have a mix of sunk and prospective investments (as would be the case with New Zealand electricity networks regulated under Part 4 of the Commerce Act).

Dobbs models the firm's WACC as a truncated normal distribution. Given this assumption, Dobbs uses a Monte Carlo simulation to explore how the optimal allowed rate of return depends on key parameters affecting the welfare loss asymmetry.

Dobbs finds that even if a supplier's potential new investment is a small proportion of its existing assets, the optimal allowed rate of return is well above the median (50th percentile) estimate. For example Dobbs finds that if deferrable new investment is:[37]

- 5% of total investment (including sunk), the optimal allowed rate of return lies at the 74th percentile.
- 10% of total investment, the optimal allowed rate of return is equivalent to the 82nd percentile.

To provide context for Dobbs assumption as to the percentage of new investment to total investment (5%), we compared the 'assets commissioned' figure from Vector's information disclosure for the year ending 31 March 2014, as a proxy for new investment, with Vector's

36 Dobbs,I.M., "Modeling welfare loss asymmetries arising from uncertainty in the regulatory cost of finance", Journal of Regulatory Economics, (2011) 39:1–28

37 Dobbs, 2011, Table 3, p.21.

RAB.[38] This suggests new investment is approximately 4.5% of the total RAB ($113,902,000 / $2,536,404,000).

However, Dobbs assumes that all incremental investment can be deferred which, as we observe in section 4.2.4, is probably unrealistic short of a substantial understatement of WACC – a firm would likely continue to invest in the short-term to meet its legal obligations, etc.

Dobbs' results are also based on a demand elasticity of -3; which is well outside of the typical range used for estimating demand responses to electricity network price changes (-0.2 to -0.4 for short-term, and -0.5 to -0.7 for long-term demand). The percentile results would be significantly higher if adjusted for the relatively inelastic demand for electricity. This is because the welfare loss from over investment is smaller if consumers are less responsive to price changes (see discussion in section 4.2 above). For example, Dobbs found that keeping the share of new investment to existing assets at 10%, but reducing demand elasticity to -1.5 (still relatively elastic compared to generally assumed estimates of -0.2), the supplier's optimal allowed rate of return increased from the 82nd to the 90th percentile.

Dobbs' work provides analytical support for Commission's approach of adopting an increment to the estimated WACC range. While his results cannot be easily extrapolated to a case of inelastic demand (such as for electricity distribution services), they do suggest that the Commission's approach is not out of line with 'theoretical' findings.

The following sections consider whether indicative empirical evidence supports these analytical findings.

5.2 Indicative loss from WACC being set too high

5.2.1 Estimating welfare losses from prices being too high

Having identified the economic characteristics of the potential loss to consumers if WACC is set higher than the true WACC, it is feasible to arrive at an approximation of the magnitude of that potential loss. Returning to the 'deadweight loss' triangle shown on Figure 3 above, we know from basic geometry that the area of B is:[39]

The area of B = $0.5\,(p_1 - p^*)\,(q^* - q_1)$ (1)

The elasticity of demand is given the by the following equation.

Elasticity of demand $e = [(q^* - q_1) / q^*]/[(p_1 - p^*)/p^*]$

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38 http://www.vector.co.nz/sites/vector.co.nz/files/Vector_electricity%20information%20disclosures%202013%20sch%201%20to%2010.pdf

39 In practice, the area of B is smaller than established by this formula if the average cost curve is sloping down over the relevant area of demand.

which implies,

$(q^* - q1) = e\,(p_1 - p^*)\, q^*/p^*$ (2)

Substituting equation (2) to (1) gives:

The area of B = $0.5\, e\,(p_1 - p^*)^2\,(q^*/p^*)$

This formula implies that, for a given initial level, the size of the dead weight loss is an increasing function of price elasticity of demand, and the price increase squared. In other words, the dead weight loss will be large (or small) if the price increase is large (or small) and if consumers are responsive (or "not particularly responsive") to price changes.

5.2.2 Indicative quantification of the welfare loss

An indicator of the magnitude of the possible welfare loss from the Commission's decision to add a margin to its estimated WACC to address parameter error can be obtained from applying the formula above to the data in the information disclosure by Vector Ltd for its electricity distribution businesses. [40]

For this illustration, we assume that the estimated WACC was set 0.73 percentage points higher than the true WACC.[41] To calculate the upper end of the potential welfare lost we conservatively assume an elasticity of demand of -0.7, which is the *highest* long-term estimate from a range of studies of elasticity of demand for electricity, with short-term elasticity estimates varying between -0.2% and -0.4%.[42] (Demand for distribution services is likely to be less elastic than demand for electricity, as consumers can reduce energy consumption at the margin relatively easily – turning off an appliance not being used - but reducing use of the electricity network is more difficult.)

On this elasticity assumption, the expected annual welfare loss, were WACC to be set 0.73 percentage points too high, would be approximately $210,000, and just $58,000 if elasticity of demand were -0.2%. This calculation is shown in table 1 below.

40 http://www.vector.co.nz/sites/vector.co.nz/files/Vector_electricity%20information%20disclosures%202013%20sch%201%20to%2010.pdf

41 High Court, paragraph 1432, cites MEUG estimates of the Commission's post tax WACC at 6.49% and thus at the 75th percentile is 7.22%,hence a differential of 0.73%.

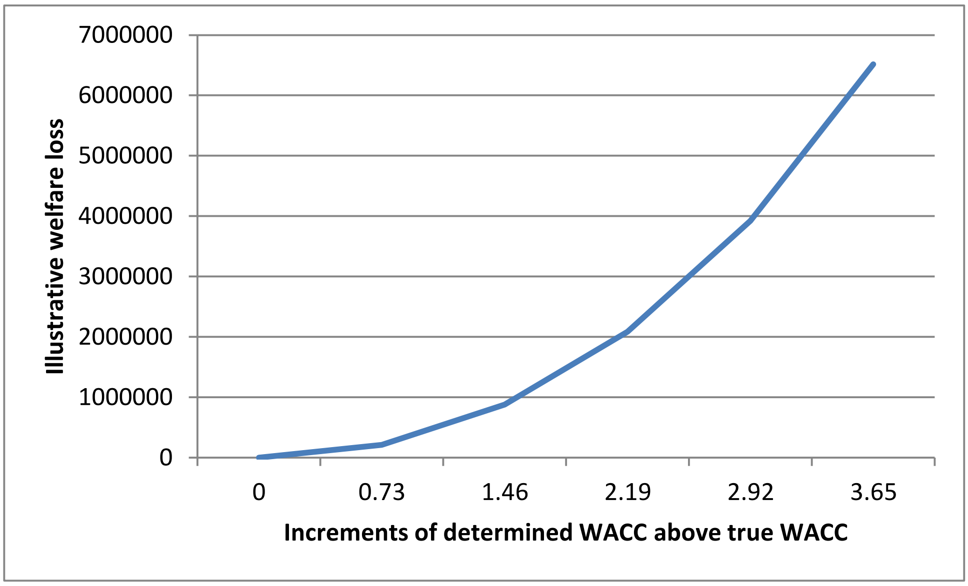
42 For a recent review of elasticity estimates for electricity demand see The price elasticity of electricity demand in South Australia Shu Fan and Rob Hyndman, Business and Economic Forecasting Unit, Monash University. This study found that the estimates that come up most often are -0.2 to -0.4 for the short run elasticity, and -0.5 to -0.7 for the long run.

Table 1 Estimate of welfare loss

Vector Ltd year ended 31 March 2013			
RAB (from regulatory accounts)		A	2,536,404,000
WACC difference		B	0.73%
Revenue difference		C = A * B	18,515,749
Total regulatory income (regulatory accounts)	75th	D	610,726,000
Total regulatory income	true	E = D - C	592,210,251
% change in regulatory income		F = C / E	3.1%
Revenue per GWh energy delivered to ICPS ($GWh)	75th	G	72,499
Implied GWh		H =D / G	8,424
Revenue per GWh energy delivered to ICPs ($GWh) 50th percentile	true	I = E/ H	70,301
Change in price		J	3.1%
Elasticity		K	0.7
Change in quantity		L = K x J	2.2%
Demand prior to price increase (q*)		M = H x (1+L)	8608
Area of B = 0.5 e $(p_1 - p^*)^2$ (q^*/p^*)			$ 207,051

Repeating these calculations for different increments of WACC, for example, 1.46%, 2.19%, 2.92% etc, results in the following curve of welfare loss as the extent of overstatement of WACC increases.

Figure 4 Illustrative welfare loss if determined WACC exceeds true WACC



The welfare loss from underpricing (setting WACC too low) would follow a similar curve. The more significant, and difficult, factor to estimate is the impact on investment.

5.3 Indicative loss from deferred investment due to WACC being set too low

5.3.1 Loss has been quantified in hindsight

With the benefit of hindsight, it is possible to look at regulatory actions that have caused firms to delay investments, and quantify the impact on consumers of these delays. Hausman (1997) showed the consumer welfare costs of delays in the introduction of new telecommunications services due to the regulator's decisions (and indecision). He estimated that delays in introducing cellular phones as a result of indecision by the regulator resulted in *annual* consumer welfare losses of between US$16.7 and $33.5 billion in 1994 dollars.[43] For the delay in introducing voice messaging services, Hausman estimated annual lost consumer welfare of US$1.10 and US$1.27 billion in 1994 dollars.[44] The delay in the introduction of these services was 7-10 years. He concluded:

> "*These findings reinforce a fundamental point: the consumer welfare cost of holding up the introduction of a new good is much larger than the effects of higher prices or other regulatory effects on demand, because the entire compensating variation is lost when regulatory delays cause demand to be zero*".[45]

Other empirical work has confirmed the well accepted theoretical proposition that investment in new products and services deliver substantial welfare gains to consumers. For example, Petrin found that the introduction of the minivan in the United States generated welfare gains of $US2.8 billion in just the first five years alone and by far the majority of these gains went to consumers.[46] Hausman found annual consumer welfare gains of US$66.8 million from the introduction of a single new cereal brand.[47] More generally, inventions reflecting new technical advances and products have been identified historically as the source of one third to one half of the growth of the US economy.[48]

5.3.2 Inference from investment decision-making

Empirical studies, such as Hausman's seminal work on the consumer welfare costs of delays in the introduction of new telecommunications services due to regulator decisions (and indecisions), are necessarily backward looking. Additional inferences as to the potential gain to consumers from incremental investment (and hence potential loss if the investment does

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[43] Hausman, J.A, "Valuing the Effect of Regulation on New Services in Telecommunications," Brookings Papers on Economic Activity: Microeconomics, 1997, pp 23

[44] Ibid, pp 14-15

[45] Hausman, J.A, "Valuing the Effect of Regulation on New Services in Telecommunications," Brookings Papers on Economic Activity: Microeconomics, 1997, pp 24

[46] Petrin, A. "Quantifying the Benefits of New Products: The Case of the Minivan", Journal of Political Economy, 2002, vol. 110, no. 4.

[47] Hausman, J. A. "Valuation of New Goods under Perfect and Imperfect Competition", National Bureau of 962, "Economic Research, Working Paper no. 4970, December 1994.

[48] Denison, E. "Sources of economic growth in the United States and the alternatives before us." New York, Committee for Economic Development

not proceed) by regulated entities can be drawn from cost benefit analysis of proposed investment projects, or assessments of the effects if the investment did not proceed.

Illustrative benefits from incremental investment

Determining the impact of incremental investment/reduced investment levels on the long-term benefits to consumers, and hence the welfare loss should WACC be set less than the true WACC, is problematic. It is well understood that there is a direct link between investment levels, average asset age, and network reliability for instance; however defining a clear relationship between these factors is not easy. [49]

In a submission to the Commission, Vector analysed the impact on network performance should adverse regulatory decisions materially restrain Vector's ability to invest and incremental investment were delayed.[50] Vector provided the following three scenarios relative to its base forecasts:

- 20% reduction
- 20% reduction and defer non-committed projects by 1 year
- 20% reduction and defer all non-committed projects by 2 years.

The Vector submission provided estimates of changes in system average interruption duration index (SAIDI) related to these scenarios. The Vector study provided estimates of the reduction in expenditure, but did not impute estimates as to the cost to consumers of the consequential SAIDI deterioration. However, the Electricity Authority provides an estimate of the load-weighted value of lost load (VOLL) for New Zealand of $50,031/MWh[51] (lost) for an 8-hour outage.[52] We calculated the MWh's lost for the three Vector expenditure reduction scenarios and by using the Electricity Authority's VOLL value for New Zealand, the cost to consumers of the SAIDI increases.[53]

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49 Statement of Ryno Verster, ibid, paragraph 5.6.

50 Statement of Ryno Verster, Manager of Engineering: Asset Investment for Vector Limited, 2010.

51 The 8 hour VOLL is lower than a shorter duration VOLL and will therefor understate the cost.

52 VOLL-technical-report.pdf (EA Website) see page 49 table 22

53 Total incremental minutes lost was calculated by multiplying Vector's 2013 ICPs by the midpoint SAIDI change for each scenario to determine the total minutes and converted to lost hours. The lost hours were then multiplied by the annual average MWh/hour to get MWhs lost and MWhs lost were multiplied by VOLL to give a dollar total. No adjustments have been made for the different time period of the figures e.g. expenditure numbers commencing from 2010/11 and VOLL from 2013. Avoided expenditure and imputed customer costs were discounted by Vector's WACC. No expenditure reductions are assumed other than detailed by Vector and the VOLL effects are assumed to occur starting in year five and continuing for 30 years with no change. No adjustment is made for inflation.

Table 2 Cost benefit of SAIDI changes

	Implied (lost) benefit cost ratio	PV of avoid expenditure $m	SAID change (min per customer per year)	PV Total value MWh lost @VOLL year
20% reduction	0.71	44.02	3.0	31.45
20% reduction and defer non-committed projects by 1 year	1.03	89.29	8.8	91.72
20% reduction and defer all non-committed projects by 2 years	1.46	114.85	16.0	167.71

These calculations suggest that the loss to a consumer from a reduction/ deferral in investment increases at a faster rate than expenditure falls. This occurs as the minutes lost are non-linear relative to the avoided expenditure and so the lost benefit (of reliability to customers) increases faster than the expenditure savings.

A further example is provided by a study undertaken by Western Power in the United Kingdom.[54] Western Power undertook a study into the willingness to pay of its customers for:

- reductions in frequency and duration of power cuts
- improvements in service to remote customers

The Western Power study provides information on the willingness of its customers to pay for a range of options and the cost of those options. Willingness to pay can be taken as a measure of the benefit to the customer of the proposed option. By making some assumptions about the timing of the expenditure, cost of capital and customer numbers, it is possible to derive the implied benefit cost ratio for these options.[55]

54 http://www.westernpower.co.uk/docs/About-us/Stakeholder-information/Stakeholder-reports/WPD-Stakeholder-12-13-final.aspx

55 We assumed that expenditure occurs at time zero and the willingness to pay (WTP) benefit is achieved from year 1 and for 30 years. The expenditure assumption is conservative but the WTP is likely to overstate the value. Customer numbers have been sourced from the OFGEM website and we assume all customers share in the benefit. The cash flows have been discounted at WP regulated WACC, and this discount rate is applied to both the company and its customers.

Table 3 Western power: benefit cost for incremental investment options

	Total cost over 8 years £m	Annual Payments £m	PV of payments over 30 years £m	PV benefit cost ratio
Option 1	39	3.18	53.9	1.4
Option 2	59	4.2	74.1	1.3
Option 3	130	7.7	134.8	1.0
Option 4	310	16.9	296.5	0.9

The Western Power examples (and discussion in the referenced documents) suggest that at any point in time, a distribution utility is considering a range of incremental investments which have a potential benefit to consumers in excess of the investment cost. In the above example, options 1 and 2 would produce benefits to consumers 40% and 30% greater than the cost. This is unsurprising as the constraints in the regulated regimes limit the returns to the utility rather than maximize the benefits to consumers.

Relatively high net benefit to cost ratios for incremental infrastructure projects is not unusual. In the US PJM markets, for example, transmission projects generally need to show a projected benefit to cost ratio of 1.25:1 to be considered for investment.[56] In New Zealand, road projects used to be financed if the estimated benefit-costs ratio was greater than four to one due to a low funding envelope relative to need.[57]

These studies do not provide direct guidance on the benefit that would be lost from deferral of incremental investment in electricity networks. However, they do suggest that investments would tend to have a positive benefit to cost ratio, recognizing the difficulty in estimating directly the benefits from investments in components of the network.

With a positive benefit to cost ratio, only a comparatively small amount of incremental investment would need to be cancelled, if WACC were set too low, to offset the expected welfare loss, if WACC were set too high. To illustrate, assume the loss from understating

56 US PJM benefit to cost ratio is the statement of current policy in the *PJM Manual 14B: PJM Region Transmission Planning Process, Appendix E*. Available at http://www.pjm.com/~/media/documents/manuals/m14b.ashx. The purpose of a Benefit/Cost Ratio Threshold is to hedge against the uncertainty of estimating benefits in the future and to provide a degree of assurance that a project with a 15-year net benefit near zero will not be approved. At the same time the threshold is not so restrictive as to unreasonably limit the economic-based enhancements or expansions that would be eligible for inclusion in the RTEP.

57 OECD Economic Surveys, New Zealand, 2009.

WACC was regarded as three times greater than the loss from overestimation (an asymmetric linear loss function with WACC estimated by the 75th percentile). With this loss function, if the welfare loss from overstating WACC were $210,000 (as estimated in section 5.2.2 above), the implied loss from under investing would be $630,000 ($210,000 x 3), for the margin on WACC to achieve, on an expected basis, a trade-off between the risk of understating WACC and the risk of overstating WACC. Table 4 shows the amount of incremental investment that would need to be cancelled to reduce consumer welfare by $630,000, for a range of plausible cost benefit ratios:[58]

Table 4 Implied reduction in investment to reduce consumer benefit by $630,000

Benefit cost ratio	Incremental invest cancelled $M
1.4:1	$1.6
1.25:1	$2.5
1.1:1	$6.3

These approximations illustrate the point, firmly established in the theoretical literature that only a comparatively small amount of investment need be curtailed to produce a much larger loss of benefit to consumers than would occur if WACC were overestimted.

5.4 Inter-sectoral effects

One 'in-principle argument' that the Court presented against the use of the 75th percentile was that, as well as being used by final consumers, the outputs of regulated suppliers are inputs to numerous other sectors of the economy. If the prices paid by user industries are higher than the resource cost of producing the regulated outputs, then inefficiency is promulgated throughout the economy. The Court suggested:

> *At the least, the inter-sectoral effects ought to be considered, and if possible estimated. This has not been done in the present regulatory processes. If evidence from studies in other times and places exists, it was not placed before us, and seems to have played no part in the Commission's thinking. That could be understandable if the inter-sectoral economic mechanisms and effects were notorious: so wellknown and accepted as not to require citing. To our knowledge, such is not the case.* [paragraph 1476]

A partial equilibrium analysis, as opposed to a general equilibrium analysis, is appropriate for assessing the asymmetry of risk. This is because in an open, competitive market economy such as New Zealand, the prices paid in particular markets can be taken as good indicators of the costs of producing goods, on the supply side, and the value of consuming them on the demand side. So, if a policy or action makes sense within a market in terms of these prices

58 For example, $630,000 / 0.4 = $1.6 million.

(and allowing for changes in the prices as a result of the policy or action), then it probably makes sense for the economy as a whole.

Consider, for example, the effects of changes in electricity network prices on a downstream dairy processing market: so long as the dairy processing market itself is reasonably competitive (and, too, its own downstream markets), then any 'efficiencies' made possible in dairy processing from, say, cheaper electricity will be already built into the partial analysis of the electricity market through the demand curve. That is, the demand curve for electricity – which is what is considered in the partial equilibrium analysis undertaken by the Commission – embodies all the relevant information about the value of electricity to dairy processing and the wider economy, and this is all the regulator needs to consider.

These insights into how a market economy works can be traced back to Adam Smith's fundamental insight into how the independent decisions of the 'butcher, the baker and the brewer', each doing their own thing in their own self-interest as best they can in reasonably competitive markets, can add up to an outcome superior to anything that could be achieved by anyone 'affecting to trade for the public good.' It does not mean that market decisions don't have consequences in terms of winners and losers, nor that mistakes are not made, but it does mean that treating a market situation on its merits, without attempting to factor in what we would now call general equilibrium effects, is likely to deliver the best system achievable in practice.

Any concerns in relation to the limits of partial equilibrium analysis are also likely to be much diminished when assessing the regulation of electricity distribution businesses. This is because residential customers account for just under 90% of all connections[59] – meaning they are by far the dominant user of electricity distribution services.

59 Energy in New Zealand". New Zealand Ministry of Economic Development. September 2013. Retrieved 3 October 2013

6. Conclusion

The WACC for regulatory purposes must be estimated, as it is unobservable. Any estimate of WACC is subject to error, because of model error and because of parameter error due to uncertainty in the values of the parameters that make up the WACC. In workably competitive markets, firms employ hurdle rates well in excess of CAPM-based estimates of WACC. The size of the margin is uncertain, but it is not zero.

We show that the Commission's estimate of WACC, which allows only for parameter error, is subject to considerable sampling error. Thus if the calculations based on the CAPM had produced an estimate of WACC at 8.0% then the 95% interval estimate of the 75th percentile is (8.0 + 0.8 ± 2.6)%, that is 6.2% to 11.4%. The meaning of this interval is that the limits may or may not enclose the percentile but 95% of the time intervals would be obtained such that the limits do enclose the percentile.

Hence, the High Court was misinformed when it commented that the expectation of a normal return should be enough; neither the Commission nor the Court can be sure that an estimate made according to the Commission's approach achieves an expectation of a normal return because that estimation is subject to considerable error.

Loss functions provide a conceptual basis to choose the probability level for the estimator of WACC in terms of the consequences of error in estimation. The Commission's decision to take P(75) as the estimate of WACC is consistent with minimising expected loss under the assumption that an asymmetric linear loss function appropriately describes the response to loss and, specifically, that the loss from underestimation would be regarded as three times greater than the loss from overestimation.

We discuss other types of loss functions. We consider a kinked piece-wise linear loss function in which the loss from error in estimation is symmetric for low levels of error but for significant underestimation the amount of loss increases by a factor of 5 compared to overestimation. We also consider LINEX loss functions. If the loss parameter for such functions is positive, the loss from underestimation increases almost exponentially while the loss from overestimation increases almost linearly.

By using data from Vector's 2012-2013 information disclosure, we provide an order of magnitude estimate of the size of the potential welfare loss from a WACC that is set too high (and thus results in higher prices). We compare this potential loss with the potential welfare loss to consumers that would arise if the determined WACC was set below the true WACC for illustrative investment decisions. We show that only a comparatively small amount of investment need be cancelled to produce a much larger economic loss were WACC understated by the same amount. This comparison also suggests a mixed loss function, where the loss is small for low over or underestimation but is exponential for significant underestimation, would appear to best model the loss from under or over estimation of WACC.

We conclude that the available analytical evidence, and inferences from investment decisions, certainly support the Commission adopting at least the 75th percentile, if not higher, to account for the risks of parameter error. This evidence also suggests that the Commission should, in addition, allow for model error in its estimate of WACC.