THE WEIGHTED AVERAGE COST OF CAPITAL FOR GAS PIPELINE BUSINESSES

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EXECUTIVE SUMMARY

The Commerce Commission has recently undertaken an inquiry into the question of whether gas pipeline businesses (transmission and distribution) should be subject to regulatory control. Inter alia, this involved an assessment of the excess profits of these businesses, and therefore estimation of an appropriate Weighted Average Cost of Capital (WACC) for them. As a result of that inquiry, it has been determined that the gas pipeline businesses of Vector and Powerco should be controlled. Accordingly, their output prices will be controlled and this will require estimation of an appropriate WACC for these businesses for the purpose of price control. The purpose of this paper is to estimate this WACC, for the purpose of assessing excess profits and also for price control, and the principal conclusions are as follows.

In respect of assessing excess profits, the (nominal) WACC model recommended is that used in the Commission's inquiries into airfield operations and electricity lines businesses, and reflected in equations (1)….(5). In addition the parameter values recommended are a market risk premium of 7% (as with the Lines Businesses, and compared to 8% in the Airfields Report), use of the three year risk free rate (set at the beginning of the review period and triennially revised), an asset beta for all of the gas pipeline businesses of .50, a company tax rate of 33%, leverage of 40%, and a debt premium for three year debt of 1.1%. If debt issue costs can be readily identified in the firm's cash flows, they should be excluded and a margin of .30% added to the cost of debt. The form of ownership of the gas pipeline businesses may affect the WACC, but any such effects would seem to be impossible to quantify. Using this model, these parameter values, and the July 2005 average three year risk free rate of 6.02%, the point estimate for WACC is 7.83% (adding debt issue costs to the cost of debt raises this figure to 7.91%).

In recognition of the inevitable estimation errors for most of these parameters, the standard deviation of the WACC probability distribution is estimated at 1.5%. Given that there is some uncertainty as to the correct parameter estimates, and that the consequences of judging excess profits to exist when they do not are more severe than the contrary error, my view is that one should choose a WACC value from the higher end of the distribution, and Table 6 in section 9.1 shows the probability distribution on WACC. Other types of possible errors such as the wrong choice of model are not open to quantification in this way. In general, they would have the effect of raising the uncertainty in the WACC estimate and this points to choosing an even larger WACC value. However, as discussed in section 9.2, there are a number of areas in which the WACC estimate is likely to be biased upwards, and these would exert a contrary effect.

This WACC estimate may be adjusted to take account of additional issues that are not inherently WACC issues. Asymmetric risks present particular difficulties. In so far as the possibility of asset stranding and miscellaneous adverse risks such as natural disasters is dealt with by firms raising their output prices ex-ante, this gives rise to the problem that assessments of excess profits will in general be too high (unless such events have occurred). Corrections for this present considerable informational difficulties to regulators. In addition, the process of regulators optimising assets out for any reason other than indisputable cases of gold-plating argues for some form of ex-ante compensation, and failure to provide this implies that excess profits will also be overestimated. Even if an appropriate allowance is provided, this still leaves the problem that excess profits will be over or under estimated if the actual level of optimisations is more or less than provided for in the allowance. In general, these issues impart an upward bias to assessments of excess profits, which is disadvantageous to the firms. However, as discussed in section 9.2, there are a number of areas in which the WACC estimate is likely to be biased upwards, and these would exert a contrary effect.

In respect of the costs of financial distress, the situation in principle is similar to that of asset stranding and natural disasters. Even in the event that firms have raised their prices ex-ante in compensation, and a regulator was able to assess any costs of this type that were actually incurred, no convincing evidence is available that the appropriate ex-ante adjustment to output prices is substantial. Accordingly, I favour no increment to WACC for the costs of financial distress borne by shareholders. In so far as this is disadvantageous to the firms, this is part of a broader collection of judgements, and some of them are advantageous to the firms.

In respect of timing options, firm resource constraints, and information asymmetries, I do not consider that any adjustment to WACC should be undertaken for the purpose of assessing excess profits.

Turning to price control situations, with a five year term, the WACC estimate employed here may differ from that used in assessing excess profits, and the points of difference are as follows. Firstly, the imposition of a five-year price cap should raise the estimated asset beta from .50 to .60. Secondly, the term of the risk free rate must accord with the term of the price cap, which is five years. Thirdly, the debt premium should reflect a debt term that matches the term of the price cap, which is five years. Fourthly, the margin added to the point estimate of WACC, in recognition of estimation errors, may differ from that used for assessing excess profits. Fifthly, a nominal WACC will be appropriate if the price cap is set in nominal terms whilst a real WACC will be appropriate if the price cap is set in real terms. Sixthly, in respect of asymmetric risks, the Commission would have to decide whether to incorporate an ex-ante allowance for them into the output price, or offer ex-post compensation in the event of relevant events occurring. Finally, price caps may induce certain non-price reactions by regulated firms, and this argues for a further margin on WACC to mitigate these reactions. With the increase in the estimated asset beta to .60, a five year risk free rate of 5.92% (July 2005 average), and a debt premium of 1.2%, the WACC estimate rises to 8.49% (adding debt issue costs to the cost of debt raises this figure to 8.57%) and the standard deviation on the WACC probability distribution rises to 1.6%.

In respect of a three year price cap situation, the WACC estimate may differ from that appropriate to a five year price cap situation. In particular, the estimated asset beta falls to .50, the term of the risk free rate should be three years, and the debt premium should reflect three year debt. The point estimate on WACC then falls back to 7.83% (adding debt issue costs to the cost of debt raises this figure to 7.91%) and the standard deviation on the WACC probability distribution falls back to 1.5%.

In respect of a seven year price cap in which the price cap is finalised after three years and retrospectively applied to the first three years, the WACC estimate again differs. In particular, the estimated asset beta rises to .53, the relevant risk free rate is the seven year rate observed at the beginning of the seven year control period (5.88%), and the debt premium reflects seven year debt (1.3%). The point estimate on WACC then rises to 8.00% (adding debt issue costs to the cost of debt raises this figure to 8.08%) and the standard deviation on the WACC probability distribution remains at 1.5%.

These WACC estimates under price control presume that the company tax rate of 33% will operate throughout any control period that is chosen. However, a recent reduction in the rate to 30% (effective from 31.3.2008) affects the tax deduction on the cost of debt within equation (1) and also leads to equations (25) and (26) replacing (3) and (4). In respect of the seven year price control scenario examined above, the effect would be to raise the point estimate of WACC from 8.00% to 8.19% (or 8.08% to 8.28% if debt issue costs are added) and leave the standard deviation on the WACC probability distribution at 1.5%.

These WACC estimates under price control are based upon the debt premiums prevailing in 2005. However, there is a prima facie case for raising debt premiums due to the sharp rise in premiums from August 2007 along with the fact that the novel nature of the regulatory regime means that the businesses may not have had an opportunity to organise their borrowing arrangements or understood the merits of hedging arrangements to insulate themselves against the conditions that have developed. In respect of the seven year price control scenario examined above, this involves an increase in WACC from 8.00% to 8.29% in August 2007 (or from 8.08% to 8.37% if debt issue costs of 0.30% are included) and a further increase to 8.50% from 31.3.2008 on account of the decrease in the company tax rate (or to 8.58% if the debt issue costs of 0.30% are included). The standard deviation on the WACC probability distribution remains at 1.5%.

1. Introduction

The Commerce Commission has recently undertaken an inquiry into the question of whether gas pipeline businesses (transmission and distribution) should be subject to regulatory control (Commerce Commission, 2004). Inter alia, this involved an assessment of the excess profits of these businesses, and therefore estimation of an appropriate Weighted Average Cost of Capital (WACC) for them. As a result of that inquiry, it has been determined that the gas pipeline businesses of Vector and Powerco should be controlled. Accordingly, their output prices will be controlled and this will require estimation of an appropriate WACC for these businesses for the purpose of price control. The purpose of this paper is to estimate this WACC, for the purposes of both assessing excess profits and for price control.

This paper deals firstly with estimation of WACC for the purpose of assessing excess profits. Section 2 of this paper presents a framework for determining nominal WACC, and the following sections then discuss and estimate relevant parameter values. In particular section 3 estimates the market risk premium, section 4 the risk free rate, section 5 asset betas, section 6 leverage, and section 7 the debt risk premium. Section 8 then assesses whether the form of ownership of the gas pipeline businesses is relevant to the methodology used in estimating WACC. Section 9 then presents WACC estimates, based on the current risk free rate. Section 10 compares nominal and real WACC approaches. Section 11 assesses whether various non-WACC issues can and should be accommodated through an adjustment to the WACC. Finally, section 12 deals with the estimation of WACC for price control purposes.

2. The Choice of Model

This section presents a model for estimating the WACC for gas pipeline businesses, in the context of assessing excess profits. The process involved here bears a strong similarity to the Commission's examinations of airfield businesses and electricity lines businesses (Commerce Commission, 2002a, 2002b). The same nominal WACC model is recommended here. In particular, the cost of capital is a weighted average of the costs of debt and equity, with the cost of debt net of the corporate tax deduction on interest at the statutory rate of 33% (the recent reduction will be addressed later), i.e.,

$$WACC = k_e(1-L) + k_d(1-.33)L \tag{1}$$

where k_e is the cost of equity capital, k_d the current interest rate on debt capital, and L the leverage ratio. In addition, k_d is estimated as the sum of the current riskfree rate (R_f) and a premium (p) to reflect inferior marketability and exposure to the possibility of default, i.e.,

$$k_d = R_f + p \tag{2}$$

In respect of the cost of equity, this is estimated from a simplified version of the Brennan-Lally version of the Capital Asset Pricing Model, i.e.,

$$k_e = R_f(1-T_I) + \phi\beta_e \tag{3}$$

where T_I is the average (across equity investors) of their marginal tax rates on ordinary income, ϕ the market risk premium, and β_e the beta of equity capital. This model is a simplified version of that in Lally (1992) and Cliffe and Marsden (1992), in which it is assumed that capital gains taxes are zero, that firms attach maximum imputation credits to their dividends (at the rate .4925), and that shareholders can fully utilise the imputation credits. The tax parameter T_I is estimated at .33 (Lally and Marsden, 2004a), implying an average (across equity investors) of their marginal tax rates on ordinary income of 33%. With these taxation assumptions, and defining k_m as the expected rate of return on the market portfolio, the market risk premium in equation (3) becomes

$$\phi = k_m - R_f(1-.33) \tag{4}$$

In respect of the equity beta, this is sensitive to the leverage ratio L, and the relationship is

$$\beta_e = \beta_a\left[1 + \frac{L}{1-L}\right] \tag{5}$$

where β_a is the asset beta, i.e., the equity beta in the absence of debt.

Equations (1) and (2) accord with generally accepted practice in New Zealand. In respect of equation (3), there are alternative specifications of the cost of equity capital. These include the standard version of the Capital Asset Pricing Model (Sharpe, 1964; Lintner, 1965; Mossin, 1966), the Officer (1994) model, and models that recognise international investment opportunities (for example, Solnik, 1974). However, equation (3) is commonly used in New Zealand, and was recommended by all parties to the airfields inquiry (Lally, 2001a), most of the parties to the inquiry into lines businesses (Lally, 2006), and one of the two parties making submissions on this issue in respect of the gas pipelines inquiry.

Equation (3) is a better reflection of the personal tax regime operating in New Zealand than the standard or Officer versions of the CAPM, since the standard version assumes that all forms of personal income are equally taxed and the Officer version assumes that interest and capital gains are equally taxed. In comparing equation (3) with international versions of the CAPM, the former assumes that national equity markets are completely closed whilst the latter assumes that they are completely integrated. The truth is clearly between these two extremes. However, in using an international version of the CAPM, estimates of the parameters needed are much less reliable than their domestic counterparts and there is no consensus on them or even of the particular model that should be used. In view of all this, the continued use of equation (3), with a value for T_I of .33, is recommended. The use of equation (5) is a logical consequence of the use of (3).

A number of submissions have also contested the use of equation (3). PricewaterhouseCoopers, hereafter PwC (2003a), have argued for recognising capital gains tax and for an ordinary tax rate equal to the highest statutory rate. In respect of the capital gains tax issue, it is clear that some investors are subject to this tax and I have earlier suggested estimates of about 25% of the ordinary tax rate (Lally, 2000a; Lally and Marsden, 2004a). However the effect on the estimated WACC is slight[1].

[1] The effect will depend upon the way in which the market risk premium is estimated. Suppose the latter is estimated by the forward-looking approach. Then, for a company with an equity beta equal to 1, the effect of varying the assumption about capital gains tax is nil, due to the offsetting effect in the market risk premium. With a beta less than one, the effect of assuming a higher capital gains tax rate is to increase the estimated WACC. For example, with an equity beta of .83 as suggested later in this

Consequently, the simplifying assumption that capital gains tax is zero is favoured. In respect of using the top marginal tax rate, the tax-adjusted CAPM requires weighting across all investors holding the market portfolio and these weights are essentially market value weights. PwC (2003b) present evidence from the US that the typical investor in shares faces a higher marginal tax rate than the typical investor in bonds or the typical taxpayer in general. They also present evidence from the US, Australia and New Zealand that equity holdings by individuals are highly concentrated amongst the wealthiest individuals, who in turn are likely to be taxed at the highest marginal rate. However the analysis in Lally and Marsden (2004a), conducted upon New Zealand income and taxation data, points to an average (across equity investors) of their marginal ordinary tax rates of about .33 rather than the top rate of .39, even in the absence of avoidance or evasion. Furthermore, for the same reasons applying to the capital gains tax issue, the effect is likely to be slight[2]. In view of all this, the assumption of a current average (across equity investors) marginal tax rate on ordinary income of .33 is favoured.

NECG (2003) argues for using the Officer version of the CAPM, on the grounds that it is used by regulatory bodies in Australia. Nevertheless, the merits of a model must still be addressed. As indicated above, equation (3) is clearly a better reflection of the personal tax regime operating in New Zealand than the Officer version of the CAPM, because the latter assumes that interest and capital gains are equally taxed and this is not a good characterisation of the New Zealand taxation regime.

NECG (2003) also reject the use of historical New Zealand data for estimating the market risk premium, on the grounds that it reflects segregation of the New Zealand market from international capital flows, and this segregation no longer applies. It is

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paper (based on an asset beta of .50 and leverage of .40), and a risk free rate of .051, the effect of assuming an average tax rate on capital gains of 25% of the ordinary rate rather than zero is to increase the estimated WACC by less than .05%.

[2] As with the examination of the capital gains tax issue in footnote 1, the effect on the estimated WACC from variation in the assumed ordinary tax rate depends upon the way in which the market risk premium is estimated. Suppose the latter is estimated by the forward-looking approach. Then, for a company with an equity beta equal to 1, the effect of varying the assumption about the ordinary tax rate is nil, due to the offsetting effect in the market risk premium. With a beta less than one, the effect is to reduce the estimated WACC. For example, with an equity beta of .83 as suggested later in this paper (based on an asset beta of .50 and leverage of .40), and a risk free rate of .051, the effect of raising the assumed ordinary tax rate from 33% to 39% is to reduce the estimated WACC by less than .05%.

implicit in this comment that an international version of the CAPM might be more appropriate than equation (3). Equation (3) assumes that national share markets are fully segregated whereas international models assume complete integration. As noted earlier, the truth is clearly between these two extremes. Furthermore, in using an international version of the CAPM, estimates of the parameters needed are much less reliable than their domestic counterparts and there is no consensus on them or even of the particular model that should be used. Accordingly, the use of a domestic model like that in equation (3) rather than an international model is favoured. Having said this, it should be noted that use of a domestic rather than an international model for New Zealand assets is likely to produce a higher estimate of the cost equity, and therefore the use of equation (3) should produce an estimate of the cost of equity that is biased upwards[3].

AECT (2007, Appendix 2) also favour the Officer version of the CAPM over the simplified Brennan-Lally version for a number of reasons.[4] Firstly, they claim that the former model reflects observed market behaviour and is better supported by empirical evidence. In support of these claims, AECT (2008, pp. 22-23) refer to SFG (2004, pp. 5-8) who cite recent empirical evidence that they claim points to dividend yields not affecting expected returns. This implies that capital gains are equally taxed with dividends and therefore (so long as interest and dividends are equally taxed) that $T_I = 0$, which is inconsistent with equation (3) but not the Officer model. However, the evidence presented by them largely relates to the US rather than New Zealand and this subtracts from its value due to differences in the tax regimes. Furthermore, one of the papers cited by SFG (Fama and French, 1998) contradicts rather than supports their claim. In particular Table 2 of that paper shows that, across 13 markets in aggregate, countries with high dividend yields generate statistically significantly larger average returns than those of low dividend yields, which implies that dividends are taxed more heavily than capital gains and therefore that T_I is positive rather than zero.

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[3] This is discussed further in section 9.2.

[4] AECT refer to the Sharpe-Lintner model (Sharpe, 1964; Lintner, 1965) but it is clear from the entirety of their comments in Appendix 2 that they are referring to the Officer model.

The remaining papers cited by SFG merely conclude that one cannot reject the hypothesis that dividends do not affect expected returns, and SFG have wrongly equated this with the quite distinct idea that one can reject the hypothesis of a positive effect. In particular, SFG cite Chen et al (1990), who regress returns on dividend yields for US firms and the coefficient on dividend yield here corresponds to the parameter T_I in equation (3) above. Chen et al (1990, Table 3) estimates this coefficient at .17 with a standard error of .17. The 95% confidence interval on the estimate is then from -.17 to .51, which embraces a wide range of positive values as well as zero. SFG also cite Kalay and Michaely (2000), who regress return on dividend yield for US firms. Again, the coefficient on dividend yield corresponds to the parameter T_I in equation (3) above. Kalay and Michaely run a number of regressions of which one example is the GLS regression presented in Table VII of their paper, yielding a coefficient of .12 with a standard error of .15. The 95% confidence interval on the estimate is then from -.18 to .42. Again, this embraces a wide range of positive values for T_I as well as zero. SFG also cite Boyd and Jagannathan (1994), who regress ex-day capital return on dividend yield for US firms. They estimate the coefficient on dividend yield at .93 with a standard error of .09 (ibid, p 737). This implies a 95% confidence interval from .76 to 1.11. The implied value for T_I is then .07 with a confidence interval from -.11 to .24. Again, this embraces a wide range of positive values as well as zero.

Somewhat more relevant evidence (to New Zealand) on the value for T_I is available from ex-dividend day studies using Australian data, which SFG fail to cite. In particular, Brown and Walter (1986, Table 1) regress ex-day capital return on dividend yield for the period 1974-1984 (the pre-imputation period), and estimate the coefficient on dividend yield as .64, with a 95% confidence interval ranging from .54 to .74. The implied value for T_I is .36 with a 95% confidence interval from .26 to .46. In addition, using data from the post-imputation period 1986-1995, Hathaway and Officer (1995, Table 4) regress $\Delta P/D$ (share price change divided by the cash dividend) on the imputation credits. The constant in such a regression can be interpreted as the mean value of $\Delta P/D$ in the absence of imputation credits. The resulting estimate of this constant is .74, with a 95% confidence interval ranging from .60 to .88. The implied value for T_I is then 0.26 with a confidence interval from .12 to

.40. In addition, using data from 1990-1993, Bruckner et al (1994, Exhibit 1) generate an implied estimate for T_I of 0.38 with a 95% confidence interval from 0.24 to 0.50. In addition, using data from 1995-2002, and drawing upon their preferred model 8, Bellamy and Gray (2004, Table 6) generate an implied estimate for T_I of 0.17 with a 95% confidence interval from 0.11 to 0.23. Finally, using data from 2001-2004, Beggs and Skeels (2006, Table 5) generate an implied estimates of T_I of .20 with a 95% confidence interval from .10 to .30. In summary, the point estimates for T_I from these five Australian studies are 0.17, 0.20, 0.26, 0.36 and 0.38, and all confidence intervals are positive. Therefore, in all five cases, one could reject the hypothesis that $T_I = 0$ in favour of a positive value. This is consistent with the model in equation (3) and inconsistent with the Officer model.

AECT (2007, Appendix 2) also favour the Officer model over equation (3) on the grounds that the latter embodies a number of assumptions that are unrealistic. However, all models make assumptions that are unrealistic and the issue must instead be which set of assumptions is better. In comparing the assumptions of the Officer model with those of equation (3), the chief difference is that the former assumes that interest and capital gains are identically taxed whilst the latter assumes that capital gains are free of personal tax. The latter assumption is clearly more consistent with the New Zealand tax regime and, as shown above, empirical evidence involving asset returns also favours equation (3) over the Officer model. Furthermore, in respect of the assumptions underlying equation (3) that firms attach maximum imputation credits to their dividends and that shareholders can fully utilise these credits, AECT argues that very few companies pay all of their taxable earnings as dividends, that foreign investors cannot utilise the credits, and that tax-exempt investors cannot utilise the credits. However, the last point is not substantial (very few investors are tax-exempt) and the first two claims are irrelevant: retention of some earnings does not imply that dividends lack full imputation credits, and foreign investors must be excluded from the model consistent with its assumption that national equity markets are closed to foreign investors.[5]

[5] Recognition of the fact that foreign investors cannot fully utilise imputation credits would be appropriate in the context of a model that assumed that national equity markets were open to foreign investors. Such a model is considered in section 9.2 and generates lower estimates of the cost of equity. So, the model used here gives rise to higher costs of equity.

AECT (2007, Appendix 2) also favour the Officer model over equation (3) on the grounds that the parameter values in the Officer model are either observable or capable of being estimated more accurately. However, this claim does not seem warranted and AECT provides no elaboration on it either here or in the subsequent cross-submission (AECT, 2008, p. 24).

AECT (2007, para 88) also argues that the allowance for the corporate tax deduction within equation (1) rather than via the cash flows involves approximation and is potentially flawed. In support of this claim they offer the following evidence. Firstly, they claim that equation (1) involves use of the same corporate tax rate for all periods (AECT, 2008, pp. 19-21). This claim is incorrect; no such restriction exists within the model and a contrary situation is addressed in section 12.4 involving the change in the corporate tax rate from 1.4.2008. Secondly, they argue that allowance for the corporate tax deduction on interest via the cash flows rather than via equation (1) has the advantage of "..simplicity and transparency.." (AECT, 2008, p. 21). Such claims have no relevance to the issue of whether equation (1) is potentially flawed. Thirdly, various critiques of equation (3) are presented (AECT, 2008, pp. 19-22). These have no relevance to equation (1). Fourthly, it is claimed that "According to Lally a higher rate of return is achieved by the Australian approach." (AECT, 2007, para 88). As revealed subsequently by AECT (2008, pp. 22-23), the reference is to the following statement in Lally (2007a, p. 7): "The second point of difference is that the process followed by the ESC assigns the corporate tax deduction on interest to the cash flows rather than the cost of capital, and the effect of this is to raise the allowed rate of return." However, this statement does not suggest that any error arises in making the adjustment through equation (1). If the adjustment is made through equation (1), the allowed rate of return generated from equation (1) will be lower than otherwise but this will be exactly offset by the cash flows being higher than otherwise; the difference in approach is purely presentational.

AECT (2007, Appendix 2) also argues that the implicit assumption of a zero debt beta underlying equation (5) is inappropriate in that it induces a lower estimate of the asset beta when starting with an estimated equity beta. However, this estimated asset beta is then converted to an estimate of the equity beta using the leverage of the firm of interest and invoking the same assumption that the debt beta is zero. Thus, the downward effect in the first stage of the process is potentially offset by the upward effect in the second stage. Thus, the effect of assuming a zero debt beta will be to underestimate the WACC for some firms and overestimate it for others. Of course, these potential errors are still of concern but the effects here are generally small[6] and there are difficulties in estimating debt betas. Accordingly, equation (5) is favoured.

3. The Market Risk Premium

3.1 Alternative Methodologies

The market risk premium in equation (4) can be estimated in a number of ways, including historical averaging of the Ibbotson (2004b) and Siegel (1992) types, the constant reward to risk methodology of Merton (1980), forward-looking approaches, and survey evidence. The pros and cons of these approaches are discussed in Lally (2001a). Since all of them have their limitations, consideration of the entire set of approaches is advisable. In addition, purely New Zealand data may be objected to on various grounds, so there are advantages to considering results from other markets.

We start with New Zealand data and the Ibbotson methodology. This involves observation of the ex-post counterpart to the market risk premium in each year, followed by simple averaging of those outcomes over a long period. Lally and Marsden (2004a) have implemented this approach, using New Zealand data over the period 1931-2002, and obtain an estimate of .073. Marsden (2005) extends the data series to 1931-2004, and this raises the estimate to .077 with a standard deviation of .027[7]. This estimate is obtained using a long-term risk free rate (around ten years), and is consistent with the taxation assumptions reflected in equation (4). An alternative estimate is that of PwC (2002), using data from 1925, and yielding a figure of .075. However, the current value for T_I that is invoked differs from that in equation

[6] For example, suppose the equity beta of a comparator firm is estimated at .68, its leverage is 53% and the prescribed leverage of the entity of interest is 40% (the first two values correspond to those for New Zealand gas pipeline businesses as shown in Table 2 and the last corresponds to the leverage level recommended in this paper). Using equation (5) and these parameter values, the equity beta of the entity of interest would be estimated at .53. By contrast, if equation (5) is augmented by a debt beta (following Conine, 1980, but absent the corporate tax terms as in equation (5)) and the debt beta is estimated at .10 (which is a typical estimate) then the resulting estimate of the equity beta of the entity of interest would be .51 rather than .53. The difference of .02 would translate into a WACC effect of .08% using a market risk premium of .07 and leverage of 40%. This effect is small.

[7] The standard deviation comprises the standard deviation of the annual outcomes of .235 (Marsden, 2005, p 20) divided by the square root of the number of years (74).

(4), and correction for that would raise their estimate for the market risk premium in (4) to .078. They also define their market risk premium relative to one year bonds, and this complicates comparison with the other results offered here[8]. Finally, they assume that the relevant ordinary personal tax rate is simply the top statutory rate for each year, whereas Lally and Marsden (2004a) estimate the average tax rate for each year, and find them to be typically well below the maximum rate. For these reasons, the results from Lally and Marsden (2004a), subject to the extension by Marsden (2005), are preferred.

The second approach is that of Siegel (1992). Siegel analyses real bond and equity returns in the US over the sub-periods 1802-1870, 1871-1925 and 1926-1990. He shows that the Ibbotson type estimate of the standard MRP is unusually high using data from 1926-1990, due to the very low real returns on bonds in that period. He further argues that the latter is attributable to pronounced unanticipated inflation in that period. Consequently the Ibbotson type estimate of the standard MRP is biased up when using data from 1926-1990. Thus, if the data used is primarily from that period, then this points to estimating the standard MRP by correcting the Ibbotson type estimate through adding back the historical average long-term real risk free rate and then deducting an improved estimate of the expected long-term real risk free rate. Siegel suggests a figure of .03-.04 for the expected US long-term real risk free rate, and this is not inconsistent with New Zealand data (see Lally and Marsden, 2004b). Applying this approach to New Zealand data, Lally and Marsden (2004b) obtain an estimate for the tax-adjusted market risk premium of .055-.062, using data from 1931-2002. Correcting these numbers, for consistency with the tax assumptions of equation (4), the result is .056-.063. Marsden (2005) extends the data series to 1931-2004, and this raises the estimate to .060-.068. The mid-point of .064 is invoked, with a standard deviation of .030[9].

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[8] I am unable to quantify the effect of this.

[9] This point estimate of .064 represents the historical average real equity return less an estimate of .035 for the expected long-term real risk free rate. The first term here is readily amenable to estimation of a standard deviation but the latter is less so. The standard deviation on the former is about .028; this comprises the standard deviation of the annual returns of .24 (Marsden, 2005, p 17) divided by the square root of the number of years (74). The standard deviation on the estimated expected long-run real risk free rate is likely to be far less than this, and therefore contributes little to the standard deviation on the Siegel estimate. For example, suppose the standard deviation on the estimated expected long-run real risk free rate is .01 and the estimation error is uncorrelated with that associated

The third approach is that of Merton (1980), who expresses the market risk premium as proportional to market volatility (variance or standard deviation), estimates the coefficient of proportionality, and then applies this to a current estimate of market volatility. Applying this methodology, with volatility defined as standard deviation and forecast over the next 15 years, Credit Suisse First Boston (1998) obtained an estimate of the market risk premium of .073. Furthermore, the estimates over the preceding few years were similar to this. However, these estimates do not reflect the taxation assumptions of equation (4), most particularly in using a value for T_I of .20 rather than .33[10]. Given a ten year risk free rate that averaged .064 in 1998, the implied value for the market risk premium in equation (4) is .081. More recently, Boyle (2005) has used this Merton methodology to estimate the market risk premium in the standard CAPM, for each year in the period 1970-2003. Volatility is defined as variance and is simply estimated from the preceding three years of data. The resulting estimates for the market risk premium vary from .009 to .336, due entirely to variation in the estimates for variance. For consistency with the definition of the market risk premium in (4), one would need to add .020 to Boyle's estimates of the market risk premium and therefore the estimates for (4) would range from .029 to .356. Such implausible variation in the market risk premium leads Boyle to conclude that the CAPM cannot be relied upon. The apparent source of the problem here is that the variance shifts unpredictably over time and the market risk premium is based upon the *expected* future variance rather than past actual variance. Since actual variance fluctuates much more than expected variance, Boyle's range overestimates the true variation across time in the market risk premium. Clearly the use of a very long period for estimating future variance would be inconsistent with the presumption of intertemporal variation that underlies this methodology. So there is a trade-off here in choosing the period for estimating variance, and no clear basis for determining the optimal period. The Credit Suisse First Boston study faces similar conceptual

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with the historical average equity return. In this case, the standard deviation on the Siegel estimate would be .030.

[10] The figure of .20 rather than .33 arises primarily because the tax circumstances of foreign investors are recognised in deriving the figure of .20. I consider this to be inappropriate because it constitutes only partial acknowledgement of the existence of foreign investors, and such partial acknowledgement may drive the WACC in the opposite direction to that implied by a full acknowledgement of their existence. Accordingly, the partial acknowledgement may produce perverse results.

difficulties in choosing to forecast variance over a 15 year period. In addition to this conceptual difficulty, the results from the latter study are no longer current. In view of all this, the overall outcome from both considering and not considering these Merton-type estimates will be examined.

The fourth approach is the forward-looking one, in which the discount rate on the market is found that is consistent with the current value of the market portfolio, the current dividend yield and estimates for the expected growth rates in dividends per share for existing companies. Insertion of this discount rate into equation (4), along with the current value for the risk free rate, then yields the estimate for the market risk premium in (4). The difficulty in this approach lies in the estimates for the expected growth rates in dividends per share. Cornell (1999, Ch 4) obtains an estimate for the short run expected growth rate in dividends per share from that of analysts' short-run forecasts of growth in earnings per share, whilst the estimate for the long-run expected growth rate in dividends per share is bounded above by the long-run expected growth rate in GDP. Lally (2001b) applies this methodology to New Zealand, and obtains estimates for the market risk premium in (4) of .058-.079. However these numbers are defined relative to the five year bond rate. If they were defined relative to the ten year rate, for comparability with the above estimates, then the range would be .054-.075. Because the long-run expected growth rate in GDP is an upper bound on the long-run expected growth rate in dividends per share for existing companies, then these estimates of the market risk premium will be biased up[11]. Lally (2007c) provides a more recent estimate of .054, net of a deduction of .010 for the biases just noted (which lowers the estimate of the market risk premium by about .70%), and with an estimated standard deviation of up to .017. Other variants on the forward-looking approach have been applied in other markets, but not yet in New Zealand.

[11] The long run growth rate in dividends per share of existing companies cannot exceed that for aggregate dividends in existing companies (due to net new share issues), which cannot exceed the long run growth rate for the aggregate dividends in all New Zealand companies (due to the creation of new companies), which cannot exceed the long run growth rate in GDP (because dividends are part of GDP). Consequently, the long-run expected growth rate in dividends per share of existing companies cannot exceed the long-run expected growth rate in GDP. Arnott and Ryan (2001) argue that the distinction between current companies and all companies alone subtracts 1-2% from the estimated growth rate, and therefore also in the estimate of the market risk premium. Bernstein and Arnott (2003) argue for subtracting 2% to deal with both this point and new share issues (net of buybacks).

The final approach considered is that of survey evidence. Lally, Roush and van Zijl (2004) have recently surveyed relevant academics and members of the Institute of Finance Professionals in New Zealand ("practitioners"). To facilitate comparability in responses, participants were asked for their estimate of the market risk premium relative to the ten year risk free rate and in respect of the standard CAPM, i.e., $k_m - R_f$. The results were a median estimate amongst the academics of .055 and one of .07 for the practitioners. Converting this to an estimate of the market risk premium in equation (4), using the ten year government stock rate of .056 at the time of the survey (May 2003 average), yields estimates of .073 for academics and .088 for practitioners. However the results for at least the practitioners may be biased up due to some practitioners mistakenly supplying an estimate of the market risk premium in equation (4) rather than for the standard CAPM. In respect of the standard deviation on this estimate, the standard formula assumes that responses are independent. However, respondents would be aware of each others views and would tend to "herd" in response to this. Consequently, the standard deviation cannot be estimated.

All of these results reflect the use of New Zealand data. However, there are some difficulties with this data. In particular, the risk free rate was controlled in the period before 1985. This would have lowered the risk free rates in that period, and this may have biased the Ibbotson-type estimate of the market risk premium[12]. This argues for consideration of estimates from foreign markets. Furthermore, even in the absence of possible bias arising from New Zealand estimates, the presence of any source of estimation error argues for consideration of estimates from foreign markets. In doing so, consistency would argue for using all methodologies considered so far. This further points towards seeking data from markets that can supply estimates of all such types. Accordingly, estimates from the US are sought, although results for a broader set of markets are also noted where they are available.

[12] The rate controls were accompanied by controls that compelled purchase of the bonds by selected entities, and the latter controls prevented investors in aggregate from switching away from low yielding government bonds. If these controls had no effect upon equity prices, and therefore no effect upon equity returns, the Ibbotson-type estimate of the market risk premium would have been raised. On the other hand, if the controls induced a rise in equity prices and therefore a fall in subsequent equity returns, there may have been no effect upon the Ibbotson-type estimate (apart from the one-off impact on equity returns at the time of introducing the controls, which would be offset by the reversal at the time of removing the controls). The difficulties in drawing conclusions in this area are noted in Boyle et al (2006, pp. 10-11).

In respect of the Ibbotson approach, Dimson et al (2006, Table 84) generates an estimate of the standard market risk premium in the US, using data from 1900-2005, long-term bonds, and arithmetic differencing, of .063 with a standard deviation of .020[13]. Converting this point estimate to an estimate of the market risk premium in equation (4), using the New Zealand ten year government stock rate of .065 (December 2007 average), yields an estimate of .084 with a standard deviation of .020. Dimson et al (ibid) also offer estimates of the standard market risk premium for sixteen other foreign markets, mostly over the same 106 year period. The mean of these point estimates is .061 and the estimated standard deviation on this estimate is .016 (see Appendix 1). Using the same conversion to equation (4), the mean of the point estimates is .082 and the estimated standard deviation on this estimate is .016.

In respect of the Siegel approach, this involves an adjustment to the Ibbotson estimate as previously discussed. Starting with the US, the Dimson et al (2006, Table 84) Ibbotson-type estimate is .063 and embodies a historical average long-term real risk free rate of .024. These numbers should be added, and from them deducted an improved estimate of the expected long-term real risk free rate. Consistent with seeking to estimate the market risk premium for New Zealand, the estimate of the expected long-term real risk free rate for New Zealand should be invoked, i.e., .035[14]. The resulting Siegel-type estimate of the standard market risk premium for the US is .052 with a standard deviation of .022[15]. Converting this figure to an estimate of the market risk premium in equation (4), using the New Zealand ten year government stock rate of .065 (December 2007 average), yields an estimate of .073 with a standard deviation of .022. Dimson et al (ibid) also offer Ibbotson type estimates and average real rates on government bonds for sixteen other foreign markets, mostly over

[13] The primary result presented by them uses geometric rather than arithmetic differencing of annual stock and bond returns, and is .065. However, geometric differencing is not consistent with the definition of the market risk premium. The result from arithmetic differencing was obtained by subtracting their average bond return from their average stock return.

[14] In seeking to estimate this rate for New Zealand, Lally and Marsden (2004b) drew heavily upon US data, and the estimates suggested by data from both markets are similar.

[15] The standard deviation for the average real return on equities is .020 (Dimson et al, 2006, Table 84). Using an estimate of .01 for the standard deviation on the estimated expected long-run real risk free rate for New Zealand, as discussed earlier in footnote 8, and assuming that the two estimation errors here are uncorrelated, the resulting standard deviation on the Siegel estimate is .022.

the same 106 year period. This data is used to replicate the process for the US. As before, the estimate of the expected long-term real risk free rates for each of these markets is .035. The resulting mean of these estimates is .045 with a standard deviation on this mean of .012 (see Appendix 1). Using the standard conversion to equation (4), the point estimate is then .066 and the standard deviation on the estimate is .012.

In respect of the Merton approach, there is some difficulty in extrapolating any foreign results to the New Zealand market. In particular, it is explicit in the Merton approach that the market risk premium is proportional to market volatility, and the latter clearly varies over markets (Cavaglio et al, 2000, Table 1). In view of this, no results are offered.

In respect of Cornell's forward-looking approach, Cornell (1999, Ch. 3) obtains an estimate of .045 for the US market risk premium in the standard version of the CAPM (as of December 1996 using 20 year bonds). Substituting 10 year bonds, for consistency with the preceding results, yields .049. Corrected for the difference in definitions of the market risk premium, using the New Zealand ten year risk free rate of .073 (December 1996 average), this implies an estimate for the market risk premium in equation (4) of .073. However this estimate does not contain any deduction for the biases discussed in footnote 11. Using the same deduction of .007 implicit in Lally (2007c), the resulting estimate for the market risk premium in (4) is .066.

Finally, in respect of survey evidence, Welch (2007a, Table 2) surveys US academics and reports a median estimate for the US market risk premium in the standard version of the CAPM (defined relative to three month bonds) of .058. At the time of the survey (December 2007), US ten year bonds were offering .01 more than three month bonds[16]. So, defined relative to US ten year bonds, Welch's survey evidence implies an estimate for the US market risk premium in the standard version of the CAPM of about .048. Corrected for the difference in definitions of the market risk premium, using a New Zealand ten year risk free rate of .065 (December 2007 average), this

[16] This data is drawn from the website of the Federal Reserve (the yields were .041 and .031).

implies an estimate for the market risk premium in equation (4) of .069. In addition, Graham and Harvey (2006, Table 1) survey US CFOs and report a median estimate of .025 for the US market risk premium in the standard version of the CAPM (defined relative to ten year bond yields).[17] Corrected for the difference in definitions, using a New Zealand ten year risk free rate of .060 (November 2005 average to match the survey date), this implies an estimate for the market risk premium in equation (4) of .045. In respect of the standard deviations on these estimates, the standard formula assumes that responses are independent. However, respondents would be aware of each others views and would tend to "herd" in response to this. Consequently, the standard deviation cannot be estimated.

3.2 Conclusions

To summarise the results in the previous section, the New Zealand results are .077 for the Ibbotson approach (standard deviation .027), .064 for the Siegel approach (standard deviation .030), .081 from the Merton approach, .054 for Cornell's forward-looking approach (standard deviation .017), and .073 (.088) from survey evidence from academics (practitioners). The corresponding US results are .084 from the Ibbotson approach (standard deviation .020), .073 from the Siegel approach (standard deviation .022), .066 from Cornell's forward-looking approach, and .069 (.045) from survey evidence from academics (practitioners). In respect of other foreign markets the results are .082 for the Ibbotson approach (standard deviation .016) and .066 for the Siegel approach (standard deviation .012). Forming a simple average of the survey results for each of New Zealand and the US, the point estimates are shown in Table 1 below (with standard deviations in brackets). Across the entire set of results, the range is .054 to .084 with a median of .073 and a mean of .071. Deletion of the results from the Merton methodology, for the reasons discussed earlier, reduces the median to .069 and the mean to .070. For those approaches amenable to estimation of a standard deviation on the estimate, the estimated standard deviations range from .013 to .030.

[17] Their Table 1 reports results for a series of surveys over time. Consistent with using the most recent estimate from academics provided by Welch (2007a), I use the most recent estimate from Graham and Harvey (2006).

Most of these figures invoke the ten year risk free rate. This term should reflect the common investor horizon assumed within the CAPM. In the face of variation across investors, it would seem reasonable to use the across-investor average period between successive equity portfolio reassessments. Froot et al (1992, Table 1) gives "average holding periods" for a wide range of US investor classes, and the weighted average of these is 3.4 years.[18] However, these "average holding periods" for each investor class are determined by simply inverting the average turnover rate and this will significantly underestimate the average holding period. On the other hand, an investor's average holding period will significantly overstate the period between successive reassessments of their portfolio because a reassessment will not in general induce sale of all assets currently held. In the face of these difficulties, the estimates of the market risk premium arising from the use of one and five year bonds are also considered. However, only the Merton, forward-looking and survey based estimates can be modified[19].

In respect of five year bonds, and applying the same process as for ten year bonds, the New Zealand Merton estimate falls to .080, the New Zealand Cornell estimate falls to .052, the New Zealand survey based estimate rises to .082, the US Cornell estimate rises to .068, and the US survey based estimate rises to .062[20]. The median over the entire set of results remains at .073 (or rises from .069 to .070 if the results from the Merton methodology are disregarded). Repeating the process for one year bonds, the new estimates for these five methods are .075, .050, .083, .076 and .065 respectively. Accordingly, the median over all of the estimates rises to .075 with or without the

[18] Estimates of this type for New Zealand investors do not seem to be available.

[19] It is not possible to adjust the results for the Ibbotson method due to the lack of time series of yields on one and five-year government bonds (for the relevant historical periods), and it is not possible to adjust the results from the Siegel method due to the lack of a term structure for inflation-proof bonds.

[20] Regarding the New Zealand Merton results, the five year yield was .066 compared to the ten year yield of .064 (averaged over 1998). Regarding the New Zealand Cornell results, the five year yield was .063 compared to the ten year yield of .059 (averaged over Dec 2006). Regarding the New Zealand survey based results, the five year yield was .053 compared to the ten year yield of .056 (averaged over May 2003). Regarding the US Cornell estimate, the US and New Zealand five year yields were .061 and .071 respectively (averaged over Dec 1996). Regarding the Welch survey of US academics, the US and New Zealand five year rates were .035 and .073 respectively (averaged over Dec 2007), leading to a revised estimate for New Zealand of .078 rather than .069. Finally, regarding the Graham and Harvey survey of US CFOs, the US and New Zealand five year rates were .044 and .062 (averaged over Nov 2005), leading to a revised estimate for New Zealand of .046 rather than .045. All yield data here were drawn from the websites of the Reserve Bank of New Zealand and the Federal Reserve.

Merton estimate. So, depending upon whether the Merton estimate is excluded and which bonds are used, the median estimate lies in the range from .069 to .075.

Table 1: Estimates of the Market Risk Premium

	NZ	US	Other
Cornell Methodology	.054 (.017)	.066	
Siegel Methodology	.064 (.030)	.073 (.022)	.066 (.012)
Ibbotson Methodology	.077 (.027)	.084 (.020)	.082 (.016)
Survey Results	.080	.057	
Merton Methodology	.081		
Median	.077	.069	.074
Mean	.072	.070	.074

The appropriate weightings for the three sets of estimates in Table 1 are debatable. The New Zealand estimates span a wider range of methodologies, although the Ibbotson-type estimate is potentially subject to the pre 1985 data problems referred to earlier. The US estimates are less relevant because some of the underlying variables that drive market risk premiums differ across the two markets. For example, US market volatility is lower, and this should induce a lower market risk premium. On the other hand, US equity returns may be subject to higher personal taxes, due to the absence of dividend imputation and the imposition of capital gains taxes on most investors; the effect of this would be to raise the required return on equity, and therefore raise the market risk premium. Finally, in respect of the other foreign estimates, they enjoy some protection from the US problem just noted because they reflect a wide range of markets. However, they offer results for only two of the approaches applied to New Zealand. On balance, this suggests that greater weight be applied to the New Zealand estimates, although the practical effect is slight because the results from using only New Zealand data are similar to the aggregate results (for medians, .077 versus .073 with inclusion of the results from the Merton methodology and .070 versus .069 with exclusion of the results from the Merton methodology).

All of the above methods assume that there is no evasion or avoidance of taxation, but allowance for such will only slightly affect the estimates[21]. Other considerations point to the estimates in Table 1 being too high, as follows. Firstly, Ibbotson-type estimates are in general liable to be biased up because market risk premiums are likely to have declined over time as a result of reductions in market volatility[22]. Secondly, the New Zealand practitioner survey results are liable to be too high for reasons indicated earlier. Finally, the set of estimates provided omits results from foreign markets for which comparable New Zealand results are not available. In particular, there are a number of forward-looking estimates (of the market risk premium in the standard version of the CAPM) for foreign markets involving approaches other than that of Cornell (1999), and the results are generally lower than that of Cornell. In respect of the US, these other approaches include Fama and French (2002), who obtain .026-.043 (defined against short term rather than ten year bond yields), Claus and Thomas (2001), who obtain .034, Jagannathan et al (2001), who obtain .013, and Welch (2007b), who obtains .080 (defined against short term rather than ten year bond yields). Correction of the first and last of these four estimates to generate estimates relative to ten year bond yields reduces these estimates by .008 each, to .018-.035 and .072.[23] In addition, all four estimates require addition of about .020 to generate estimates of the market risk premium in equation (4), yielding estimates of .038-.055, .054, .033 and .092. By comparison, Cornell's estimate with the same latter adjustment is .066.

Taking account of all this, I favour an estimate of .07 for the market risk premium in equation (4). This point estimate corresponds to that recently offered in respect of the lines companies (Lally, 2006), and contrasts with the estimate of .08 offered earlier in respect of airfield activities (Lally, 2001a). The latter difference is attributable to

[21] The assumption of no evasion or avoidance is implicit in basing the estimate of T_I on tax paid and reported income rather than tax paid and taxable income. Evasion and avoidance reduces both tax paid and reported income, and is therefore essentially not detected through this approach to estimating T_I. The effect of lowering the effective tax rate is discussed in footnote 2, and shown there to be slight.

[22] In addition to the theoretical linkage between the market risk premium and market volatility, further evidence for declines in the former lies in the rise in P/E ratios over time. Both of the principal providers of Ibbotson-type estimates have alluded to this evidence in support of the conclusion here (Dimson et al, 2004; Ibbotson and Chen, 2003).

[23] Welch (2007b, p. 9) reports the average differential in the bond yields at .83% for the period 1962-2007. This period corresponds sufficiently well to the period 1951-2000 used by Fama and French (2002) to justify applying the same differential there.

additional estimates becoming available in the intervening period, and is discussed in Lally (2006).

To formalise my confidence in the point estimate of .07, I estimate the standard deviation for this. In doing so, I draw upon the standard deviations of the individual estimates in Table 1 along with the fact that the estimate proposed here is essentially an equally-weighted average over those individual estimates. Given that some of the estimators are not very strongly correlated, the act of forming an equally-weighted average over a set of individual estimates will produce a standard deviation on the equally-weighted average that is less than the average of the standard deviations on the individual estimates (which is .021). Appendix 2 analyses this issue, and concludes with an estimated standard deviation of .015.

The above point estimate of the market risk premium is obtained using data available at the present time. If one requires estimates of the WACC for earlier years, the question of whether the current estimate for the market risk premium is equally applicable to these earlier years arises. Of the estimation methods used here, the Ibbotson and Siegel methods are not in general particularly sensitive to re-estimation of the parameter a few years earlier. Furthermore, the estimates invoked at earlier times should draw upon all available information, and this points to using the *current* estimate for these earlier years. In respect of the forward-looking and survey approaches, different estimates will be appropriate at earlier points in time but these are not in general available at those earlier points in time. All of this suggests that the current estimate for the market risk premium should *not* be adjusted when the WACC is estimated for earlier years.

3.3 Contrary Views

Amongst the submissions presented to the Commission, LECG (2003a) have argued for a higher estimate of the market risk premium than .070. In particular, they argue for an estimate of .090, on the grounds that the Ibbotson approach is the best methodology, that New Zealand data of this kind is ruled out by the highly controlled nature of the economy prior to the mid 1980s, and therefore US data is invoked. This consists of two steps. First, they invoke the Dimson et al (2002, Table 12-2) estimate of the US market risk premium in the standard CAPM, using geometric differencing, of .070. This is converted to an estimate for the market risk premium in equation (4) of .090. The deficiencies in alternative estimation approached are noted, in support of this reasoning. In a subsequent paper concerned with electricity lines businesses, but with implications for the current inquiry, they lower their estimate of the US market risk premium to .064, and therefore that for New Zealand to .085 (LECG, 2003d)[24]. The latter figure is almost identical to the Ibbotson-type estimate of .084 for the US that was noted in the previous section. In a subsequent paper, LECG (2007) widens the range of foreign markets considered and offers an estimate of the market risk premium within the standard CAPM for these markets of about .06, implying an estimate for the market risk premium within equation (4) of .080.[25]

The difficulty with this argument is the *exclusive* reliance upon one estimation methodology (Ibbotson). In my view all approaches to estimation are imperfect, and this argues for considering all of them. Furthermore, as discussed in the previous section, Ibbotson-type estimates are likely to be biased up. Finally, and even leaving aside the New Zealand data that I have drawn upon, most US studies generate significantly lower estimates of the market risk premium in the standard CAPM (defined against long-term bond yields) than the .064 figure favoured by LECG (2003d). These studies include Cornell (1999, Chapter 3), who obtains .045, Fama and French (2002), who obtain .026-.043 (defined against short term bonds, implying less than this against long-term bonds), Claus and Thomas (2001), who obtain .034, and Jagannathan et al (2001), who obtain .013. In addition, and presumably in recognition of studies of this kind, the US survey results described earlier generate estimates of .025 and .048 (defined against long-term bond yields). LECG give no weight to these results. They critique forward-looking methods on the basis of the "huge uncertainty and subjectivity" (LECG, 2004, p 10). However they fail to acknowledge the substantial statistical uncertainty surrounding Ibbotson-type estimates. As noted in the previous section, the standard deviation on an Ibbotson-type estimate based upon US data is .020. Furthermore, the use of an estimate drawn from foreign data presumes that there are no cross-country differences in market risk

[24] The lower US figure is based upon Dimson et al (2003).

[25] The figure of .060 is the median estimate across 17 markets presented in Dimson et al (2006, Table 11).

premiums or that these differences wash out over a large set of markets, i.e., New Zealand is typical. The first possibility is untenable and the second is unproven.

Similar to LECG, NECG (2003) also argue for estimating the market risk premium using the Ibbotson methodology along with US data, but subject to corrections for differences between the US and New Zealand markets and for the version of the CAPM used. However, a numerical estimate is not offered. Their argument for rejecting historical New Zealand data is that it reflects segregation of the New Zealand market from international capital flows, and this segregation no longer applies. However, the logical conclusion to draw from this observation is that the appropriate CAPM to use is an international rather than a domestic one, and the effect is likely to lower the cost of equity (as discussed in section 9.2). They also argue that forward-looking approaches to estimation of the market risk premium are flawed, on the grounds that they generate a range of estimates. However, they do not acknowledge the difficulties with Ibbotson estimates based on even US data (outlined in Lally, 2001a). My view is that all approaches have their drawbacks, and therefore a wide range of alternative approaches should be considered.

In a subsequent submission, NECG (2004a) offers quantification of this argument. In particular, they estimate the US market risk premium in the standard CAPM at 3.5-7%, they add 3% to reflect the greater risk of the New Zealand market, and finally add 2% for consistency with equation (4). The result is an estimate of 8.5-12%. In support of this increment of 3%, NECG argue that a reasonable methodology would be to consider the New Zealand market as part of the US market, they suggest that the average beta of New Zealand firms against the US market would be 1.25-1.5, and this leads to an increment of 3%. Such a process is equivalent to invoking an international version of the CAPM, along with the use of the US market as a proxy for the world market portfolio, and is consistent with NECG's beliefs noted above concerning integration of markets. However, no empirical evidence is offered here in support of the beta figures of 1.25-1.5. In a further submission, NECG (2004b) reports the results of regressing the NZSE against the US market over the period 1988-2002, and the figure is 0.48 rather than 1.25-1.5. In the context of an international CAPM, this implies that the market risk premium for New Zealand would be *less* than the US rather than greater, and this point is discussed in detail in section 9.2. Thus, NECG's

(2004b) own analysis undercuts their argument for a 3% increment.

In the face of this empirical outcome, NECG (2004b) appears to dismiss the empirical results as simply implausible. In particular, they assert that one consequence of this kind of empirical approach is that all country betas would be less than one, and this is simply impossible (the average must be one)[26]. However, their claim that all country betas would be less than one is incorrect. For example, suppose the world market comprised only the NZSE and the US, with the former of trivial relative value. Accordingly, the beta of the US against the "world" would be almost identical to the beta of the US against itself, and this result would have to be close to one. Furthermore, given that the NZSE has a beta against the US of 0.48, and the US is almost identical to the “world”, then the beta of the NZSE against the "world" would have to be very similar to 0.48. The value-weighted average of these two betas (approximately 1 and 0.48) would be one. So, the difficulty alleged by NECG evaporates[27]. Their error arises from interpreting the result of regressing US against NZ returns (.31) as the US beta in the context of an international CAPM. In fact, within this context, the US beta would be that of the US against a *world* index or some proxy for it; given the weight of the US in the world, such a figure would be close to one.

In a further response to their own empirical estimate of the New Zealand market beta (0.48) diverging from that anticipated, NECG (2004b) emphasises the fact that the variance of New Zealand market returns is 56% greater than that of the US, and this supports a higher market risk premium for New Zealand. This is a quite distinct line of argument, because the variance of a market is irrelevant to its market risk premium in the context of an international CAPM. Variance would instead matter if markets were segmented, with higher variance markets requiring higher market risk premiums. Nevertheless, the variance argument should be assessed on its own merits. Implicitly, NECG is arguing here that the estimate for the US market risk premium (arrived at through considering a variety of methods) should be corrected for differential variance

[26] In support of this claim, they observe that a regression of the US market return against that of New Zealand yields a “beta” of .31.

[27] Section 9.2 examines this issue more closely.

to produce the estimate for New Zealand. Presumably, if the NZSE variance is 56% larger than that of the US, then the market risk premium for New Zealand should be 56% larger than that of the US. However, if this view were advanced, then one would have to believe that the market risk premium within a market was proportional to variance, and this is the Merton approach. So, the appropriate means of drawing upon US data would be to estimate the ratio of the market risk premium to variance (λ), and then couple this with an estimate of the variance of the New Zealand market. This differs from the earlier discussion of the Merton approach only in invoking a US estimate of λ. Furthermore, LECG (2003a) have also suggested this approach, and it is discussed in detail shortly.

Bowman (2005) follows the same approach as NECG (2004a), differing from NECG only in invoking an estimate for the US of .055 defined relative to long-term bonds[28]. With the same country risk adjustment of .03, and addition of .02 to reflect the conversion to the market risk premium in equation (4), his point estimate is .105 rather than .10. This approach suffers from all of the same difficulties as NECG's[29].

NECG (2004a) also argues that my own advice to the ACCC has been for a market risk premium of 6% (Lally, 2002a), this is an estimate for the standard CAPM, and it implies an estimate of 8% rather than 7% for the market risk premium in (4). The second of these claims is false. The figure of 6% that is referred to is an estimate for the market risk premium in the Officer (1994) version of the CAPM, which differs from the standard CAPM in including imputation credits (to the extent of being usable) within the definition of dividends, i.e., the market risk premium in the Officer model is

$$\hat{k}_m - R_f = k_m - R_f + UD_m \frac{IC_m}{DIV_m}$$

where U is the utilisation rate for imputation credits, D_m the market dividend yield and

[28] Bowman was the author of the NECG reports, and therefore the similarity in approach is unsurprising.

[29] It should be noted that, despite this line of argument being presented in his section 3.7, Bowman (2005) offers a point estimate of .08 at the beginning of that section, in section 3.9 and in his Executive Summary.

IC_m/DIV_m the ratio of imputation credits to dividends for the market portfolio. Within the New Zealand market, empirical estimates for the last two parameters are .04 and .40 (Lally, 2000, p 6). In addition, in the context of a domestic version of the CAPM (in which markets are assumed to be fully segregated), an appropriate estimate for U is 1. Thus, an estimate of 6% for the market risk premium in the Officer model implies an estimate of 4.4% for the standard CAPM. In turn, this implies an estimate for the market risk premium in (4) of 6.5% (using the July 2004 average yield on New Zealand ten year government bonds to make the conversion), not the 8% suggested by NECG (2004a). In response to this, NECG (2004b) argue for $U = 0$ because foreigners are the "price-setting" investors in both Australia and New Zealand. Whether this claim concerning the price-setting investors is true is unclear. This paper invokes a domestic version of the CAPM, and use of such a model implies that foreign investors must be disregarded; the appropriate value for U is then one. By contrast, if foreign investors are the price-setters, then the appropriate CAPM to use is an international version and the question of the New Zealand market risk premium is then irrelevant. Section 9.2 demonstrates that the cost of equity under an international CAPM will be even lower than suggested in this paper for a domestic CAPM.

NECG (2004a) also questions the implicit granting of equal weight to the various methodologies considered in estimating the market risk premium. However they do not indicate what alternative weights should apply. In my view, the most obvious candidates for lower weight are the results from survey evidence because survey evidence is not an estimation method per se. If these results were completely ignored, there would be no significant effect upon the overall estimate. Consequently, the assignment of lower weight to them will have the same property.

NECG (2004a) also argue for a standard deviation around the point estimate of .02 compared to the .015 suggested here. In support of the higher figure, they note that Fama and MacBeth (1973) generate a point estimate for the US market risk premium of .02 whilst French et al (1987) generate estimates as high as .30. These US results are for the standard version of the CAPM, and therefore require addition of .02 for consistency with equation (4). In respect of the Fama and MacBeth (1973) paper, the analysis covers the period 1934-1968, and this is insufficiently recent to warrant much attention. Furthermore, there is no available New Zealand work of this kind.

Nevertheless, it has been noted above that there are a number of US studies (of the forward-looking type) that generate estimates even lower than those explicitly considered, and which have not been explicitly considered because there are no corresponding studies based upon New Zealand data. In respect of the French et al (1987) paper, this is a variant of Merton (1980). More detailed analysis of this kind is presented by LECG (2003c), also leading to figures as large as .30 and this is discussed in detail below. To anticipate the conclusion there, estimates as large as .30 are so far removed from both historical average outcomes, and plausible assumptions about the future growth in real GNP, as to undermine the usefulness of the methodology that gives rise to them. Thus, these papers do not persuade me that the probability distribution on the estimated market risk premium warrants a standard deviation as high as .02. Furthermore, as discussed in Appendix 2, the estimate of .015 suggested here for the standard deviation on the point estimate reflects a point estimate for the market risk premium that averages over results from eleven different methodologies and the effect of this averaging is to significantly lower the standard deviation on the estimate; NECG's estimate of .02 for the standard deviation on the point estimate takes no account of this effect.

Bowman (2005) favours an estimate of at least .03 for the standard deviation on the point estimate rather than the estimate of .015 favoured here. However, Bowman's point estimate appears to be largely based on the results of one methodology (Ibbotson). By contrast, the point estimate favoured here draws upon the results from eleven approaches. As just discussed, recourse to such a wide variety of approaches induces a significant reduction in the standard deviation on the point estimate.

In a submission relating to the lines businesses, but with implications for regulatory behaviour in general, LECG (2003c) observe (correctly) that all of the above estimates for the market risk premium are generated independently of the CAPM, i.e., none of them is a consequence of the CAPM. LECG then presents two estimation methods that derive from the CAPM. The first of these arises from the fact that the market risk premium in the single-period version of the CAPM is proportional to market variance, i.e.,

$$MRP = \lambda Var(R_m) \tag{6}$$

where λ is the average investor's coefficient of relative risk aversion. With an estimate for market variance of .06 (based on New Zealand data for the last 50 years), and an estimate for λ of 5, the resulting estimate of the market risk premium is about .30. The second estimation method arises from the fact that the market risk premium in the "consumption CAPM" (Breeden, 1979) is proportional to the covariance between aggregate consumption C and market return, i.e.,

$$MRP = \lambda Cov(C, R_m) \tag{7}$$

LECG estimate this covariance using New Zealand data over the last 50 years at .002. In conjunction with the previously noted estimate for λ of 5, the resulting estimate of the market risk premium is about .01. LECG argue that these two estimates are at least as reliable as those obtained earlier, on the grounds of being based on relationships that are implied by the CAPM. Nevertheless, these two estimates are vastly different and lead LECG to conclude that there must then be considerable uncertainty about the true value of the market risk premium. Accordingly, it seems prudent to allow a wide range for the parameter. LECG do not indicate how wide this range should be. In a subsequent submission they further argue that "any sensible application of the CAPM should use a value for the market risk premium that is explicitly consistent with the CAPM pricing process", i.e., from equations (6) and/or (7) (LECG, 2004, p. 11).

There are a number of difficulties with this line of argument. First, the claim that the use of equation (6) and/or (7) is necessary for a sensible application of the CAPM appears to be inconsistent with their own point estimate of .085, which is derived from applying the Ibbotson methodology to a wide range of foreign markets (LECG, 2004, pp. 10-11). In response to this observation, Professor Boyle argues that equations (6) and (7) produce estimates that "don't seem to make any sense" and the Ibbotson methodology is necessary to obtain numbers that are "not completely out of kilter" (Gas Conference transcript, July 22, 2004, p 131). Such views suggest that little weight should be placed upon the results from equations (6) and (7).

Second, equation (7) is associated with the "consumption CAPM" rather than the single period model that is used in this paper. It could be argued that the single period model is merely a special case of the consumption CAPM, and therefore (7) must also characterise the single period model. However it is not apparent that these conditions are realised, and the fact that estimates from equation (7) are implausibly low is consistent with that[30]. An alternative view is that the single period model is a distinct model rather than a special case of the consumption CAPM, in which case (7) is irrelevant to it.

Third, and in respect of equation (6), the two parameter estimates underlying the figure of .30 presented by LECG are arguable[31]. In respect of their estimate for the market variance of .06, this accords with results in Lally and Marsden (2004a, Table 2) using data for the period 1931-2002. However, use of data from the more recent period 1985-2000 produces the significantly lower figure of .04 (Cavaglio et al, 2000, Table 1). In addition, and using data over the period 1968-1997 to implement a similar model to that of (6), Credit Suisse First Boston (1998) generate an average estimate of .022 with a resulting estimate for the market risk premium of .081[32]. In respect of the parameter λ, LECG's estimate of 5 is claimed to be a typical figure. By contrast, Mehra (2003, p 59) suggests that a typical figure is 2, and this accords with the empirical estimates in Harvey (1991, Table VIII) for 17 countries over the period 1970-1990, and also with Merton's (1980, Tables 4.1, 4.2, 4.3) estimates for the US using data from 1926-1978. Furthermore, Boyle (2005) subsequently estimates λ at 1.4 for New Zealand[33]. Using an estimate for the market variance of .04 and one for λ of 2, the market risk premium would then fall from LECG's figure of .30 to .08, which is similar to the estimate recommended in the present paper. Thus, if equation

[30] Conditions under which the single-period model arises in this way include the world being only one period in nature and reinvestment opportunities not altering over time. However, the world is multi-period in nature and reinvestment opportunities do change over time (particularly the risk free rate).

[31] They also relate to the standard version of the CAPM rather than to the tax-adjusted version invoked in this paper. However, this point is secondary in the sense that a figure of .30 for the standard version of the CAPM would imply an even larger figure for the tax-adjusted version.

[32] This work was discussed in the previous section. The underlying model differs from (6) in assuming that the market risk premium is proportional to market standard deviation rather than variance. Merton (1980) presents and estimates both models.

[33] Boyle was the author of the LECG (2003c) paper referred to above.

(6) were employed, it would appear to admit a wide range of possible results. Rather than dramatically expanding the range of feasible estimates for the market risk premium, this suggests to me that results from equation (6) should be treated with great caution. This is consistent with the views of Professor Boyle noted above and in Boyle (2005). Furthermore, ceteris paribus, estimators with high variability warrant lower weight, and this strengthens the argument for treating results from equation (6) very cautiously.

Finally, whilst equation (6) gives rise to a wide range of possible estimates, values as large as .30 cannot be reconciled with past average returns or market dividends, and this argues for even more caution in drawing upon equation (6). In respect of past average returns, Marsden (2005) presents an estimate based on this of .077 with a standard error on it of .027. A figure of .30 is then over eight standard errors away. In respect of market dividends, and considering the methodology of Cornell (1999) discussed earlier, a market risk premium of .30 along with the current dividend yield of about .04 and a risk free rate of .05 would require a long-run expected growth rate in dividends per share of about .30 per annum, and therefore a long-run expected growth rate in GDP of more than .30 per annum. This is simply inconceivable, and this view appears to be shared by Professor Boyle as noted above. In summary then, LECG's results from application of equations (6) and (7) do not suggest that any variation from the estimate of .015 for the standard deviation of my point estimate for the market risk premium is warranted.

AECT (2007, section 6.4.2) argue for an estimate of the market risk premium in the simplified Brennan-Lally model of .07-.08, on the basis that Dimson and Marsh have estimated the premium (in the standard form of the CAPM) for developed economies over the period 1900-2002 at .065, the adjustment for the simplified Brennan-Lally model raises this to .082, and recognition of both noise and bias in this estimate then warrants a reduction to .07-.08.[34] However, the presence of noise in an estimate does not warrant a downward adjustment. Furthermore, in respect of bias, AECT provide no justification for the extent of their downward adjustment for it. Furthermore, as

[34] AECT do not provide a reference for Dimson and Marsh but Dimson et al (2002, Table 33-1) presents a figure of .065.

discussed earlier, the deficiencies in all estimation methodologies (which includes noise and bias in Ibbotson-type estimates) warrants consideration of the results from a wide range of methodologies and doing so leads to the estimate for the market risk premium of .07.

AECT (2008, para 50) also argues for an estimate of the market risk premium of .075 on the quite distinct grounds that the estimate is exposed to estimation error and therefore should be raised in compensation for this. However, this argument contradicts that described in the previous paragraph. Furthermore, protection against estimation error is reflected in the recommendation in section 9.1 here to select a WACC estimate from above the 50th percentile of the distribution and AECT's proposal would then involve duplicating the allowance.

Powerco (2007, pp. 74-75) argues for a market risk premium of .08, rather than the figure of .07 proposed here, for three reasons. Firstly, they cite Bowman (2005). However, the arguments in the latter paper have been addressed above and Powerco offers no counter-arguments. Secondly, they argue that an estimate of .06 is generally employed by Australian regulators for the Officer (1994) version of the CAPM (an estimate with which I concur) and that this implies an estimate of .08 for the simplified Brennan-Lally model. This line of argument has already been raised by NECG (2004a, 2004b), and discussed above.[35] Powerco offers no counter-arguments. Thirdly, Powerco observes that the Commission used an estimate of .08 in the 2001 Airfields Inquiry (with which I concurred). The rationale for the reduction in my estimate is discussed in Lally (2006, section 3.1) and again Powerco offers no counter-arguments.

Powerco (2008, section 6.1) also cites two recent papers concerned with estimating the US market risk premium in the standard version of the CAPM (the estimates are .058 and .08), and offers these in further support for Bowman's (2005) estimate of at least .055 for the same parameter (the latter estimate being integral to Bowman's estimate for the New Zealand market risk premium in equation (3) of .08). However, as discussed earlier in this section, the difficulties in Bowman's (2005) estimate of .08

[35] The author of the NECG reports was Professor Bowman, who is also an adviser to Powerco.

lie in his adjustments for country risk differences rather than in his estimate of the market risk premium for the US. Consequently, these new estimates for the US market risk premium do not vindicate Bowman's estimate for the New Zealand market risk premium in equation (3).[36]

4. The Risk Free Rate

4.1 The Period of Averaging

The choice of the risk free rate, being the first term in equation (3), involves two issues: the term of the risk free rate and the period of averaging. In respect of the latter, the data should be current but the use of the rate on a single day (or less) yields exposure to a freakish rate, due to the volume of trades or to trades motivated by particularly strong incentives to transact. Accordingly, I favour averaging of the rate over the preceding month. NECG (2003) argues instead for the rate on a single day. Their rationale seems to be that the appropriate rate is that at a point in time. In this event one should choose the last transaction on a particular day. Thus the act of using even a daily rate involves a degree of averaging. The debate then seems to be merely about the degree of averaging. In my view, use of a daily average generates too much exposure to unusual transactions.

4.2 The Term of the Risk Free Rate

Under price control situations, regulatory decisions should be such that the present value of the future cash flows is equal to the initial investment. Lally (2002b, 2004a) shows that this implies that the appropriate term is that matching the period for which output prices are set. In respect of assessing excess profits, excess profits are the ex-post counterpart to cash flows whose present value exceeds the initial investment. Furthermore, for an unregulated firm, the counterpart to periodic price-setting by a regulator is the frequency with which prices are reset by the firm. So, the argument of Lally (2002b, 2004a) implies that the relevant risk free rate term for the purposes of assessing excess profits is that matching the frequency with which prices are reset. This is potentially distinct from the period over which excess profits will be assessed.

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[36] The papers to which Powerco refers are Welch (2007a) and Welch (2007b). The results from both papers are now noted in sections 3.1 and 3.2 respectively. However, both estimates use short-term rather than ten year bond yields and correction for this reduces the estimates from .058 and .08 (as reported by Powerco) to .048 and .072 (as discussed in sections 3.1 and 3.2 respectively). With these corrections, the estimates are still consistent with Bowman's (2005) estimate for the US market risk premium of at least .055.

That the choice of the risk free rate should be governed by the frequency with which prices are reset, rather than in some other way (such as the life of the assets), can be demonstrated through an example appearing in Lally (2001a). Suppose that the period for which prices are set is five years commencing now, i.e., from time 0 till time 5. In five years, prices will be reset then for a further five years, and so on. The life of the firm's assets is ten years. Also, suppose that the five year bond rate is currently 5% and the ten year bond rate is currently 7.5%, the latter due to expectations that interest rates in five years will be 10%. Suppose these expectations are certain to be vindicated, i.e., in 5 years, the bond rate will be 10% for all terms to maturity. If prices were set using the risk free rate matching the period for which prices are fixed, then a rate of 5% would be used for the next five years, followed by the use of 10% thereafter. By contrast, if prices were set using a rate matching the asset life, the rate used would be 7.5% for the first five year period, followed by 10% thereafter. The latter approach then leads to double-dipping in the sense of the firm being rewarded for future high interest rates not only when they occur but also in *anticipation* of it.

Regarding the period for which output prices are set, in the case of the airfields this was judged to be three years in some cases and five in others, reflecting the presence of either formal or informal understandings on this question (Lally, 2001a). In respect of the electricity lines businesses, no conclusion was reached, as there has been neither explicit regulation nor even informal understandings as to the frequency with which prices are reset (Lally, 2006). The situation for the gas pipeline businesses seems to be as unclear as that for the lines businesses. The feasible candidates for the frequency with which prices are reviewed are in the 1-5 year range, and I therefore suggest the midpoint of three years. So, this points to using the three year risk free rate. This would be set at the beginning of the review period (i.e., the month preceding it), and then reset in three years at the three year rate prevailing at that time, and so forth.[37]

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[37] This assumes that firms coincidentally revise their prices at the commencement of any review period. Of course, this will not generally be the case. If, for example, firms revised their prices one year before the beginning of the review period, the appropriate risk free rate would be that set one year before the beginning of the review period. Since information of this type is not readily available, and there will in

Having suggested the use of the three year risk free rate for the first term in equation (3), with averaging over a period of one month, it may be useful to consider the result from doing so. The two and five year rates averaged over the month of December 2006 have been 6.49% and 6.22% respectively[38]. These numbers reflect simple interest rather than compounding over six month periods, and correction for this (see Lorimar, 2005, p. 34) yields 6.60% and 6.32% respectively. Using linear interpolation, the implied three year risk free rate is then 6.51%.

Setting the first term of equation (3) in accordance with the frequency with which prices are reset potentially conflicts with the use of ten year bonds for estimating the market risk premium. This conflict arises because the discrete time version of the CAPM is insufficiently flexible to accommodate a range of different regulatory situations.

4.3 Contrary Arguments

A number of contrary arguments have been raised concerning the appropriate term for the risk free rate. The principal such argument is that the term should be based on the life of the firm's assets (NECG, 2003; LECG, 2003a, 2007). However, to support any conclusion in this area, it is necessary to show that the resulting present value of the future cash flows matches the initial investment (as in Lally, 2002b, 2004a). None of the presentations of this contrary line of argument shows that their preferred term for the risk free rate satisfies this requirement. However, in response to the example presented in the previous section, LECG (2004) argue that it merely illustrates that there will sometimes be over-recovery, but this should be balanced over the life of the asset by instances of under-recovery unless "the expectation is that interest rates…will remain constant after an initial period of rising." (ibid, p. 12). There are two difficulties with this line of argument. First, the circumstances referred to in the qualification expressed may in fact be operative. If they are, then LECG's own defence fails. Secondly, even if the under-and over recoveries tend to offset over time

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any case be variation across firms, a pragmatic solution is to simply invoke the risk free rate at the commencement of the review period.

[38] Data from the Reserve Bank (www.rbnz.govt.nz).

in frequency, they need not offset in present value terms, and the present value principle is paramount. LECG's use of the word "under-recovery" is significant. It constitutes recognition of the fact that the use of a long-term risk free rate gives rise to an error.

LECG (2004) also argue that the use of a short-term risk free rate "introduces an additional and unnecessary degree of volatility and uncertainty into the business" (ibid, p 12). Such a comment does not address the present value argument. Furthermore, if firms reset output prices every (say) three years, they can be presumed to recognise prevailing interest rates in doing so, i.e., their revenues reflect the three year risk free rate. Accordingly, the use of a three year risk free rate in assessing excess profits matches the cost of capital to the firm's revenues, and therefore *removes* rather than introduces interest rate risk.

In a variant of the argument concerning matching the risk free rate term to the life of the firm's assets, NECG (2004b) and Bowman (2005) focus upon debt finance and argues that firms will choose debt maturities longer than the price-resetting cycle, so as to protect themselves against "re-contracting risk". Accordingly, the risk free rate used in assessing the WACC should match the term of this debt. However, the assessment of the risk free rate in this way, with revision at the end of the price-resetting cycle, violates the present value principle noted above. It would also manifest itself in the form of interest rate risk to the firm, i.e., its cost of debt is set for long periods but output prices are reset more frequently to, inter alia, reflect prevailing interest rates. NECG (2004b) acknowledge this point, and suggest that it could be resolved through firms borrowing for long periods whilst undertaking hedging arrangements that would effectively alter the term of their debt to that matching the price resetting cycle[39]. Such hedging arrangements involve certain costs, and NECG argues that these should be included in the allowed set of costs. In so far as these hedging costs are not greater than the costs incurred in reissuing debt at the end of each price resetting cycle, such an approach should be accepted and the resulting

[39] NGC (2004, Treasury Memorandum, p 3) uses hedging arrangements to produce an effective duration on their debt of five years, due to interest rate risk considerations.

hedging costs treated in the same way as debt issue costs[40]. However this approach still implies that the appropriate risk free rate for assessing WACC is that matching the price resetting cycle, not the maturity of the debt.

As an alternative to this particular hedging process, NECG (2004b) suggests that firms might instead borrow for a term matching the regulatory cycle, and enter hedging arrangements to protect itself against "re-contracting risk", i.e., to protect itself against the possibility of the debt margin rising. This involves costs in addition to those arising from simply borrowing for a term matching the price resetting cycle. Given that the cost of debt invoked by the Commission at the end of each cycle would be open to reassessment, and this would include reassessment of the debt margin, then any allowance for such hedging costs would involve double-counting. Accordingly, these additional hedging costs should not be included.

Bowman (2005) also argues, in respect of this "re-contracting" risk upon the maturity of the debt, that recognition of it undermines the Present Value argument. However, Bowman offers no analysis in support of the assertion nor does he demonstrate that matching the risk free rate to the life of the firm's assets would satisfy the Present Value test.

LECG (2007, section 3.2) also argues that use of a risk free rate whose term matches the price-resetting cycle for the firm "..ignores the fact that regulated companies do not exist just in the regulatory period..", i.e., they continue in operation beyond the current regulatory period. The latter assertion is correct, but LECG present no analysis that links this assertion to their belief that the appropriate term of the risk free rate is that matching the life of the firm's assets.

LECG (2007, section 3.2) also claim that unregulated firms with the ability to frequently reset prices borrow for a longer term, and this is inconsistent with the matching of the risk free rate to the regulatory cycle. However, this claim concerns how unregulated firms *do* behave whereas the issue here is how regulators *should*

[40] As argued in section 7, inclusion of these costs within WACC is conceptually superior to inclusion within the cash flows, but the slight impact on WACC and the difficulty in extracting any such costs from the cash flows argues for ignoring the issue.

behave. In the presence of price regulation and debt, Lally (2007b) shows that the regulator *should* continue to choose the risk free rate to match the regulatory cycle and the firm *should* choose a debt term to match this (this simultaneously protects the firm's equity holders from interest rate risk and generates cash flows whose present value matches the initial investment). In the absence of regulation, the question of how regulators should behave does not arise, conclusions about how a firm should behave are less clear and, again, there is no prediction as to how firms actually behave. Thus, evidence on how firms actually behave in unregulated situations is not relevant to how regulators should behave.

Boyle et al (2006, pp. 14-15) argues that setting the risk free rate to match the period for which prices are set presumes that cash flows are received only at the end of the cycle, and this is clearly an inappropriate assumption for a cycle greater than one year. This argument is correct, but the effect is slight, particularly if one uses the yield to maturity rather than the spot rate. To illustrate this point, consider the following example in which all cash flows are certain. Suppose the book value of assets is currently $100m and remains so over the next three years, the output price is reset triennially, demand is fixed, there are no operating costs or taxes or depreciation, revenues are received annually at the end of each year, and the output price is set now and in three years to match the present value of the future cash flows to the contemporaneous book value of the assets. In addition, the current spot interest rates for the next one, two and three years are .06, .065 and .07 respectively. Following the prescription in Lally (2002b, 2004a), the interest rate used in setting the output price and therefore the revenues for the next three years would be the prevailing rate for the next three years. Using the spot rate of .07, the revenues for each of the next three years would then be as follows.

$$REV = \$100m(.07) = \$7m$$

The present value of these revenues along with the value of the firm in three years would then be as follows.

$$V_0 = \frac{\$7m}{1.06} + \frac{\$7m}{(1.065)^2} + \frac{\$7m + \$100m}{(1.07)^3} = \$100.12m$$

This deviates only slightly from the appropriate value of \$100m. Turning to the use of the yield to maturity, suppose the coupon interest rate on the three-year bonds used to derive the three-year yield to maturity is .08. Denoting the face value of these bonds by *F*, the market value of these bonds would be as follows.

$$B_0 = \frac{.08F}{1.06} + \frac{.08F}{(1.065)^2} + \frac{1.08F}{(1.07)^3} = 1.0276F$$

The yield to maturity on this bond (y) would then satisfy the following equation.

$$1.0276F = \frac{.08F}{1+y} + \frac{.08F}{(1+y)^2} + \frac{1.08F}{(1+y)^3}$$

This implies that $y = .0695$. Using this interest rate to set the firm's revenues rather than the three year spot rate of .07, the resulting revenues for each of the next three years would be \$6.95m. The present value of these revenues along with the value of the firm in three years would then be as follows.

$$V_0 = \frac{\$6.95m}{1.06} + \frac{\$6.95m}{(1.065)^2} + \frac{\$6.95m + \$100m}{(1.07)^3} = \$99.99m$$

This present value of \$99.99m is even closer than before to the appropriate value of \$100m. So, in summary, setting the risk-free interest rate equal to the yield to maturity for the term matching the frequency with which prices are set almost perfectly satisfies the requirement that the present value of the future cash flows matches the current book value of the assets.

Another widespread, and potentially contrary, view in this area is that the risk free rate used here should match that used in estimating the market risk premium (LECG, 2003a; NECG, 2003; Bowman, 2005; Boyle et al, 2006; Unison, 2007).[41] This "consistency" argument would appear to be confirmed by considering the case when beta equals one. In this event the cost of equity must coincide with the expected return on the market portfolio E_m. To simplify the presentation, assume that the tax parameter $T_I = 0$, the price resetting cycle is one year and the risk free rate used in estimating the market risk premium is the two year rate R_{f2}. Following the present value test presented above, the risk free rate used as the first term in equation (3) should be the one year rate R_{f1}. The cost of equity would then be as follows

$$k_e = R_{f1} + E_m - R_{f2} \tag{8}$$

and this appears to diverge from E_m whenever R_{f1} diverges from R_{f2}. The essential difficulty in this area is that the CAPM generates a cost of equity for only one future period, coinciding with the investor horizon. In this example, this future period is assumed to be two years. In this event, the CAPM cannot specify the cost of equity for the price resetting cycle of one year. The choice then lies between discarding the model and adapting it to the situation in question. The former possibility can be dismissed for lack of an alternative model, leaving us with the need to adapt the model to a one year period. In seeking to adapt it, the first term in the model must be the risk free rate for the price resetting cycle, so as to ensure that the correct cost of equity results as beta goes to zero (the correct rate in this case is R_{f1} to ensure that the present value of the future cash flows matches the initial investment). Consideration of the case when beta equals one seems to argue for consistency, and therefore for also using the rate R_{f1} in estimating the market risk premium. However, data limitations would preclude estimates of the market risk premium that varied with the regulatory term (see section 3.2). Furthermore, even in the absence of data limitations, the critique reflected in equation (8) is not quite as compelling as it seems. It presumes that the expected market return E_m is the same for all future periods, and this appears to conflict with the fact that R_{f1} differs from R_{f2}. Differences in the latter two rates may be due to the expectations hypothesis, i.e., to the expectation that the

[41] Most of these submissions favour a risk free rate throughout the CAPM whose term matches the life of the firm's assets, and this violates the Present Value principle described earlier. However, consistency would equally be achieved by choosing a risk free rate throughout the CAPM that matched the regulatory cycle, and this would satisfy the Present Value principle. So, this "consistency argument" will be assessed as if it took the latter form.

one year risk free rate in one year will differ from the current one year rate. For example, if R_{f1} = .05 and R_{f2} = .06, this implies a market belief that the one year risk free rate in one year will be .07. Accordingly, the value for E_m over the next year (E_{m1}) may differ from the annualised value applicable to the next two years (E_{m2}). With a two year horizon implicit in the model, equation (8) becomes

$$k_e = R_{f1} + E_{m2} - R_{f2}$$

To assess whether this yields a cost of equity equal to E_{m1}, one must make some assumption about the "term structure" for the market risk premium. For example, suppose that the expectations hypothesis fully describes the term structure of interest rates, i.e., R_{f2} differs from R_{f1} solely due to expectations that the one year rate in one year will differ from its current value of R_{f1}. Prima facie, this should induce E_{m2} to differ from E_{m1} by the same amount. It follows that $E_{m2} - R_{f2} = E_{m1} - R_{f1}$ and the preceding equation then reduces to

$$k_e = R_{f1} + E_{m1} - R_{f1} = E_{m1}$$

So, the apparent error in equation (8) then evaporates. Having said this, it should be recognised that the term structure of interest rates is not fully explained by the expectations hypothesis (McCulloch, 1975; Fama, 1984). Nevertheless, the expectations hypothesis partly explains the term structure of interest rates and therefore ameliorates the problem highlighted in equation (8).

On the question of how much difference there might be between $E_{m2} - R_{f2}$ and $E_{m1} - R_{f1}$, Boyle et al (2006, page 19) note results from Harris and Marston (1999), in which a 1% rise in R_f raises the estimate of E_m by less than .30%, and therefore lowers the market risk premium by over 0.70%. However, whilst a change in R_f can be observed, estimation of the associated change to E_m is difficult, and the implications for the term structure in the market risk premium are therefore dependent upon the quality of these E_m estimates. Furthermore, and in contrast with Cornell (1999, Chapter 3), the forward-looking methodology used by Harris and Marston (1999) to estimate E_m is not subject to the (essential) constraint that the long-run expected growth rate in dividends per share is no more than the long-run expected growth rate in GDP; the absence of this constraint induces little confidence in their E_m estimates, and therefore little confidence in the claim that a 1% rise in R_f raises the estimate of E_m by less than .30%.

LECG (2004a), Bowman (2005) and Boyle et al (2006) also argue that "consistency" is mandated by use of the CAPM, i.e., "using different risk free rates is not the CAPM" (LECG, 2004a, p 14). However, whilst this is true, LECG argues for matching the risk free rate everywhere in the CAPM to the life of the assets in question. This life will vary over projects, and therefore LECG's recommended market risk premium would vary over projects. Such variation is also incompatible with the CAPM. So, whatever course of action is taken will lead to conflict with the CAPM. The choice is not between theoretical perfection and imperfection but with a number of theoretically imperfect solutions, simply because the CAPM is insufficiently flexible to accommodate all possible situations.

In conclusion, a theoretically satisfactory application of the CAPM is not possible and some adaptation of the model is unavoidable. Adaptation is not necessary in respect of the market risk premium (and therefore in respect of the risk free rate involved in estimating the market risk premium), which should then be defined relative to the common investor horizon. Since this common horizon is unknown, estimates of the market risk premium are generated using a range of bond terms but with an emphasis on ten year bonds due to data availability (as discussed in section 3.2). In respect of the risk free rate within the first term of the CAPM, adaptation of the model is necessary and the present value principle is paramount, i.e., the present value of future cash flows should match the initial investment. This principle leads to the conclusion that the risk free rate within the first term of the CAPM must match the price-setting period, which is assumed to be three years.

5. Asset Betas

5.1 Underlying Factors

The asset beta of firm j is defined as the covariance between the unlevered return on the firm (R_j) and that of the market (R_m), divided by the variance of the latter, i.e.,

$$\beta_j = \frac{Cov(R_j, R_m)}{Var(R_m)} \quad (9)$$

Although beta arises within the CAPM, the model itself has nothing to say about how returns are formed. However Arbitrage Pricing Theory (Ross, 1976) models returns on assets as a linear function of certain macro-economic shocks (F_1, $F_2 \ldots\ldots F_k$) and a residual attributable to firm specific events (e_j), i.e.,

$$R_j = a_j + b_{1j}F_1 + b_{2j}F_2 + \ldots\ldots\ldots + b_{kj}F_k + e_j \quad (10)$$

where b_{1j}, $b_{2j} \ldots\ldots b_{jk}$ are the sensitivities of R_j to these common shocks. If these macro-economic shocks are defined to be independent of one another, then substitution of (10) into (9) reveals the following (Dybvig and Ross, 1985)

$$\beta_j = b_{1j}\left[\frac{Cov(F_1, R_m)}{Var(R_m)}\right] + \ldots\ldots\ldots\ldots\ldots + b_{kj}\left[\frac{Cov(F_k, R_m)}{Var(R_m)}\right] \quad (11)$$

So the beta of asset j is a linear function of its sensitivity coefficients $b_{1j} \ldots . b_{kj}$. Since the terms [ ] in equation (11) are identical across assets, then differences in asset betas must arise from differences in the sensitivity coefficients. Chen, Roll and Ross (1986) suggest that these common shocks are unexpected changes in real GNP, inflation, market risk aversion and the long-term real interest rate. Amongst equities, the chief source of variation in betas should be in the sensitivities of asset returns to real GNP. The sensitivity to inflation and the long-term real interest rate should be similar[42], whilst the sensitivity to market risk aversion should essentially reproduce that for real GNP[43].

[42] By contrast bonds will have sensitivities to inflation and real interest rate shocks which vary significantly according to their term to maturity (Cornell and Green, 1991).

[43] Changes in market risk aversion should lead to changes in the market risk premium, and the effect on asset returns will depend upon betas.

The sensitivity of unlevered returns to real GNP shocks will be driven by a number of underlying factors. The first factor is industry, i.e. the nature of the product or service. Firms producing products with low income elasticity of demand (necessities) should have lower sensitivity to real GNP shocks than firms producing products with high income elasticity of demand (luxuries), because demand for their product will be less sensitive to real GNP shocks[44]. Rosenberg and Guy (1976, Table 2) document statistically significant differences in industry betas after allowing for various firm specific characteristics, and these differences accord with intuition about the income elasticities of demand. For example energy suppliers have particularly low betas whilst recreational travel is particularly high.

The second factor is the nature of the customer. There are a number of aspects to this. One of them is the split between private and public sector demand. Firms producing a product whose demand arises exclusively from the public sector should have lower sensitivity to real GNP shocks than for firms producing a similar product demanded exclusively by the private sector, because demand should then be less sensitive to real GNP shocks. A second aspect of customer composition is the residency mix, i.e., demand from foreigners tends to reduce the asset beta[45]. A third aspect of customer composition is the personal/business mix, and the former may be less sensitive to GNP shocks in the case of gas pipeline businesses[46].

The third factor is pricing structure. Firms with revenues comprising both fixed and variable elements should have lower sensitivity to real GNP shocks than firms whose revenues are entirely variable. Such fixed components are embodied in the revenues of gas pipeline businesses.

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[44] Real GNP shocks are unexpected changes in real GNP, of any duration.

[45] This is due to their demand having less sensitivity to New Zealand's GNP shocks than the demand from local customers. Instead, such demand from foreign customers would be sensitive to their own country's GNP shocks, and these are imperfectly correlated with those of New Zealand.

[46] This would be true if gas constituted an "essential" product to consumers (whether consumed directly or indirectly through its conversion to electricity). By contrast, business demand for gas constitutes intermediate demand, whose sensitivity to GNP shocks will be driven by the sensitivity of consumers' demands for the final products in question. A clear contrary case is air travel, in which the personal demand for it would have greater sensitivity to GNP shocks than business demand, because personal consumption of it is a luxury.

The fourth factor is the duration of contract prices with suppliers and customers. The effect of this on beta will depend upon the type of shock and the firm's reaction to it in the absence of a temporarily fixed price. For example, in the absence of any such restrictions on prices, and in the face of a positive economy-wide demand shock, a firm might increase its output price. However an output price that is contractually fixed for some period prevents a firm from immediately acting in that way, and thereby reduces the firm's beta. By contrast, in the presence of an adverse cost shock (which induces an adverse economy-wide reduction in output), the same restriction on output price also prevents a firm from immediately raising its output price to mitigate the adverse cost shock, and this magnifies its beta[47]. In respect of the gas pipeline businesses, long-term contracts exist with some of their customers, and in some cases with their suppliers.

The fifth factor is the presence of regulation. Rate of return regulation involves a regulator setting prices consistent with the firm's actual costs and a prescribed rate of return. Prices are reset if the actual rate of return deviates materially from the prescribed rate, with the resetting initiated by either the firm or its customers (Brennan and Schwartz, 1982; Beesley and Littlechild, 1989). Firms subject to this form of regulation should have low sensitivity to real GNP shocks, because prices reflect (recent) actual costs and cost shocks induce a resetting of prices. This form of regulation approximates that faced by US electric and gas utilities[48]. Consistent with this, Rosenberg and Guy (1976, Table 2) find that these firms have amongst the lowest betas after allowing for various firm specific variables. By contrast, price cap regulation involves a regulator setting prices for a fixed term (commonly five years), except in respect of "uncontrollable" costs for which automatic "pass-through" is permitted. Furthermore, prices are set in accordance with "efficient" rather than

[47] In the case of a negative demand shock, a firm might seek to reduce their price. In this case, a price fixed by contract would not restrict them from doing so.

[48] These US firms are subject to the possibility of some costs being disallowed by the regulator. Furthermore, some of the electric utilities have recently experienced changes in their regulatory regime. Prior to 1998, they were all vertically integrated and all elements of the chain of activities (generation, transmission, distribution and retail) were regulated in all states. Since 1998, deregulation has occurred in some states and has involved opening up retail and generation activities to new (unregulated) firms. However, even in these states, transmission and distribution activities continue to be regulated. Furthermore, in these states, firms that are still vertically integrated continue to be subject to controls upon their retail and generation charges (Joskow, 2005, pp. 56-57).

actual costs, and therefore a change in "efficient" costs relative to actual costs will induce a price shock (Beesley and Littlechild, 1989; Guthrie, 2006). The fact that significant macro-economic cost shocks may not induce a rapid revision to prices, along with the exposure to divergences between efficient and actual costs, implies that firms subject to this form of regulation will face greater risk than firms subject to rate-of-return regulation[49]. This form of control approximates that faced by UK power utilities[50]. Consistent with this, Alexander et al. (1996) show that such utilities have significantly larger average asset betas than for utilities subject to US rate-of-return regulation. Lally (2002c) attributes part of the difference in asset betas to market leverage differences, but this still leaves a substantial residue, apparently attributable to the difference in regulatory regime. In respect of the gas pipeline businesses, there are no price controls yet in force. However they have operated for some time in the knowledge that excess profits might induce price controls. Thus they have faced a quasi-regulatory regime.

The sixth factor is the degree of monopoly power, i.e. price elasticity of demand. So long as firms act to maximise their cash flows, theory offers ambiguous results – Conine (1983) shows that the direction of impact depends upon firm specific characteristics including the sensitivity of demand for the firm's product to market shocks and the sensitivity of the prices of its inputs to market shocks. By contrast, if monopolists do not optimise their cash flow, in the sense of reacting to demand shocks by varying the cushion provided by suboptimal pricing and cost control more than do non-monopolists, then their returns should exhibit less sensitivity to demand, and hence to real GNP shocks. The empirical results in this area are equally mixed – Sullivan (1978, 1982) concludes that increased market concentration is associated with lower asset betas whilst Curley et al (1982) finds no relationship. In respect of

[49] At least some of the risks arising from divergences between efficient and actual costs should be systematic. To the extent that macro demand shocks alter the efficient costs of a hypothetical new entrant, and the regulator takes account of this, then the risk will be systematic. Certain other sources of risk, including population shifts and demand changes for only this product, would not seem to be systematic. Still other sources of risk, including the costs of producing capital goods of the existing type and new technologies, may or may not be systematic. Evans and Guthrie (2006) allude to these systematic risks, and raise the possibility that they might be sufficiently high that systematic risk increases with the frequency of the reviews under a price cap. However, they offer no empirical evidence on this question.

[50] However, it does not seem that the UK electricity regulator (OFFER) took account of changes in demand or technological developments in revising the regulatory asset base for existing assets in this period (Whittington, 1998; Littlechild, 1998, pp. 43-45).

gas pipeline businesses, they seem to be local monopolists but their monopoly power may be diluted by the countervailing power of their large customers and the presence of competing power sources. So, if monopoly power affects beta, then the effect of any such countervailing power and competing energy sources would be to mitigate that beta effect.

The seventh factor is the extent of the firm's real options, most particularly the option to adopt new products ("growth" options). Myers and Turnbull (1977, pp. 331-2) note that the betas of firms will diverge from those of their individual projects if the firms have growth options. The existence of such growth options should increase the firm's sensitivity to real GNP shocks, because the values of these growth options should be more sensitive to real GNP shocks than the firm's value exclusive of them, and these two value components should be positively correlated. Chung and Chareonwong (1991) model the relationship between beta and growth options, and find empirical support for a positive relationship. Black and Scholes (1973) show that the sensitivity of an option value to an underlying variable (and hence that of a firm possessing one) will vary with the term to maturity of the option and with how close it is to "the money". Prima facie, gas pipeline businesses do not have significant growth options arising from new products. However their networks are incomplete and therefore the option to expand their existing networks may be significant.

The eighth factor is operating leverage. If firms have linear production functions and demand for their output is the only random variable, then firms with greater operating leverage (higher fixed operating costs to total operating costs) should have greater sensitivity to real GNP shocks because their cash flows will be more sensitive to own demand, and hence to real GNP shocks. A number of papers including Rubinstein (1973), Lev (1974) and Mandelker and Rhee (1986) have modeled this. However the assumptions noted above, which underlie this work, are very restrictive. Booth (1991), by contrast, examines a perfectly competitive firm facing price uncertainty, and reaches the opposite conclusion about the sign of the relationship between operating leverage and beta. In respect of empirical work, Lev (1974) shows that operating leverage is positively correlated with equity beta, for each of three industries. Mandelker and Rhee (1974) refine the procedure and reach the same conclusion in respect of a set of firms spanning numerous industries. However Lev's conclusions are specific to the three industries examined. Furthermore Mandelker and Rhee's conclusions are at best valid for the majority of firms included in the data set, i.e. some industries may exhibit the opposite pattern but are outweighed in the data set. These concerns about lack of generality of the results are prompted and supported by the theoretical literature just surveyed. Nevertheless, since the gas pipeline businesses seem to exhibit significant local monopoly power, then the situation would seem to correspond more closely to that modelled by Rubinstein et. al. than Booth, and this implies that their high operating leverage should magnify their asset betas.

The last factor is market weight. Increasing an industry's weight in the market proxy against which its beta is defined will draw its beta towards 1, although not necessarily in a monotonic fashion (Lally and Swidler, 2003). Gas pipeline businesses and possible comparators have very limited weights in market indexes[51]. Consequently this point is not significant. Lally (2004b) extends this argument to show that the composition of the rest of the market index may affect the beta for a given industry whilst Lally and Swidler (2008) extend this analysis to cost of capital effects. A possible effect of this kind will be discussed later.

5.2 Estimates

With this background, I now turn to the question of estimates. The usual practice is to seek estimates from the firms themselves, and also from comparable companies suitably adjusted for sources of difference between them and the firms of interest. In respect of New Zealand gas pipeline businesses, only Vector is currently traded; NGC ceased trading in 2005, PowerCo in 2004 and United Networks in 2002. Furthermore, such beta estimates could only be used for the period since their energy businesses were sold, i.e., from 1999. Using monthly data over the period from January 2000 until January 2007 (or until the firm ceased trading) to estimate the equity betas β_e of these four firms, the results are shown in Table 2 below (with standard errors in brackets). In addition, an equally weighted portfolio of these firms is formed, using

[51] In respect of New Zealand, the current weight of gas pipeline businesses in the NZSE50 index is under 5%, in the form of Vector's weight of less than 5% (data from the NZX) and further reduced to reflect the fact that Vector has other activities. Even in 2004, when NGC and Powerco were included in the index, their aggregate weight was under 5% (data from the NZX); again, they were also involved in other activities and this would further reduce the weight of gas pipeline businesses in the index. In respect of the US and the UK, the weights are similarly low (Dimson et al, 2002, Table 2-6).

all of the firms that are traded at each point in time; the equity beta of this portfolio is also estimated and the result (along with its standard error) is also shown in Table 2.

These figures must be stripped of leverage to yield estimated asset betas β_a. Equation (5) formalises the relationship between equity and asset betas, but it is only valid at a point in time. However the equity betas are estimated over a period of up to six years, and therefore reflect average debt/equity levels (*B*/*S*) over that period rather than current leverage[52]. The debt/equity levels for each firm, for the beginning and end of their estimation periods and the average, are shown in Table 2 (with dates in brackets)[53]. Substituting these estimated equity betas and average debt/equity levels into equation (5) yields the estimated asset betas shown in Table 2 (standard errors in brackets)[54]. These estimated asset betas range from -.08 to .48, along with .32 for the equally-weighted portfolio. Due to the small number of companies, the size of the standard errors, and the fact that all of these firms have or had significant activities in addition to gas pipeline operations, these results must be viewed cautiously.

Table 2: Asset Beta Estimates for New Zealand Gas Pipeline Businesses

Company	$\hat{\beta}_e$	*B*/*S* Initial	Terminal	Mean	$\hat{\beta}_a$
Powerco	1.03 (.29)	0.93 (2000)	1.84 (2004)	1.38	0.43 (.12)
United Networks	-0.17 (.21)	1.14 (2000)	0.95 (2002)	1.04	-0.08 (.10)
NGC	0.48 (.30)	0.90 (2000)	0.29 (2005)	0.60	0.30 (.19)
Vector	1.06 (.41)	1.14 (2005)	1.30 (2006)	1.22	0.48 (.18)
Portfolio	0.68 (.16)	0.97 (2000)	1.30 (2006)	1.13	0.32 (.08)

[52] Lally (1998a) shows that substituting such averages into (5) yields a good approximation. He also observes that variation across time in market leverage is relevant, but data for this period is lacking and the variation over the five years is unlikely to be substantial.

[53] For the individual firms, the debt levels are drawn from Financial Statements for those years, and the equity values are the product of share prices and number of shares outstanding (at the same time as the debt levels are observed). For the equally-weighted portfolio, the initial and terminal *B*/*S* ratios arise from averaging over all firms included in the portfolio at those points (Powerco, United Networks and NGC in 2000, and Vector at the end of 2006).

[54] The standard error for an estimated asset beta is that for the estimated equity beta subject to the gearing correction in equation (5). Thus, for Powerco, the calculation is .29/(1 + 1.38) = .12.

I turn now to an examination of comparable foreign companies. If the gas pipeline businesses operated in a largely cost-plus fashion (i.e., cost and volume shocks were rapidly transmitted to their customers via price changes) then they would closely resemble US firms in the gas distribution sector, which are subject to rate of return regulation. Furthermore such firms would appear to be very similar in their activities and regulatory environment to US Electric Utilities. The latter are more numerous, and are also the natural comparators for the New Zealand electricity lines businesses, which have been subject to a thresholds regime by the Commerce Commission. Naturally the Commission seeks consistency across industries in its regulatory judgements. In view of all this, I favour drawing upon both groups of US firms in drawing conclusions about both the New Zealand gas pipeline and electricity lines businesses.

Damodaran (2004) presents estimated equity betas for 64 US electric utilities (SIC codes 4911-4913) and 29 gas distribution firms (SIC code 4920)[55]. The book value of debt and the market value of equity are also presented. Using this data, estimated asset betas are generated for each of the firms, using the Hamada (1972) formula with a company tax rate of .39.[56] The result is an average of .27 for the electric utilities and .17 for the gas distribution firms, with an overall average of .24. However these average asset betas reflect market leverage and the tax environment in the US rather than for New Zealand. The adjustment formula is detailed in Lally (2002c), and requires knowledge of market leverages and tax parameters in the two markets. Furthermore, Lally (1998a) shows that the relevant market leverage for the foreign market is the average over the beta estimation period, along with the current value for New Zealand. The New Zealand equivalent to the foreign asset beta is then as follows

[55] The estimates are in fact taken from Value Line, and involve standard OLS regressions involving the previous five years of weekly data (with no adjustments). The market index is the NYSE composite.

[56] The federal rate for the period 1986-1993 was .34, and .35 since then. Addition of state taxes raises these numbers by about .04 (Tax Foundation, 2005). So, we use the figure .39.

$$\beta_a = \beta_{aF} \frac{\left[1 + \frac{L_F}{(1-L_F)}(1-T_c)\right]}{\left[1 + \frac{L}{(1-L)}\right]} \tag{12}$$

where β_{aF} is the foreign beta estimate, L_F is the foreign market leverage averaged over the beta estimation period, T_c is the foreign company tax rate and L is current New Zealand market leverage. The absence of a company tax term for New Zealand is a reflection of the operation of dividend imputation here. Recent estimates for the leverages of the two markets are .26 for the US and .19 for New Zealand (Ernst and Young, 2000). In addition, the US company tax rate is 0.39. Following equation (12), the US asset betas of .27, .17 and .24 for electric utilities, gas distribution firms and the overall average are unchanged by this adjustment formula, i.e., the taxation and market leverage differences coincidentally net out.

Estimates of this type are subject to estimation error and vary with the length of the historical period. Consequently one should consider the results from a variety of periods. In respect of Damodaran, the fact that his current beta estimates are based on returns data over the last five years implies that 1998 estimates would be additional independent information. Damodaran (1998) presents industry average asset betas for that year, of 0.46 for both electric utilities (93 firms) and natural gas distribution firms (54 firms). However these averages involve degearing at the industry rather than the individual firm year, which is inappropriate. They are also clearly based on the Value Line "adjusted" betas rather than the raw regression betas, and this adjustment formula is of the Blume (1971, 1975) type. Lally (1998c) shows that this is biased upwards for low beta industries such as these. Thus, one needs to draw upon unadjusted betas for the individual firms. Unfortunately, this data is not displayed on Damodaran's website and attempts to obtain this 1998 data fom both Damodaran and Value Line were unsuccessful. However, Damodaran's (2004) industry average asset betas are .46 for electric utilities and .40 for gas distribution firms, compared to the figures of .26 and .17 properly derived above. The discrepancy (of about .20 in both cases) is primarily attributable to the use of the Blume betas[57]. Thus, Damodaran's

[57] Conversion of Damodaran's reported Blume betas to asset betas, followed by averaging over the electric utilities, yields a figure of .46, which is identical to Damodaran's industry average of .46.

1998 industry average asset beta of .46 for both electric utilities and gas distribution would imply a value of about .26 if calculated in the way desired here, and this latter figure will be invoked. The adjustment in equation (12) requires the average US market leverage over the beta estimation period 1994-1998. Fama and French (1999, Figure 1) give US market leverages for each the years 1994-1997, and the average is 0.27. Again, following equation (12), the adjustment for differences in market leverage and the taxation regime between the US and New Zealand has no net effect. So, the estimated asset beta for both US electric utilities and gas distribution firms remains 0.26.

A second source of estimates is Bloomberg, although only recent estimates of the equity betas are available. The equity betas are estimated using returns data from 2002-2003, and are therefore more "recent" than the Damodaran estimates, although facing greater exposure to estimation error on account of the shorter period used[58]. Conversion of the equity to asset betas as above produces an average of .28 for the US electric utilities (65 companies), .23 for the gas distribution firms (26 companies) and an overall average of .27 (91 companies). Again, following equation (12), the adjustment for differences in market leverage and the taxation regime between the US and New Zealand has no net effect.

A third source of estimates is Alexander et al (1996, Appendix A2), using returns data from the period 1990-94. In this case, only asset betas are disclosed, with the de-gearing having been performed by the authors. The result is .30 for the electric utilities (9 companies), .20 for the gas distribution companies (12 companies) and .25 for firms with dual operations (14 companies). The overall average is .25. The adjustment in equation (12) requires the average US market leverage over the beta estimation period 1990-1994. Fama and French (1999, Figure 1) give US market leverages for each year in this period, and the average is 0.34. So, following equation (12), but disregarding the corporate tax adjustment for the US[59], the resulting figures are .36 for the electric utilities, .24 for the gas distribution companies and .30 overall.

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[58] The data is provided courtesy of JBWere Goldman Sachs, with the authorisation of Bloomberg.

[59] This is to compensate for Alexander et al (1996, page 5) ignoring the corporate tax adjustment in generating their estimated asset betas from the estimated equity betas.

A fourth source of evidence is estimates provided by Ibbotson Associates (1997, 2002, 2007). Again, the equity beta estimates are based on the previous five years of returns data and are available for several earlier years. Estimates for 1992-1997, 1997-2002 and 2002-2007 were therefore used.[60] Ibbotson reports only the industry median asset beta rather than the individual company figures, and the individual company estimates are based on the Vasicek (1973) adjustment process. Lally (1998c) identifies a number of difficulties in this process, although the effect on an industry median should be modest. For electric utilities, the estimates are .32 for 1992-1997 (69 companies), .03 for 1997-2002 (37 companies) and .33 for 2002-2007 (45 companies). For the gas distribution firms, the estimates are .29 for 1992-1997 (32 companies), .04 for 1997-2002 (11 companies) and .16 for 2002-2007 (10 companies). Following equation (12), the adjusted results are .33, .03 and .32 for the electric utilities, whilst those for the gas distribution firms are .30, .04 and .16. The weighted averages across the two sets of firms are .32 for 1992-1997, .03 for 1997-2002 and .30 for 2002-2007.

A final source of estimates is Standard and Poors. Their equity betas are estimated using five years of data, and estimates for 1989-1993, 1994-1998 and 1999-2003 were obtained. In respect of the electric utilities, conversion of the equity beta estimates to asset betas as before yields average asset beta estimates of .33 for 1989-1993 (36 firms), .20 for 1994-1998 (37 firms) and .18 for 1999-2003 (42 firms). For the gas distribution firms, the figures are .27 for 1989-1993 (29 firms), .33 for 1994-1998 (36 firms) and .16 for 1999-2003 (38 firms). Following equation (12), the adjusted results are .36, .20 and .18 for the electric utilities, whilst those for the gas distribution firms are .29, .33 and .16. The averages across the two sets of firms are .30 for 1989-1993, .27 for 1994-1998 and .17 for 1999-2003.

Table 3 below summarises these ten sets of results. The median for gas distribution firms (.23) is below that of electric utilities (.27). However, the difference is small. In view of this, and the fact that my prior belief was for equal asset betas across the

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[60] The estimates each use five years of data ending in March. So, 2002-2007 means April 2002 to March 2007 inclusive. In respect of 1997, this book could not be located and therefore estimates from the 1996 and 1998 books were averaged.

two industries, I propose to treat the data for the two industries as being drawn from the same underlying population. This leads to focusing upon the median of the overall results, which is .27.

Table 3: Asset Beta Estimates for US Utilities

Source	Data Period	Electric	Gas	Overall
Value Line	1999-2003	.27	.17	.24
Value Line	1994-1998	.26	.26	.26
Bloomberg	2002-2003	.28	.23	.27
Alexander	1990-1994	.36	.24	.30
Ibbotson	2002-2007	.33	.16	.30
Ibbotson	1997-2002	.03	.04	.03
Ibbotson	1992-1997	.33	.30	.32
S & P	1999-2003	.18	.16	.17
S & P	1994-1998	.20	.33	.27
S & P	1989-1993	.36	.29	.33
Median		.27	.23	.27

The outliers in the set of results are the Ibbotson estimates for 1997-2002. A possible explanation is offered by Annema and Goedhart (2003), who show that industry equity betas for the TMT sector (telecommunications, media and technology) were unusually high in the period 1998-2001, while those for other industries were unusually low. The reason here may be chance or a reflection of the (temporary) surge in the market weight of the TMT sector in the period 1998-2001[61]. If this is the explanation, then it has not affected the Standard and Poors results to this degree, and does not *seem* to have affected the Value Line results at all[62]. The outcome from

[61] If the market is partitioned into the TMT and other sectors, and the former beta is higher than the latter, then a rise in the market weight of the TMT sector must induce a reduction in the betas of the other sectors, because the weighted average beta is necessarily equal to one. If, in addition, the beta of the TMT sector also rises, then the reduction in the beta of the other sectors will be even greater.

[62] In fact, Value Line's estimates rose in the period 1998-2003. For example, Damodaran's industry average Blume betas for 2001, 2002 and 2003 are .32, .37 and .47 (each based on the preceding five years of data). Making the adjustment described earlier to remove the effect of using Blume betas (subtracting .20), this would yield estimates of .12, .17 and .26.

simply ignoring all estimates that draw upon data from the period 1998-2001 inclusive is to raise the median of the overall results from .27 to .30. Taking account of all this, I favour an estimate of .30 for the asset beta of US electric utilities and gas distribution firms.

The estimate just developed reflects rate of return regulation. However, the New Zealand electricity lines and gas pipeline businesses are not subject to rate of return regulation. Consequently, their output prices could be expected to conform less closely to their costs than the US firms, and the effect of this would be to raise their asset betas. Thus, the US estimate of .30 should be seen as a lower bound on that of the New Zealand firms.

A second useful comparator is UK regulated firms in the gas and electricity industries. These firms were subject to price capping with five yearly price resetting, in the period 1990-1994[63]. Alexander et al (1996) presents asset beta estimates for both these firms and their US counterparts, using data from the period 1990-1994. Only one UK gas firm is included, and therefore only the results for electric utilities are drawn upon. Furthermore, in respect of the UK firms, I focus upon the twelve regional electricity companies because they were essentially involved in distribution and transmission rather than generation and only distribution/transmission were regulated (Green, 2005). Alexander et. al. (ibid, Appendix A2) offers average estimated asset betas of .30 for the US firms (9 companies) and .58 for the UK firms (12 companies). The difference is then .28, and this is in the direction suggested by the earlier discussion. However this difference is contaminated by differences in market leverages. Following the analysis in Lally (2002c), correction for differences in market leverage reduces this figure of .28 to .18 as follows.

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[63] These firms were privatised around 1990, and were subject to a five year price cap in the early 1990s, with the generation costs of the regional electricity companies subject to “pass-through”. From the mid 1990s, the regulatory regime was altered from price to hybrid price/revenue capping (Alexander et al, 1996). This removed exposure to volume shocks and this should have led to lower asset betas. Consequently, only their beta estimates for the early 1990s are useful for comparison with the US firms. Similarly, regulated Australian electricity lines and gas pipeline businesses are not useful comparators because they are revenue capped (ACCC, 1999).

$$.93\bar{\hat{\beta}}_{UK} - 1.2\bar{\hat{\beta}}_{US} = .93(.58) - 1.2(.30) = .18$$

Thus the effect of moving from rate of return regulation to five-year price-cap regulation would seem to be to raise the asset beta of electric utilities by about .20.

To summarise, an analysis of US electric utilities and gas distribution firms suggests an asset beta for these firms of about .30. Furthermore, the effect of price-cap regulation with a five yearly price-reset period would be to raise the asset beta of electric utilities by about .20. The next step is to compare the regulatory environment in New Zealand with that of the UK price-cap situation. Consistent with the UK data being limited to electric utilities, this comparison will involve New Zealand electricity lines businesses (in the absence of a price threshold, consistent with the situation facing the New Zealand gas pipeline businesses). The last step will involve a comparison of these New Zealand electricity lines businesses with New Zealand gas pipeline businesses.

In comparing the New Zealand lines businesses with counterparts subject instead to a five year price cap ("price cap" firms), three factors are significant. Firstly, in the face of cost increases other than generation costs, the price-cap firms would be unable to raise their prices within the five year regulatory cycle, and this fact would have led to them having higher asset betas than the New Zealand firms. Secondly, the price-cap firms would also be subject to regulatory errors, some of which may increase their asset betas[64]. Thirdly, in the face of falling costs, the price-cap firms would be less likely to have lowered their output prices within the regulatory cycle so as to conform more closely with costs (because the price-cap regime clearly encouraged the earning of excess profits within the regulatory cycle, subject to the price cap, whereas the New Zealand firms would have been constrained by the fear of price control being imposed); this is likely to have increased the asset betas of the price-cap firms relative to the New Zealand firms. Taking account of these three factors, my judgement is

[64] For example, suppose the market risk premium falls over the revision interval but the regulator fails to recognize this at the review time, through a reduction in the allowed cost of capital. The result will be that the firm's value at the end of the revision interval is larger than anticipated at the beginning of it. This shock originates from a decline in the market risk premium, which is also associated with higher than expected actual market returns. Consequently the market value of the firm at the end of the revision interval is exposed to systematic risk.

that the New Zealand lines businesses would have lower asset betas than firms subject to a five-year price cap. In particular, I consider that they would lie about midway between the US rate of return regulated firms and the price-capped firms. This implies adding .10 to the asset beta of the US firms to reflect the effect of regulatory differences.

I now turn finally to the New Zealand gas pipeline businesses. The gas pipeline and electricity lines businesses (in the absence of price thresholds for the latter) are similar in respect of most of the factors underlying asset betas. In particular, they are similar in their pricing structure (fixed plus variable), in their exposure to a "regulatory" threat of price control, in their operating leverage, and finally in both sectors being a small proportion of the market index. The situation regarding monopoly power is less clear. The remaining three factors are growth options, the nature of the product and the composition of customers, and here there are four potentially significant differences.

First, unlike the lines businesses, which have largely exhausted the opportunity to expand their networks, the gas businesses have significant options to expand their networks. This may raise their asset betas relative to the lines businesses.

Second, unlike electricity, which is used exclusively as a power source, a large proportion (30%) of gas is used as an intermediate product in the petrochemical industry, in particular for the production of methanol (Ministry of Economic Development, 2004, p 86). This points to a higher income elasticity of demand for gas, and therefore for gas pipeline services. Accordingly the asset beta should be higher than for lines businesses. However, there are two mitigating factors here. First, virtually all the methanol is exported[65]. This fact will lower the correlation between the demand for this product and the return on the New Zealand market portfolio. Thus, the impact of gas being used in methanol production upon the asset beta of the pipeline businesses will be mitigated. Secondly, despite the fact that 30% of the gas is used in the petrochemical industry, very little revenue arises from this,

[65] A figure of 98% is reported on the website of Methanex New Zealand (www.methanex.com/ourcompany/locations_newzealand).

because the distance that it is piped is relatively short. Since the revenue contribution is small, the impact upon the overall asset beta will also be small.

The third possible point of distinction between the gas pipeline and electricity lines businesses is that, whilst a large proportion of gas is used in the generation of electricity, some of it is used to generate the variable rather than the base supply. If the extent of this variable supply were substantial, then the demand for gas would be more sensitive to macro economic shocks than the demand for electricity and this would point to a higher asset beta for the gas pipeline businesses than that for the electricity lines businesses. However, most of the gas used for electricity generation is supplied to the Otahuhu, TCC and Huntly plants (Ministry of Economic Development, 2004, p 86), and these plants generally provide base rather than variable supply. So, this issue does not point to any significant increase in the asset beta for gas pipeline businesses.

The final point relates to the use of gas by residential or commercial users. Leaving aside the gas used by the petrochemical industry, 30% of gas is directly supplied to commercial and industrial users, 6% to residential users and the remaining 64% used for generating electricity (ibid, p 86). Of this electricity generation, 68% is supplied to commercial and industrial users (ibid, p 106). The overall use of gas by these users is then 74% [30% + .64(68%)]. Inclusion of the gas supplied to the petrochemical industry raises the figure from 74% to 82%.[66] By contrast, only 68% of electricity generation is supplied to commercial and industrial users. The supply of gas or electricity to commercial and industrial users constitutes an intermediate product whose demand will be driven by the demand for the final goods and services. The demand for these final goods and services is likely to be more sensitive to macro economic shocks than the demand for gas or electricity by residential users. So, with gas supply more heavily tilted towards commercial and industrial users than for electricity, the demand for gas is likely to be more sensitive to macro economic

[66] As noted by AECT (2007, para 93), these figures relate to gas transmission rather than gas distribution businesses, because the gas used by the petrochemical industry and for generating electricity passes exclusively through the transmission network. In respect of the gas distribution businesses, we therefore ignore the gas used by the petrochemical industry and that used for generating electricity; commercial users then receive 83% of the gas passing through the distribution network (30%/36%).

shocks. This implies a higher asset beta for the gas pipeline businesses than for the electricity lines businesses.

Taking account of these four points, particularly the first and the last, the gas pipeline businesses would seem to warrant a modestly higher asset beta than the lines businesses. My point estimate here is .10[67]. I therefore suggest an asset beta for the gas pipeline businesses as follows. I use US electric utilities and gas distribution firms as a base, and estimate their asset beta (β_{Ea}) at .30, i.e., $\hat{\beta}_{Ea} = .30$. I add a margin of .10 to reflect the difference in regulatory regimes between New Zealand and the US (in the electricity lines sector). This represents an estimated margin ($\hat{\Delta}$) of .20 for five year price-cap regulation, subject to an estimated adjustment factor ($\hat{Q}$) of .50 to reflect the fact that the New Zealand lines businesses are more risky than the US firms but less risky than a five-year price-cap situation. Finally I add a further estimated margin ($\hat{G}$) of .10 to reflect the greater risk of gas pipeline businesses relative to electricity lines businesses in New Zealand. The result is an estimated asset beta of .50, i.e.,

$$\hat{\beta}_a = \hat{\beta}_{Ea} + \hat{Q}\hat{\Delta} + \hat{G} = .30 + .50(.20) + .10 = .50$$

In using these foreign firms as comparators, there is a further source of difference in the "regulatory" environments that warrants some comment. This is asset valuation methodology. If output prices reflect costs, then the firm's choice of asset valuation methodology will affect output prices and therefore the riskiness of the entity's cash flows. In respect of the US firms, output prices reflect costs with assets valued at Depreciated Historic Cost (DHC) along with some exposure to assets being optimised out (Guthrie, 2006). In respect of the UK firms, output prices also reflect costs but the asset valuation basis is less clear, i.e., there seem to have been some adjustments to DHC (presumably in the direction of replacement cost) but the precise nature of these

[67] This estimate is applied equally to gas transmission and distribution businesses despite the fourth point above favouring a higher estimate for the distribution businesses; the grounds for doing so are that the first point above (the growth options) applies equally to both types of businesses and the differential effect of the fourth point above would seem to be small. Also, this margin of .10 for gas pipeline businesses relative to electric utilities appears to conflict with the US results, which suggest that the two types of businesses warrant the same asset beta. However, the considerations that point to a higher asset beta for the gas pipeline businesses in New Zealand do not seem to be applicable to the US situation.

are unclear (Littlechild, 1998, pp. 43-45). In respect of the New Zealand gas pipeline businesses, the asset valuation methodologies underlying their output prices are unclear and may vary over firms. However, the most likely possibilities are DHC and ODV (essentially optimised depreciated replacement cost).[68] The former matches that for the US firms and the latter bears some similarities to the situation facing the UK firms[69]. Thus, the risk facing a gas pipeline business that arises from its choice of asset valuation methodology would seem to be bounded by that of the US and UK firms, and these are the very firms used to estimate the asset betas for the gas pipeline businesses. Thus, the process for estimating the asset betas of the gas pipeline businesses would seem to be consistent with the risks arising to them from asset valuation methodology.

The analysis here leads to the same asset beta for both gas transmission and distribution. However there are some possible points of difference in these two activities that are suggestive of differences in beta. In particular, transmission may be characterised by less competition. However the effect of competition upon beta is unclear, as discussed earlier in section 5.1. So, in light of these difficulties, the same asset beta is applied to both gas transmission and distribution.

5.3 The Uncertainty in the Estimate

Having developed a point estimate for the asset beta of a New Zealand gas pipeline business based upon point estimates for four underlying parameters, I now turn to estimating the uncertainty surrounding these four underlying point estimates. The point estimate for a New Zealand firm comprises an estimate for the average true asset beta of US electric and gas utilities ($\hat{\beta}_{Ea}$) coupled with an estimated margin ($\hat{Q}\hat{\Delta}$) to reflect the difference in regulatory regimes between New Zealand and the US ($\hat{\Delta}$ being the estimated margin for five year price-cap regulation relative to rate-of-

[68] Consistent with uncertainty in this area, and the desirability of assessing Excess Earnings using an asset valuation methodology that corresponds to that used by a firm in setting its output prices (Lally, 2002d), the Commerce Commission sought to determine Excess Earnings under both DHC and ODV (Commerce Commission, 2004, Ch. 6).

[69] In fact, the risks arising to the New Zealand gas pipeline businesses using ODV are likely to be less than for the UK firms, because any revaluations of the assets of the New Zealand firms are liable to have affected only the distribution over time of the recovery of the historic cost of the asset rather than the total amount recovered. By contrast, the UK firms were exposed to the possibility of the total depreciation allowance being more or less than the historic cost of the asset.

return regulation and $\hat{Q}$ being an estimate of the adjustment to reflect the fact that the New Zealand lines businesses lie between these two bounds) and also an estimated margin ($\hat{G}$) to reflect the greater risk of New Zealand gas pipeline businesses relative to electricity lines businesses, i.e.,

$$\hat{\beta}_a = \hat{\beta}_{Ea} + \hat{Q}\hat{\Delta} + \hat{G}$$

We utilise $\hat{\beta}_{Ea}$ to estimate the true asset beta of a New Zealand lines business β_{0a} (absent regulatory differences between the two markets). Equivalently, $\hat{\beta}_{Ea}$ is an estimator for the true asset beta (β_{0a}) of a randomly selected US utility that is not part of the set of firms used to generate $\hat{\beta}_{Ea}$. Appendix 3 analyses this issue and shows that the standard deviation of ($\hat{\beta}_{Ea} - \beta_{0a}$) is as follows

$$\sigma(\hat{\beta}_{Ea} - \beta_{0a}) = \sqrt{v\left(\frac{N+1}{N}\right) - \sigma_e^2(1-2\rho)}$$

where *v* is the expectation of the cross-sectional sample variance in the estimated asset betas, σ_e^2 is the variance in the estimation error for an individual firm's asset beta, ρ is the correlation coefficient between the beta estimation errors for any two firms, and *N* is the number of firms used in estimating *v*. Applying this formula, the resulting estimate of $\sigma(\hat{\beta}_{Ea} - \beta_{0a})$ is .136 (as shown in Appendix 3).

Turning now to the margin for firms subject to five-year price capping relative to rate-of-return regulated firms (Δ), my estimate of this parameter is .20 based upon the average asset beta estimates for the nine US and twelve UK electric utilities in Alexander et al (1996), subject to corrections for country leverage differences relative to New Zealand followed by rounding to .20, i.e.,

$$\hat{\Delta} = .93\overline{\hat{\beta}}_{UK} - 1.2\overline{\hat{\beta}}_{US} = .93(.58) - 1.2(.30) = .18 \cong .20$$

Errors in the estimates for each of the two countries will arise from industry and firm specific effects rather than market-wide effects, and the industry effects for the two countries are not likely to be highly correlated. So, the two estimators are likely to be close to independent. It follows that the standard deviation of the estimator is as follows.[70]

$$\sigma(\hat{\Delta}) = \sqrt{(.93)^2 \sigma^2(\bar{\hat{\beta}}_{UK}) + (1.2)^2 \sigma^2(\bar{\hat{\beta}}_{US})}$$

Estimation of $\sigma^2(\bar{\hat{\beta}}_{UK})$ and $\sigma^2(\bar{\hat{\beta}}_{UK})$ is complicated by the fact that the individual beta estimates within each market will be positively correlated, as discussed in Appendix 3. Appendix 4 therefore derives estimates for each of these two markets of .0063 and .0072 respectively, using the S&P data referred to in Table 3 rather than Alexander's data (because the latter does not disclose standard errors on the individual beta estimates). Using these estimates, the result is as follows.

$$\sigma(\hat{\Delta}) = \sqrt{(.93)^2(.0063) + (1.2)^2(.0072)} = .126$$

In respect of the adjustment to reflect the location of a New Zealand firm between that of the US and UK firms (Q), my estimate of this parameter is .50. The uncertainty over this parameter must reflect not merely uncertainty about where a typical New Zealand electricity lines business would lie in the range between US rate of return and five-year price-cap regulation, but also an allowance for variation in the extent to which individual electricity lines businesses operate in a cost-plus fashion[71]. No statistical data is available to estimate the standard deviation here. Nevertheless, the true value for the parameter must lie between zero and 1, and a plausible probability distribution for Q is the uniform distribution over that interval.[72] Invoking the

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[70] The coefficients 0.93 and 1.2 reflect country leverages, and are therefore observed without error.

[71] Lines businesses that operate in a more cost-plus fashion would have asset betas towards the lower end of the scale (.30), and those which are not embedded within private sector firms may be of this type. These include community trusts, consumer trusts and councils. Quantifying variation across these entities does not seem to be feasible.

[72] The choice of the uniform distribution is conservative, i.e., alternatives would have lower standard deviations.

formula for the standard deviation of a uniform distribution (see Mood et al, 1974, page 106), the result is

$$\sigma(Q) = \sqrt{\frac{(1-0)^2}{12}} = .29$$

Finally, in respect of the parameter *G* reflecting differences between New Zealand gas pipeline and electricity lines businesses, again no statistical data is again available to estimate the standard deviation. However, a plausible probability distribution for *G* is the uniform distribution over the interval from 0 to .20. Invoking the formula for the standard deviation of a uniform distribution (see Mood et al, 1974, page 106), the result is

$$\sigma(G) = \sqrt{\frac{(.20-0)^2}{12}} = .06$$

In summary, the standard deviations for the probability distributions associated with $\hat{\beta}_{Ea}$, $\hat{\Delta}$, $\hat{Q}$ and $\hat{G}$ are .136, .126, .29 and .06 respectively. Implicit in the first two of these estimates is the assumption that parameter values applicable to foreign markets are also applicable to New Zealand, and Boyle et al (2006, page 20) allude to this issue. In so far as this assumption is not valid, the standard deviations on these estimates for New Zealand firms should be raised, but quantification of this potential source of error does not seem to be possible.

5.4 Contrary Views

A number of submissions by or on behalf of the gas pipeline businesses have argued for a higher value for the asset beta than suggested above. LECG (2003a) argue for a point estimate of .55. This point estimate appears to be based on an asset beta for US electric utilities of .35, an increment of .10 to allow for the difference between the New Zealand and US regulatory situations, and an increment of .10 to allow for the difference between New Zealand electricity lines and gas pipeline businesses. The only point of difference with the present paper concerns the estimate for US electric utilities, and reflects LECG's preference for 1998-2002 Damodaran (Value Line) data on electric utilities. However, Damodaran's estimates are Blume-adjusted betas rather than raw betas and are therefore inappropriate (as discussed in section 5.2).

Furthermore, consideration of a wider set of estimates in that section, and as shown in Table 3, supports the estimate of .30 rather than .35.

In a subsequent submission, LECG (2003c) argue instead that the best estimate of Powerco's asset beta is obtained from Powerco's own returns data rather than from the data of "..some other more or less comparable firm" (ibid, p 8). However the use of returns data from only one firm exposes one to enormous estimation errors. These are illustrated in section 5.2, where the estimates for the four New Zealand firms were .43, -.08, .30 and .48 for Powerco, United Networks, NGC and Vector respectively. Had LECG been representing United Networks in this matter, it seems unlikely that they would have placed any faith in the figure of -.08. Furthermore, the asset beta estimated from Powerco's own returns data could very well have generated a result considerably larger than .43. In this case, LECG would then have argued for this much higher figure. The problem here is that beta estimates based upon the returns data of only one firm are statistically very unreliable. Because of this statistical problem, one is bound to draw upon returns data from other firms. In statistical terms, one is trading off bias against variance. Of course, there will be judgement questions in this area. LECG observes that there are particular difficulties in drawing upon beta estimates from foreign firms, and I concur (Lally, 2002c, 2004b). Nevertheless, if the foreign firms are ignored, then one is left with only three local firms. In my view this is too small a number to obtain a reliable estimate[73], and the average so obtained of .36 (see Table 2) is presumably not one that would appeal to Powerco.

LECG (2003c) also argue that the beta estimates obtained in the usual way are likely to be biased because they are estimated against a "market" portfolio that includes only equities rather than equities and risky debt. In particular, they argue that they will be biased down for reasons articulated in Ferguson and Shockley (2003). However this bias argument is incomplete. It is readily agreed that the market portfolio in the CAPM encompasses much more than equities. In fact it includes a great deal more than equities and risky debt. However the use of equities as a proxy for the market portfolio is driven by the lack of returns data on other assets. It is readily

[73] This issue is further discussed in section 9.1, and it is shown there that the standard deviation on the estimate arising from using the New Zealand firms is almost twice is great as that arising from using the US and UK firms.

acknowledged that this gives rise to biases, but the biases are not limited to betas and extend to the estimation of the market risk premium (Lally, 1995a, 2002e). In particular, if risky debt were included in the market portfolio proxy, then the effect would be to lower the estimate of the market risk premium. Thus, even if the effect of including risky debt in the market portfolio proxy were to raise the betas of the gas pipeline businesses, the downward effect upon the market risk premium may offset it. In a subsequent submission, LECG (2004) acknowledge this point and argue that error in either direction is possible. This is agreed and the point will be referred to later in section 9.1.

In a further submission, LECG (2004) revert to their earlier position of broadly concurring with the approach taken in this paper, in which foreign comparators are used rather than local companies. However they raise a number of further concerns. Firstly, they argue that the asset beta recommended here reflects a three yearly price resetting cycle whereas the Commission proposes to use a five yearly period for assessing excess profits. On this basis, they argue for raising the asset beta. However, the Commission's proposal to reassess excess profits over a five year period has no bearing on the risk faced by the firms. By contrast, their risk is affected by their price resetting period, and the asset beta estimate that is recommended here reflects that.

Secondly, LECG (2004) refer to the work of Evans and Guthrie (2004), which implies that short regulatory cycles can *raise* the risk of firms using the ORC methodology. This suggestion contradicts that noted in the previous paragraph. However Evans and Guthrie are concerned with price setting under incentive regulation (in which the risks relating to ORC values are borne entirely by the firm). This scenario is not relevant to the gas pipeline or electricity lines businesses in New Zealand.

Thirdly, LECG (2004) invoke Campbell and Mei (1993), and decompose the covariance term within beta into four components, including the covariance of cash flows on the asset to market cash flows ("cash flow covariance") and the covariance of changes in the discount rate on the asset to changes in the discount rate on the market portfolio ("discount rate covariance"). They then argue that the analysis presented in the present paper is focussed on the first of these components to the exclusion of the others. This implies that the list of factors underlying asset betas that has been presented in section 5.1 is incomplete. In particular, asset betas might differ across industries or even firms because they differ in respect of their discount rate covariances. However, in the present situation, the comparators are drawn from the same industry (utilities). So, the discount rate covariances would have to differ across firms. However, Campbell and Mei present no evidence on this question; in fact, on account of conducting their analysis at the industry level, they imply otherwise (ibid, Table 1). So, the implications of Campbell and Mei for the present paper are limited to raising the possibility that there is a difference between the discount rate covariances of the comparators and those for the New Zealand firms; accordingly, the estimate offered here may be in error. However no quantification of the potential error is offered or would even appear to be possible. I consider it unlikely that there would be any material difference here.

LECG (2007, section 3.5) notes that there is variation in the asset beta estimates presented in Table 3 above and in particular that the Ibbotson estimates for 1997-2002 are unusual. Accordingly, LECG favours use of only the Value Line estimates. However the conclusion does not follow from the observation. If one estimate amongst a set of estimates is highly unusual, the appropriate course of action would seem to be to avoid reliance upon any one estimate, as has been done above rather than simply to choose another estimate. Furthermore, as noted in the discussion following Table 3 above, deletion of estimates that draw upon data from the 1998-2001 period raises the median estimate from .27 to .30 and the latter figure has been adopted.

LECG (2007, section 3.5) also argues for estimating the standard deviation on the asset beta estimate from the standard deviation associated with the beta estimate for an individual firm. However, the standard deviation invoked must reflect the estimate that is used. The standard deviation proposed by LECG would be appropriate if the asset beta for (say Vector) was estimated using data for only Vector; in this case, the point estimate and the standard deviation would be .48 and .18 respectively (as shown in Table 2 above). However, the estimate proposed above is not of this type and therefore the standard deviation cannot be determined in this way. This raises the question of whether the asset betas for individual businesses should be estimated in this way. If this were done, the estimates would differ across businesses, as shown in Table 2 above. Such differences in estimates could reflect differences in their true betas but they will also reflect estimation errors, and therefore the use of different estimates for different businesses would be problematic. Furthermore, such an approach could not be adopted for an unlisted company. Consequently, application of the same estimate to all companies in the industry is appropriate, and the analysis above follows this approach.

NECG (2004a) argues that the asset beta of .50 is too low and cites Annema and Goedhart (2003, Exhibit 3) in support of the higher figure of .62. However the latter figure is an *equity* beta, and it relates to US Electric Utilities whereas the former figure of .50 is an asset beta and it is not an estimate for US Electric Utilities (although it is derived from an estimate for these entities of .30). So, the appropriate comparison is between this figure of .30 and the asset beta implied by the Annema and Goedhart paper. Derivation of this implied asset beta would require knowledge of the set of companies involved, and the process for estimating the equity beta. Neither of these is disclosed, and this precludes further analysis. Nevertheless, Annema and Goedhart do present evidence that betas for US firms outside the TMT sector (telecommunications, media and technology) fell dramatically over the period 1998-2001 inclusive, and they attribute this to the TMT "bubble" in that period. They conclude that current estimates for the betas of non-TMT firms should not draw upon data from that period. This issue has already been noted in section 5.2, and the conclusions drawn there reflect it.

NECG (2004a) also favours a larger standard deviation on the asset beta than implied here. In particular, they favour a figure of .30 whereas the figure implied here is about .17 (as derived in section 9.1). However they offer no evidence in support of their suggestion.

MEUG (2004) argue that the point estimate for β_a of .50 cannot be reconciled with estimates of the asset betas of US natural gas distribution firms, and they cite figures from Ibbotson (over the period 1996-2004) ranging from .06 to .33. The latter figures relate to US firms subject to rate of return regulation, and therefore cannot be compared to the estimate of .50 for the New Zealand firms, which involves a different regulatory situation. The appropriate comparison would be between the Ibbotson figures (.06 - .33) and the estimate of .30 offered in this paper for US electric utilities and gas distribution firms. The Ibbotson data has contributed to forming this estimate of .30, and the latter figure lies within the band of figures cited by MEUG. Nevertheless, as noted earlier in section 5.2, the most recent Ibbotson estimates are outliers relative to other data sources, and a potential explanation has been offered for that.

Boyle et al (2006, pp. 21-23) argue that the US electric and gas utilities used in the earlier analysis to estimate the asset beta under rate-of-return regulation are unsatisfactory on a number of grounds. In particular, some of them are unregulated, some of them are involved in unregulated activities (Jandik and Makhija, 2005), and some of them faced alternative regulatory regimes, most particularly rate freezes and price caps (Sappington et al, 2001). The effect of all of these points would be to raise risk, and therefore imply that the estimated asset beta under rate-of-return regulation of .30 is in fact too high. Finding perfect comparators is difficult, if not impossible, and the issue therefore reduces to whether these firms are a satisfactory proxy. In respect of unregulated activities, Jandik and Makhija (2005, Table 1) report a growth in "diversified assets" from 10% to 20% over the period 1980-1997 for US electric utilities; such percentages are not large, and some of the diversification is into other rate-of-return regulated areas (gas distribution). Potentially the strongest evidence presented by Boyle et al relates to 28 electric utilities that have been subject to higher risk regulatory regimes, most particularly a price cap or a rate freeze (Sappington et al, 2001, Table 2). However, removal of such firms from the data sets in Table 3 does not exert a material effect upon the results. For example, in respect of the S&P data sets referred to in Table 3, only 6 of the 28 firms listed by Sappington appear in the S&P data sets[74]. Removal of these firms from the data sets that are associated with the period of incentive regulation leads to all six being removed from the 1999-2003 data set and three of them (the first three in footnote 73) from the 1994-1998 data set. The average asset betas are then recalculated, thereby reducing the 1994-1998 average by .01 and raising the 1999-2003 average by .02. These effects are trivial, and

[74] These firms are AmerenUE, Black Hills Power and Light, EntergyLA, NSTAR, Otter Tail Power, and Southern California Edison Co.

suggest that the data in Table 3 are satisfactory for estimating the asset beta under rate-of-return regulation.

Boyle et al (2006, page 25) also argue that the estimate for the asset beta of the UK electric utilities in the period 1990-1994 was biased downwards by the anticipation of a switch to a hybrid price/revenue cap. However, they do not attempt to quantify this effect, and there is no apparent means of doing so. Accordingly, we are bound to treat this possible bias as simply part of the broader set of estimation errors to which all parameter estimates are subject.

Boyle et al (2006, pages 25-26) also argue that the estimates for the asset betas of the UK price-capped firms (drawn from Alexander et al, 1996) are based on daily price data, that the use of weekly or monthly data raises the estimates (Alexander et al, 1996, Table A3.5), and that the latter data is preferable due to concerns about infrequent trading. However, Alexander et al (1996, pp. 25-26) address this potential concern and conclude by favouring the use of daily returns data. Furthermore, since the results of interest here are the differences between the asset beta estimates for the US and UK electric utilities, any resort to weekly or monthly data for the UK firms would have to be accompanied by use of the same data frequency for the US firms, and Alexander et al do not disclose results for the US firms using weekly or monthly data.

Boyle et al (2006, page 53) also argue for estimating the asset betas of the UK regional electricity companies in the period since 1995, and using these estimates to complement the existing estimates (from 1990-1994). However, from 1995, the regulatory regime imposed upon these firms changed from a price cap to a hybrid price/revenue cap (Alexander et al, 1995), and it is less clear how the risk of such entities would compare with the New Zealand firms than for the firms actually examined (comprising US firms subject to rate-of-return regulation, which should have lower risk than the New Zealand firms, and UK firms subject to five-year price-capping, which should have higher risk than the New Zealand firms). Furthermore, during the late 1990s, a switch to an explicit profit-sharing regime was considered for these firms and, although not eventually adopted, appears to have significantly lowered their estimated betas during that period (Grout and Zalewska, 2006). For both of these reasons, asset beta estimates are not sought for these firms after 1995.

Boyle et al (2006, pp. 27-29) also favours an estimate of .30 for the standard deviation of $(\hat{\beta}_{Ea} - \beta_{0a})$, and this is based largely upon an estimate for the cross-sectional variance in the estimated asset betas of the US utilities of v = $.314^2$ = .0986. This estimate for v is based upon only one data set (Value Line as reported by Damodaran). In addition, Boyle et al also fail to offer estimates for two further underlying parameters. By contrast, the estimate for v used here of .0298 (see Appendix 3, Table 10) is based upon averaging over three data sets and using period-average leverage rather than the period-end leverage presumably used by Boyle et al. In addition, point estimates for the two additional underlying parameters are developed. For all of these reasons, the estimate of .136 for the standard deviation of $(\hat{\beta}_{Ea} - \beta_{0a})$ that is presented earlier is preferred to that of .30 favoured by Boyle et al.

AECT (2007, para 93) argue that the estimate of .30 for the US electric utilities is too low and claim that research conducted by Damodaran points to a higher figure. Although they do not present any specific results from him, they are presumably referring to the industry average asset betas presented by him and drawn from Value Line (.40 for 2004 and .46 for 1998, as noted in section 5.2). However, as discussed in section 5.2, these estimates arise by use of the Blume (1971, 1975) adjustment technique and Lally (1998c) shows that this induces upward bias. AECT do not offer any contrary argument on this point. Furthermore, even if it were true that the unadjusted Value Line estimates were in excess of .30, AECT would be implicitly selecting only the highest estimates from the available set and this would induce overestimation of the parameter. In response to the latter point, AECT (2008, para 39) argue that high estimates should be chosen to protect against estimation error. However, protection against estimation error is reflected in the recommendation to select a WACC estimate from above the 50th percentile of the distribution (see section 9.1) and AECT's proposal would then involve double-counting. Presumably in anticipation of this counter-argument, AECT (2008, para 40) asserts that both adjustments are warranted but offers no explanation for this claim.

AECT (2007, para 93) also argue that "Lally largely underestimates the full nature of the competitive/commercial threats faced by New Zealand gas distributors compared with their overseas counterparts." However, AECT does not elaborate upon this issue, let alone suggest an appropriate allowance for it and provide evidence in support of it. In the absence of such detail, their point has no persuasive value. Furthermore, whatever their point is may relate to unsystematic rather than systematic risk and therefore warrant no allowance in accordance with the CAPM.

AECT (2007, para 95) also argue that the estimated asset beta should allow for stranding risk. AECT are presumably referring to the expected losses that arise from the possibility of stranding. However, this is not a systematic risk, it should be addressed through the cash flows rather than beta, and it is discussed in section 12.1.

MEUG (2007) also argues that recent data (2004-2007) should be used for estimating the asset beta in addition to earlier data. This has now been done in respect of the Ibbotson estimates (see Table 3). In respect of the Value Line and S&P estimates, the underlying equity beta estimates are based upon five years of data and therefore use of estimates for the most recent five year period (2003-2007 inclusive) would involve abandoning the existing estimates (and replacing them at considerable effort with estimates for the periods 1998-2002 and 1993-1997). Consequently, I favour retaining the existing Value Line and S&P estimates and, at the end of 2008, supplementing these with estimates based upon the period 2004-2008.

MEUG (2007) also suggest that the older data sets used to estimate the asset beta should be dispensed with. Clearly, the more recent data is more relevant to present conditions. However, the use of older data improves the statistical reliability of results and permits identification of periods in which highly unusual conditions have prevailed (thereby admitting the opportunity to disregard such data). Thus, there is a trade-off here. My judgement is that use of data from the last 15-20 years is desirable.

Unison (2007, section 4.2) appears to object to the use of data from firms subject to rate-of-return regulation in forming an estimate of the asset beta relevant to a price control situation. Given that the estimate presented above is actually generated by adding together an estimate for rate-of-return regulation, an estimated margin for five year price control over rate-of-return regulation in respect of electricity distributors, and an estimated margin for gas pipeline businesses over electricity lines businesses in New Zealand, Unison's point is presumably that the asset beta for electricity lines businesses subject to five year price control ought to have been estimated directly rather than as the sum of the first two terms. If this is their point, the rationale for developing the estimate in the way described here lies in the deficiency in data on utilities subject to five year price caps; the only available information here relates to 12 UK firms in the period 1990-1994.

Unison (2007, section 4.2) also appears to object to the use of data from US electricity utilities on the grounds that they are not a homogenous group subject to rate-of-return regulation.[75] In support of this claim, they refer to Boyle et al (2006, pp. 21-22). However these points have been examined above and Unison does not address these counter-arguments.

6. Leverage

The WACC of a firm is affected by its leverage. In general, the possible measures of leverage include actual leverage, optimal leverage, and the firm's target leverage. In the context of assessing excess profits based on an ex-post analysis, the choice must lie between the first two. If a business' actual costs are utilised in assessing excess profits, then consistency suggests that actual firm level leverage should be invoked (in so far as it can be observed). By contrast, if efficient costs are utilised in assessing excess profits, then consistency suggests the use of optimal leverage. Both should be measured in market value terms, and the rationale for this is discussed in Appendix 5. Efficient costs are suggested in the Draft Framework Paper (Commerce Commission, 2003, p 7), but the practice has involved a mixture of actual and efficient costs. Thus it is unclear whether actual or optimal leverage should be employed. However, the

[75] Unison actually describe them as operating under "price cap regulation" but this appears to be an oversight.

use of actual leverage is complicated by the impossibility of measuring it when a firm is not listed[76]. So, this points to the use of optimal leverage.

The optimal leverage level of a firm cannot be directly determined, as it reflects a trade-off between competing considerations such as taxes, bankruptcy costs and the financial flexibility offered by debt. If the firm were listed, this optimal leverage level might be estimated from the leverage level actually employed by the firm at a given point in time. However, there is some evidence that leverage levels reflect the random outcomes of past investment decisions as well as assessments of what is "optimal"; this is generally referred to as "pecking order theory" (Myers, 1984; Titman and Wessels, 1988). Accordingly, a better estimate of optimal leverage ("optimal" in light of current circumstances) might be obtained by averaging over the observed levels of a number of listed firms within the relevant industry, and imputing it to all firms in the industry. If a firm is not listed, recourse to estimating optimal leverage in this way is unavoidable.

Recent leverage values for gas pipeline businesses are shown in Table 2 (for the years 2002, 2004, 2005 and 2006), and the average is 0.48 over the four firms. However, the number of firms here is very limited, and therefore leverage levels for listed firms in similar industries should also be considered, i.e., monopolistic industries with relatively stable cash flows and similar regulatory environments. The only close comparators are electricity lines businesses and airfields. Across these two industries, the only additional companies for which leverage can be observed in market value terms are Horizon Energy and Auckland Airport. Recent values are .20 for Horizon Energy (Lally, 2006, Table 2) and .32 for Auckland Airport[77]. Averaging across these six firms yields 0.41, i.e., about .40. By way of comparison, the average leverage of New Zealand firms is around .20 (Ernst and Young, 2000). In view of all this, I estimate the "optimal" leverage at .40. Fortunately one does not need to assess this level with great precision because the effect of such variations in leverage (along with

[76] In the context of assessing excess profits, book leverage is not a satisfactory substitute for market value leverage because the market value for the business can differ significantly from the book value of its assets.

[77] Re Auckland Airport, this is based on debt of $828m at 31.12.2005 (as per the Annual Report), 1.222b shares (as per the Annual Report) and a share price at that time of $2.12.

the associated debt premium) on WACC is modest when the tax-adjusted version of the CAPM is employed (as discussed in the next section).

We turn now to an estimate of the uncertainty in this estimated optimal leverage of 40%. The estimate is essentially an average over the six observations referred to above $(\overline{L})$ and this serves to estimate the true optimal leverage of an individual company (L_0). The six leverage observations could be regarded as sample data in a fashion paralleling that for estimated asset betas of individual companies or estimated market risk premiums for individual countries. Accordingly, the standard deviation on $(\overline{L} - L_0)$ follows from equation (31) in Appendix 3, i.e.,

$$\sigma(\overline{L} - L_0) = \sqrt{v\left(\frac{N+1}{N}\right) - \sigma_e^2(1-2\rho)}$$

Unfortunately, of the four parameters on the right hand side of this equation, only two are known or amenable to estimation: the sample size N and the expectation of the cross-sectional sample variance v. So, the remaining terms are disregarded to yield the following estimate:

$$\sigma(\overline{L} - L_0) = \sqrt{v\left(\frac{N+1}{N}\right)}$$

This is likely to be conservative (i.e., too high) because the correlation coefficient is unlikely to exceed .50. Using the six sample observations above, the estimated value for $\sqrt{v}$ is .19. Substitution into the last equation yields an estimate for $\sigma(\overline{L} - L_0)$ of .20.

In respect of contrary submissions, LECG (2003a, 2004) argue for leverage of 55%, on the grounds that the companies intend to adopt that level of leverage. However, as indicated above, in the context of examining past profits, the choice must lie between actual and optimal leverage during the period examined; intentions are irrelevant.

7. The Debt Premium

This is the margin by which the cost of debt exceeds the risk free rate, and may be defined to include an allowance for debt issue costs. The premium was set at .01 for the airfields and .012 for the lines businesses (Commerce Commission, 2002a, 2002b). However, more recently, I have suggested .01 for the lines businesses (Lally, 2006). Such premiums are towards the low end of the range for this parameter, in recognition of levels of operating risk that almost precluded bankruptcy[78]. Such low operating risk in turn springs from the essential nature of the products and the monopolistic nature of the industries. Gas pipeline businesses appear to be similar to the airfields and the lines businesses in the latter two senses. In addition, the suggested leverage of 40% for the gas pipeline businesses is comparable to that suggested for the lines businesses, and higher than the 25% suggested for the airfields.

The best information for estimating debt premiums is market yields from the traded bonds of gas pipeline businesses. However, trades are infrequent and we therefore utilise indicative valuations provided by ABN AMRO Craigs. As of July 2005, indicative valuations were available for four classes of Powerco bonds, one class of Vector bonds and one class of United Networks bonds.[79] However, disregarding all bonds with features that disguise the true cost of debt leaves only one class of Powerco bonds (PWC070) with debt premiums as shown in Table 4A for July 2005 and the adjoining two months (ABN AMRO Craigs, 2005).[80]

[78] The range spanning most companies is .01-.02 (JBWere Goldman Sachs, 2004).

[79] July 2005 is chosen because it is relevant to the price control situation considered later. The issue of estimating the debt premium at the commencement of the regulatory cycle was raised by Unison (2007, section 4.3)

[80] The indicative yields shown here are those arising in the event of selling bonds rather than buying them and ABN AMRO Craigs advises that the spread between buy and sell yields would be about 10 basis points at the time in question. So, five basis points has been deducted from the reported yields. "Capital Bonds" are ignored because the issuer can redeem the bond in shares rather than cash, and this put option held by the issuer would induce an increase in the interest rate to compensate the bondholder. In addition, all bonds involving a guarantee from a third party are ignored, which includes "credit-wrapped" bonds and the United Networks bonds. The debt premium is calculated by comparing the yield on the bond (k_d) with the yield on government stock (R_f) with the same maturity.

Table 4A: Debt Margins for Gas Pipeline Businesses' Bonds

	30 June 2005			1 Aug 2005			31 Aug 2005		
	k_d	R_f	ρ	k_d	R_f	ρ	k_d	R_f	ρ
PWC070	7.25	5.82	1.43	7.16	5.73	1.43	7.10	5.63	1.47

The median debt premium here is 1.43%. However, these PWC070 bonds are subordinated and are therefore not representative of the full set of PWC bonds.[81] Accordingly debt premiums are considered around December 2006, when data is available for both subordinated (PWC070) and senior bonds (VCT020) as shown in Table 4B (ABN AMRO Craigs, 2006).[82]

Table 4B: Debt Margins for Gas Pipeline Businesses' Bonds

	15 Nov 2006			15 Dec 2006			16 Jan 2007		
	k_d	R_f	ρ	k_d	R_f	ρ	k_d	R_f	ρ
VCT020	7.36	6.37	1.01	7.47	6.47	1.00	7.54	6.46	1.08
PWC070	7.45	6.25	1.20	7.53	6.34	1.19	7.51	6.36	1.15

The bonds shown in this table are of similar residual term to maturity (five and four years respectively) and the book leverages of the two firms at this time were similar (69% and 61% respectively)[83], which supports use of these two bonds to estimate the margin between senior and subordinated debt. The median difference in the debt premiums is 19 basis points and we therefore estimate the debt premium on senior

[81] Powerco's Annual Report for the year ended 30.6.2005 reveals that it had senior debt at this time and that most of the debt was of this type. Consequently, subordinated debt is particularly unrepresentative.

[82] Senior and subordinated bonds in the same company were preferred, but no such cases were available after elimination of all bonds with features that disguise the true cost of debt. Also, the bond yields referred to here are based upon indicative valuations for buying rather than selling bonds and therefore 5 basis points has been added to the reported yields.

[83] Powerco's leverage of 69% is based on book values for debt and equity of $504m and $1105m respectively, drawn from the Annual Report for the year ended 30.6.2006. Vector's leverage of 61% is based on book values for debt and equity of $1997m and $3085m, drawn from the Annual Report for the year ended 30.6.2006.

Powerco debt to be 19 basis points less than 1.43%, i.e., 1.24%. Applying greater weight to the latter figure of 1.24% rather than the former figure of 1.43%, in recognition of the fact that most of Powerco's debt is senior, suggests a debt premium across Powerco's aggregate debt in July 2005 of about 1.3%.

This debt premium of 1.30% also reflects Powerco's leverage in July 2005, and this was 68% compared to the 40% figure proposed in the previous section.[84] Accordingly, the debt premium should be adjusted downwards to reflect leverage of 40%. Using Australian data, Lally (2006, section 7, equation (13)) shows that reducing book leverage by 28% would raise the S&P credit rating by one category. Furthermore, the Essential Services Commission (2005, Tables 9.12 and 9.13) reports premiums on Australian firms sourced from CBA Spectrum and Bloomberg, for ratings from A+ to BBB+ and terms from four to ten years. In respect of five year bonds (corresponding to the residual life of the PWC070 bonds), averaging over these two sources reveals that the effect of raising the credit rating by one category is to lower the debt premium by 7 basis points. So, the debt premium on the Powerco bonds consistent with leverage of 40% and a five year term would be about 1.2%.

Finally, and in recognition of the fact that the debt premium increases with the term of the debt (Essential Services Commission, 2005, Tables 9.12 and 9.13), it is necessary to assess the appropriate debt term. In the context of price control, Lally (2007b) shows that the firm faces strong incentives to match the duration of its debt with that of the regulatory cycle, although this could be achieved through suitable swap contracts rather than through the choice of debt term. Thus, in the absence of information concerning swap contracts undertaken by firms, the debt term should be matched to the regulatory cycle. By contrast, the situation envisaged here involves the assessment of excess profits of an unregulated firm. However, as argued in section 4.2, the counterpart in the case of an unregulated firm to periodic price-setting

[84] Powerco delisted at the end of 2004 and therefore market value leverage cannot be determined in mid 2005. However, book value leverage at 30.6.2005 was 68% (based on equity and debt book values of $520m and $1132m respectively, as shown in Powerco's Annual Report for the year ended 30.6.2005). In addition, Powerco's book and market leverages closely corresponded at 31.3.2004 with book leverage of 66% (based on equity and debt book values of $554m and $1098m respectively as shown in Powerco's Annual Report for the year ended 31.3.2004) and market value leverage of 65% (based upon a share price of $1.89, 316m shares and book debt of $1098m). So, book leverage in mid 2005 should be a good proxy for market leverage at that time.

by a regulator is the frequency with which prices are reset by the firm. So, the analysis in Lally (2007b) implies that the relevant debt term for the purposes of assessing excess profits is that matching the frequency with which prices are reset. Since a frequency of three years has been assumed for the purposes of setting the risk free rate, the same frequency should be assumed here. To estimate the effect of reducing the debt term from the five years referred to above to three years, we draw upon the Essential Services Commission (2005, Tables 9.12 and 9.13). Averaging over both data sources, the effect of reducing the debt term from five to four years is to reduce the premium by 5 basis points. So, the effect of reducing the term from five to three years would be to reduce the premium by about 10 basis points. Deducting this from the estimate of 1.2% above, in respect of five year bonds, yields a premium consistent with three year debt of 1.1%.

The analysis here invokes leverage of 40%, and this estimate is imprecise. However, if a different leverage level were invoked, with an associated change in the debt margin, the WACC would not significantly change. With the WACC governed by equations (1)….(5), WACC can be reduced to

$$WACC = k_u + p(1-.33)L \quad (13)$$

where k_u is the unlevered cost of equity. The only effect of changes in leverage and the debt premium lies in the last term here. With leverage at 40%, and the debt premium at 1.1%, this term is .0029. With leverage at 50%, and the debt premium raised to 1.13% in accordance with equation (13) in Lally (2006, section 7), this term rises to .0038. The difference is only .09%, which is small.

We turn now to an estimate of the uncertainty in this estimated debt premium. The best data above for estimating this is the six observations in Table 4B $(\overline{p})$ and this serves to estimate the true debt premium of an individual company (p_0). This parallels the situation relating to leverage, and the same process for estimating the standard deviation of the estimator is then adopted, i.e.,

$$\sigma(\bar{p} - p_0) \cong \sqrt{v\left(\frac{N+1}{N}\right)}$$

where v is the expectation of the cross-sectional sample variance in the six debt premium observations in Table 4 and N is the number of observations. Using these six sample observations, the estimated value for $\sqrt{v}$ is 0.09%, and therefore $\sigma(\bar{p} - p_0)$ is estimated at 0.10%. However, application of the same methodology to electricity lines businesses yields the much higher estimate of 0.26% (Lally, 2006, section 7), and the uncertainty is likely to be very similar across the two situations. So, the higher value of 0.26% is adopted.

In respect of contrary submissions, LECG (2003a) argue for a debt premium of 2%. However the assumed leverage level is 55%, and no supporting evidence for such a margin is offered. In a subsequent submission, LECG (2004) argues for 1.7%. The assumed leverage level is 60% and, again, no supporting evidence is offered.

NGC (2004) argues for a margin of 1.8% on the basis of the average of the margins paid by it in respect of debt issues since 1991. However data from several years ago is not relevant to the present circumstances. Furthermore, some of the debt issues referred to in their submission involve conversion options, and are therefore inappropriate for estimating the ordinary cost of debt. Finally, their most recent issues involve margins of .60% and .88% and this suggests that a margin of 1.8% is too high.

AECT (2007, section 6.4.3) argues for a debt premium of 1.2%-1.8% for Vector. However the assumed leverage is 60-65% rather than the 40% adopted here, and AECT present no evidence in support of this margin.

Powerco (2007, pp. 76-77) argues for using only Powerco data for estimating its debt premium. In support of this, they note that recourse to data from Vector as well as Powerco lowers the estimate, the Vector bonds are of higher credit quality due to being “senior” rather than “subordinated” and this imparts a downward bias. Powerco is correct in suggesting that the Vector data is biased downwards. However, the Powerco data is biased upwards because it reflects only subordinated debt whereas we require a debt premium that is applicable to all of Powerco’s debt. Thus, averaging over the results for both senior and subordinated debt would seem to offer a better estimate than drawing upon data from only one of these two types of debt. Implicit in this judgement is the (reasonable) belief that the upward bias arising from using only Powerco data on subordinated bonds is more significant than any bias arising from using data from another company (Vector).

Unison (2007, section 4.3) argues that the relevant debt margin is that for a stand-alone gas distribution business whereas the data used here is for companies with other activities. This point is acknowledged but there does not seem to be any means of overcoming it, Unison does not suggest any such means, and it does not seem likely that any effect would be significant.

Unison (2007, section 4.3) also argues that the debt margin should be a benchmark rather than an actual margin, and that failure to use the former undercuts any incentive for the firm to seek efficiency gains in the context of price control. The implication underlying the first claim (that the actual debt margin of a firm is proposed) is false. The analysis above uses data from the maximum available number of firms and does so with the intention of applying the margin to all gas pipeline businesses. Furthermore, the leverage level (40%) and debt term (3 years) are specified rather than using those for the firms examined.

Unison (2007, section 4.3) also argues that standard practice amongst other regulators is to specify an appropriate credit rating for the bonds of the firms in question and then estimate the debt margin from that of firms with the same credit rating. This is a fair description of the behaviour of Australian regulators (see, for example, Essential Services Commission, 2007, pp. 403-407) but it is not a fair description of the behaviour of UK regulators (see, for example, Ofgem, 2007, pp. 88-90). In any event, the proposal should be assessed on its merits. It differs from the approach adopted here only in that it specifies a credit rating and is potentially able to utilise debt premiums from a larger set of firms. However, it is not apparent what credit rating should be invoked (consistent with whatever leverage level is specified). Furthermore, in the present case, there would be no gain in the number of firms for which debt premiums were available. For example, if the credit rating was specified as BBB and therefore debt premiums on BBB bonds were sought, the 2006 ABN AMRO Craigs data referred to above would provide such information on only one bond (VCT010) and this bond would be unusable because the issuing firm (Vector) holds an option to redeem the bond in shares rather than cash (a feature that will raise the debt margin but not necessarily the credit rating). In view of these difficulties, I do not favour this approach.

LECG (2007, section 3.4) argues for a debt margin of 1.85% rather than the figure of 1.2% proposed here. In support of this, they claim that they have been advised by Vector to this effect. However, Vector's advice on this matter has little persuasive value.

PwC (2007, p. 18) argues that the use of the "tax payable" rather than the "tax expense" method for incorporating company taxes into the price cap (which is contemplated by the Commission) will induce a rise in the cost of debt of 0.25-0.35% and cites US research by Berndt et al (1979) and Morris (1980). Furthermore PwC (2008, p. 11) goes on to argue for at least a matching adjustment to the cost of equity. However, in respect of the cost of debt, Berndt et al's (statistically significant) estimate of 0.35% only relates to part of the period that they examine (1972-1976) whilst their estimate for the considerably longer period 1962-1971 is both much less (0.08%) and not statistically significant. Furthermore, these results are for the US rather than New Zealand and are far from recent. Thus, I do not think that there is a compelling case for an adjustment to the cost of debt in the event that the "tax payable" method is adopted by the Commission.[85] Even if there were such a case, extrapolation to the cost of equity would not be warranted because the cost of equity is an expected rate of return whilst the cost of debt is a promised yield (comprising an expected rate of return and compensation for expected default losses) and any effect from the use of the "tax payable" approach on the cost of debt would appear to be on the expected default losses suffered by bondholders (which would induce a rise in the promised yield but not the expected rate of return).

[85] It did not prove possible to locate a copy of the Morris (1980) paper.

The above estimates of the debt risk premium incorporate no allowance for debt issue costs. These costs could be recognised through WACC or the operating cash flows. However, I consider that allowance for them through WACC is superior, because (like the depreciation on fixed assets) it allocates the costs to all periods rather than concentrating them in the periods in which they are paid. Lee et al (1996, Table 2) suggests an average issue cost for utilities of about 1.3% (by averaging over issues of at least US$40m). Discussion with New Zealand investment bankers indicates similar figures here. Annualisation of this figure requires a bond term. Using a ten year bond term, the equivalent annual figure would be about .20%. If a three year term was used, to match the assumed frequency of price resetting, then the equivalent annual figure would rise to .50%. However, triennial refinancing is likely to be inferior to longer-term debt coupled with a swap contract to ensure exposure to triennial interest rate movements (with swap costs added to the issue costs). This suggests an allowance of about .30%. Consistent with this, NGC (2004) argues for an allowance of .25%. Invoking equation (13) above, with leverage of 40%, the effect upon WACC of adding .30% to the debt premium would be less than .10%. This is trivial. Furthermore, the inclusion of an allowance of this kind in WACC would require that all actual costs of this kind be removed from the firm's reported costs, and this may prove difficult. If it does not prove to be difficult, then the conceptual advantage lies in doing so and therefore raising the cost of debt by .30%. If it does prove to be difficult, the effect of leaving these costs in the cash flows and not adjusting the cost of debt would appear to be slight[86].

In respect of contrary submissions, Bowman (2005) argues for issue costs of 1.8%-2.4% of the issue proceeds, on the grounds that the costs for New Zealand utilities would be more like those for US non-utilities, but he presents no evidence in support of this claim. So, the figure of 1.3% referred to above is preferred.

Powerco (2007, p. 76) argues that an appropriate allowance for debt issue costs would be .40% rather than the .30% proposed here and cites Bowman (2005, section 3.6.2) in support of this. However, Bowman's figure of .40% is based upon an issue cost of 1.8-2.4% of the issue and this in turn is based upon the claim that the issue costs for

[86] In respect of the issue costs of equity, this is even less of an issue because most equity capital is drawn from retained earnings.

New Zealand utilities would be more like those for US non-utilities. As discussed above, Bowman presents no evidence in support of the latter claim. In the absence of such evidence, the claim is not sustained.

8. The Form of Ownership

In applying the CAPM for estimating the WACC of an entity, the usual presumption is that the entity is a private sector company with individual shareholders. However, the ownership of the companies in which the gas pipeline businesses are embedded includes councils and community trusts. This has a number of implications, as follows.

The first implication concerns asset betas. As previously argued in section 5.2, the asset betas for rate-of-return regulated power utilities constitutes a lower bound on that for the New Zealand firms whilst the asset betas for five-year price-capped power utilities constitutes an upper bound. Gas pipeline businesses that are not privately owned are more likely to operate in a cost-plus fashion, as with the rate-of-return regulated firms; their asset betas are therefore likely to be lower than gas pipeline businesses that are privately owned. Quantification of this possible effect does not seem to be possible.

The second issue concerns tradability. The ultimate ownership claims over the shares owned by local councils devolve to local ratepayers. In respect of the shares owned by community trusts, the ultimate beneficiaries are even less clear. Neither of these ultimate "shareholdings" can be traded. Stapleton and Subrahmanyam (1978) consider this issue in the context of public sector entities, but their conclusions extend to non-tradable shareholdings in general. They show that if the allocation of claims on public sector entities differs from that arising if trading were possible, then some investors will prefer (in a utility sense) an increase, and others a decrease, in the level of investment by such entities, relative to the level if all entities were private. Thus no discount rate, market based or otherwise, could determine the optimal level of investment by public sector entities[87]. However they demonstrate that decreased investment by such entities is optimal in the Hicks (1940) and Kaldor (1939) sense, i.e. if the investors preferring the reduction could make compensating payments to the others, then the first such group would still be better off in utility terms. Thus a lower level of investment, and hence a higher discount rate, is implied relative to the circumstance in which all entities were private. This is to compensate for risks that cannot be efficiently allocated through trading. The implications for WACC are that it should be higher. However quantification of the effect does not seem to be possible. Amongst private-sector firms, there are variations in the ease with which assets can be traded ("liquidity"), and a considerable academic literature on the implications of this for expected returns (Amihud and Mendelson, 1986; Chordia et al, 2001; Acharya and Pedersen, 2005). Furthermore, the issue appears to be of considerable interest to practitioners (Damodaran, 2005). However, as observed by Damodaran (ibid, page 59), there is substantial controversy over how to measure illiquidity and to incorporate it into expected returns or valuations. Boyle et al (2006, page 33) alludes to this liquidity issue but (consistent with Damodaran's observation) does not offer an estimate of the appropriate adjustment for non-traded assets.

The third issue concerns personal taxation. In respect of the shares in gas pipeline businesses that are owned by local councils and community trusts, the ultimate beneficiaries of these shares (ratepayers in respect of local councils) are exempt from tax on both the defacto dividends and capital gains that flow to them. In respect of any capital gains to these ultimate beneficiaries (which would arise upon the disbursement of the shares to ratepayers by a local council), there is no conflict with the taxation assumption underlying the CAPM in equation (3), with the latter assuming that investors are exempt from tax on capital gains. In respect of the tax-exempt defacto dividends to these ultimate beneficiaries (which might be in the form of lower rates than would otherwise prevail in respect of ratepayers), there is an apparent conflict with the taxation assumptions underlying the CAPM in equation (3), with the latter assuming that investors can utilise imputation credits and are taxed on the gross dividends. However, imputation credits are assumed to be attached at the

[87] As the discount rate rises, the set of projects that have a positive NPV contracts. So, those investors favouring an increase in investment will consider that a lower discount rate is appropriate, whereas those favouring a reduction in investment will consider that a higher discount rate is appropriate. Thus, there is no discount rate that determines the optimal set of investments.

maximum rate. In conjunction with the other assumptions, this implies that investors face no personal taxation on the cash dividends and this situation matches that for the ultimate beneficiaries of shares held by local councils and community trusts. Thus, in respect of personal taxation on shares by the ultimate owners, the situation facing the ultimate beneficiaries of shares held by local councils and community trusts is identical in substance with that assumed for other classes of shareholders.

In summary, two of the issues raised here argue for adjustments to WACC (an increase and a reduction) but neither appears to be readily amenable to quantification.

9. WACC

9.1 Estimates

Drawing upon the above estimates for various parameters, WACC estimates can now be offered, using equations (1)…(5). The market risk premium ϕ is estimated at .07, with a standard deviation on the estimate of .015. Regarding the risk free rate R_f, the suggested rate is the three year one, retrospectively set at the beginning of the assessment period for excess profits, and then reset every three years. The three year rate for July 2005 is .0602[88]. The appropriate asset beta β_a for the gas pipeline businesses is estimated at .50, comprising three elements: firstly, an estimate for US electric utilities and gas distribution firms of $\hat{\beta}_{Ea} = .30$ (standard deviation .136); secondly, an estimated margin of $\hat{Q}\hat{\Delta} = .10$ for differences in regulation between New Zealand electricity lines businesses and the US firms, comprising an estimated margin of $\hat{\Delta} = .20$ for five year price-capping (standard deviation .126) and an estimate of $\hat{Q} = .50$ to reflect lower risk on the New Zealand electricity lines businesses compared to five-year price capped firms (standard deviation .29); finally, an estimated margin of $\hat{G} = .10$ for gas pipeline versus electricity lines businesses in New Zealand (standard deviation .06). In respect of optimal leverage L, I recommend an estimate of $\hat{L} = .40$ (standard deviation .20) for all gas pipeline businesses.

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[88] This date is chosen to enable comparison with the WACC estimates under price control, as discussed in section 12. The two and five year rates reported by the Reserve Bank for July 2005 (being the averages of the five year yields over that month) are .0599 and .0583 respectively. These figures embody simple interest rather than compounding in converting a semi-annual to an annual figure (see Lorimar, 2005, p. 34), and correction for this yields figures of .0608 and .0592 respectively. The three year rate is then obtained by interpolation, yielding .0602.

Finally, in respect of the associated debt premium p, I recommend an estimate of $\hat{p} = .011$ (standard deviation .0026) for all gas pipeline businesses, with an increment of .003 to the cost of debt for issue costs if they can be excluded from the cash flows. These results are summarised in Table 5.

Table 5: Parameter Estimates and Standard Deviations

	β_{Ea}	Q	Δ	G	β_a	ϕ	ρ	L	$WACC$
Estimate	.30	.50	.20	.10	.50	.07	.011	.40	.078
σ	.136	.29	.126	.06	.175	.015	.0026	.20	.015

Excluding the debt issue costs, these parameter estimates imply an estimated cost of equity of .0987 and an estimated WACC of .0783 as follows.

$$\hat{k}_e = .0602(1-.33) + .50\left[1+\frac{.40}{.60}\right].07 = .0987$$

$$W\hat{A}CC = .60(.0987) + .40(.0602 + .011)(1-.33) = .0783$$

Addition of the debt issue costs (.30%) to the cost of debt raises the WACC estimate to .0791. The WACC estimate reflects seven parameter estimates over which there is significant uncertainty, i.e., the market risk premium, the four components of the asset beta, leverage and the debt risk premium. Such parameter uncertainty gives rise to uncertainty over the WACC estimate, and this can be formalised in a standard deviation for the WACC estimate[89]. Translating standard deviations for the underlying parameter estimates into a standard deviation for the WACC estimate requires an assumption about the relationship between these underlying parameter estimates, and the assumption of independence seems appropriate, i.e., the particular estimation error for one parameter has no implications for the estimation errors on the

[89] This kind of analysis was suggested by NECG (2004a).

other parameters[90]. Invoking values for all parameters except the seven uncertain ones, the *WACC* estimate is as follows.

$$W\hat{A}CC = [.0602(1-.33) + \hat{\phi}\hat{\beta}_a\left(1+\frac{\hat{L}}{1-\hat{L}}\right)](1-\hat{L}) + (.0602+\hat{p})(1-.33)\hat{L}$$

$$= .0403 + \hat{\phi}\hat{\beta}_a + \hat{p}\hat{L}(0.67)$$

$$= .0403 + \hat{\phi}\left[\hat{\beta}_{Ea} + \hat{Q}\hat{\Delta}\right] + \hat{p}\hat{L}(0.67)$$

Appendix 6 shows that the standard deviation of the WACC estimate is thus.

$$\sigma(W\hat{A}CC) = \sqrt{\begin{array}{l}\sigma^2(\hat{\phi})\sigma^2(\hat{\beta}_a) + E^2(\hat{\phi})\sigma^2(\hat{\beta}_a) + E^2(\hat{\beta}_a)\sigma^2(\hat{\phi}) \\ +(0.67)^2\left[\sigma^2(\hat{p})\sigma^2(\hat{L}) + E^2(\hat{p})\sigma^2(\hat{L}) + E^2(\hat{L})\sigma^2(\hat{p})\right]\end{array}} \qquad (14)$$

where

$$\sigma^2(\hat{\beta}_a) = \sigma^2(\hat{\beta}_{Ea}) + \sigma^2(\hat{Q})\sigma^2(\hat{\Delta}) + E^2(\hat{Q})\sigma^2(\hat{\Delta}) + E^2(\hat{\Delta})\sigma^2(\hat{Q}) + \sigma^2(\hat{G}) \qquad (15)$$

Substituting the point estimates and estimated standard deviations in Table 5 into the last two equations yields $\sigma(\hat{\beta}_a)$ = .175 and therefore $\sigma(W\hat{A}CC)$ = .015. These results are also reported in Table 5. The crucial standard deviation here is $\sigma(\hat{\beta}_{Ea})$; even if all of the other standard deviations were zero, $\sigma(W\hat{A}CC)$ would still be .010. Thus, errors in estimating the other standard deviations are not very significant in estimating $\sigma(W\hat{A}CC)$. This is significant because the evidence presented in support of the estimate for $\sigma(\hat{\beta}_{Ea})$ is amongst the strongest evidence presented in this report.

[90] For example, consider the market risk premium and the asset beta. Suppose the market risk premium is estimated using historical averaging of the Ibbotson type and US data. It then draws upon US returns data over the last 70 years. In particular, the level of returns matters. By contrast, the asset beta is largely estimated from US returns data over the last 15 years. In particular, the sensitivity of electric utility returns to market returns matters (as opposed to the level of returns). These two sources of data would appear to be essentially independent. Furthermore, even if the beta and the market risk premium were estimated from the same data, multivariate normality in asset returns would imply independence of these estimates (Fama and French, 1997).

The asset beta estimate of .175 embodied in this analysis draws upon estimates for US and UK firms rather than New Zealand firms. Had the data on New Zealand firms (see Table 2) been used instead (excluding Vector due to the presence of only one year of data), and following equation (23) in Appendix 3, then the standard deviation on the estimated asset beta would have been .285 rather than .175; the higher estimate largely reflects the smaller number of firms and the higher estimate for the variation in the estimated asset betas of these firms (v). Furthermore, the estimate for v arising from this New Zealand data would be very unreliable due to the presence of only three firms. All of this highlights the advantages in using the US and UK data rather than the New Zealand data.

The above analysis makes no allowance for uncertainty surrounding the estimate for the tax parameter T_I, for which the point estimate is .33. This parameter also appears within the market risk premium and exerts a partly offsetting effect there. So, an upper limit on the effect of uncertainty over this parameter is attained by ignoring the countervailing effect within the market risk premium. Consequently, following the set of equations preceding equation (14) and recognising that estimation error on this tax parameter would be uncorrelated with other estimation errors, the adjustment to $\sigma(W\hat{A}CC)$ would be as follows:

$$\begin{aligned}\sigma(W\hat{A}CC) &= \sqrt{.015^2 + \sigma^2\left[(.0602)(.33 - \hat{T}_I)(1 - \hat{L})\right]} \\ &\cong \sqrt{.015^2 + \sigma^2\left[(.0602)(.33 - \hat{T}_I)(1 - .40)\right]} \\ &= \sqrt{.015^2 + (.0602)^2(1 - .40)^2\sigma^2(\hat{T}_I)}\end{aligned}$$

An upper limit on the standard deviation of T_I would be .10, arising from assigning all probability to the most extreme marginal tax rates of 39% and 19.5%.[91] Substitution of this standard deviation into the last equation then raises $\sigma(W\hat{A}CC)$ from .015 to .0154, and this is an upper limit on the effect. So, the effect of uncertainty over the tax parameter T_I is inconsequential.

[91] Consistent with estimating the parameter value at .33, the probabilities attaching to these upper and lower tax rates would then be .70 and .30 respectively.

The WACC point estimate and the estimated standard deviation associated with this point estimate permit construction of a "probability distribution" for WACC around the point estimate[92]. Assuming "normality" in this distribution, the percentiles of this WACC distribution are then as shown in Table 6 below. Thus, if one wished to choose a WACC value for which there is only a 20% chance that the true value is in excess of this (80th percentile), that WACC value would be 9.1%. If one wished to choose a WACC value for which there is only a 10% chance that the true value is in excess of this (90th percentile), that WACC value would be 9.7%.

Table 6: Percentiles of the WACC Distribution

Percentile	50th	60th	70th	80th	90th	95th
WACC	.078	.082	.086	.091	.097	.103

In the context of assessing excess profits, it would be appropriate to choose a WACC value from above the 50th percentile (this margin is denoted type 1), because the consequences of judging excess profits to exist when they do not are more severe than the contrary error[93]. In particular, judging excess profits to exist when they do not leads to unnecessarily incurring the direct costs of control (implementation and monitoring costs), damage to the Commission's credibility, and the *possibility* that price control leads to prices that are controlled at too low a level to encourage the gas pipeline businesses to replace assets or expand their networks. The contrary (but less serious) risk is that control is not imposed when it should be; consumers are then charged too great a price and businesses using gas as an input face a cost burden that they may not be able to pass through. In respect of the point that the imposition of price control raises only the *possibility* of prices being set too low, this possibility may be quite low if a sufficiently large margin is added to the WACC estimate used in setting the output price under price control (type 2 WACC margin); this type 2 margin

[92] The "probability distribution" referred to here is the posterior probability distribution in the absence of any prior information.

[93] This WACC adjustment could be done directly or indirectly through an allowance for "indirect" costs of control.

should protect against the possibility of the allowed output price being so low as to deter investment. Thus, prima facie, the risk of deterring investment may be a less significant concern in setting the type 1 WACC margin than in setting the type 2 margin. However the type 1 WACC margin should be at least as great as the type 2 margin, so as to avoid the possibility that control fails to "bite", i.e., prices at level X induce control but the resulting allowed output price is then set above X. Accordingly the type 1 WACC margin should implicitly incorporate a significant allowance for the risk of deterring investment.

Both LECG (2003a) and NECG (2004a) concur with the view expressed above about the asymmetrical nature of the errors in assessing WACC. In choosing a percentile from the WACC distribution, NECG (2004a, p 9) suggests using at least the 90th percentile. By contrast, MEUG (2004) argues for use of the 50th percentile of the WACC distribution rather than a higher percentile, on the grounds that there are no asymmetric consequences of errors in choosing this WACC value. They offer two points in support. Firstly, they argue that any underestimate of WACC, leading to firms failing to invest, would induce litigation by them so as to reach a solution. It seems to be assumed here that any such litigation would lead to a correct estimate of WACC. Of course, the arbitrating authority in that case would face the same difficulties as the Commission does here and the former could hardly judge the litigation as proof of the insufficiency of the WACC estimate used by the Commission. Secondly, MEUG argue that various other costs have been conservatively assessed, and this offers protection against a WACC underestimate. This issue lies outside the scope of the present paper, but will presumably be taken into account by the Commission in choosing a percentile from the WACC distribution.

Bowman (2005) argues that the WACC distribution should be generated from a Monte Carlo simulation because the distribution is skewed rightwards. LECG (2004b) also favours a Monte Carlo analysis, presumably for the same reason. However, such a simulation would require knowledge of the shape of the probability distributions for each of the six parameter estimates underlying WACC, and these distributions are not in general known. An alternative approach is to examine some rightward skewed distributions for WACC, to determine whether there is much effect upon the WACC values in the relevant range (50th to 95th percentiles). This analysis is undertaken in Appendix 7, and reveals that the effect is trivial within this range. Boyle et al (2006, page 34) suggest that a series of simulations be conducted, using a variety of assumptions for the probability distributions on the six parameter estimates. My judgement is that this is unlikely to produce results differing materially from the considerably simpler approach adopted here.

LECG (2004b) also contests the argument that the estimates for the four parameters underlying the WACC estimate are independent. However, they do not offer any grounds for contesting this. Boyle et al (2006, pp. 33-34) also argue that dependence exists, and point to correlation between the estimated beta for the US firms, which is based on 1989-2003 data, and the estimated beta margin for price cap versus rate-of-return regulation, which is based upon data for 1990-1994. However, seven of the nine data sets used to estimate the first of these parameters do not involve data from 1990-1994, and therefore the correlation in the estimates should be small.

AECT (2008, section 3.2) argues that allowances of the type envisaged here must be for *both* estimation error and the asymmetric consequences of errors, i.e., there must be allowances for both phenomena. This is incorrect; although both phenomena must exist in order to justify an allowance, there is only one allowance. AECT are confusing the number of necessary conditions (two) with the number of distinct allowances that are required (one).

BARNZ (2007, p. 7) argues that the use of a WACC value above the 50th percentile of the distribution is inappropriate because it permits returns above the normal level to be earned, i.e., it permits returns in excess of WACC. BARNZ appear to be equating the 50th percentile of the WACC distribution with the true value. However, the 50th percentile is simply one possible value and it may be too high or too low. In recognition of the fact that the 50th percentile could be too low, and that underestimation is a more serious error than overestimation, an estimate above the 50th percentile is warranted.

MEUG (2007) argues that the use of a WACC value above the 50th percentile is unjustified in respect of "sunk" capital, on the grounds that the incentive arguments supporting a value above the 50th percentile are irrelevant in this case. However, such a course of action will damage the investment incentives of firms that are contemplating investment in areas that are currently unregulated but which may be subject to regulation at some future point. Accordingly, I favour a WACC value above the 50th percentile even for the sunk capital of the gas pipeline businesses.

MEUG (2007) also argues that use of a WACC value above the 50th percentile raises costs to firms that use gas and consideration of this point argues for a lower percentile than otherwise. However, this point has already been recognised above and by the Commerce Commission (2007, para 1093).

Powerco (2007, p. 77) argues for a standard deviation on the WACC estimate of .03 rather than the estimate of .015 proposed here. In support of this estimate, Powerco cites Bowman (2005), who presents a mid-point estimate for WACC of .093 and a preferred estimate of .12 corresponding to one standard deviation.[94] By implication, the standard deviation of the WACC distribution is then .027 rather than .03. In support of the figure of .027, Bowman offers estimates of the standard deviations on individual parameters of which the most important are standard deviations on the market risk premium and the asset beta of .03 and .30 respectively (Bowman, 2005, sections 3.7.2 and 3.8.2). Although Bowman does not formally translate these standard deviations into an estimate for the standard deviation on WACC, application of equation (14) above yields an estimate for the standard deviation of the WACC estimate of .031, which corresponds closely to Powerco's figure of .03.

The question then reduces to whether Bowman's estimates for the standard deviations on the market risk premium (.03) and the asset beta (.30) are reasonable. In respect of the former, and as noted in section 3.3 above, the estimate of .03 presumes the use of only the Ibbotson methodology for estimating the market risk premium whereas the estimate actually proposed here considers a range of methodologies and this exerts a downward effect upon the standard deviation. Powerco does not address this counter-argument.

[94] Powerco refers to sections 3.6.1, 3.6.2, 3.7, 3.8.4 and 6.3 of Bowman. However, none of these sections present an estimate for this parameter and the relevant section is 3.9.

In respect of Bowman's estimate of .30 for the standard deviation on the estimated asset beta, most of the evidence presented by Bowman (2005, section 3.8.2) concerns the unreliability of beta estimates for individual firms. Such evidence presumes that the asset beta estimated here is an estimate drawn from data on an individual firm whereas the estimate actually employed is an industry average; since the presumption is wrong, then the evidence offered is irrelevant. However, at one point, Bowman does refer to evidence on the statistical unreliability of industry averages. In particular, he refers to a standard error on the Australian industry average equity beta of 0.22. However, there are three shortcomings in such a figure. Firstly, since it concerns equity rather than asset betas, correction for leverage will be required and the effect of this will be to significantly reduce the estimate. For example, if average leverage is 30%, then equation (5) above implies that the standard error on the asset beta would be about

$$\sigma(\beta_a) = \frac{\sigma(\beta_e)}{1 + \frac{L}{1-L}} = \frac{0.22}{1 + \frac{.30}{1-.30}} = 0.15$$

Secondly, the figure of 0.22 is an average across Australian industries rather than for gas pipeline businesses in particular, and is therefore likely to be too high. Thirdly, the relevant standard deviation is that associated with using an industry average to estimate the beta for an individual firm and this reflects both errors in estimating the industry average and cross-sectional variation in true asset betas across firms within an industry; the effect of this would be to raise the estimate (see Appendix 3). Thus, none of the evidence presented by Bowman (2005, section 3.8.2) is relevant to the asset beta estimate presented here.

Bowman (2005, section 3.8.3) presents further evidence on the unreliability of beta estimates for individual firms in the form of a median absolute prediction error. However, there is no clear connection between a median absolute prediction error and a standard deviation. Furthermore, even if there were, this information relates to equity rather than asset betas and therefore, as explained above, overstates the unreliability of asset beta estimates. In addition, the information also relates to the unreliability of beta estimates for individual firms whereas the estimate actually employed here is an industry average; accordingly the evidence offered is again irrelevant.

Powerco (2008, section 6.2) offers further evidence in support of a standard deviation of .03 on the estimate of the market risk premium. In particular, they cite standard deviations from Welch (2000) that range from .018 to .042. However, these are estimated standard deviations for the cross-sectional distribution of survey responses (*s*) rather than estimated standard deviations for the mean survey response (which constitutes the estimate for the market risk premium). If the individual survey responses were statistically independent, then the estimated standard deviation of the mean response would be $s/\sqrt{N}$ where *N* is the number of respondents (Mood et al, 1974, p. 231). However, as noted in section 3.1, survey responses are likely to be positively correlated (because respondents are aware of others' views and tend to "herd") and this would raise the estimated standard deviation on the mean response by an indeterminate amount. Thus, it would appear to be impossible to estimate the standard deviation of the mean survey response. Furthermore, even if it was possible to do so and the estimate coincided with Welch's estimate for *s*, this does not support Powerco's estimate of .03 for the standard deviation on the estimate of the market risk premium because the estimate of the market risk premium is generated by averaging over the results from a number of methodologies in addition to survey results, and this averaging process generates a standard deviation that tends to be much less than those for individual methodologies. In particular, Table 9 in Appendix 2 reports standard deviations for individual methodologies as large as Powerco's figure of .03, and averaging .022, but the standard deviation of the mean is only .014.

Powerco (2008, section 6.2) also refers to the work of Gray et al (2005) in support of a standard deviation on the estimate of the asset beta of .30 rather than the figure of .175 appearing in Table 5 above. However, Gray et al (2005) does not present any estimated standard deviations on beta estimates. Instead, Gray et al (2005, Tables 2..8) uses various beta estimation techniques in conjunction with the standard version of the CAPM to forecast returns, and then determines two measures of forecast accuracy: the mean squared error in the forecast return relative to the realised return, and (in a paired comparison of two beta estimation methods) the proportion of times that one beta estimation method generates a forecast return that is closer to the realised value than that from using the other beta estimation method. Furthermore, even if the mean squared forecast errors presented by Gray et al could be used to infer something about the standard deviations of the beta estimates, the results would still not be relevant to the present situation for the following reasons. Firstly, the analysis in Gray et al is concerned with equity rather than asset betas. Secondly, their analysis is largely concerned with beta estimates for individual companies rather than industry averages. Thirdly, their analysis considers Australian firms in general rather than gas pipeline businesses in particular. These problems match those in Bowman (2005).

LECG (2007, section 4) argues that there is no “WACC distribution” because WACC is the true but unknown value of a parameter; instead the distribution is that of the WACC estimate. Such an interpretation would be correct in the context of classical statistics. However, a Bayesian approach gives rise to the concept of a probability distribution over a parameter value. As noted in footnote 91 above, the WACC distribution referred to is a posterior distribution and this coincides with the sample distribution in the absence of any prior information.

LECG (2007, section 4) also argues that the margin chosen over the point estimate of WACC should be determined not simply by the random nature of the point estimate but by the random nature of the estimate for its standard deviation. This point is acknowledged. However, estimation of the incremental margin is complex, and has only been achieved by LECG through assuming an estimation scenario that is significantly different to that actually invoked here. If the actual estimation scenario is recognised, it is not apparent how this additional margin might be estimated. Furthermore the likely effect of this issue is very small; LECG’s estimate is raised by only .001 (from .016 to .017) if a margin equivalent to the 84th percentile is chosen (ibid, p. 10).

LECG (2007, section 4) also argues that the estimated standard deviation of the point estimate for WACC is .016 rather than the estimate of .015 presented in Table 5 above. In doing so, LECG assumes that the estimates for beta and the market risk premium are generated from five years of monthly data on one company. This assumed scenario differs significantly from that underlying the point estimate for

WACC presented here, as follows. Firstly, the analysis here estimates the market risk premium from "market" portfolio data rather than data on one company. Secondly, the market risk premium is estimated here using a number of methodologies, only some of which use historical data; even amongst those that do use historical data, the shortest period is over 70 years compared to the five years assumed by LECG. Thirdly, the beta estimated here is an asset beta whereas LECG assumes estimation of an equity beta. Fourthly, the (asset) beta is estimated here using data from numerous companies and with up to 15 years of data rather than five years of data for one company. Lastly, the analysis here recognises that beta estimation error arises not only from statistical error in estimating the average asset beta of the companies whose data is used but also from variation between this average beta and the beta of the firm of interest. The effect of the last point is to raise estimation error whilst the effect of the preceding points is to lower it. In view of this, LECG's estimate of .016 for the standard deviation of the point estimate for WACC is not relevant to the estimation process actually employed here.

LECG (2007, section 4) also argues that the choice of a percentile from the WACC distribution should be based upon a "loss function". LECG shows, by recourse to an asymmetric linear loss function, that the 75th percentile from the WACC distribution is consistent with losses from WACC underestimation being three times that of WACC overestimation. Clearly, there are a range of alternative loss functions and these would yield different results. Nevertheless, I think that LECG's analysis is very useful and analysis of this type might assist the Commission in selecting the appropriate percentile from the WACC distribution. Appendix 8 provides further details on this approach.

9.2 Further Considerations

The results in the previous section reflect the WACC model that is used along with an allowance for possible errors in parameter estimates. However there are further potential concerns, including the possibility that the CAPM does not fully describe expected returns, that the version used is inappropriate, the possibility of error arising from the fact that the "market" portfolio in the CAPM is proxied by listed equity, the possibility of error arising from the use of foreign beta estimates, and the possibility of error arising from the fact that betas have been estimated using data whose frequency diverges from the investor horizon within the CAPM. The first three of these concerns are raised by LECG (2003c). In general, these issues give rise to further uncertainties concerning the WACC point estimate, and therefore suggest selecting a WACC value from an even higher level in the probability distribution. Although these additional uncertainties are in general impossible to quantify, two of them are amenable to some quantification and suggest that the WACC estimates in the previous section are biased upwards. Within the upper reaches of the WACC distribution, such biases will tend to offset other possible errors (which effectively raise the standard deviation of the distribution)[95]. Consequently, the argument for selecting a WACC value even further up the probability distribution presented above is countermanded.

The first of these biases arises from the fact that the beta estimates invoked in this paper are based upon weekly or monthly data whereas the appropriate period is that corresponding to the investor horizon within the CAPM, and the latter is likely to be much longer than one month; for example, use of the ten year risk free rate in estimating the market risk premium implies that this investor horizon is ten years. Levi and Levhari (1977) show that beta estimates will be biased up when the investor horizon is longer than the data frequency used in estimating betas and the true beta is less than one; both conditions would seem to be satisfied here. Furthermore, empirical estimates of the upward bias are substantial. Levy and Levhari (1977, Table 1) examine ten stocks with betas less than one, and estimate these betas using data frequencies ranging from one month to 30 months. Across the ten stocks, the median beta estimates for 1, 12, and 30 months are .63, .31 and .06 respectively. Handa et al (1989, Table 1) examine a larger set of stocks and group these into 20 portfolios. For those portfolios whose betas are less than .90 when estimated using monthly data, the estimates using annual data are always less and the average margin is .09. Furthermore, the difference in the estimates tends to expand as the beta declines, consistent with the theoretical relationship specified in Levi and Levhari. Suppose the equity betas for the US firms underlying the WACC estimate in the previous section

[95] For example, if the standard deviation of the WACC distribution is raised from .013 to .02 coupled with a reduction in the mean of the distribution from .073 to .067, the 80th percentile of the distribution remains at .084, i.e., a reduction in the mean WACC by .006 neutralises the effect of an increase in the standard deviation to .02, at the 80th percentile.

are overestimated by .10 on account of this point. Applying the conversion formula for asset betas, with an average debt/equity ratio of 1.1 (this characterises the S&P data) and a US corporate tax rate of .39, the resulting overestimate of the asset beta of these firms would be .06. Following the analysis in the previous section, WACC would then have been overestimated by .40%. Such an estimate reflects the more conservative results in Handa et al (1989), and is therefore likely to be conservative.

The second of these points involves the use of a domestic rather than an international version of the CAPM, and quantification of this potential bias is now offered. Assessment of this effect involves choosing an international version of the CAPM, and the first such version is that of Solnik (1974). Inter alia, this version assumes that all sources of investment income are equally taxed at the personal level. Of course, this is inconsistent with equation (3), but the Solnik model implies that most investors in New Zealand assets would be foreigners, and tax differences across sources of income are likely to be less significant in this case[96]. So, one could assume that personal tax rates are equal in an international CAPM[97]. In this case, Solnik's model applies, and the cost of equity for a New Zealand company is

$$k_e = R_f + MRP_w \beta_{ew} \tag{16}$$

where R_f is (as before) the New Zealand riskfree rate, MRP_w is the risk premium on the world market portfolio and β_{ew} is the beta of the company's equity against the world market portfolio[98]. The last two parameters must be estimated.

[96] One reason for this is that foreigners gain only slight benefits from dividend imputation credits, and therefore the tax rate on dividends is similar to that on interest. A second reason is that taxes of all kinds are more difficult to collect, and lower effective rates imply that any differences across types of income are less substantial in absolute terms.

[97] If taxes differences are retained in the model, as in Lally (1998d), then the reduction in WACC from the use of an international version of the CAPM is even greater.

[98] In this model, the cost of equity for a New Zealand asset reflects the risk free rate for New Zealand coupled with a risk premium rather than a world average risk free rate coupled with a risk premium. The presence of the New Zealand risk free rate arises from an assumption in the model that every risky asset is identified with a particular market, and the asset's return in terms of that currency is independent of that currency's exchange rates against all other markets.

By contrast with equation (3), equation (16) assumes that world equity markets are integrated, i.e., investors will now be holding a world rather than a national portfolio of equities, and the latter portfolio will have a considerably lower variance due to the diversification effect. Since the market risk premium is a reward for bearing risk, then the world market risk premium under integration should be less than that for New Zealand under segmentation. This market risk premium cannot be estimated in the Ibbotson (2004b) fashion, by averaging of the ex-post outcomes over a long period. This is because integration would reduce the market risk premium, and therefore the averaging process would have to be conducted over the period since integration (assuming it has been achieved). This would leave 25 years of data at most, and this is too short to be satisfactory. An alternative approach is suggested by Stulz (1995), who argues that, if the ratio of the market risk premium to variance (λ) is the same across countries under segmentation, the same ratio will hold at the world level under integration and this fact should be invoked in estimating the world market risk premium (the product of λ and the world market variance). As indicated in section 3.3, there is considerable controversy concerning the appropriate value for this ratio λ. Nevertheless, for the present purposes, the value chosen should generate results that are consistent with the estimate of the market risk premium for New Zealand under a domestic CAPM that was offered earlier. As discussed in section 3.3, this points to a value for λ of about 2[99]. Using this figure implies a market risk premium for the Solnik CAPM of

$$MRP_w = 2\sigma_w^2 \tag{17}$$

Cavaglia et al (2000, Table 1) estimates the world market variance over the period 1985-2000 as $.135^2$, and the use of this period is consistent with that used in assessing the New Zealand market variance in section 3.3. Substitution of this estimated variance for the world market portfolio into equation (17) then implies an estimate for the world market risk premium of about .04.

[99] So long as the estimate of the New Zealand market risk premium in a domestic CAPM is compatible with the chosen value for λ, the chosen value for the latter will not alter the conclusion that the world market risk premium under an international CAPM will be less than the New Zealand market risk premium under a domestic CAPM. Furthermore, higher values for λ will raise this differential in the market risk premiums.

Turning now to the question of betas, Bryant and Eleswarapu (1997, Table 5) estimate betas for various portfolios of New Zealand equities against the NZSE40 and the MSCI (world index), over the period 1973-1992. The average reduction in beta is 30%, implying an estimate of about 0.70. Using more recent data from 1980-2006, the resulting estimate is 0.63 (standard error .08), and decomposing the latter period into the subperiods 1980-1992 and 1993-2006 yields estimates of 0.62 (standard error .14) and 0.63 (standard error .07) respectively[100]. Using either the 1980-2006 data or the 1992-2006 data, the estimate is 0.63 and the estimates are statistically quite different from 1[101].

I now estimate the cost of equity under equation (16). Using a risk free rate of .0602, a market risk premium of .04 and an equity beta that is 37% less than that used in equation (3), the result is as follows.

$$k_e = .0602 + .04[(.63)(.50)(1.67)] = .081$$

By contrast, the cost of equity arising under equation (3), and shown earlier, is .099. So, the use of a domestic rather than an international CAPM yields a cost of equity that is higher by about 1.8%, due to both a larger market risk premium and equity beta. With leverage of 40%, this raises the WACC by about 1%. Thus, the upward bias to WACC resulting from use of the domestic CAPM is *up* to 1%, i.e., the bias would be 1% if markets were completely integrated and zero if they were completely segmented.

NECG (2004a) disputes the contention that the use of a domestic CAPM would produce a higher cost of equity than use of an international CAPM. In particular, they cite Koedijk et al (2002), who present evidence that the costs of capital resulting from the domestic and international versions are very similar. Mishra and O'Brien (2001) present similar evidence. However both of these papers assume that the market risk

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[100] The regressions involve monthly data, the Barclays index for New Zealand until 1991 followed by the NZSE40 gross index, and the MSCI world index with each country's returns measured in its local currency (this is consistent with the definition of the return on the world market portfolio in the Solnik model).

[101] Ragunathan et al (2001) report even lower estimates for Australia.

premium in the domestic CAPM (MRP_d) is calculated in a fashion that is consistent with the international CAPM, i.e.,

$$MRP_d = MRP_w \beta_{dw} \tag{18}$$

where β_{dw} is the beta of the local market against the world market. This assumption is crucial to their conclusion. However, none of the estimation processes employed in this paper, or argued for by others such as NECG, match the process in (18). If equation (18) were employed, and using the estimates for the world market risk premium and the beta of the NZSE against the world portfolio presented above (0.63), the result would be as follows.

$$MRP_d = .04(.63) = .025$$

To this might be added a correction for the tax effect in equation (4), yielding a market risk premium for New Zealand of .046. Substitution of this into equation (3), along with an asset beta of .50, would yield a cost of equity of .079. This is still less than the figure of .099 recommended in this paper.

In summary, there is a choice. One option is to invoke equation (3) and to estimate the market risk premium in the way suggested in this paper (.07). This yields a cost of equity under a domestic CAPM (.099) that is higher than that for the international CAPM calculated above (.081), implying upward bias from use of the former model. The second option is to estimate the market risk premium for equation (3) in the way suggested by Koedijk et al, and this leads to a cost of equity of .079 under the domestic CAPM (which differs from the result under the international CAPM due to taxes). In either case, the estimate for the cost of equity presented in this paper is likely to be too high.

In response to this argument, Bowman (2005, section 4.1) claims that his estimate of the New Zealand market risk premium is in fact consistent with Koedijk et al and Mishra and O'Brien, i.e., consistent with equation (18). Bowman (2005, section 3.7) considers a number of issues in estimating the market risk premium for New Zealand. His closest line of analysis to equation (18) is to estimate the market risk premium for

New Zealand as the product of the US market risk premium and the beta of New Zealand against the US market, and this will coincide with equation (18) if he regards the US market as a good proxy for the world market. However, in his section 4.2, he quite explicitly distinguishes between the US and world market risk premiums. Thus, Bowman's estimate of the New Zealand market risk premium is not consistent with the analysis in Koedijk et al and Mishra and O'Brien. Accordingly he cannot invoke their arguments in support of the proposition that the domestic CAPM approximates the international CAPM. Furthermore, Bowman's estimate for the beta of New Zealand against the US of 1.25-1.5 is pure speculation, and is inconsistent with the statistically derived estimate of .48 cited in NECG (2004b), i.e., inconsistent with Bowman's own statistically derived estimate.

Bowman (2005, section 4.2) also rejects the estimate of 0.63 for the beta of the New Zealand market against the world market, and appears to be suggesting that the figure should be greater than 1. However Bowman does not present any empirically derived estimate for New Zealand. He does nevertheless presents beta estimates for a number of other markets (from Harvey, 2000, Exhibit 1B), estimated over the period 1988-2000. If the New Zealand beta is estimated over that same period, the resulting estimate is 0.72 with a standard error of .10 (see footnote 100). Although larger than the estimate of 0.63 reported above, this estimate is still well below 1 and statistically significantly different from 1.

LECG (2004a) suggest that all versions of the CAPM may be inappropriate. Although they do not argue for an alternative model, they suggest that the band of uncertainty around the estimated cost of equity be significantly raised. However they do not offer any quantification in this area. As indicated earlier, my judgement is that the very probable upward bias arising from using a domestic rather than an international CAPM is likely to compensate for this possibility and other (unquantifiable) sources of error.

LECG (2004b) also argue that possible errors in estimating the cost of equity from using a domestic rather than an international version of the CAPM should give rise to a direct allowance for the error. However, the degree of error is not open to quantification, beyond observing that it will overestimate WACC by *up to* 1%, and this may compensate for other errors that effectively raise the standard deviation of WACC, at least in the upper reaches of the WACC distribution.

LECG (2007, section 5, footnote 17) argues that any upward bias in the WACC estimate that arises from using a domestic rather than an international version of the CAPM involves comparing the prevailing approach to WACC estimation with an approach that is "not practicable". However, the proposition that an approach is subject to upward bias is not invalidated by any pragmatic difficulties that might exist in acting otherwise. For example, conducting an opinion poll on some question through email is subject to the potential bias arising from computer owners not being representative of the population and the bias does not cease to exist merely because alternative survey methods are impractical. Furthermore, as discussed in section 11.2, LECG has argued that failure to incorporate allowance for financial distress costs borne directly by shareholders imparts a *downward* bias to the WACC estimate notwithstanding the considerable difficulties in acting otherwise (i.e., in quantifying the bias).

In summary, there are a number of possible errors that could be made in estimating WACC that are not open to uncertainty quantification in this fashion described in section 9.1. In general, they would have the effect of raising the uncertainty in the WACC estimate and this points to choosing an even larger WACC value. However, as discussed in this section, there are a number of areas in which the WACC assessment is likely to be biased upwards, and this would exert a contrary effect.

10. Real versus Nominal WACC

The analysis so far reflects a nominal WACC, and this would be used to assess Excess Earnings defined to include revaluation gains on assets (see Lally, 2006). One possible difficulty with this approach is the fact that revaluations are volatile and therefore impart volatility to assessments of excess earnings; this in turn gives rise to difficulties in determining whether control is warranted. An alternative approach is to exclude revaluations from earnings, and therefore the WACC used must be real rather than nominal (Lally, 1995b; The Treasury, 1997, Appendix 5). A real WACC is generally defined as a nominal WACC deflated using expected CPI inflation.

However we will also consider deflating the nominal WACC using the expected rate of appreciation in the relevant asset price, and designate this as a quasi-real WACC[102]. In choosing between these three approaches, the crucial consideration is whether they give rise to assessments of Excess Earnings that induce control when control would be unwarranted, or fail to induce control when it is warranted. Following Lally (2006), it is assumed that regulatory interventions are based upon compounded Excess Earnings. To assess this issue, four possible scenarios are examined. In all cases, the firm is assumed to set prices by the building block method, so as to merely cover costs. In addition, the setting of prices uses a nominal WACC and incorporates allowance for expected asset revaluations as at the commencement of the project[103]. We start by examining these situations in which Excess Earnings are assessed through the use of a nominal WACC, and then consider the use of real and quasi-real WACCs.

10.1 Nominal WACC

Case 1: The asset value is expected to inflate at the CPI rate (depreciation aside), and this appreciation rate is realised. In addition, the firm invests \$100m in a project with a life of four years, there are no operating costs, depreciation is straight line, the nominal WACC is 10%, and CPI inflation is 2%. The expected asset values, depreciation and revaluation are then as follows.

Yr (end)	Asset Value	Depreciation	Revaluation
1	\$100*m*(.75)(1.02) = \$76.50*m*	\$100*m*(.25) = \$25*m*	\$1.50*m*
2	\$76.50*m*(.666)(1.02) = \$52.02*m*	\$76.50*m*(.333) = \$25.50*m*	\$1.02*m*
3	\$52.02*m*(.50)(1.02) = \$26.53*m*	\$52.02*m*(.50) = \$26.01*m*	\$0.52*m*
4	\$26.53*m*(0) = 0	\$26.53*m*(1) = \$26.53*m*	0

[102] If the actual rate of appreciation in the asset price was used then the resulting Excess Earnings would be identical to those arising from using the nominal approach (in effect, actual revaluations would be captured through the "real" WACC rather than in dollar terms). So, we do not need to examine this method as a fourth possible approach.

[103] If the firm set prices using a nominal WACC along with use of a historic cost asset valuation method, the time profile of revenues will differ but the NPV of the project will still be zero. The complications arising here in assessing Excess Earnings are discussed in Lally (2002d).

Following the building block method, prices are set so that the expected revenues are equal to the nominal cost of capital, plus depreciation, less revaluations, as follows.

$$E(REV_1) = \$100m(.10) + \$25m - \$1.5m = \$33.5m$$

$$E(REV_2) = \$76.5m(.10) + \$25.5m - \$1.02m = \$32.13m$$

$$E(REV_3) = \$52.02m(.10) + \$26.01m - \$0.52m = \$30.69m$$

$$E(REV_4) = \$26.53m(.10) + \$26.53m - 0 = \$29.18m$$

Of course, the present value of these expected revenues, using a discount rate of .10, is equal to the initial investment of \$100m, i.e., the NPV is zero. Using the nominal WACC, the Excess Earnings are revenues less depreciation less the nominal cost of capital plus revaluations. Suppose that expected revenues are in fact realised. In conjunction with an NPV of zero, this implies that the project does not generate excess profits. The Excess Earnings that are assessed are then as follows.

$$ExcessEarnings_1 = \$33.5m - \$25m - .10(\$100m) + \$1.5m = 0$$

$$ExcessEarnings_2 = \$32.13m - \$25.5m - .10(\$76.5m) + \$1.02m = 0$$

$$ExcessEarnings_3 = \$30.69m - \$26.01m - .10(\$52.02m) + \$0.52m = 0$$

$$ExcessEarnings_4 = \$29.18m - \$26.53m - .10(\$26.53m) + 0 = 0$$

So, the Excess Earnings that are assessed are consistent with the underlying economic situation of no excess profits.

Case 2: The asset price is now expected to appreciate at a rate other than the CPI rate, and this appreciation rate is realised. In particular, suppose that the asset is expected to decline in value at 1% per year, in addition to the effect of straight line depreciation. The expected asset values, depreciation and revaluations are thus.

Yr (end)	Asset Value	Depreciation	Revaluation
1	\$100*m*(.75)(.99) = \$74.25*m*	\$100*m*(.25) = \$25*m*	-\$0.75*m*
2	\$74.25*m*(.666)(.99) = \$49*m*	\$74.25*m*(.333) = \$24.75*m*	-\$0.50*m*

3	\$49*m*(.50)(.99) = \$24.25*m*	\$49*m*(.50) = \$24.5*m*	-\$0.25*m*
4	\$24.25*m*(0) = 0	\$24.25*m*(1) = \$24.25*m*	0

Following the building block method, prices are set so that the expected revenues are as follows.

$$E(REV_1) = \$100m(.10) + \$25m + \$0.75m = \$35.75m$$

$$E(REV_2) = \$74.25m(.10) + \$24.75m + \$0.50m = \$32.67m$$

$$E(REV_3) = \$49m(.10) + \$24.50m + \$0.25m = \$29.65m$$

$$E(REV_4) = \$24.25m(.10) + \$24.25m - 0 = \$26.67m$$

These revenues differ from those in the first example, but their present value is still equal to the initial investment of \$100m, i.e., NPV = 0. As before, we now suppose that expected revenues are realised, so that the project does not give rise to excess profits. The Excess Earnings that are assessed are then as follows.

$$ExcessEarnings_1 = \$35.75m - \$25m - .10(\$100m) - \$0.75m = 0$$

$$ExcessEarnings_2 = \$32.67m - \$24.75m - .10(\$74.25m) - \$0.50m = 0$$

$$ExcessEarnings_3 = \$29.65m - \$24.50m - .10(\$49m) - \$0.25m = 0$$

$$ExcessEarnings_4 = \$26.67m - \$24.25m - .10(\$24.25m) + 0 = 0$$

Again, the assessed Excess Earnings are consistent with the underlying economic situation of no excess profits.

Case 3: The asset value is expected to appreciate at the CPI inflation rate, but grows more rapidly than this. In particular, the asset value evolves as indicated in the second column below. Actual depreciation then follows in accordance with the straight line rule, and the actual revaluations follow from the asset values and the depreciation.

Yr (end)	Asset Value	Depreciation	Revaluation
1	\$80*m*	\$100*m*(.25) = \$25*m*	\$5*m*
2	\$60*m*	\$80*m*(.333) = \$26.66*m*	\$6.66*m*

3	\$25*m*	\$60*m*(.50) = \$30*m*	-\$5*m*
4	0	\$25*m*(1) = \$25*m*	0

The expected revenues are as indicated in the first example above, and therefore the NPV is zero. As before, we suppose that expected revenues are realised, so that the project does not give rise to excess profits. The Excess Earnings that are assessed will then be as follows.

$$ExcessEarnings_1 = \$33.5m - \$25m - .10(\$100m) + \$5m = \$3.5m$$

$$ExcessEarnings_2 = \$32.13m - \$26.66m - .10(\$80m) + \$6.66m = \$4.13m$$

$$ExcessEarnings_3 = \$30.69m - \$30m - .10(\$60m) - \$5m = -\$10.31$$

$$ExcessEarnings_4 = \$29.18m - \$25m - .10(\$25m) + 0 = \$1.68m$$

These Excess Earnings now diverge from zero, and this is inconsistent with the underlying economic situation of no excess profits. The compounded Excess Earnings at the end of each year are as follows.

Yr (end)	Excess Earnings	Compounded Excess Earnings
1	\$3.5*m*	\$3.5*m*
2	\$4.13*m*	\$7.98*m*
3	-\$10.31*m*	-\$1.53*m*
4	\$1.68*m*	0

So, the compounded Excess Earnings over the full life of the project are zero, and this is consistent with the underlying economic situation of no excess profits. However, the fact that the compounded Excess Earnings are positive before the end of the project life gives rise to the difficulty that, in the event of a regulator assessing compounded Excess Earnings to be positive at the end of the first or second years in the project life, they may consider that control is warranted. Such a conclusion would be unwarranted.

Case 4: The asset value is expected to appreciate at the CPI inflation rate, but appreciates less rapidly than this. In particular, the asset value evolves as indicated in the second column below. Actual depreciation then follows in accordance with the straight line rule, and actual revaluations follow from this and the asset values.

Yr (end)	Asset Value	Depreciation	Revaluation
1	\$75*m*	\$100*m*(.25) = \$25*m*	0
2	\$40*m*	\$75*m*(.333) = \$25*m*	-\$10*m*
3	\$20*m*	\$40*m*(.50) = \$20*m*	0
4	0	\$20*m*(1) = \$20*m*	0

The expected revenues are as indicated in the first example above, and therefore the NPV is zero. As before, we suppose that expected revenues are realised, so that the project does not give rise to excess profits. The Excess Earnings that are assessed will then be as follows.

$$ExcessEarnings_1 = \$33.5m - \$25m - .10(\$100m) + 0 = -\$1.5m$$
$$ExcessEarnings_2 = \$32.13m - \$25m - .10(\$75m) - \$10m = -\$10.37m$$
$$ExcessEarnings_3 = \$30.69m - \$20m - .10(\$40m) + 0 = \$6.69m$$
$$ExcessEarnings_4 = \$29.18m - \$20m - .10(\$20m) + 0 = \$7.18m$$

These Excess Earnings diverge from zero, and this is inconsistent with the underlying economic situation of no excess profits. The compounded Excess Earnings at the end of each year are as follows.

Yr (end)	Excess Earnings	Compounded Excess Earnings
1	-\$1.5*m*	-\$1.5*m*
2	-\$10.37*m*	-\$12.02*m*
3	\$6.69*m*	-\$6.53*m*
4	\$7.18*m*	0

So, the compounded Excess Earnings over the full life of the project are zero, and this is consistent with the underlying economic situation of no excess profits. The fact that the compounded Excess Earnings are negative before the end of the project life gives rise to the possible difficulty that the firm could earn higher (i.e., monopolistic) revenues prior to the final year without control being prompted at that time. However, any such increase in revenues will eventually generate compounded Excess Earnings that are positive, and this is likely to discourage such activity.

10.2 Real and Quasi-Real WACC

We now consider the above examples in a situation in which a regulator uses a real or quasi-real WACC rather than a nominal WACC to assess Excess Earnings, and consequently omits actual asset revaluations from that assessment. Notwithstanding this, the firm still sets its prices in the fashion indicated earlier. In calculating Excess Earnings using a real or quasi-real WACC, the Excess Earnings are revenue less depreciation (some proportion of the asset value at the beginning of the year in accordance with SL depreciation) less the real or quasi-real cost of capital (the product of the real or quasi-real WACC and the asset value at the beginning of the year). However, the deductions for depreciation and the cost of capital reflect the asset value at the beginning of the year, and this nominal figure at the beginning of the year (as used in the previous section) must be converted to a nominal equivalent at the end of the year by inflating it at the appropriate inflation rate (the expected CPI rate in respect of a real WACC and the expected rate of appreciation in the relevant asset prices in respect of a quasi-real WACC). This adjustment ensures that Excess Earnings are zero for each year, under idealised conditions, i.e., the project NPV is zero, revenues match those expected, asset revaluations match those expected, and the expected rate of appreciation in the asset value matches the expected CPI rate.

Case 1: The asset value is expected to appreciate at the CPI rate (the real and quasi-real WACCs are then equal), and this appreciation rate is realised. Expected revenues are determined by the firm, and are as shown in the first example of the previous section. As before, expected revenues are realised, so that the project does not give rise to excess profits. The Excess Earnings are then assessed as follows, with the real cost of capital being [1.10/1.02] – 1 = .0784.

$$ExcessEarnings_1 = \$33.5m - \$25m(1.02) - .0784(\$100m)(1.02) = 0$$

$$ExcessEarnings_2 = \$32.13m - \$25.5m(1.02) - .0784(\$76.5m)(1.02) = 0$$

$$ExcessEarnings_3 = \$30.69m - \$26.01m(1.02) - .0784(\$52.02m)(1.02) = 0$$

$$ExcessEarnings_4 = \$29.18m - \$26.53m(1.02) - .0784(\$26.53m)(1.02) = 0$$

So, as with the use of a nominal WACC under the same scenario, the Excess Earnings are assessed to be zero in each year and this is consistent with the underlying economic situation of no excess profits.

Case 2: The asset price is now expected to appreciate at a rate other than the CPI rate (giving rise to a distinction between the real and quasi-real WACCs), and this appreciation rate is realised. In particular, the asset is expected to decline in value at 1% per year. The expected revenues, asset values and depreciation are as indicated in the second example of the previous section. As before, we suppose that expected revenues are realised, so that the project does not give rise to excess profits. Using a real WACC, the Excess Earnings that would be assessed are then as follows.

$$ExcessEarnings_1 = \$35.75m - \$25m(1.02) - .0784(\$100m)(1.02) = \$2.25m$$

$$ExcessEarnings_2 = \$32.67m - \$24.75m(1.02) - .0784(\$74.25m)(1.02) = \$1.49m$$

$$ExcessEarnings_3 = \$29.65m - \$24.50m(1.02) - .0784(\$49m)(1.02) = \$.73m$$

$$ExcessEarnings_4 = \$26.67m - \$24.25m(1.02) - .0784(\$24.25m)(1.02) = 0$$

These figures diverge from zero, and this is inconsistent with the underlying economic situation of no excess profits. The compounded Excess Earnings at the end of each year are then as follows.

Yr (end)	Excess Earnings	Compounded Excess Earnings
1	$2.25*m*	$2.25*m*
2	$1.49*m*	$3.96*m*
3	$.73*m*	$5.09*m*
4	0	$5.60*m*

So, despite the underlying situation being one in which no excess profits arise, the compounded Excess Earnings that are assessed using a real WACC are positive at every point in the project's life. This may lead a regulator to conclude that control is warranted, and such a conclusion would be unjustified. This is a significant defect in the use of a real WACC.

The fundamental problem here is that the rate used to convert the nominal WACC to a real WACC is the CPI inflation rate, and this is inconsistent with the expected appreciation rate in the asset value. The use of a quasi-real WACC eliminates this problem, i.e., the quasi-real WACC is [1.10/.99] – 1 =.1111, and the Excess Earnings are then as follows.

$$ExcessEarnings_1 = \$35.75m - \$25m(0.99) - .1111(\$100m)(0.99) = 0$$

$$ExcessEarnings_2 = \$32.67m - \$24.75m(0.99) - .1111(\$74.25m)(0.99) = 0$$

$$ExcessEarnings_3 = \$29.65m - \$24.50m(0.99) - .1111(\$49m)(0.99) = 0$$

$$ExcessEarnings_4 = \$26.67m - \$24.25m(0.99) - .1111(\$24.25m)(0.99) = 0$$

So, the Excess Earnings are then zero for each year. However this approach does suffer from difficulties in estimating the expected rate of inflation in the relevant asset prices, to a much greater degree than in respect of CPI inflation.

Case 3: The asset value is expected to appreciate at the CPI inflation rate (the real and quasi-real WACCs are then equal), but appreciates more rapidly than this, as detailed in the third example in the previous section. Since the expected rate of appreciation in the asset price matches that same case, then the expected revenues are also as described there. These expected revenues are also realised, so that the project does not give rise to excess profits. The assessed Excess Earnings would then be thus.

$$ExcessEarnings_1 = \$33.5m - \$25m(1.02) - .0784(\$100m)(1.02) = 0$$

$$ExcessEarnings_2 = \$32.13m - \$26.67m(1.02) - .0784(\$80m)(1.02) = -\$1.47m$$

$$ExcessEarnings_3 = \$30.69m - \$30m(1.02) - .0784(\$60m)(1.02) = -\$4.71m$$

$$ExcessEarnings_4 = \$29.18m - \$25m(1.02) - .0784(\$25m)(1.02) = \$1.68m$$

The compounded Excess Earnings at the end of each year are reported below.

Yr (end)	Excess Earnings	Compounded Excess Earnings
1	0	0
2	-\$1.47*m*	-\$1.47*m*
3	-\$4.71*m*	-\$6.33*m*
4	\$1.68*m*	-\$5.28*m*

So, despite the underlying situation being one in which there are no excess profits, compounded Excess Earnings are negative over the full life of the project and at most earlier points. This gives rise to the possibility of regulatory error, i.e., the firm earning higher (monopolistic) revenues without detection by the regulator. The problem here bears some resemblance to that arising with a nominal WACC in the fourth example in the previous section. However the situation is worse here because the compounded Excess Earnings here do not go to zero at the end of the project life. Consequently, the monopolistic revenues will never be detected here whilst they will eventually be detected when a nominal WACC is used.

Case 4: The asset value is expected to appreciate at the CPI inflation rate (the real and quasi-real WACCs are then equal), but appreciates less rapidly than this, as detailed in the fourth example of the previous section. Since the expected rate of appreciation in the asset price matches that same case, then the expected revenues are also as described there. These expected revenues are also realised, so that the project does not give rise to excess profits. The Excess Earnings that would be assessed are then as follows.

$$ExcessEarnings_1 = \$33.5m - \$25m(1.02) - .0784(\$100m)(1.02) = 0$$

$$ExcessEarnings_2 = \$32.13m - \$25m(1.02) - .0784(\$75m)(1.02) = \$0.63m$$

$$ExcessEarnings_3 = \$30.69m - \$20m(1.02) - .0784(\$40m)(1.02) = \$7.09m$$

$$ExcessEarnings_4 = \$29.18m - \$20m(1.02) - .0784(\$20m)(1.02) = \$7.18m$$

The compounded Excess Earnings at the end of each year are then as reported below.

Yr (end)	Excess Earnings	Compounded Excess Earnings
1	0	0
2	\$0.63*m*	\$0.63*m*
3	\$7.09*m*	\$7.78*m*
4	\$7.18*m*	\$15.74*m*

So, despite the project merely covering its costs, compounded Excess Earnings are positive over the full life of the project and at most earlier points. This gives rise to the possibility of unwarranted regulatory interventions. This bears some similarity to the problem arising from the use of a nominal WACC in the third example of the previous section. However the situation is potentially worse here because the problem may accumulate over the life of the project whereas the problem must go to zero over the full life of the project when using a nominal WACC. This is a consequence of compounded Excess Earnings going to zero over the full life of a project when using a nominal WACC, but not when using a real or quasi-real WACC.

10.3 Summary

The previous two sections have considered assessments of Excess Earnings using nominal, real and quasi-real WACCs, under four scenarios. In all cases, the firm sets output prices so that it expects only to cover its costs, and the resulting expected revenues are realised. So, the project does not give rise to excess profits. The Excess Earnings that are assessed should then be zero. The first scenario involves the idealised conditions in which the asset value is expected to appreciate at the CPI rate, and does so. Excess Earnings are zero in each year, whether assessed using a nominal, real or quasi-real WACC. In the second scenario, the asset value is expected to appreciate at a rate other than the CPI rate, and does so. In this case, Excess Earnings assessed using the nominal WACC are zero in each year. Excess Earnings assessed using a quasi-real WACC are also zero in each year, but estimation of the appropriate quasi-real rate is problematic. By contrast, Excess Earnings assessed using a real WACC diverge from zero, and the compounded Excess Earnings diverge from zero even at the end of the project life. This gives rise to the possibility of regulatory errors. In the third and fourth scenarios, the asset value is expected to appreciate at the CPI rate, but appreciates at either a greater or lesser rate. In these cases, compounded Excess Earnings that are assessed will diverge from zero under each of the nominal, real and quasi-real approaches, and this gives rise to the possibility of regulatory errors. However, the errors are likely to be worse in the case of a real or quasi-real WACC because compounded Excess Earnings will not go to zero over the full life of the project.

So, in comparing the nominal and real approaches, the nominal approach is free of the possibility of regulatory errors in the second scenario but the real approach is not. In addition, in respect of the third and fourth scenarios, both approaches may give rise to regulatory errors but these are likely to be worse under the real method because compounded Excess Earnings do not go to zero over the full life of the project. Accordingly, the use of a nominal WACC is superior to the use of a real WACC in assessing Excess Earnings. If the real WACC were replaced by a quasi-real rate, the conceptual difficulty in the second scenario would be removed. However, difficulties will arise here for the regulator in estimating this quasi-real rate. Furthermore, the difficulties in the third and fourth scenarios still remain. So, the use of a quasi-real WACC is still inferior to the use of a nominal WACC. In light of all this, I favour the use of a nominal WACC.

11. Allowances for Other Issues

The analysis so far has yielded WACC estimates for assessing excess profits, based upon a methodology and parameter estimates. These WACC values provide rate of return compensation to investors for the time value of money and risk. Nevertheless, in the context of assessing excess profits, allowed rates of return sometimes incorporate (or could be argued to warrant) allowances for additional factors that are not inherently WACC issues, and these are considered here.

11.1 Asymmetric Risks

The first of these additional factors are called asymmetric risks, and they include the risk of assets being stranded, of assets being optimised out by a regulator, and of miscellaneous exposures to such events as natural disasters. Stranding is the circumstance in which a demand shortfall prevents a business from recovering certain costs from either the intended or other customers. By contrast, optimisation is an accounting device that may be employed or required by regulators, and under which certain assets are excluded from the asset base in an investigation of excess profits. The reasons for doing so include penalising over-investment (gold plating), recognising technology improvements, and recognising reductions in demand. Thus, demand shortfalls inducing stranding involve both a real economic effect (revenue loss) as well as possible consequences in the form of assets being optimised out by the regulator.

In respect of these asymmetric risks, and in the context of investigating whether excess profits have arisen, the appropriate actions by the Commission are now considered. In respect of the miscellaneous risks such as natural disasters, the situation is as follows. The businesses deal with the matter as they choose, either by raising prices ex-ante or ex-post to protect themselves. If a business raises prices ex-post, the increased revenues will offset the increased costs and there is no resulting effect upon profits. No action is then required by the Commission. By contrast, if the business raises prices ex-ante, then during the period of the profit assessment, the business might experience a low incidence of these adverse events and consequently its profits will appear to be excessive. In the same way, an insurance company that did not experience any large claims during a period would appear to be charging excessive premiums. A possible response by the Commission to this problem would be to assess excess profits over a sufficiently long period that extreme events are represented to an extent that reflects their expected incidence. However, by virtue of being extreme, this will always be difficult to attain. Thus, if the business deals with these events through ex-ante price adjustment, then the Commission may have to form a view about an appropriate ex-ante allowance (possibly expressed as a margin on WACC) and this would have to be deducted from the firm’s actual revenues (or equivalently added as a margin to the WACC). In this event, the firm’s costs would have to exclude any such costs that were incurred in the period examined. Since the businesses are likely to possess the best information on this matter, and have clear incentives to overstate the extent of the problem, then it seems to me that the burden of proof lies with them. As noted by Boyle et al (2006, pp. 35-36), the position is more complicated if the firm deals with some of these miscellaneous risks on an ex-ante basis and others on an ex-post basis.[104]

In respect of optimisation risk, this would primarily arise if the businesses were assessed against an ODV or an ORC asset valuation basis, and the latter possibility has been raised (Commerce Commission, 2003, p. 10). In the event of assets being optimised out by the Commission, the resulting profit calculation will involve a smaller depreciation cost and a smaller base for determining the cost of capital. This will raise the assessment of excess profits. In so far as the optimisation is induced by cost or demand changes as opposed to gold-plating (the former being beyond the control of the firm), some form of ex-ante protection would be warranted, and this could take the form of a "margin on WACC" or an ex-ante allowance in the cash flows. If the actual level of optimisations by the Commission matches that reflected in the ex-ante protection, then the two effects offset; however, if the actual level of optimisations is higher or lower, then positive or negative excess profits will tend to be observed and this gives rise to a problem akin to that of the miscellaneous risks discussed above. In so far as the optimisation is induced by gold-plating, the latter may be indisputable in which case no ex-ante compensatory margin would be warranted. However, a regulatory judgement of gold-plating may simply represent a divergence of opinion amongst reasonable people, and this would then suggest that some form of ex-ante compensation to be granted[105]. In respect of airfields, the Commission made no such allowance (Commerce Commission, 2002a)[106]. By contrast, in its draft decisions in respect of lines businesses (Commerce Commission, 2002b), the Commission proposed such a "margin on WACC" for those businesses that elected to be assessed against an ODV rather than a DHC asset valuation base. The airfields situation would seem to be more relevant to the gas pipeline situation, in

[104] This situation contrasts with that of price control, in which firms lack the power to set their prices and an explicit allowance for these costs must be provided by the regulator.

[105] Failure to do so would imply that firms were subject to the possibility of costs being reduced, and therefore excess profits being assessed, without any counterbalancing possibility of costs being raised. This would induce a bias towards concluding that excess profits existed.

[106] It should be noted that the Commission applied the historic cost methodology to depreciable assets, and this limits the opportunities for optimisation.

the sense that both involve an ex-post assessment of excess profits by the Commission.

Finally, in respect of stranding, there are implications for both regulators and firms. In respect of regulation, there are essentially two possible approaches. The first is similar to that of optimisation, in which stranded assets are removed from the asset base used to assess excess profits. As with optimisation this argues for some form of ex-ante compensation, such as a "margin on WACC". The alternative approach is not to remove such assets from the asset base used to assess excess profits, in which case no ex-ante compensation is required from the regulator. In its draft decisions relating to electricity lines businesses, the Commission proposed no allowance for stranding (Commerce Commission, 2002b), although the risk there may be less than in the case of gas pipeline businesses. Turning now to the firms, regardless of which approach is adopted by the regulator, the business must still protect itself against the real economic risk of revenues falling, and it can only do so by increasing prices ex-ante[107]. This gives rise to the "insurance problem" discussed in the penultimate paragraph. However the issue *may* not be substantial in the present context because stranding is most likely to occur for dedicated assets (supplying individual industrial consumers, which are at risk of closure) and the gas pipeline businesses *may* have entered into bilateral contracts to manage such risks. This paper does not attempt any assessment in this area.

In summary, in so far as the possibility of asset stranding or miscellaneous adverse risks such as natural disasters is dealt with by firms raising their output prices ex-ante, this gives rise to the problem that excess profit assessments will in general be too high (unless such events have occurred). Corrections for this present considerable informational difficulties to regulators. In addition, the process of regulators optimising assets out for any reason other than indisputable cases of gold-plating argues for some form of ex-ante compensation, and failure to provide this implies that excess profits will be overestimated. Even if an appropriate allowance is provided, this still leaves the problem that excess profits will be over or under estimated if the actual level of optimisations is more or less than provided for in the allowance. The

[107] If they were able to raise them ex-post then this would not constitute a stranding situation.

problem of optimisation allowances still giving rise to errors in assessing excess profits involves both positive and negative errors, and could simply be ignored if the errors were thought to be slight. The remaining issues will generally give rise to overestimates of excess profits, which is disadvantageous to the firms. However, as discussed in section 9.2, there are a number of areas in which the WACC assessment is likely to be biased upwards, and this would exert a contrary effect.

Some of the issues analysed here argue for the regulator adopting an ex-ante allowance for some potential loss, through a WACC margin or directly in the cash flows, and this gives rise to the question of which approach is better. In respect of the *expected loss*, a cash flow adjustment is the natural mechanism to use. Of course, there is always some discount rate adjustment that is equivalent to the cash flow adjustment, but it can *never* be determined until the cash flow adjustment is first articulated. Consequently, discount rate adjustments involve superfluous detail at best. At worst, they are undertaken without first establishing the appropriate cash flow adjustment, and therefore simply disguise the failure to ever articulate the appropriate cash flow adjustment. For these reasons, I strongly favour cash flow over discount rate adjustments for these issues; this is generally described as an "implied insurance premium". The ACCC (1999, 2001) also favours cash flow rather than discount rate adjustments. In respect of any *systematic risk* that arises here, a discount rate adjustment is appropriate and this will be captured in the estimate for the asset beta. In particular, the US and UK firms used to estimate the asset beta for the New Zealand gas pipeline businesses are exposed to such risks, and their estimated asset betas will reflect any systematic risk element. Thus, and by contrast with the situation in respect of the expected loss, no additional action is required by the regulator.

Finally, some of the issues examined here involve either ex-ante or ex-post actions by firms, and therefore requires a judgement by the Commission as to which approach is being employed by the firm. The Commission might put this question to the firm. If its response is to claim that these matters are addressed ex-post, the Commission might simply accept that on the grounds that the business has no incentive to falsely claim this. By contrast, if the business claims to engage in ex-ante adjustment, some evidence of that would be required. One possibility is evidence that it has not recently engaged in ex-post allowance, i.e., it did not raise prices in response to recent adverse events of the type in question.

11.2 Market Frictions: Costs of Financial Distress

LECG (2003a) argues that project volatility of the unsystematic type is costly, because losses on a project can make it

"…costly or even impossible to raise further funds from capital markets. Yet without such funds, the firm may have to forego future valuable projects or shut down existing ones. This potential loss of value on other investments represents an additional cost to the firm's providers of capital for which they require compensation" (ibid, p 20).

This could be expressed as saying that shareholders are exposed to a class of low probability adverse events arising from the failure of some or all of a firm's projects, and firms with high levels of unsystematic risk face the greatest exposure. The risk in question here is asymmetric, and is therefore a particular case of the miscellaneous adverse events in the previous section. The same approach by the Commission would then be warranted. In particular, the Commission should first ask whether the firm addresses the issue through ex-post adjustment of prices. If it does so, then no further action by the Commission is warranted. LECG offer no information on this question. By contrast, if the firm addresses the issue through an ex-ante adjustment of its prices, then the Commission may have to form a view about the appropriate ex-ante allowance (possibly framed as a margin on WACC), and deduct this from the firm's revenues (or add it to its costs) in conjunction with excluding any costs of this type that were actually incurred in the period examined. LECG do not mention this question of deducting incurred costs, but they do seem to indicate that such costs may have arisen for NGC in 2001 (LECG, 2003a, p 20).[108]

Assuming that the gas pipeline businesses engage in ex-ante adjustment of their prices, I now consider the appropriate level of the ex-ante allowance. Since the businesses are likely to possess the best information on this matter, and have clear

[108] Bond holders are also exposed to these events, in so far as they induce bankruptcy, and are protected ex-ante through the promised rate of return, which is observable and reflected in costs via WACC.

incentives to overstate the extent of the problem, then it seems to me that the burden of proof lies with them. LECG (2003a) do not offer any evidence about the behaviour of the gas pipeline businesses. Instead they offer evidence that firms in general use hurdle rates in excess of WACC values, and cite Poterba and Summers (1995) in support of this. However, this behaviour by firms is open to a number of possible interpretations other than allowance for the expected losses arising from rare events; these include the existence of timing options, the use of high hurdle rates as an internal control device for countering overly optimistic cash flow forecasts, and the risk aversion of managers.

Mindful that various possible explanations exist for hurdle rates in excess of WACC values, LECG (2003a) offer evidence that project-specific risks are a significant element, in the form of papers by Mukherjee and Hingorani (1999), Keck et al (1998) and Graham and Harvey (2001b). However there are a number of difficulties with these papers. First, most of the non-market risks referred to in the last two papers are macro-economic rather than project-specific, and therefore do not necessarily support the point under discussion[109]. Secondly, even in respect of Mukherjee and Hingorani in which project-specific risks are apparent, the quantitative effect upon hurdle rates is not indicated. Thirdly, reference to the actual behaviour of firms presumes that firms are acting appropriately, and yet both Keck et al and Graham and Harvey identify a number of ways in which the firms appear to be acting in error. If the firms are in error on some points, they might also be unwittingly overstating the WACC margin to address project-specific risks.

LECG (2007, section 5) also cite a survey of managers by Meier and Tarhan (2007), in which hurdle rates are partly ascribed to unsystematic risks.[110] However, even if it were appropriate to raise costs of capital to reflect this, Meier and Tarhan offer no quantification of the required margin. Furthermore, an appropriate cost of capital is one that *investors* require to induce them to invest rather than what *managers* believe to be appropriate; a difference would arise if managers were concerned with their

[109] Consideration of the exposure to macro-economic shocks such as inflation in the course of setting a discount rate is consistent with the use of a multi-factor model like Arbitrage Pricing Theory (Ross, 1976), and this does not involve any recognition of market frictions.

[110] They also cite a survey by Bruner et al (1998). I have elected to focus upon the more recent paper.

personal risk rather than risk to investors or alternatively to misunderstandings on their part about asset pricing. On the latter point, Meier and Tarhan (ibid, page 33) note that "..it is possible that managers may lose sight of the fact that shareholders have diversified portfolios and consider unsystematic risk to be important."

LECG (2003a) are mindful of the possibility that discount rates in excess of WACC could simply be an internal control device for countering overly optimistic cash flow forecasts, and they go to some trouble to rebut this suggestion. For example, they suggest that if such a practice exists then it will be known to the target, and the sequence of resulting responses would be "…inconsistent with any sort of unsustainable equilibrium" (ibid, p 24). However we observe such behaviours in a wide variety of situations (such as the advertised prices for houses and cars) and yet it is clear that equilibria are attained in these cases. Furthermore, Mukherjee and Hingorani (1999, Exhibit 5) report that firms do increase their hurdle rates in response to this issue, although it is not the dominant reason for doing so.

LECG (2003b) attempt to quantify the effect of market frictions. In doing so, they invoke the work of Kerins et al (2003). However this paper is concerned with the increment to WACC that is required when investors in a firm are highly undiversified, most particularly in the case of venture capital operations. This is a quite different form of market friction to that discussed in LECG (2003a). Furthermore, it is a type of market friction that appears to have little relevance to the gas pipeline industry. In a subsequent paper, LECG (2003c, p 13) appear to recognise this point and argue that it merely illustrates the potential effect of market frictions. My view is that a significant burden of proof lies with the industry, and this kind of illustration does not discharge it.

In a further submission relating to the lines businesses, but with implications for regulatory behaviour in general, LECG (2003c) observe that hedging of risks is widespread, and argue that its prevalence is attributable to the importance of financial distress costs, i.e., hedging is undertaken to protect the firm against cash flow shocks that make it costly or impossible to raise external finance. From this it follows that the unsystematic risks that cannot be hedged by the gas pipeline businesses require a margin on WACC in compensation. In support of this argument, Froot et al (1993) is cited. However, as noted in the latter paper, there are a host of complementary explanations for the prevalence of hedging, including tax-based explanations and the risk aversion of managers. Furthermore, this kind of evidence gives no insight into the size of the WACC margin even for firms in general.

LECG (2003c, 2007) also refer to the market for catastrophe insurance, and argue both that discount rates well in excess of those indicated by the CAPM appear to prevail and that this can be attributed to financial distress costs. In support of this, Froot (1999) and Froot (2001) are cited. Leaving aside the difficulties of estimating the expected return in such an industry, Froot's (2001) conclusion is more guarded than suggested by LECG, in that he admits barriers to entry as a possible explanation for the apparently super-normal discount rates in the industry (ibid, p 569). Furthermore, this kind of evidence gives little guidance as to the appropriate WACC margin for gas pipeline businesses.

In response to the suggestion that a burden of proof lies with the businesses, LECG (2004b) argues that the burden lies with the Commission. By analogy, one could say that, in criminal law, the onus of proof lies with the prosecution rather than the defence. Nevertheless, if the defendant has access to a type of information that could point to their innocence (such as the provision of an alibi) and declines to supply such evidence, the jury could reasonably conclude that the information is unhelpful to the defence.

Finally, on the question of whether or not the businesses have engaged in ex-post or ex-ante adjustment of their output prices to reflect these costs of financial distress, LECG (2004a) notes that "the Commission has yet to indicate what its approach in this regard would be" (ibid, p 20). However, LECG are referring here to the question of whether the Commission uses historical or projected information in assessing excess profits. This is a completely unrelated point. Regardless of whether the Commission uses historical or projected information, the Commission need not make any allowance for the costs of financial distress if it is satisfied that the businesses deal with these costs ex-post.

In summary, LECG have identified a potential basis for adding a margin to WACC, in the form of the costs of financial distress borne directly by shareholders, and they present a wide range of evidence on the question. However, a necessary condition for adding a margin to WACC is that the gas pipeline businesses deal with this issue through ex-ante rather than ex-post adjustment of their prices, and LECG offers no evidence on this question. Furthermore, even if the businesses engage in ex-ante adjustment of prices, any increment to WACC requires the netting out of any such costs that have been incurred, and the only evidence offered on this matter by LECG indicates that such costs may have been recently incurred by NGC. Finally, in respect of the appropriate ex-ante increment to WACC, I consider that a significant burden of proof lies with the industry. LECG offer no evidence directly relating to gas pipeline businesses, some of the evidence presented may be peculiar to the industries examined, explanations other than financial distress costs may be applicable in some cases, and the evidence concerning firms *in general* does not support either a particular choice of number or even the proposition that the size of the WACC margin is substantial. In light of all this, I do not recommend any adjustment to WACC for the costs of financial distress borne by shareholders. In so far as this is disadvantageous to the firms, this is part of a broader collection of judgements, and some of them are advantageous to the firms. In particular, as discussed in section 9.2, there are a number of areas in which the WACC assessment is likely to be biased upwards.

11.3 Timing Flexibility

LECG (2003a) also argue that timing flexibility leads firms to delay investment past the point at which the present value first exceeds the project cost, and that this can be expressed as requiring a margin over WACC. They also suggest a margin of 6.7% for NGC (LECG, 2003b). The general principle here that timing options exist, and that the firm's optimal response is to delay until the expected rate of return exceeds the traditionally defined WACC by some margin, is not controversial (Dixit and Pindyck, 1994). However the significant issue is whether this margin *should be applied by the Commission in assessing excess profits*; LECG do not discuss this but they must be implying it.

To facilitate discussion, consider the following example based on the examples in LECG (2003a). Suppose a proposed new project costs $10m in plant, equipment, etc, its WACC is estimated (in the traditional way) to be 10% per year, and the future cash flows are currently expected to be $1m per year indefinitely. The firm has flexibility in deciding the date on which to begin this project. If the firm invests now, the present value of the future cash flows is $10m, and therefore the NPV is zero. However, delay may be optimal. In particular, suppose that it is not optimal to invest until the expected future cash flow equals $1.7m per year. This is equivalent to saying that the firm should not invest until the expected rate of return on the $10m investment is 17% rather than 10%. If the firm invests at this point, there is a "surplus" of $0.7m per year over traditionally defined costs. If the cost of capital is defined in the traditional way then this "surplus" will be identified as excess profits. By contrast, LECG appears to imply that the Commission should apply an allowed rate of return of 17% rather than 10%, for the purpose of assessing excess profits. If this were done, then no excess profits would be identified.

The fundamental issue here is whether this "surplus" of $0.7m per year is an excess profit. If the timing option, and therefore the surplus, is a manifestation of market power then the surplus must be identified as an excess profit, and therefore defining WACC in the traditional way would be appropriate. Professor Boyle appears to concur with this (Gas Conference transcript, July 22, 2004, p 138). However he argues that this timing option might arise even in a competitive market, i.e., it may not be a manifestation of market power. Boyle et al (2006, p. 38) repeat this point, and cite Novy-Marx (2004) in support of it (but without elaboration). In this case, it might be argued that the Commission's assessment should not identify the surplus as an excess profit, and therefore the traditionally defined WACC should be augmented by a 7% margin.

There are a number of difficulties with this argument. Firstly, whilst Novy-Marx (2004) examines situations characterised by timing options, he attributes the timing options to a *lack* of competition (ibid, p. 34) and this is contrary to the claim by Boyle et al (2006). Secondly, LECG (2003b) tentatively suggests a margin of 6.7% for NGC, on the basis of a standard formula for which the crucial input is the volatility in NGC's return (.267). However the use of this standard formula presumes that NGC benefited from the timing option, and no evidence is offered on that question. NGC may never have benefited from a timing option, but it may be exercising market power. Nevertheless, the application of the formula cited by LECG would still yield a margin of 6.7%, and addition of this to the traditionally defined WACC would merely serve to disguise the market power that was exercised by them.

Thirdly, NGC may have benefited from a timing option in respect of some but not all of its assets. However LECG's proposal would simply add 6.7% to the traditionally defined WACC of the company, for application to *all* of its assets. Under the assumed situation, this would be excessive.

Fourthly, NGC may have benefited from a timing option, with the benefit *partly* but not entirely reflected in the exercise of market power. However the standard formula invoked by LECG cannot differentiate between these causes. Use of the formula to determine the WACC margin would then overstate the margin, and accordingly disguise the exercise of market power.

Further complications arise in considering other types of options. In particular, if the exercise of timing options warrants an increment to the WACC used for assessing excess profits, then the acquisition of "growth" options might warrant a reduction in the WACC used for this purpose[111]. Professor Boyle concurs with this suggestion in principle, but doubted whether there were any significant "growth" options in the gas pipeline industry (Gas Conference transcript, July 22, 2004, pp. 140-141). However one might have said this about the telecommunications industry before the arrival of the internet or cellular phones.

The present situation resembles that in respect of the costs of financial distress. In particular, the gas pipeline businesses are likely to possess the best information on this matter, and have clear incentives to overstate the extent of the issue. Consequently a significant burden of proof lies with them. However, the evidence offered by them is unpersuasive, on account of failing to demonstrate that timing options can arise in competitive markets, that any timing option was ever exercised by NGC, that it was

[111] In this context, "growth" options represent opportunities to invest in NPV positive projects (in areas related to gas pipelines) that spring from the earlier investment in gas pipelines.

exercised in respect of all of their assets, that it was unrelated to the exercise of market power, and that it was not offset by other options. In view of this, I do not favour any provision of a margin to reflect the existence of these options.

11.4 Firm Resource Constraints

LECG (2003c) also argue that some firms are unable to undertake all desirable projects because of certain resource limitations such as managerial talent. So, undertaking any one project entails the sacrifice of other good projects, and this "..foregone opportunity is an additional capital cost of the current project" (ibid, p 11). Accordingly, a margin should be added to WACC in compensation. LECG (2007) also cite Meier and Tarhan (2007), whose survey of management practices suggests that managers do add margins to hurdle rates to account for resource constraints. However, neither LECG (2003a, 2007) nor Meier and Tarhan (2007) quantify this margin. Furthermore, an appropriate cost of capital is one that *investors* require to induce them to invest rather than what *managers* believe to be appropriate. Consequently, evidence that managers are subject to misunderstandings in this area (of which examples are presented in section 11.2) undercuts the value of survey evidence relating to managers.

A further difficulty parallels that in respect of timing options considered in the previous section. In particular, even if a margin on WACC is appropriate for the purpose of assessing new investment by a firm, it does not follow that it will also be appropriate for the purpose of assessing excess profits by a regulator. In fact, the existence of this opportunity cost *may* simply reflect the existence of excess profits on the project that was not adopted, and adding a margin to WACC would simply undercut the whole process of seeking to identify excess profits.

To illustrate the point, suppose that a firm has just been established and is confronted by two desirable projects. Both cost $10m to undertake, both have a WACC of 10%, and both are expected to generate net cash flows of $1.7m per year indefinitely. The net present value of each project is $7m. Suppose the firm can only undertake one of them, for the reasons noted by LECG, and does so. In doing so, there is a foregone opportunity worth $7m, which is equivalent to a WACC increment of 7%. If the $7m were a manifestation of the firm's market power, then it would be inappropriate for the Commission to add 7% to WACC and doing so would simply disguise the excess profits that are present.

As with the timing options, a significant burden of proof lies with the businesses, and their failure to even quantify the WACC margin reveals that this burden has not been discharged. Accordingly, I do not favour any WACC margin for firm resource constraints.

11.5 Information Asymmetries

LECG (2003d) argues that information asymmetries between existing and new shareholders increase the cost of capital. In particular, potential new shareholders know that existing shareholders have an incentive to issue shares to finance new projects when the latter know the company to be currently overvalued. Consequently the act of issuing new shares lowers the share price, and this is an additional cost that new projects face. This is equivalent to a margin on WACC in compensation. This argument concerning the hurdle rate on new investment is unobjectionable. However, the fact that a firm might be discouraged from undertaking *new* projects for fear that doing so would reveal the *true* situation within it (and it therefore raises the hurdle rate on new investment) does not have any bearing on the question of whether it is earning excess profits on its *existing* projects. Accordingly, it would be inappropriate for the Commission to add a margin to WACC, for the purpose of assessing excess profits on existing projects.

To examine this argument, consider the following example. A firm has just been established for an investment of \$100m, a WACC of 10%, and is expected to generate cash flows of \$15m per year indefinitely. The firm is therefore valued at \$150m, with \$50m of this being the present value of excess profits. In the first year, the realised cash flows are \$15m, and therefore excess profits of \$5m are realised. Now suppose that new information becomes available to the firm suggesting that the expected future cash flows will be only \$13m per year, and therefore the firm is overvalued by \$20m. As a result the firm become reluctant to adopt certain otherwise desirable projects because the act of issuing the shares might signal the overvaluation of \$20m. In particular, it raises the hurdle rate on new investment rises from 10% to 15%, with the 5% increment just compensating existing shareholders for the loss in value occasioned by the issue of shares (and therefore the revelation that the firms existing assets are overvalued). If the WACC used by the Commission were raised to 15%, the assessment of excess profits would fall to zero, i.e., raising the WACC to 15% would undercut the whole process of identifying the excess profits that are clearly present.

This analysis assumes that the firm is overvalued. However, this is not material to the analysis. Even if the firm is valued correctly, the issue of new shares may still signal otherwise and therefore induce the firm to raise the hurdle rate on new investment above 10%. Doing so compensates existing shareholders for a reduction in the market value of their existing assets but it is irrelevant to the question of whether any excess profits exist. Accordingly, it does not justify an increment to the WACC for the purpose of assessing excess profits.

In summary, the arguments presented by LECG do not support a WACC margin for the purpose of assessing excess profits. However, as implied by LECG and stated more explicitly by Boyle et al (2006, page 40), the WACC invoked by a regulator for the purpose of controlling prices might be raised to overcome this information asymmetry problem, i.e., raised to ensure that socially desirable investments are not thwarted by information asymmetry. Clearly, there would be significant difficulties in quantifying any such margin, and neither LECG (2003d) nor Boyle et al (2006) attempt to do so.

12. Estimating WACC in Setting a Price Cap

12.1 Five Year Price Caps

The analysis so far has been concerned with estimating WACC in the context of assessing excess profits. We now turn to estimation of WACC in the context of price caps, starting with consideration of a five year price cap. Relative to the assessment of excess profits, several points of difference arise as follows.

Firstly, the estimation of WACC in the assessment of excess profits must reflect the environment in which the business operates. In particular, it must reflect the fact that the business is not subject to a price cap at that point. By contrast, once the price cap is imposed, the WACC estimate used in setting the price cap must reflect the existence of that price cap. Whether this raises or lowers the WACC depends upon the nature of the price cap including the interval of time before the price cap is revised. If the price cap were set for five years (in real terms), then the regulatory situation would match that for the UK price-capped electricity distributors examined in section 5.2. Accordingly, the asset beta implied by the analysis in section 5.2 would be .60; this involves .30 for rate-of-return regulated electricity lines businesses, an increment of .20 for five year price caps, and a further increment of .10 to reflect differences between gas pipeline businesses and electricity lines businesses in New Zealand[112].

Secondly, as argued in Lally (2002b, 2004a), the term of the risk free rate used in price capping should accord with the term of the price cap. Thus, if prices were capped for five years, then the relevant risk free rate would be the five year rate prevailing at the date at which capping was initiated (or is expected to be retrospectively initiated, i.e., August 2005). Averaging the five year rates over July 2005 yields the figure of .0592 as noted in section 9.1.

Thirdly, the choice of the leverage level may differ from that which is appropriate to the assessment of excess profits. By contrast with the situation involving the assessment of excess profits, the firm's target leverage is at least potentially admissible. However, the inability to independently verify any claim in this area precludes use of target leverage and the choice is therefore again between actual and "optimal" leverage. Furthermore, and again in contrast to the situation involving the assessment of excess profits, the use of actual leverage is not ruled out for unlisted companies because (regulatory) book leverage should be a good proxy for market leverage once price control is initiated (because the price control process should drive the market value of equity to that of its regulatory book value, as discussed in Appendix 5). However, incentive considerations point to the use of "optimal" rather

[112] Boyle et al (2006, page 45) argues that the estimate suggested in section 5.2 for five-year price-capped electric utilities is 0.56 rather than .50, corresponding to the estimated asset beta of 0.56 for the UK firms. However, this latter estimate reflects a limited number of firms, estimates from one source, and estimates reflecting only the period 1990-1994. By contrast, the process suggested above and also used in section 5.2 utilises a much wider range of firms, periods and data sources to estimate the asset beta for the US firms, and draws upon the more limited evidence concerning the UK firms only to estimate the beta margin relative to the US firms.

than actual leverage. In particular, the use of actual leverage would incite firms to raise it beyond any assessment of an optimal level absent price control because higher leverage raises the allowed WACC (and therefore the price cap) as shown in equation (13). As discussed in section 6, optimal leverage is best estimated by averaging over the observed levels of a number of listed firms within the relevant industry, and imputing it to all firms in the industry. The resulting estimate is 40%.

Fourthly, and in view of the fact that the debt premium varies with the term of the debt, the question of which debt term to adopt arises. Lally (2007b) shows that the firm faces strong incentives to match the duration of its debt with that of the regulatory cycle, although this could be achieved through suitable swap contracts rather than through the choice of debt term. Thus, in the absence of information concerning swap contracts undertaken by firms, the debt term should be matched to the regulatory cycle. Thus, if prices were capped for five years, the debt premium should reflect five year debt, and the analysis in section 7 yields an estimate of 1.2%.[113]

Fifthly, in choosing a WACC estimate from the distribution of possible values, the costs and benefits of estimation error differ from those arising in the case of assessing excess profits. Accordingly, the WACC value chosen may differ from that appropriate for assessing excess profits. As discussed earlier in section 9.1, the estimate of WACC should be drawn from the upper end of the distribution, because the consequences of setting the WACC too low (in the form of deterring investment) are more severe than the consequences of setting it too high (in the form of imposing excessive prices upon consumers). Although empirical evidence on the relative size of these adverse effects is lacking, Evans and Guthrie (2005) demonstrate through a theoretical analysis that prices below the welfare-maximising level reduce welfare by much more than when prices are above that level.

The sixth issue concerns the choice between real and nominal WACC. In respect of price cap situations, and unlike that of assessing excess profits, use of a real WACC

[113] This issue of aligning the debt term with that of the regulatory cycle was raised by Unison (2007, section 4.3).

could be appropriate under certain conditions. In particular, if the price cap is set in real terms, then a real WACC could be invoked. By contrast, if the price cap is set in nominal terms, then a nominal WACC should be invoked.

The seventh issue concerns "asymmetric risks". These comprise the risks of assets being stranded, of assets being optimised out by the Commission, and of miscellaneous exposures to such events as (uninsurable) natural disasters. In the context of setting a price cap, the Commission must determine whether to deal with these risks through ex-ante compensation (possibly via an addition to WACC) or through ex-post compensation (if and when the events occur)[114]. An ex-ante allowance implies that investors bear the risk whereas an ex-post allowance implies that (future) consumers bear the risk. Ex-ante compensation suffers from the difficulty that it is simply impossible to know what the appropriate level should be. Thus, to ensure investment is forthcoming, one must err on the generous side[115]. Even this may not be enough. If an extreme asymmetric event occurs to the extent that the ex-ante compensation received up until that time is insufficient, the regulated business is liable to claim that the ex-ante compensation should be raised. By contrast, if the asymmetric events do not occur to the extent envisaged, the regulated business will likely retain the excess. So, even if the ex-ante allowance is appropriate, there will still be a bias towards subsequent increases. Nevertheless, ex-post compensation also suffers from certain disadvantages. Firstly, businesses then lack proper incentives to avoid or mitigate such adverse events. Secondly, there is always the possibility of ex-post compensation being denied, such as in the case of actions by businesses that are judged by the regulator to be grossly imprudent (whether they are or not). Since there will always be uncertainty on the part of the businesses as to the regulator's decisions in this area, then a regulator's promise to provide ex-post compensation must be worth less than face value, in which case businesses face a

[114] Ex-post compensation would take the form of increasing prices to other consumers, or to the same consumers in the form of accelerated depreciation in the face of a downward revision in an asset's residual life. For example, an asset might have an anticipated life of 20 years at the time of purchase. After 5 years, it becomes clear that it will be stranded in five years. At this point, the depreciation allowance would be raised so as to depreciate the asset fully over the next 5 rather than 15 years (if this is possible). This is broadly consistent with the approach required by accounting standards.

[115] An exception to this is in respect of optimisation risk whenever businesses have a choice of whether they are exposed to it, through a choice of a DHC or ODV asset valuation basis. A firm's decision to be subject to optimisation risk implies an acceptance of the ex-ante compensation offered.

disincentive to invest. A hybrid approach, involving features of both ex-ante and ex-post approaches, would be to set an ex-ante allowance and modify it over time in light of actual events.

The views of the Australian regulators on this question are instructive. In respect of price caps for Victorian gas distributors, the ACCC (1998) seems to have explicitly chosen an asset beta from the upper region of the band in order to compensate investors ex-ante for bearing such asymmetric risks. However no quantitative analysis supported this feature of the decision. Since then the ACCC has clearly disavowed that approach. In particular it favours mitigating such risks through such devices as accelerated depreciation (ACCC, 1999, 2001). Otherwise, it recommends explicit identification of the risks along with appropriate adjustment of the cash flows, although the mechanics of this are not articulated. In the ORG's recent decision concerning Victorian electricity distributors (Office of the Regulator General, 2000) the principal form of these cash flow adjustments appears to be through conservative (i.e., enlarged) estimates of costs, and asset stranding was considered too unlikely to warrant adjustment. These experiences suggest that it is very difficult to make ex-ante adjustments for asymmetric risks.

Finally, the act of controlling prices is much more intrusive than assessing excess profits, and may therefore give rise to non-price reactions on the part of the regulated firm. These reactions include delaying investment, favouring assets that offer flexibility at the expense of economics of scale, and favouring assets with lower sunk costs (Guthrie, 2006). These possible reactions argue for a margin on WACC to mitigate their effects, and any such margin would be in addition to that suggested earlier (section 9.1) to deal with errors in estimating WACC. Quantifying this effect is problematic.

Taking account of the first four points discussed above, and relative to the WACC estimate for assessing excess profits, the estimate for WACC rises from .0783 to .0849 as follows.

$$\hat{k}_e = .0592(1-.33) + .60\left[1+\frac{.40}{.60}\right].07 = .1100$$

$$\hat{WACC} = .60(.1100) + .40(.0592 + .012)(1 - .33) = .0849$$

If debt issue costs of 0.3% are added to the cost of debt, then the WACC estimate rises to .0857. In respect of the standard deviation for this WACC estimate, this follows the analysis in equations (14) and (15) in section 9.1 subject to setting the parameter $Q = 1$ with certainty in equation (15). Accordingly, the standard deviation on the estimated asset beta becomes

$$\sigma^2(\hat{\beta}_a) = \sigma^2(\hat{\beta}_{Ea}) + \sigma^2(\hat{\Delta}) + \sigma^2(\hat{G})$$

Invoking the parameter estimates in section 9.1, this standard deviation on the estimated asset beta then rises from .175 to .193. Following equation (14), the standard deviation on the WACC estimate then rises from .015 to .016; the same change then applies to the standard deviation of the WACC "probability distribution".

In the context of price control, LECG (2007, section 3.3) argues for leverage for Vector of 65% rather than the figure of 40% proposed here, on the grounds that this is Vector's target leverage. However, as argued above, target leverage cannot be independently verified and therefore the choice must still lie between actual and "optimal" leverage. In respect of this choice, incentive considerations point to estimating "optimal" leverage and applying this estimate to all firms within the industry.

In the context of price control, AECT (2007, section 6.4.1) argues for a leverage figure of 60-65% for Vector on the following grounds. Firstly, use of industry data that excludes Vector is inappropriate. However, AECT are mistaken; the industry data used (as discussed in section 6) *does* include Vector (see Table 2). Secondly, AECT claim that Vector's current target leverage is 60-65%. However, as noted above, target leverage is inadmissible because it cannot be independently verified. Furthermore, this argument conflicts with their first argument in that the first argument implicitly supports the use of industry as opposed to firm specific data. Thirdly, AECT argues that the leverage ratio adopted must be consistent with the debt risk premium adopted. I agree, and this is reflected in the analysis in section 7. So, again, AECT are suffering from a misunderstanding. Fourthly, AECT argues that the leverage ratio selected should reflect various future considerations. However, future leverage cannot be predicted and AECT do not even offer a prediction. Finally, AECT refer to the figure of 60% adopted by Australian regulators. However, this argument is inconsistent with their first, second and fourth arguments.

MEUG (2007) argue for leverage of zero on the grounds that it leads to the minimum level for WACC. This statement is consistent with the WACC model used here. However, there are a number of arguments favouring debt that are not embodied in the WACC model used here.[116] Furthermore, the fact that most firms have significant debt levels suggests that the net effect is advantageous. Thus, leverage of zero is not optimal. As discussed above, I favour estimating the optimal level for leverage by examination of the actual leverage level of firms in the relevant industry. In response to this, MEUG (2008) alludes to Cameron Partners (2005), who favour leverage of zero on the quite distinct grounds that WACC is independent of leverage and simplicity therefore favours leverage of zero. In support of the claim that WACC is independent of leverage, they present a formula for the cost of debt that equates the cost of debt to its expected return determined in accordance with the CAPM in equation (3). However, the cost of debt is a promised rather than an expected rate of return (the difference being expected default losses) and in addition the expected rate of return will include an allowance for inferior liquidity (relative to government bonds) that is not incorporated within equation (3). MEUG (2008) also argue that the WACC model used here unjustifiably induces regulated firms to maximise leverage. However, this claim presumes that the optimal leverage is zero and this argument has already been rebutted above.

12.2 Three Year Price Caps

We now turn to an assessment of the appropriate WACC in the context of a three rather than a five year price cap. Relative to the analysis in the previous section, three

[116] These include potentially lower agency costs for debt than for equity up to some level of debt, greater financial flexibility from debt, and the advantages in signalling management's views about the future cash flows of the firm. For a discussion of these additional issuers, see Copeland et al (2005, Ch. 15). These additional benefits from debt cannot be specified with any great confidence, and are therefore not generally formally considered in specifying the cost of capital.

parameter values require adjustment: the asset beta, the risk free rate and the debt premium.

In respect of the asset beta, as argued earlier in section 5.2, the appropriate asset betas for electricity lines businesses under rate-of-return regulation and five year price caps are .30 and .50 respectively. Furthermore, the asset beta under a one year price cap should be similar to that under rate-of-return regulation, because both systems induce rapid resetting of prices in response to cost or demand shocks.[117] I therefore estimate the asset beta for one year price capping at .30. Using linear interpolation, the appropriate asset beta for a three-year price cap would then be .40. Adding the usual margin of .10 for gas pipeline businesses in New Zealand, the resulting estimate of the asset beta for gas pipeline businesses is .50.

In respect of the risk free rate and the debt premium, and following the discussion in the previous section, recourse to a three-year price cap implies use of the three year risk free rate and a debt premium for three year debt. The three year risk free rate is .0602, as noted in section 9.1. In respect of the debt premium, section 7 estimates the premium on three year debt at 1.1%.

Using these parameter values, the estimate for WACC is then .0783 as follows.

$$\hat{k}_e = .0602(1-.33) + .50\left[1+\frac{.40}{.60}\right].07 = .0987$$

$$W\hat{A}CC = .60(.0987) + .40(.0602 + .011)(1-.33) = .0783$$

[117] Evans and Guthrie (2006) raise the *possibility* that systematic risk rises with the frequency of price resetting, due to prices being reset in accordance with efficient rather than actual costs, to systematic shocks arising here in respect of demand (and therefore the level of capital required by an efficient new entrant), and to systematic shocks arising here through technological developments changing the cost of capital goods facing a hypothetical efficient new entrant. However, the estimate here for the asset beta under a five-year price cap is derived from that of UK electric utilities in the 1990-1995 period, and it does not seem that the UK electricity regulator took account of changes in demand or technological developments in revising the regulatory asset base for existing assets in this period (Whittington, 1998; Littlechild, 1998). Even if there were (limited) effects of this type, or exposure to the possibility of such effects, implying a higher asset beta for one-year price caps relative to rate-of-return regulation, one-year price caps may also involve a more rapid regulatory response to the cost and demand shocks to which the firm is actually exposed, and this would imply a lower asset beta for one-year price capping relative to rate-of-return regulation. The net effect of these two points would seem to be close to zero.

If debt issue costs of 0.3% are added to the cost of debt, then the WACC estimate rises to .0791. In respect of the uncertainty surrounding this WACC estimate, the estimate of the asset beta is now as follows

$$\hat{\beta}_a = \hat{\beta}_{Ea} + \hat{P}\hat{\Delta} + \hat{G} = .30 + .50(.20) + .10 = .50$$

where P is a parameter that reflects the systematic risk of three-year price capped electric utilities relative to rate of return regulation and five year price capping (the point estimate of .50 reflecting a belief that the three-year price capped firms are midway between these two bounds). By comparison with the analysis in section 9.1, concerned with assessing excess profits, the parameter P simply replaces Q. In respect of the uncertainty surrounding the true but unknown value for P, a plausible probability distribution for P is that it is uniformly distributed on the range from zero to 1, i.e., the systematic risk on three year price capped firms may be as high as that for five year price capped firms or as low as that for rate of return regulation. Invoking the formula for the standard deviation of a uniform distribution (see Mood et al, 1974, page 106), the result is

$$\sigma(P) = \sqrt{\frac{(1-0)^2}{12}} = .29$$

So, the point estimate for P and the standard deviation of its distribution matches that for Q, which it replaces. Accordingly, the standard deviation for the WACC "probability distribution" will be the same as that in section 9.1, i.e., .015.

12.3 Seven Year Price Caps

We turn finally to seven year price caps. This possibility arises from the possibility of the Commission imposing a four year price cap from 2008 in conjunction with clawing back (or compensating for) any difference between the provisional price cap set in 2005 and the final price cap set in 2008. This is equivalent to setting a price cap in 2008 for the period 2005-2012. Again, relative to the analysis in section 12.1, three parameter values potentially require adjustment: the asset beta, the risk free rate and the debt premium.

We start with the risk free rate. This must satisfy the NPV = 0 rule, i.e., the present value in 2005 (when the control process was initiated) of future cash flows must be equal to the book value of the assets in 2005. Consider the following three schemes.

(i) Set a price cap in 2008 (for 2008-2012) to reflect the four year risk free rate observed at that time, and retrospectively apply the same price cap to the period 2005-2008.

(ii) Set a price cap in 2008 (for 2005-2012) to reflect the seven year risk free rate observed in 2005.

(iii) Set a price cap in 2005 (for 2005-2008) to reflect the three year risk free rate observed at that time, and then reset the price cap in 2008 (for 2008-2012) to reflect the four year risk free rate observed at that time.

Scheme (i) fails the NPV test, and is therefore inadmissible. Scheme (iii) satisfies the NPV test, but it does not involve setting the same price cap for both 2005-2008 and 2008-2012; consequently, it is also inadmissible. Scheme (ii) satisfies the NPV test and involves setting the same price cap for both 2005-2008 and 2008-2012. So, scheme (ii) is appropriate. Consistent with previous analysis, the relevant data from 2005 is the average yield for July 2005. The average such rates for five and ten year bonds were .0592 and .0583, and the appropriately weighted average is then .0588.[118]

Having set the risk free rate at the seven year rate, the debt premium must then reflect the use of seven year bonds. The analysis in section 7 yields a debt premium of 1.2% for five year bonds. To adjust this debt premium to reflect a seven year term, we draw upon the Essential Services Commission (2005, Tables 9.12 and 9.13), which reports premiums on Australian firms sourced from CBA Spectrum and Bloomberg, for ratings from A+ to BBB+ and terms from four to ten years. Averaging across the five and seven year bonds, and both data sources, the latter premium exceeds that of the former by seven basis points. So, adding this to the 1.2% yields a debt premium of 1.3%.

[118] For July 2005, the average yields on five and ten year bonds reported by the Reserve Bank (www.rbnz.govt.nz) were .0583 and .0575. These figures reflect simple interest rather than compounding in converting a semi-annual to an annual figure (Lorimer, 2005, p. 34), and correction for this yields figures of .0592 and .0583 respectively.

We turn now to the asset beta. This must reflect the risk to which the firm is exposed. Consider the following three schemes.[119]

(a) Set a price cap in 2008 for the period 2008-2012, and retrospectively apply the same price cap to the period 2005-2008, i.e., set a price cap in 2008 for the period 2005-2012.

(b) Set a price cap in 2005 for the period 2005-2012.

(c) Set a price cap in 2005 for the period 2005-2008, and then reset the price cap in 2008 for the period 2008-2012.

Each of these schemes satisfies the NPV test so long as the asset beta that is invoked reflects the risk to which the firm is exposed. However, only scheme (a) is consistent with setting a price cap in 2008 for the period 2005-2012. So, scheme (a) is appropriate. Prima facie, scheme (a) is equivalent to scheme (b), and scheme (b) clearly warrants a seven year asset beta; accordingly, scheme (a) would seem to also warrant a seven year asset beta. However, scheme (b) involves setting a price cap for the period 2005-2012 on the basis of information available in 2005 (cost and demand forecasts) whereas scheme (a) involves setting a price cap for the period 2008-2012 on the basis of information available in 2008 and simultaneously applying that price cap retrospectively to the period 2005-2008. Thus, the potential for divergence between the price cap and the costs/demand actually experienced by the firm is less under scheme (a) than (b). Accordingly, the risk faced by a firm subject to scheme (a) is less than that for scheme (b). In fact, the risk faced by a firm subject to scheme (a) is similar to that faced by a firm simultaneously subject to a four year price cap and a three year price cap.[120] Thus, the appropriate asset beta for scheme (a) will not be that

[119] Since the issue of the risk free rate has already been discussed, the following discussion refers to all other aspects of the price setting process.

[120] The fact that the three year price cap is applied retrospectively to the previous three years rather than forwards for the next three years does not of itself give rise to a difference in risk faced by the firm. To illustrate this point, suppose the firm incurs costs at annual intervals (times 1, 2, 3, etc), demand is fixed and costs at any point in time are equally likely to be $10 more or less than costs incurred at the preceding point in time, i.e., costs follow a random walk with no drift. If the price cap is set at the beginning of year t, to deal with prevailing costs and costs to be incurred one year later, then it will be set equal to the prevailing unit cost, and revenues will therefore cover the prevailing costs and will be equally likely to exceed or fall short of costs incurred at the end of the year by $10. On the other hand, if the price cap is set at the end of year t to deal with prevailing costs and costs to be incurred one year later, but the resulting price cap is also retrospectively applied to the situation one year earlier, then the price cap will be set equal to the prevailing unit cost at the end of year t. In respect of events at the beginning and end of year t, the revenues will match the costs incurred at the end of the year and will be equally likely to exceed or fall short of costs that were incurred one year earlier by $10. Thus, in respect of year t, the risk to the firm would be identical under forward and backward looking price setting.

for scheme (b) but something between that for a three year price cap and a four year price cap. In particular, since the three year price cap (for the period 2005-2008) embraces $3/7^{th}$ of the total period subject to control, it should contribute that weight to the averaging process. Thus, the appropriate asset beta for scheme (a) should place a weight of $3/7^{th}$ on a three year asset beta and $4/7^{th}$ on a four year asset beta.

The three year asset beta has been estimated at .50 in section 12.2. In respect of a four year asset beta, the estimation process parallels that for a three year asset beta and this yields .55, i.e., linear interpolation between .30 and .50 for one and five year price caps for electricity distributors yields .45 and addition of the usual margin of .10 for gas pipeline businesses then yields the figure of .55. Applying weights of $3/7^{th}$ and $4/7^{th}$ to these three and four year asset betas of .50 and .55 respectively, the appropriate asset beta for scheme (a) is .53.

To summarise, the Commission sets a price cap in 2008 to cover both the period 2008-2012 and also (retrospectively) the period 2005-2008. The only risk free rate consistent with this process, and also satisfying the NPV test, is the seven year risk free rate observed in (July) 2005; this is .0588 In addition, the debt risk premium is .013 and the appropriate asset beta is 0.53. In conjunction with other parameter values shown in Table 5, the estimate for WACC is .0800 as follows.

$$\hat{k}_e = .0588(1-.33) + .53\left[1+\frac{.40}{.60}\right].07 = .1012$$

$$W\hat{A}CC = .60(.1012) + .40(.0588 + .013)(1-.33) = .0800$$

If debt issue costs of 0.3% are added to the cost of debt, then the WACC estimate rises to .0808. In respect of the uncertainty surrounding this WACC estimate, the estimate of the asset beta is now as follows

$$\hat{\beta}_a = \hat{\beta}_{Ea} + \hat{\Delta}\hat{F} + \hat{G} = .30 + .20(.64) + .10 = .53$$

where F is a parameter that reflects the systematic risk of three/four year price capped electric utilities relative to rate of return regulation and five year price capping (the point estimate of .64 arising from the fact that the weighted average of the three/four year terms underlying the proposed price cap is 3.57 years, which is 64% of the way from one to five years). In respect of the uncertainty surrounding the true but unknown value for *F*, a plausible probability distribution for *F* is that it is uniformly distributed on the range from .28 to 1, i.e., the systematic risk on three/four year price capped firms may be as high as that for five-year price capped firms and with matching uncertainty below the point estimate of .64. Invoking the formula for the standard deviation of a uniform distribution (see Mood et al, 1974, page 106), the result is

$$\sigma(F) = \sqrt{\frac{(.72-0)^2}{12}} = .21$$

Following the penultimate equation above, the standard deviation on the estimated asset beta becomes

$$\sigma^2(\hat{\beta}_a) = \sigma^2(\hat{\beta}_{Ea}) + \sigma^2(\hat{\Delta}\hat{F}) + \sigma^2(\hat{G})$$

Also, following the analysis in Appendix 6

$$\sigma^2(\hat{\Delta}\hat{F}) = \sigma^2(\hat{\Delta})\sigma^2(\hat{F}) + E^2(\hat{\Delta})\sigma^2(\hat{F}) + E^2(\hat{F})\sigma^2(\hat{\Delta})$$

Invoking the parameter estimates in Table 5, along with a mean and standard deviation for *F* of .64 and .21 respectively, the standard deviation on the estimated asset beta is .176. Following equation (14), along with the parameter estimates in Table 5, the standard deviation on the WACC estimate is then .015; the same estimate then applies to the standard deviation of the WACC "probability distribution".

Unison (2007, section 4.2) argues for an asset beta to be applied to the future period (2008-2012) that is relevant for a period of that length (four years) rather than a beta of .53.[121] However, as discussed above, the latter figure is simply a time-weighted

[121] Unison's submission was in response to an earlier proposal by the Commission to set the price cap in 2007 for the following five years and retrospectively apply the same price cap to the preceding two years. Given that the Commission is now proposing to set the price cap in 2008 rather than in 2007,

average of .55 for the four year period 2008-2012 and .50 for the three year period 2005-2008, and it is applied to the seven year period 2005-2012 (the first three years retrospectively). Thus, applying the asset beta of .53 to the period 2005-2012 is equivalent to applying a beta of .55 to the period 2008-2012 and a beta of .50 retrospectively to the period 2005-2008. Thus, there is no inconsistency between the application of .53 to the period 2005-2012 and Unison's proposal to apply a different number to the period 2008-2012.

Unison (2007, section 4.3) also argues that there is an inconsistency between using the seven year risk free rate and an asset beta that reflects a regulatory period between three and four years. However, the explanation for this difference is provided above and Unison offers no counter-arguments.

Vector (2007, para 486) argues that the control period is seven years, at least in the sense that Vector faces the possibility that some of its expenditures incurred in the 2005-2008 period might be disallowed by the Commission in 2008 and Vector has no opportunity to retrospectively reduce such expenditures. Accordingly, the estimate of the asset beta should reflect a seven year regulatory period rather than three and four year periods. However, the point raised by Vector concerns asymmetric risk (see section 11.1) rather than systematic risk, and therefore has no implications for the beta estimate.[122]

12.4 Implications of the Recent Reduction in the Company Tax Rate

The preceding analysis presumes that the company tax rate of 33% will operate throughout any control period that is chosen. However, the rate has recently been reduced to 30% (effective from 31.3.2008) and this has implications for the tax deduction on the cost of debt within equation (1) and the cost of equity capital shown in equations (3) and (4).[123] The cost of equity is estimated using the simplified

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Unison's critique is reinterpreted in light of this change. Vector's submission (referred to below) is treated in the same way.

[122] Other points raised by Vector (2007) are addressed by LECG (2007) in more detail and these have been addressed.

[123] There are also effects upon the tax expense within the cash flows. However, this is not a WACC issue.

Brennan-Lally CAPM. The general form of the model is as follows (Lally, 1992; Cliffe and Marsden, 1992)

$$k_e = R_f(1-T) + DT_d + \phi\beta_e \tag{19}$$

where

$$\phi = k_m - D_m T_{dm} - R_f(1-T) \tag{20}$$

and D is the firm's cash dividend yield, T is a tax parameter that reflects differential tax treatment of interest and capital gains, T_d is a tax parameter that reflects differential tax treatment of capital gains and the firm's cash dividends, k_m is the expected rate of return on the market portfolio, D_m is the dividend yield on the cash market portfolio, and T_{dm} is a tax parameter that reflects differential tax treatment of capital gains and the market portfolio's cash dividends. Lally (2000b) shows that the tax parameters T_d and T_{dm} can be expressed as follows

$$T_d = T - (1-T)U\frac{IC}{DIV} \tag{21}$$

$$T_{dm} = T - (1-T)U\frac{IC_m}{DIV_m} \tag{22}$$

where U is the weighted average utilisation rate on imputation credits, DIV is the cash dividend paid by the firm, IC is the imputation credits attached to the firm's cash dividend, DIV_m is the cash dividends on the market portfolio, and IC_m is the imputation credits attached to the cash dividends on the market portfolio. Equations (3) and (4) arise from this general form by assuming that capital gains taxes are zero (implying that $T = T_I$), that all firms attached maximum imputation credits to their dividends (at the rate .4925), that shareholders can fully utilise the imputation credits (implying that $U = 1$), and by adopting an estimate for T_I of .33, i.e., with these assumptions, the tax parameters T_d and T_{dm} are zero and the tax parameter T reduces to T_I.

The company tax rate is relevant to this model through the maximum attachment rate for imputation credits. At the current tax rate of .33, this maximum attachment rate is .4925 as noted above, i.e.,

$$\frac{T_c}{1-T_c} = \frac{.33}{1-.33} = .4925$$

However, a reduction in the company tax rate to .30 will reduce this maximum attachment rate for imputation credits to .4286. Substitution of this into equations (21) and (22), whilst retaining the other assumptions of the simplified Brennan-Lally model, yields

$$T_d = T_{dm} = .33 - (1-.33)(1)(.4286) = .043$$

Consequently, so long as a firm is paying dividends, the dividend term no longer disappears from equations (19) and (20), and the simplification manifest in equations (3) and (4) is lost. Thus, equations (3) and (4) would have to be replaced by the following equations.

$$k_e = R_f(1-T_I) + .043D + \phi\beta_e \tag{23}$$

$$\phi = k_m - .043D_m - R_f(1-T) \tag{24}$$

In respect of estimating the market risk premium shown in equation (24), the increase in the parameter T_{dm} should induce a countervailing increase in k_m. Consequently, the prevailing estimate of .07 for the market risk premium should not be affected, and therefore the cost of equity would rise due to the increase in the tax parameter T_d. Intuitively, the reason is as follows. Dividend imputation reduces the tax rate on cash dividends, by reclassifying corporate tax as personal tax, and therefore lowers the cost of equity. Consequently, a reduction in the corporate tax rate constitutes a reduction in the benefits flowing from imputation, and therefore raises the cost of equity.

Consistent with the approach to leverage, this cash dividend yield *D* should be the firm's actual dividend yield if actual costs are generally employed in setting the price cap, the firm's optimal dividend yield if efficient costs are generally employed in setting the price cap, and the optimal yield should be determined from averaging over firms in the relevant industry.[124] If firms used in the latter exercise are restricted to currently listed firms, then the relevant set matches that discussed in section 6, i.e., Auckland International Airport, Horizon Energy and Vector. The current dividend yields of these firms are .031, .051 and .045, with an average of .042.[125]

To illustrate the effect upon the WACC estimate of this tax change, we invoke equation (23), a cash dividend yield of .042, a company tax rate of .30, and the other parameter values used in the previous section. The result is as follows.

$$\hat{k}_e = .0588(1-.33) + .042(.043) + .53\left[1+\frac{.40}{.60}\right].07 = .1030$$

$$W\hat{A}CC = .60.1030) + .40(.0588 + .013)(1-.30) = .0819$$

So, the WACC estimate has risen from .0800 to .0819. If debt issue costs of 0.3% are added to the cost of debt, then the WACC estimate would rise from .0808 to .0828. In respect of the uncertainty in the estimate, the estimated standard deviation is still .015.

The analysis above leads to the incorporation of dividend terms into the CAPM, and therefore loss of the simple structure shown in equations (3) and (4). Since the latter model rests upon a number of simplifying assumptions[126], we now consider whether there is an alternative set of simplifying assumptions consistent with the absence of the dividend terms from the CAPM. As noted above, a reduction in the corporate tax rate to 30% implies that the maximum attachment rate for imputation credits is now .4286. In respect of the assumption that capital gains taxes are zero, this leads to the tax parameter T being equal to T_I, with the latter empirically estimated at .33 (Lally and Marsden, 2004a). However, the most recent empirical estimate for T is .275, due to some investors being subject to capital gains tax (Lally and Marsden, 2004a, Table 1). So, adopting the assumption that T is .30 would be more accurate. The resulting

[124] Since D is defined within equation (21) in market value terms (i.e., annualised cash dividend as a proportion of equity value) then such firms must be either listed or subject to price cap regulation (in which case the book value of equity should be a good proxy for its market value).

[125] Data from the National Business Review, June 8 2006.

[126] As noted on page 9, these are that capital gains taxes are zero, firms attach imputation credits to cash dividends at the maximum rate of .4925, and that shareholders can fully utilise these imputation credits.

set of assumptions is now that T is .30, that all firms attach maximum imputation credits to dividends (at the rate .4286), and that shareholders can fully utilise the imputation credits (implying that U = 1). Substitution of these assumptions into equations (21) and (22) yields $T_d = T_{dm} = 0$. Substitution of this into the general form of the CAPM shown in equations (3) and (4) yields the following model.

$$k_e = R_f(1-.30) + \phi\beta_e \tag{25}$$

$$\phi = k_m - R_f(1-.30) \tag{26}$$

In respect of estimating the market risk premium shown in equation (26), the reduction in the estimate for T from .33 to .30 should induce a countervailing increase in k_m. Consequently, the prevailing estimate of .07 for the market risk premium should not be affected. Thus, in the face of a reduction in the corporate tax rate to 30%, replacing the simplifying assumption that $T = T_I = .33$ with $T = .30$ is both more realistic and continues to be consistent with the absence of the dividend terms from the CAPM.

To illustrate the effect upon the WACC estimate of this change, we invoke equation (25), a company tax rate of .30, and the other parameter values used in the previous section. The result is as follows.

$$\hat{k}_e = .0588(1-.30) + .53\left[1+\frac{.40}{.60}\right].07 = .1030$$

$$W\hat{A}CC = .60(.1030) + .40(.0588+.013)(1-.30) = .0819$$

So, relative to the results in the previous section, the WACC estimate has risen from .0800 to .0819. If debt issue costs of 0.3% are added to the cost of debt, then the WACC estimate would rise from .0808 to .0828. In respect of the uncertainty in the estimate, the estimated standard deviation remains at .015. These results are identical to those in the preceding set of calculations, although a different model has been used.

In summary, the recent reduction in the company tax rate to 30% (effective from 31.3.2008) affects the tax deduction on the cost of debt within equation (1) and also leads to equations (25) and (26) replacing (3) and (4). Using the price control scenario examined in the previous section, the effect would be to raise the point estimate of WACC from 8.00% to 8.19% (or 8.08% to 8.28% if debt issue costs are added) and leave the standard deviation on the WACC probability distribution at 1.5%.

12.5 Implications of the Recent Credit Crisis

The WACC estimates presented above reflect debt premiums in 2005 on account of the control period commencing then. However, in August 2007, a major financial crisis erupted with implications for the WACC estimate. In particular, debt premiums have significantly increased since then and it might therefore be argued that the WACC should be increased. This section seeks to assess this proposition.

Before consideration of the current circumstances, it may be useful to consider a well established regulatory regime, i.e., one which has been in force prior to the current control period of 2005-2012. Under such circumstances the regime would now be clear to regulated businesses and they would have had the opportunity to make appropriate changes to their borrowing arrangements. Thus, with price caps being set in 2005 for the period 2005-2012, the businesses could have chosen to undertake borrowing arrangements in 2005 for the period of seven years matching the control period. In this case, they would be immune to the recent dramatic increase in debt premiums (and any changes in the risk free rate). Furthermore, even if these debt premiums remained at the new higher level until 2012 when the debt was rolled over, the new price caps set in 2012 would reflect the higher debt premiums prevailing at that point (as well as the new risk free rate). So, the businesses would be protected against these higher debt premiums at that point. Alternatively, the businesses might have chosen to stagger the maturity dates of their borrowing arrangements over time (with some maturing in 2005 and rolled over for seven years at that time whilst others matured in 2008 and were rolled over for seven years at that time). In this case the businesses would be exposed to the possibility of an increase in debt premiums (and the risk free rate) during the 2005-2012 control period. However, even in this case, the business could protect itself against either or both of these risks through appropriate hedging contracts. For example, if the business had bank debt maturing on 1.6.2009, it could enter a forward contract with its bank at any point before

1.6.2009 to fix the cost of debt prevailing from 1.6.2009 to the end of the control period in 2012.

In view of these points, I would not favour adjustments to WACC within a regulatory cycle in response to significant shifts in debt premiums so long as the regulatory regime was well established. However, the present situation does not involve a well established regulatory regime. In particular, businesses may not yet have had the opportunity to adjust their borrowing arrangements to match the regulatory cycle or understood the merits of the alternative hedging strategy described above in view of the novelty of the situation. Consequently it might be argued that the Commission should adjust WACC to reflect the recent dramatic rise in debt premiums. We therefore seek to assess the WACC impact.

We start with an assessment of the current (October 2008) debt premiums for gas pipeline businesses. As in section 7, we utilise indicative valuations provided by ABN AMRO Craigs. As of October 2008, indicative valuations were available for four classes of Powerco bonds and two classes of Vector bonds. Furthermore, following section 7, we disregard all bonds with features that disguise the true cost of debt and this leaves only one class of Powerco bonds (PWC070) and one class of Vector bonds (VCT020). Table 7 shows yields on these bonds in October 2008 and two earlier months, along with contemporaneous risk free rates for the matching terms (ABN AMRO Craigs, 2008).[127] The debt premium shown in Table 7 is then estimated by deducting the risk free rate from the yield to maturity on the corporate bonds. The median debt premium for Vector is 2.22% whilst that for Powerco is 3.79%. However, the PWC070 bonds are subordinated and the most recent Annual Report for Powerco (30.6.2008) reveals that less than 10% of its debt is subordinated; so, the PWC070 bonds would be particularly unrepresentative of the overall situation. By contrast, the VCT020 bonds are senior and the most recent Annual Report for

[127] The indicative yields shown here are those arising in the event of buying rather than selling bonds and ABN AMRO Craigs advises that the current spread between buy and sell yields on these bonds would be about 25 basis points. So, 12 basis points has been added to the reported yields. In respect of the risk free rates, linear interpolation is used if the desired maturity date does not match that for available government stock. For example, the PWC070 bonds mature on 15 April 2010. So, on 16 October 2008, they mature in one year and six months. Thus, the relevant risk free rate places 50% weight on the yield for one year government bonds and 50% weight on that for two year government bonds.

Vector (30.6.2008) reveals that over 90% of its debt is senior; so, the VCT020 bonds would be close to representative of the overall situation. Thus, the median Vector result is favoured over the median Powerco result or some average of the two. This suggests a debt premium for the gas pipeline businesses of about 2.2%.

Table 7: Debt Margins for Gas Pipeline Businesses' Bonds

	15 Aug 2008			16 Sept 2008			16 Oct 2008		
	k_d	R_f	ρ	k_d	R_f	ρ	k_d	R_f	ρ
VCT020	9.52	7.59	1.93	9.22	7.00	2.22	9.12	6.58	2.54
PWC070	10.37	6.58	3.79	9.42	6.06	3.36	10.12	5.94	4.18

This debt premium of 2.2% reflects the current leverage of Vector. Using the most recently available Financial Statements (30.6.2008), the market and book leverages are 61% and 65% respectively.[128] This contrasts with the 40% figure proposed in section 6 and therefore the debt premium should be adjusted downwards to reflect leverage of 40%. Using 2005 Australian data, Lally (2006, section 7, equation (13)) shows that reducing book leverage by 20% would raise the S&P credit rating by approximately one category. Furthermore, the Essential Services Commission (2005, Tables 9.12 and 9.13) reports premiums on Australian firms sourced from CBA Spectrum and Bloomberg, for ratings from A+ to BBB+ and terms from four to ten years. Both sources reveal that the effect of raising the credit rating by one category is to lower the debt premium by only about seven basis points. So, the debt premium on the Vector and Powerco bonds consistent with leverage of 40% would be about seven basis points less than for 65%.

The estimated debt premium of 2.2% also reflects the fact that the VCT020 bonds mature in six months. In recognition of the fact that the debt premium increases with the term of the debt (Essential Services Commission, 2005, Tables 9.12 and 9.13), it is

[128] The market leverage of 61% is based on debt of $3.16b at 30.6.2008 (as per the Annual Report), 1b shares (as per the Annual Report) and a share price at that time of $1.99 (National Business Review). The book leverage of 65% is based on debt of $3.16b and book equity of $1.68b (as per the Annual Report).

necessary to assess the appropriate debt term, which is for seven years. So, the estimate of 2.2% for six month bonds requires adjustment for this difference in maturity. To estimate the effect, we again draw upon the Essential Services Commission (2005, Tables 9.12 and 9.13). Averaging over both of their data sources, the effect of raising the debt term by one year is to raise the debt premium by about 5 basis points. So, the effect of raising the term from six months to seven years would be to raise the premium by about 30 basis points.

In summary, examination of New Zealand data from the VCT020 bonds points to a debt premium of 2.2% for gas pipeline businesses, with leverage of 65% and the term to maturity of six months. However, the desired leverage is 40% and the desired term to maturity is seven years. Allowance for the lower leverage level of 40% reduces this figure by less than 10 basis points, and allowance for the higher term to maturity raises the figure by about 30 basis points. All of this suggests a debt premium of about 2.40% for seven year bonds with leverage of 40%. This contrasts with the figure of 1.3% using 2005 data (see section 12.3). The rise from 1.3% to 2.4% is broadly in line with the recent increase allowed by the ESC for Australian gas pipeline businesses, from 1.25% in August 2007 (ESC, 2007), which precedes the crises, to 2.02% in February 2008 (ESC, 2008, Table 10.6).[129]

We now turn to the WACC estimate. For the period from August 2007 (when the crises commenced) till 31.3.2008 (when the corporate tax rate changed), the relevant WACC parameters are β_a = .53, L = .40, R_f = .0588, T = .33, ϕ = .07, ρ = .024, and T_c = .33. Substituting these figures into equations (1), (2), (3) and (5) yields the following result:

$$\beta_e = .53\left[1 + \frac{.40}{.60}\right] = .883$$

$$k_e = .0588(1-.33) + .07(.883) = .1013$$

$$k_d = .0588 + .024 = .0828$$

$$WACC = .1013(.60) + .0828(1-.33).40 = .0829$$

[129] All figures are exclusive of debt issue costs.

Relative to the debt risk premium of .013 prevailing in 2005, and therefore a WACC of .0800 as shown in section 12.3, the WACC has increased by 0.29%. If debt issue costs of 0.30% are added to the cost of debt, this WACC figure of .0829 rises .0837. For the period from 31.3.2008, $T_c = T = 0.30$ and the result is then as follows.

$$\beta_e = .53\left[1 + \frac{.40}{.60}\right] = .883$$

$$k_e = .0588(1 - .30) + .07(.883) = .1030$$

$$k_d = .0588 + .024 = .0828$$

$$WACC = .1030(.60) + .0828(1 - .30).40 = .0850$$

If debt issue costs of 0.30% are added to the cost of debt, this WACC figure rises further to .0858. Neither of these changes to WACC induce a change in the standard deviation of the WACC probability distribution of .015.

Finally, I note that Powerco (2008) has submitted a letter to the Commission suggesting that the WACC increase resulting from the credit crises would be about .80% compared to the increase of 0.29% described above. This figure of 0.80% largely reflects an increase in the debt premium from 1% in the Commission's Draft Decision (Commerce Commission, 2007) to the figure of 4% claimed by Powerco based on recently traded Powerco bonds.[130] However the debt premium of 1% in the Commission's Draft Decision has been superseded by a figure of 1.3%, as noted above. Furthermore the figure of 4% presumably reflects trades on the PWC070 bonds referred to in Table 7.[131] However, as noted above, these PWC070 bonds are subordinated and only 10% of Powerco's bonds are of that type. Thus, current yields on these bonds are not representative of the current yields on Powerco's entire set of bonds and should then be ignored in favour of the Vector bonds. Accordingly, the

[130] Powerco also revise the risk free rate. However, even if there were merit in doing so, the change is inconsequential, i.e., using the average yield in September 2008 on seven year government bonds (by interpolating over five and ten year bonds), the resulting rate is 5.87% compared to the rate of 5.88% proposed based upon data from July 2005.

[131] The other traded bonds of Powerco are PWC040, PWC050, and PWC060, with considerably lower debt premiums. This is presumably due to the fact that they are "credit wrapped", which involves a guarantee from a third party; this would lower the yield and render a result that was not indicative of the true cost faced by the firm.

change in the debt premium is from 1.3% to 2.4%, leading to a rise in WACC of 0.29% rather than the figure of 0.80% suggested by Powerco.

The conclusions are then as follows. Firstly, if the regulatory process here had been well established, I would not favour any adjustment to WACC for the credit crisis on the grounds that businesses would have had ample opportunity to either organise their borrowing arrangements to approximately match the regulatory cycle or undertake appropriate hedging contract so as to insulate themselves against the conditions that have developed. Secondly, because the present regime is novel, the businesses may not have had an opportunity to organise their borrowing arrangements or understood the merits of hedging arrangements to insulate themselves against the conditions that have developed. Consequently there is a prime facie case for an adjustment to WACC. If current debt premiums (which are about 1.1% larger than those prevailing in 2005) prevail over the remainder of the regulatory period, this would involve an increase from .0800 to .0829 in August 2007 (or from .0808 to .0837 if debt issue costs of 0.30% are included) and a further increase to .0850 from 31.3.2008 on account of the decrease in the company tax rate (or to .0858 if the debt issue costs of 0.30% are included). The standard deviation on the WACC probability distribution remains at 1.5%.

13. Conclusions

This paper has examined the estimation of the WACC for gas pipeline businesses, for the purposes of assessing excess profits in the industry and also for price control purposes. The primary conclusions are as follows.

Regarding the estimation of WACC for assessing excess profits, the (nominal) model recommended is that used in the Commission’s inquiries into airfield operations and electricity lines businesses, and reflected in equations (1)….(5). In addition the parameter values recommended are a market risk premium of 7% (as with the Lines Businesses, and compared to 8% in the Airfields Report), use of the three year risk free rate (set at the beginning of the review period and triennially revised), an asset beta for all of the gas pipeline businesses of .50, a company tax rate of 33%, leverage of 40%, and a debt premium for three year debt of 1.1%. If debt issue costs can be readily identified in the firm's cash flows, they should be excluded and a margin of .30% added to the cost of debt. The form of ownership of the gas pipeline businesses may affect the WACC, but any such effects would seem to be impossible to quantify. Using this model, these parameter values, and the July 2005 average three year risk free rate of 6.02%, the point estimate for WACC is 7.83% (adding debt issue costs to the cost of debt raises this figure to 7.91%).

In recognition of the inevitable estimation errors for most of these parameters, the standard deviation of the WACC probability distribution is estimated at 1.5%. Given that there is some uncertainty as to the correct parameter estimates, and that the consequences of judging excess profits to exist when they do not are more severe than the contrary error, my view is that one should choose a WACC value from the higher end of the distribution, and Table 6 in section 9.1 shows the probability distribution on WACC. Other types of possible errors such as the wrong choice of model are not open to quantification in this way. In general, they would have the effect of raising the uncertainty in the WACC estimate and this points to choosing an even larger WACC value. However, as discussed in section 9.2, there are a number of areas in which the WACC estimate is likely to be biased upwards, and these would exert a contrary effect.

This WACC estimate may be adjusted to take account of additional issues that are not inherently WACC issues. Asymmetric risks present particular difficulties. In so far as the possibility of asset stranding and miscellaneous adverse risks such as natural disasters is dealt with by firms raising their output prices ex-ante, this gives rise to the problem that assessments of excess profits will in general be too high (unless such events have occurred). Corrections for this present considerable informational difficulties to regulators. In addition, the process of regulators optimising assets out for any reason other than indisputable cases of gold-plating argues for some form of ex-ante compensation, and failure to provide this implies that excess profits will also be overestimated. Even if an appropriate allowance is provided, this still leaves the problem that excess profits will be over or under estimated if the actual level of optimisations is more or less than provided for in the allowance. In general, these issues impart an upward bias to assessments of excess profits, which is disadvantageous to the firms. However, as discussed in section 9.2, there are a number of areas in which the WACC estimate is likely to be biased upwards, and these would exert a contrary effect.

In respect of the costs of financial distress, the situation in principle is similar to that of asset stranding and natural disasters. Even in the event that firms have raised their prices ex-ante in compensation, and a regulator was able to assess any costs of this type that were actually incurred, no convincing evidence is available that the appropriate ex-ante adjustment to output prices is substantial. Accordingly, I favour no increment to WACC for the costs of financial distress borne by shareholders. In so far as this is disadvantageous to the firms, this is part of a broader collection of judgements, and some of them are advantageous to the firms.

In respect of timing options, firm resource constraints, and information asymmetries, I do not consider that any adjustment to WACC should be undertaken for the purpose of assessing excess profits.

Turning to price control situations, with a five year term, the WACC estimate employed here may differ from that used in assessing excess profits, and the points of difference are as follows. Firstly, the imposition of a five year price cap should raise the estimated asset beta from .50 to .60. Secondly, the term of the risk free rate must accord with the term of the price cap, which is five years. Thirdly, the debt premium should reflect a debt term that matches the term of the price cap, which is five years. Fourthly, the margin added to the point estimate of WACC, in recognition of estimation errors, may differ from that used for assessing excess profits. Fifthly, a nominal WACC will be appropriate if the price cap is set in nominal terms whilst a real WACC will be appropriate if the price cap is set in real terms. Sixthly, in respect of asymmetric risks, the Commission would have to decide whether to incorporate an ex-ante allowance for them into the output price, or offer ex-post compensation in the event of relevant events occurring. Finally, price caps may induce certain non-price reactions by regulated firms, and this argues for a further margin on WACC to mitigate these reactions. With the increase in the estimated asset beta to .60, a five year risk free rate of 5.92% (July 2005 average), and a debt premium for five year debt of 1.2%, the WACC estimate rises to 8.49% (adding debt issue costs to the cost of debt raises this figure to 8.57%) and the standard deviation on the WACC probability distribution rises to 1.6%.

In respect of a three year price cap situation, the WACC estimate differs from that appropriate to a five year price cap situation. In particular, the estimated asset beta falls to .50, the term of the risk free rate should be three years, and the debt premium should reflect three year debt. The point estimate on WACC then falls back to 7.83% (adding debt issue costs to the cost of debt raises this figure to 7.91%) and the standard deviation on the WACC probability distribution falls back to 1.5%.

In respect of a seven year price cap in which the price cap is finalised after three years and retrospectively applied to the first three years, the WACC estimate again differs. In particular, the estimated asset beta rises to .53, the relevant risk free rate is the seven year rate observed at the beginning of the seven year control period (5.88%), and the debt premium reflects seven year debt (1.3%). The point estimate on WACC then rises to 8.00% (adding debt issue costs to the cost of debt raises this figure to 8.08%) and the standard deviation on the WACC probability distribution remains at 1.5%.

These WACC estimates under price control presume that the company tax rate of 33% will operate throughout any control period that is chosen. However, a recent reduction in the rate to 30% (effective from 31.3.2008) affects the tax deduction on the cost of debt within equation (1) and also leads to equations (25) and (26) replacing (3) and (4). In respect of the seven year price control scenario examined above, the effect would be to raise the point estimate of WACC from 8.00% to 8.19% (or 8.08% to 8.28% if debt issue costs are added) and leave the standard deviation on the WACC probability distribution at 1.5%.

These WACC estimates under price control are based upon the debt premiums prevailing in 2005. However, there is a prima facie case for raising debt premiums due to the sharp rise in premiums from August 2007 along with the fact that the novel nature of the regulatory regime means that the businesses may not have had an opportunity to organise their borrowing arrangements or understood the merits of hedging arrangements to insulate themselves against the conditions that have developed. In respect of the seven year price control scenario examined above, this involves an increase in WACC from 8.00% to 8.29% in August 2007 (or from 8.08% to 8.37% if debt issue costs of 0.30% are included) and a further increase to 8.50% from 31.3.2008 on account of the decrease in the company tax rate (or to 8.58% if the debt issue costs of 0.30% are included). The standard deviation on the WACC probability distribution remains at 1.5%.

APPENDIX 1

This appendix seeks to estimate the standard deviation on the estimate for the market risk premium for New Zealand derived from estimates for sixteen foreign markets.

Let the average of the estimates across the N foreign countries be denoted $\bar{\hat{\phi}}$ and the true value for New Zealand be denoted ϕ_0. We use the former as an estimate of the latter and the estimation error is therefore $(\bar{\hat{\phi}} - \phi_0)$. Letting the average true value for the foreign markets be denoted ϕ, the true value for New Zealand can be expressed as $\phi_0 = \phi + d_0$, where d_0 is a random drawing from the cross-sectional distribution of true market risk premiums with variance denoted σ_d^2. Thus, there are two sources of error in using $\bar{\hat{\phi}}$ as an estimator for ϕ_0: $\bar{\hat{\phi}}$ may deviate from ϕ due to sampling error and ϕ_0 may differ from the world average ϕ because New Zealand is untypical. Letting e_j denote the estimation error in the estimate for foreign market j, this estimate for foreign market j can be expressed as follows.

$$\hat{\phi}_j = \phi_j + e_j = \phi + d_j + e_j$$

Recognising that ϕ_0 is independent of $\bar{\hat{\phi}}$, the variance of interest is as follows.

$$\begin{aligned} Var(\bar{\hat{\phi}} - \phi_0) &= Var(\bar{\hat{\phi}}) + Var(\phi_0) \\ &= Var\left[\frac{\hat{\phi}_1 + ... + \hat{\phi}_N}{N}\right] + \sigma_d^2 \\ &= \frac{1}{N^2} Var(d_1 + e_1 + ... + d_N + e_N) + \sigma_d^2 \end{aligned}$$

Recognising that the random variables d_j and e_j are independent for each j, and that $d_1 \ldots.. d_N$ are also independent, and defining ρ as the correlation between e_i and e_j, the result is as follows.

$$Var(\bar{\hat{\phi}} - \phi_0) = \frac{N\sigma_d^2}{N^2} + \frac{1}{N^2}Var(e_1 + ... + e_N) + \sigma_d^2$$

$$= \sigma_d^2\left[\frac{N+1}{N}\right] + \frac{1}{N^2}\sum_{i=1}^{N}\sum_{j=1}^{N}Cov(e_i, e_j)$$

$$= \sigma_d^2\left[\frac{N+1}{N}\right] + \frac{1}{N^2}\left[N\sigma_e^2 + (N^2 - N)\rho\sigma_e^2\right]$$

$$= \sigma_d^2\left[\frac{N+1}{N}\right] + \frac{\sigma_e^2}{N} + \rho\sigma_e^2\left[\frac{N-1}{N}\right] \qquad (27)$$

We therefore require estimates for σ_d^2, σ_e^2 and ρ. The first of these cannot be directly estimated, but can be inferred from the cross sectional distribution of the estimated market risk premiums for the *N* countries. Defining *v* as the expectation of the cross-sectional sample variance in the estimated market risk premiums, it follows that

$$v = E\left[\frac{\sum_{j=1}^{N}(\hat{\phi}_j - \bar{\hat{\phi}})^2}{N-1}\right]$$

$$= \frac{1}{N-1}\sum_{j=1}^{N}E(\hat{\phi}_j - \bar{\hat{\phi}})^2$$

$$= \frac{N}{N-1}Var(\hat{\phi}_j - \bar{\hat{\phi}})$$

Without loss of generality, let country *j* be country 1. It follows that

$$v = \frac{N}{N-1}Var\left[\hat{\phi}_1 - \frac{1}{N}(\hat{\phi}_1 + ... + \hat{\phi}_N)\right]$$

$$= \frac{N}{N-1}Var\left[\phi + d_1 + e_1 - \frac{1}{N}(\phi + d_1 + e_1 + ... + \phi + d_N + e_N)\right]$$

$$= \frac{N}{N-1}Var\left[d_1\left(\frac{N-1}{N}\right) + e_1\left(\frac{N-1}{N}\right) - \frac{1}{N}(d_2 + ... + d_N) - \frac{1}{N}(e_2 + ... + e_N)\right]$$

Recognising that the random variables d_j and e_j are independent, and that $d_1 \ldots d_N$ are also independent, it follows that

$$v = \frac{N}{N-1}\left[\sigma_d^2\left(\frac{N-1}{N}\right)^2 + \frac{\sigma_d^2}{N^2}(N-1)\right] + \frac{N}{N-1}Var\left[e_1\left(\frac{N-1}{N}\right) - \frac{e_2}{N} - ..... - \frac{e_N}{N}\right]$$

$$= \sigma_d^2 + \frac{N}{N-1}\left[\sigma_e^2\left(\frac{N-1}{N}\right)^2 + \frac{\sigma_e^2}{N^2}(N-1)\right] + \operatorname{cov} ariance\ terms$$

$$= \sigma_d^2 + \sigma_e^2 + \frac{N}{N-1}\rho\sigma_e^2\left[-2\left(\frac{N-1}{N}\right)\frac{1}{N}(N-1) + \frac{(N-1)^2 - (N-1)}{N^2}\right]$$

$$= \sigma_d^2 + \sigma_e^2 - \rho\sigma_e^2$$

Solving this equation for σ_d^2 yields the following result.

$$\sigma_d^2 = v - \sigma_e^2(1-\rho)$$

Substituting this result into equation (27) then yields the following.

$$Var(\bar{\hat{\phi}} - \phi_0) = [v - \sigma_e^2(1-\rho)]\left[\frac{N+1}{N}\right] + \frac{\sigma_e^2}{N} + \rho\sigma_e^2\left[\frac{N-1}{N}\right]$$

$$= v\left(\frac{N+1}{N}\right) - \sigma_e^2(1-2\rho) \qquad (28)$$

We now seek to estimate the values for v, σ_e^2 and ρ for the sixteen foreign markets referred to earlier. We start with the Ibbotson methodology. Table 8 below reports the Ibbotson estimates for the sixteen foreign markets (column 1) along with their standard errors (column 4), with the data drawn from Dimson et al (2006). In respect of v, an unbiased estimate will arise from the cross-sectional sample variance in the estimated market risk premiums in the first column, and this is .00032. In respect of σ_e^2, an unbiased estimate arises by averaging over the estimates in the fourth column, and this yields .00045. Finally, ρ is estimated by averaging over the time-series correlations between the pairs of markets, and the result is .40.[132] Following equation (28), the result is .016 as follows.

$$\sigma(\bar{\hat{\phi}} - \phi_0) = \sqrt{.00032\left(\frac{17}{16}\right) - .00045[1-2(.40)]} = .016$$

Table 8: Market Risk Premiums for Various Foreign Markets

	$\hat{\phi}_I$	Real R_f	$\hat{\phi}_S$	$\sigma(\hat{\phi}_I)$	$\sigma(R_m^r)$	$\sigma(\hat{\phi}_S)$
Australia	.074	.022	.061	.018	.017	.020
Belgium	.045	.006	.016	.020	.021	.023
Canada	.053	.025	.043	.017	.016	.019
Denmark	.036	.037	.038	.016	.020	.022
France	.063	.007	.035	.022	.022	.024
Germany	.089	.007	.061	.027	.032	.034
Ireland	.051	.022	.038	.018	.021	.023
Italy	.083	-.004	.044	.029	.028	.030
Japan	.087	.015	.067	.032	.029	.031
Netherlands	.058	.018	.041	.021	.021	.023
Norway	.051	.024	.040	.027	.026	.028
S Africa	.075	.023	.063	.019	.022	.024
Spain	.042	.021	.028	.020	.021	.023
Sweden	.075	.032	.072	.022	.022	.024
Switzerland	.034	.029	.028	.017	.019	.021
UK	.056	.023	.044	.016	.019	.021

[132] The estimates for individual markets are drawn from Dimson et al (2002, Table 8-3) because Dimson et al (2006) does not present such estimates using the entire time series of returns. The process is as follows. Using the time series of returns for (say) the French and German markets over 101 years, an unbiased estimate of the correlation coefficient between the returns in these two markets is obtained in the standard fashion. Estimates are obtained in the same way for all 105 possible pairings of the 15 markets, and these 105 estimated correlation coefficients are then averaged. These estimated correlations involve equity returns rather than equity returns net of risk free rates, and the latter are used in Ibbotson estimators. Examination of data for New Zealand and the US for the period 1931-1997 (from Cornell, 1999, and Lally and Marsden, 2004a) suggests that this slightly overestimates the relevant correlation coefficient (0.21 versus 0.18). So, the results here are conservative.

We now turn to the Siegel methodology. The Siegel estimates for the individual markets are shown in the third column of Table 8, and are generated by adding the average real risk free rate for each market as shown in the second column (Dimson et al, 2006) to the Ibbotson estimate for that market, and then deducting an estimate for the expected long-run real risk free rate for New Zealand of .035. The result is approximately equal to the average real return on equities less the estimate for the expected long-run real risk free rate, i.e.,

$$\hat{\phi}_S \cong \hat{R}_m^r - \hat{E}(R_f^r)$$

Assuming that the last two estimates are uncorrelated, the standard deviation of the Siegel estimate is then as follows.

$$\sigma(\hat{\phi}_S) = \sqrt{\sigma^2(\hat{R}_m^r) + \sigma^2(\hat{E}(R_f^r))}$$

The values for $\sigma(\hat{R}_m^r)$ are shown in the penultimate column of Table 7, drawn from Dimson et al (2006), and $\sigma(\hat{E}(R_f^r))$ has been estimated earlier at .01. The resulting values for $\sigma(\hat{\phi}_S)$ are shown in the final column of Table 8. Turning now to equation (28), an unbiased estimate of v arises from the cross-sectional sample variance in the estimated market risk premiums in the third column of the table, and this is .00025. In respect of σ_e^2, an unbiased estimate arises by averaging over the estimates in the last column, and this yields .00059. Finally, ρ is estimated as before at .40. Following equation (28), the result is .012 as follows.

$$\sigma(\bar{\hat{\phi}} - \phi_0) = \sqrt{.00025\left(\frac{17}{16}\right) - .00059[1 - 2(.40)]} = .012$$

APPENDIX 2

This Appendix seeks to estimate the standard deviation associated with the estimated market risk premium for New Zealand of .070. This estimate is a weighted average over the eleven estimates shown in Table 1. Of these eleven estimates, there are significant concerns about the reliability of the estimates arising from the Merton methodology. Furthermore, as discussed earlier, survey evidence is not amenable to estimation of a standard deviation. Finally, the Cornell estimate based on US data lacks an estimated standard deviation, and the standard deviation for the Cornell estimate based upon New Zealand data has not been objectively derived in the fashion characteristic of the Ibbotson and Siegel estimates. Thus, for the purposes of estimating the standard deviation associated with the estimated market risk premium for New Zealand, the Merton and survey estimates are disregarded and a standard deviation is attributed to each of the two Cornell estimates equal to the average for the Ibbotson and Siegel estimates (.021).[133] The estimate for the New Zealand market risk premium is then a weighted average over the remaining eight estimates (comprising the Ibbotson, Siegel and Cornell estimates based upon New Zealand data, the Ibbotson, Siegel and Cornell estimates based upon US data, and the Ibbotson and Siegel estimates based upon data from 16 other countries). With equal weight on the eight estimators

$$\hat{\phi}_{NZ} = \frac{\sum_{j=1}^{8} \hat{\phi}_j}{8}$$

The standard deviation on the estimator is then as follows.

$$\sigma(\hat{\phi}_{NZ}) = \sqrt{\frac{\sum_{i=1}^{8} \sum_{j=1}^{8} Cov(\hat{\phi}_i, \hat{\phi}_j)}{64}} \qquad (29)$$

Table 9 presents a set of correlation coefficients between these eight estimators. In respect of the Cornell and Ibbotson estimators, the correlation is judged to be zero

[133] The effect of disregarding some of the estimators for the purposes of estimating the standard deviation of the estimated market risk premium is likely to be that the standard deviation of the combined estimator is overestimated, and this is conservative.

because the Cornell estimate is based upon current and forecast data whilst the Ibbotson estimate is based entirely upon historical data[134]. In respect of the Cornell and Siegel estimators, the same principle operates. In respect of the Ibbotson and Siegel estimators for the same market, strong positive correlation should arise due to both methods drawing upon historical returns data. An estimate of this correlation arises from the sixteen pairs of estimates reported in Table 8 of Appendix 1, i.e., .80. In respect of the Ibbotson or Siegel estimators for two distinct markets, the correlation is estimated from the average of the cross-country correlations in equity returns in Dimson et al (2002, Table 8-3) for 16 markets, i.e., .40. This estimate is extended to the correlation between the Cornell estimators for New Zealand and the US. Finally, in respect of the correlation between an Ibbotson or Siegel estimator for an individual market and that for 16 countries in aggregate, this is estimated from the average of the country-world correlations reported in Dimson et al (2002, Table 8-3, column 1), i.e., .60. These results are shown in Table 9.

Table 9: Correlations Between Estimators

	$\hat{\phi}_{NZ}^{C}$	$\hat{\phi}_{NZ}^{S}$	$\hat{\phi}_{NZ}^{I}$	$\hat{\phi}_{US}^{C}$	$\hat{\phi}_{US}^{S}$	$\hat{\phi}_{US}^{I}$	$\hat{\phi}_{W}^{S}$	$\hat{\phi}_{W}^{I}$
$\hat{\phi}_{NZ}^{C}$	1							
$\hat{\phi}_{NZ}^{S}$	0	1						
$\hat{\phi}_{NZ}^{I}$	0	.8	1					
$\hat{\phi}_{US}^{C}$	.4	0	0	1				
$\hat{\phi}_{US}^{S}$	0	.4	.4	0	1			
$\hat{\phi}_{US}^{I}$	0	.4	.4	0	.8	1		
$\hat{\phi}_{W}^{S}$	0	.6	.6	0	.6	.6	1	
$\hat{\phi}_{W}^{I}$	0	.6	.6	0	.6	.6	.8	1

[134] Boyle et al (2006, page 13) argue that the forecast data used in the Cornell estimator will draw upon some historical data. However, this data does not involve equity returns or interest rates, and therefore the two estimators should be close to being independent.

Coupling these correlation coefficients with the standard deviations for these eight estimators (as shown in Table 1, subject to the two Cornell estimators being assigned a standard deviation of .021) yields the covariance matrix for the eight estimators, as shown in Table 10 below.

Table 10: Covariances Between Estimators

	$\hat{\phi}_{NZ}^{C}$	$\hat{\phi}_{NZ}^{S}$	$\hat{\phi}_{NZ}^{I}$	$\hat{\phi}_{US}^{C}$	$\hat{\phi}_{US}^{S}$	$\hat{\phi}_{US}^{I}$	$\hat{\phi}_{W}^{S}$	$\hat{\phi}_{W}^{I}$
$\hat{\phi}_{NZ}^{C}$	.00044							
$\hat{\phi}_{NZ}^{S}$	0	.00090						
$\hat{\phi}_{NZ}^{I}$	0	.00065	.00073					
$\hat{\phi}_{US}^{C}$	.00018	0	0	.00044				
$\hat{\phi}_{US}^{S}$	0	.00026	.00024	0	.00048			
$\hat{\phi}_{US}^{I}$	0	.00024	.00022	0	.00035	.00040		
$\hat{\phi}_{W}^{S}$	0	.00022	.00019	0	.00016	.00014	.00014	
$\hat{\phi}_{W}^{I}$	0	.00029	.00026	0	.00021	.00019	.00015	.00026

Substitution of these covariances in Table 10 into equation (29) yields $\sigma(\hat{\phi}_{NZ})$ = .014.

This process assumes that the eight estimators are equally-weighted. However, as discussed in section 3.3, the US results warrant some down-weighting in recognition of the likelihood that the US market risk premium is lower than that for New Zealand. An upper bound on $\sigma(\hat{\phi}_{NZ})$ arises by disregarding the three estimators utilising US data, and equally weighting the remaining five. The resulting estimate for $\sigma(\hat{\phi}_{NZ})$ is .015. Furthermore, on the question of equal weighting across estimators, the fact that there are differences in the estimated standard deviations for the individual estimators suggests that greater weighting be placed on the estimators with the lower standard deviations, which would have the effect of lowering the standard deviation of $\hat{\phi}_{NZ}$, and might change the combined estimate. Setting the weights proportional to the inverse of variance, the results are identical to four decimal places (.0708 each) whilst the estimate for $\sigma(\hat{\phi}_{NZ})$ falls from .014 to .012.[135] Taking account of all this, I favour an estimate for the standard deviation of the estimated market risk premium for New Zealand of .015.

[135] See Granger (1989, section 8.3) for a discussion of combining estimators and the use of this particular weighting scheme.

APPENDIX 3

This appendix seeks to estimate the variance associated with using $\bar{\hat{\beta}}$ as an estimator for β_0, where $\bar{\hat{\beta}}$ is the average estimated asset beta of a set of firms and β_0 is the true asset beta for a randomly selected firm from the same industry but which is not included in the average.

Letting the average true beta of the set of firms be denoted β, the true beta for firm 0 can be expressed as $\beta_0 = \beta + d_0$, where d_0 is a random drawing from the cross-sectional distribution of firms' true asset betas with variance denoted σ_d^2. Thus, there are two sources of error in using $\bar{\hat{\beta}}$ as an estimator for β_0: $\bar{\hat{\beta}}$ may deviate from β due to sampling error and β_0 may differ from β because firm 0 is untypical. Letting d_j denote the (random) divergence between β and the true beta for firm j, and e_j denote the beta estimation error for firm j, it follows that the estimated asset beta for firm j is as follows.

$$\hat{\beta}_j = \beta_j + e_j = \beta + d_j + e_j$$

Letting the average $\bar{\hat{\beta}}$ be generated from estimates for firms 1, 2….N, and recognising that β_0 is independent of $\bar{\hat{\beta}}$, the variance of interest is as follows.[136]

$$Var(\bar{\hat{\beta}} - \beta_0) = Var(\bar{\hat{\beta}}) + Var(\beta_0)$$
$$= Var\left[\frac{\hat{\beta}_1 + ... + \hat{\beta}_N}{N}\right] + \sigma_d^2$$
$$= \frac{1}{N^2} Var(\hat{\beta}_1 + ... + \hat{\beta}_N) + \sigma_d^2$$
$$= \frac{1}{N^2} Var(d_1 + e_1 + ... + d_N + e_N) + \sigma_d^2$$

[136] The development down to equation (30) closely follows that in Boyle et al (2006, pp. 27-28).

Recognising that the random variables d_j and e_j are independent for each j, and that $d_1.....d_N$ are also independent, and defining ρ as the correlation between e_i and e_j, the result is as follows.

$$Var(\bar{\hat{\beta}} - \beta_0) = \frac{N\sigma_d^2}{N^2} + \frac{1}{N^2}Var(e_1 + ... + e_N) + \sigma_d^2$$

$$= \sigma_d^2\left[\frac{N+1}{N}\right] + \frac{1}{N^2}\sum_{i=1}^{N}\sum_{j=1}^{N}Cov(e_i, e_j)$$

$$= \sigma_d^2\left[\frac{N+1}{N}\right] + \frac{1}{N^2}\left[N\sigma_e^2 + (N^2 - N)\rho\sigma_e^2\right]$$

$$= \sigma_d^2\left[\frac{N+1}{N}\right] + \frac{\sigma_e^2}{N} + \rho\sigma_e^2\left[\frac{N-1}{N}\right] \tag{30}$$

We therefore require estimates for σ_d^2, σ_e^2 and ρ. The first of these cannot be directly estimated, but can be inferred from the cross sectional distribution of the estimated betas for the N firms. Defining v as the expectation of the cross-sectional sample variance in the estimated betas, it follows that

$$v = E\left[\frac{\sum_{j=1}^{N}(\hat{\beta}_j - \bar{\hat{\beta}})^2}{N-1}\right]$$

$$= \frac{1}{N-1}\sum_{j=1}^{N}E(\hat{\beta}_j - \bar{\hat{\beta}})^2$$

$$= \frac{N}{N-1}Var(\hat{\beta}_j - \bar{\hat{\beta}})$$

Without loss of generality, let firm j be firm 1. It follows that

$$v = \frac{N}{N-1}Var\left[\hat{\beta}_1 - \frac{1}{N}(\hat{\beta}_1 + ... + \hat{\beta}_N)\right]$$

$$= \frac{N}{N-1}Var\left[\beta + d_1 + e_1 - \frac{1}{N}(\beta + d_1 + e_1 + ... + \beta + d_N + e_N)\right]$$

$$= \frac{N}{N-1}Var\left[d_1\left(\frac{N-1}{N}\right) + e_1\left(\frac{N-1}{N}\right) - \frac{1}{N}(d_2 + ... + d_N) - \frac{1}{N}(e_2 + ... + e_N)\right]$$

Recognising that the random variables d_j and e_j are independent, and that $d_1 \ldots .. d_N$ are also independent, it follows that

$$v = \frac{N}{N-1}\left[\sigma_d^2\left(\frac{N-1}{N}\right)^2 + \frac{\sigma_d^2}{N^2}(N-1)\right] + \frac{N}{N-1}Var\left[e_1\left(\frac{N-1}{N}\right) - \frac{e_2}{N} - \ldots.. - \frac{e_N}{N}\right]$$

$$= \sigma_d^2 + \frac{N}{N-1}\left[\sigma_e^2\left(\frac{N-1}{N}\right)^2 + \frac{\sigma_e^2}{N^2}(N-1)\right] + \text{cov}\,ariance\ terms$$

$$= \sigma_d^2 + \sigma_e^2 + \frac{N}{N-1}\rho\sigma_e^2\left[-2\left(\frac{N-1}{N}\right)\frac{1}{N}(N-1) + \frac{(N-1)^2-(N-1)}{N^2}\right]$$

$$= \sigma_d^2 + \sigma_e^2 - \rho\sigma_e^2$$

Solving this equation for σ_d^2 yields the following result.

$$\sigma_d^2 = v - \sigma_e^2(1-\rho)$$

Substituting this result into equation (30) then yields the following.

$$Var(\bar{\hat{\beta}} - \beta_0) = [v - \sigma_e^2(1-\rho)]\left[\frac{N+1}{N}\right] + \frac{\sigma_e^2}{N} + \rho\sigma_e^2\left[\frac{N-1}{N}\right]$$

$$= v\left(\frac{N+1}{N}\right) - \sigma_e^2(1-2\rho) \qquad (31)$$

We now seek to estimate the values for v, σ_e^2 and ρ for the US electric and gas utilities examined earlier. Given that the estimator $\bar{\hat{\beta}}$ invokes data on a set of firms over a period of 15 years, the estimates for v, σ_e^2 and ρ should be based upon a set of estimated asset betas that are each estimated using 15 years of data. However, none of the data sets in Table 3 are of that type. So, we use the three five-year S&P data sets described in Table 3 (spanning both the gas and electric utilities). For each of these five-year spans, an unbiased estimate for v will arise from the cross-sectional sample variance in the estimated asset betas. These three estimates are shown in the first column of Table 11 below.[137] Averaging over these estimates yields an estimate of .0381.

Turning now to σ_e^2, and again in respect of a five-year span, an unbiased estimate arises from each of the regressions that generate an estimate of the asset beta. However, each regression generates an estimate of an equity beta, and corrections for leverage then produce an estimate of an asset beta. Letting $\hat{\beta}_{ej}$ denote the estimated equity beta for firm j arising from the regression, the estimate for the asset beta for a US firm is as follows.[138]

$$\hat{\beta}_j = \frac{\hat{\beta}_{ej}}{\left[1 + \frac{L}{1-L}(1-0.39)\right]} \qquad (32)$$

It then follows that

$$Var(\hat{\beta}_j) = \frac{Var(\hat{\beta}_{ej})}{\left[1 + \frac{L}{1-L}(1-0.39)\right]^2} \qquad (33)$$

where the left hand side corresponds to σ_e^2. For each of the three S&P data sets described in Table 3, we average over the estimates for the individual firms (with the same deletions noted in footnote 89). The results are shown in the second column of Table 11 below, and averaging over these estimates yields .0205.

[137] For the second of these periods (1994-1998), data from 2 out of 73 firms was disregarded on the grounds of being exceptional outliers (an asset beta in one case and a standard error in another). For the last period (1999-2003), 1 out of 80 estimates was deleted for the same reason.

[138] This differs from equation (5) due to the adjustment for corporate tax, at the US company tax rate of 0.39. The further correction for differences between country leverage in the US and New Zealand is omitted here on the grounds of having little effect (see section 5.2).

Table 11: Estimates of v and σ_e^2

	End-Period Leverage		Average Leverage	
	v	σ_e^2	v	σ_e^2
1989-1993	.0256	.0172	.0256	.0172
1994-1998	.0330	.0166	.0253	.0153
1999-2003	.0557	.0278	.0386	.0254
Mean	.0381	.0205	.0298	.0193

Turning finally to ρ, the S&P data will not provide an estimate of this. However, an estimate can still be obtained by consideration of the regression model that underlies the beta estimation process. Let R_{jt} denoting firm j's unlevered return in period t, R_{mt} the market return in period t, and u_{jt} the firm specific return component for that period:[139]

$$R_{jt} = a_j + \beta_j R_{mt} + u_{jt} \tag{34}$$

The regression based estimate of β_j is then as follows.

$$\hat{\beta}_j = \frac{\hat{C}ov(R_j, R_m)}{\hat{V}ar(R_m)} = \frac{\beta_j \hat{C}ov(R_m, R_m) + \hat{C}ov(u_j, R_m)}{\hat{V}ar(R_m)} = \beta_j + \frac{\hat{C}ov(u_j, R_m)}{\hat{V}ar(R_m)}$$

So the error in estimating the asset beta for firm j is as follows.

$$\begin{aligned} e_j &= \hat{\beta}_j - \beta_j \\ &= \frac{\hat{C}ov(u_j, R_m)}{\hat{V}ar(R_m)} \\ &= \frac{\sum_{t=1}^{T} (u_{jt} - \overline{u}_j)(R_{mt} - \overline{R}_m)}{\hat{V}ar(R_m)} \end{aligned}$$

[139] We assume here that the regression process directly estimates the asset beta. In fact, the regression process directly estimates the equity beta, from which the estimate of the asset beta arises by an adjustment for leverage. This detail is not significant to the issue examined here.

$$= \frac{\sum_{t=1}^{T} \tilde{u}_{jt} \tilde{R}_{mt}}{\hat{V}ar(R_m)} \qquad (35)$$

where the tilde indicates that the variable in question is expressed as the difference from its sample mean. Consequently, the estimation errors e_j will be independent across firms so long as the regression residuals u_{jt} are independent across firms. However, "industry effects" imply that the regression residuals are positively correlated amongst firms in the same industry, and therefore the estimation errors e_j will have the same property. Using equation (35), it follows that

$$\rho = Corr(e_i, e_j)$$

$$= \frac{Cov(e_i, e_j)}{\sqrt{Var(e_i)Var(e_j)}}$$

$$= \frac{Cov(e_i, e_j)}{Var(e_j)}$$

$$= \frac{Cov\left(\sum_{t=1}^{T} \tilde{u}_{it} \tilde{R}_{mt}, \sum_{t=1}^{T} \tilde{u}_{jt} \tilde{R}_{mt} \right)}{Var\left(\sum_{t=1}^{T} \tilde{u}_{jt} \tilde{R}_{mt} \right)}$$

Recognising that the random variables $\tilde{u}_{it}$ and $\tilde{R}_{mt}$ are each serially independent, it follows that

$$\rho = \frac{Cov\left(\tilde{u}_i \tilde{R}_m, \tilde{u}_j \tilde{R}_m\right)T}{Var\left(\tilde{u}_j \tilde{R}_m\right)T}$$

Recognising that each of the random variables here is mean zero, and that both $\tilde{u}_i$ and $\tilde{u}_j$ are independent of $\tilde{R}_m$, it follows that

$$\rho = \frac{E\left(\tilde{u}_i \tilde{u}_j \tilde{R}_m^2\right)}{E\left(\tilde{u}_j^2 \tilde{R}_m^2\right)}$$

$$= \frac{E(\tilde{u}_i \tilde{u}_j) E(\tilde{R}_m^2)}{E(\tilde{u}_j^2) E(\tilde{R}_m^2)}$$

$$= \frac{Cov(\tilde{u}_i, \tilde{u}_j)}{Var(\tilde{u}_j)}$$

$$= \frac{Cov(u_i, u_j)}{Var(u_j)}$$

If we represent u_i as the sum of an industry effect (I) and an uncorrelated firm-specific effect θ_j, it then follows that

$$\rho = \frac{Cov(I + \theta_i, I + \theta_j)}{Var(u_j)}$$

$$= \frac{Var(I)}{Var(u_j)}$$

and this is the proportion of $Var(u_j)$ that is explained by the "industry effect". In respect of US utilities, King (1966) shows that around 30% of the variance in the regression residual u_j is explained by industry effects for US utilities.[140] This implies an estimate for ρ of .30. Using a larger data set, Meyers (1973, Table 1) generates the lower estimate of .12, but this is for the market as a whole. Nevertheless, it can be compared with King's market-wide estimate of .27, and suggests an estimate for ρ of .14 for US utilities. Giving somewhat more weight to the more recent of the two studies suggests an estimate for ρ of .20.

We are now in a position to conduct the estimation in equation (31). Using the average estimates presented in the first two columns of Table 11 above for v and σ_e^2, the estimate for ρ of .20, and the average number of firms in the three S&P data sets in Table 3 (73), the result is as follows.

[140] This is an average over the 10 utilities examined by King. For these 10 firms, on average, the market factor explains 57% of the variance (King, 1966, Table 5) and industry effects explain a further 13% (ibid, Table 9). So, industry effects explain .13/.43 = .30 of the regression residual. If we average over all of the firms examined by King, the estimate of .30 falls slightly to .27.

$$Var(\hat{\bar{\beta}} - \beta_0) = .0381\left(\frac{74}{73}\right) - .0205(1-.40) = .0263$$

This implies a standard deviation of .162. Inter alia, the process described above invokes equations (32) and (33) and, following standard practice, defines leverage L to be that prevailing at the end of the five year period used to estimate the equity betas. However Lally (1998a) shows that a superior estimate of the asset beta arises by using the average leverage over the five year beta estimation period, because the regression based estimate of the equity beta will reflect the average rather than the terminal leverage. Adopting this alternative approach may not exert much effect upon the average estimated asset beta but it is liable to materially reduce the cross sectional variance of the estimated asset betas, and the intuition is thus. Suppose that a firm has leverage of .30 over most of the five year beta estimation period, but significantly raises (or reduces) its leverage shortly before the end of this period. Its true and estimated equity betas will not be materially affected by this event, and its true asset beta will be invariant to it. However, if leverage is measured at the period end, the estimated asset beta following equation (32) will be significantly lowered (or raised). Across a large number of firms, the average estimated asset beta may not be materially affected. However, the cross-sectional variance in these estimated asset betas will be raised. By contrast, in using average leverage to implement equation (32), these spurious effects will be avoided.

In light of this issue, we now estimate $\hat{\beta}_j$ and $Var(\hat{\beta}_j)$ from equations (32) and (33) using average rather than period end leverage. The resulting estimates for v and σ_e^2 are shown in Table 11, but only for the periods 1994-1998 and 1999-2003, because leverage data is lacking for 1989.[141] As expected, the estimates for v are significantly less for each of these two periods. These results are combined with results from 1989-1993 based upon period end leverage, and averaging over the three sets of results yields estimates for v and σ_e^2 of .0298 and .0193 respectively. Combined with the earlier estimate for ρ of .20, and following equation (31), the result is as follows.

[141] Using average rather than period end L has a small effect upon one of the numbers in the last column of Table 3, but does not change the median for that column. Consequently, no adjustment is made to the table.

$$Var(\bar{\hat{\beta}} - \beta_0) = .0298\left(\frac{74}{73}\right) - .0193(1 - .40) = .0186$$

This implies a standard deviation of .136.

This estimate arises by averaging over three five-year estimates for v and about 200 five-year estimates for σ_e^2. However, as noted earlier, the preferred approach would be to use a single estimate for v based on 15 year regression estimates and estimates for σ_e^2 that also arose from 15 year regressions. Had this been done, the estimates for v and σ_e^2 are liable to have been lower than those used, because the longer time span for the regressions would reduce the estimation error within each regression. If the estimates for v and σ_e^2 declined by the same proportion, then the estimate for $Var(\bar{\hat{\beta}} - \beta_0)$ would also have declined. So, the estimate of .136 above would be too high. Since this effect cannot be quantified, we use the estimate of .136.

APPENDIX 4

This appendix seeks to estimate the variance of $(\bar{\hat{\beta}} - \beta)$ where $\bar{\hat{\beta}}$ is the average estimated asset beta of a set of N firms with an average true beta of β.

Following the analysis in Appendix 3 down to equation (30), but with β substituting for β_0, the result is as follows

$$Var(\bar{\hat{\beta}} - \beta) = \frac{\sigma_d^2}{N} + \frac{\sigma_e^2}{N} + \rho\sigma_e^2\left[\frac{N-1}{N}\right]$$

where σ_d^2 is the variance in the cross-sectional distribution of true betas within the industry, σ_e is the standard error in the beta estimate and ρ is the correlation between the beta estimation errors of any two firms. Defining v as the expectation of the cross-sectional sample variance in the estimated betas, Appendix 3 shows that

$$\sigma_d^2 = v - \sigma_e^2(1-\rho)$$

Substituting this result into the preceding equation then yields the following.

$$Var(\bar{\hat{\beta}} - \beta) = \frac{v - \sigma_e^2(1-\rho)}{N} + \frac{\sigma_e^2}{N} + \rho\sigma_e^2\left[\frac{N-1}{N}\right]$$

$$= \frac{v}{N} + \sigma_e^2\rho$$

We therefore require estimates for v, σ_e^2 and ρ for the US and UK electric utilities. Appendix 3 estimates ρ at .20, and estimates for v and σ_e^2 arise from the set of beta estimates and their estimated standard errors. However, Alexander (1996) does not present estimated standard errors for his beta estimates. So, rather than estimate v from Alexander's data and σ_e^2 from the S&P data, we estimate both parameters from the S&P data. Following Table 11 in Appendix 3, these estimates are v = .0298 and σ_e^2 = .0193. So, for a set of 12 UK electric utilities

$$Var(\bar{\hat{\beta}} - \beta) = \frac{.0298}{12} + .0193(.20) = .0063$$

For a set of 9 US electric utilities, the result is as follows.

$$Var(\bar{\hat{\beta}} - \beta) = \frac{.0298}{9} + .0193(.20) = .0072$$

APPENDIX 5

This appendix investigates the question of whether WACC should be defined using book or market value leverage, within the context of assessing excess profits and also within the context of price control.

To simplify the presentation, we assume that a firm has just been set up, that its assets have a life of one year, and that costs and revenues are incurred at the end of each year. We also assume that the firm's only cash outflows are interest (*INT*), taxes (*TAX*) and repayment of the amount borrowed (*B*). Define *S* as the current market value of the firm's equity, k_e as the cost of equity capital, and *E*(*X*) as the expected value for *X*. Recognising that the interest payment and the repayment of debt in one year are certain, it follows that

$$S = \frac{E(REV) - E(TAX) - INT - B}{1 + k_e}$$

The tax payment *TAX* can be decomposed into the payment arising in the absence of debt (TAX_u) less the tax savings arising from the interest payment to debt holders (*INT* times T_c). It follows that

$$S = \frac{E(REV) - E(TAX_u) - INT(1 - T_c) - B}{1 + k_e}$$

Since the interest payment *INT* is the product of *B* and the cost of debt k_d, the last equation becomes

$$S = \frac{E(REV) - E(TAX_u) - k_d B(1 - T_c) - B}{1 + k_e}$$

Rearrangement of terms yields the following.

$$S + B + Sk_e + k_d B(1 - T_c) = E(REV) - E(TAX_u)$$

The term B is the current book value of debt, and should also be equal to the current market value of debt[142]. Consequently the sum of S (current market value of equity) and B is the current market value of the firm (V). So, the last equation can be written as follows.

$$V\left[1+k_e\frac{S}{V}+k_d(1-T_c)\frac{B}{V}\right]=E(REV)-E(TAX_u)$$

The bracketed term is $1+WACC$, and therefore

$$V=\frac{E(REV)-E(TAX_u)}{1+WACC} \qquad (36)$$

This equation says that the current market value of the firm is equal to the expected unlevered cash flows, discounted at the *WACC*. This statement is the usual one, and the derivation reveals that the leverage ratio within WACC (B/V) involves market rather than book values. To illustrate the distinction, suppose the cost of the firm's assets (A) is \$5m, B = \$2m, $E(REV)$ = \$10m, $E(TAX_u)$ = \$3m, and $WACC$ = .10. It follows from the last equation that

$$V=\frac{\$10m-\$3m}{1.10}=\$6.36m$$

The market value of the firm then exceeds the cost of its assets. Its book value leverage is then

$$\frac{B}{A}=\frac{\$2m}{\$5m}=.40$$

whilst its market value leverage is

$$\frac{B}{V}=\frac{\$2m}{\$6.36m}=.31$$

[142] If the value exceeds the amount borrowed, equity holders will have offered an unnecessarily high interest rate. If the value is less than the amount borrowed, this implies an interest rate that is too low and this is inconsistent with rational behaviour on the part of the debt holders.

Turning now to the activities of a regulator, price control can be interpreted as seeking to constrain the market value of the firm to that of the cost of its assets (*A*). In this case, the regulator would set prices and therefore expected revenues so that

$$A = \frac{E(REV) - E(TAX_u)}{1 + WACC}$$

That is,

$$E(REV) = E(TAX_u) + A(1 + WACC) \qquad (37)$$

So, WACC is applied to the regulatory book value of the firm's assets. Since *V* is constrained to the regulatory book value of assets, then the leverage ratio within WACC is both market and book leverage.

Turning now to the activities of a regulator concerned with assessing excess profits at the end of the year, these excess profits must be defined so that their present value over the life of the assets is equal to the net present value (*NPV*) of the cash flows arising from the assets[143]. In the scenario above, *NPV* = *V* – *A*. Invoking the valuation equation (36) above, it follows that

$$NPV = \frac{E(REV) - E(TAX_u)}{1 + WACC} - A$$

$$= \frac{E(REV) - E(TAX_u) - A - A(WACC)}{1 + WACC}$$

Since the present value of the numerator here is equal to *NPV*, then the ex-post counterpart to this numerator must be Excess Profits, i.e.,

$$Excess\ \mathrm{Pr}\,ofits = REV - TAX_u - A - A(WACC) \qquad (38)$$

where the third term on the right hand side (*A*) equates to regulatory depreciation. So, Excess Profits involve application of a *WACC* to the book value of assets, but the

[143] This issue is discussed in further detail in Lally (2006, section 12.1).

WACC embodies market rather than book value leverage (except in the unusual case in which the book value of assets matches their market value).

In summary, regulatory activity involves the application of WACC to the book value of assets, as shown in equations (37) and (38), corresponding to price control and to the assessment of excess profits respectively. In both cases, WACC embodies market value leverage. Under price control, regulation can be interpreted as seeking to match the market value of the firm to the book value of its assets, and therefore book value leverage will tend to match market value leverage. In respect of assessing excess profits, book value leverage will not thereby tend to match market value leverage.

APPENDIX 6

This appendix seeks to prove equations (14) and (15), involving the relationship between the variance of the estimated WACC distribution and the properties of the seven parameter estimates that are embedded within it. It is assumed that these seven parameter estimates are independent of one another. Following section 9.1, the estimated WACC is related to these parameter estimates as follows.

$$W\hat{A}CC = .0436 + \hat{\phi}\hat{\beta}_a + \hat{p}\hat{L}(0.67) \quad (39)$$

$$\hat{\beta}_a = \hat{\beta}_{Ea} + \hat{Q}\hat{\Delta} + \hat{G} \quad (40)$$

For independent random variables X and Y

$$\begin{aligned} Var(XY) &= E[XY - E(X)E(Y)]^2 \\ &= E(X^2)E(Y^2) - E^2(X)E^2(Y) \\ &= [Var(X) + E^2(X)][Var(Y) + E^2(Y)] - E^2(X)E^2(Y) \\ &= Var(X)Var(Y) + E^2(X)Var(Y) + E^2(Y)Var(X) \quad (41) \end{aligned}$$

Applying this result to equation (39) yields the following

$$\begin{aligned} Var(W\hat{A}CC) &= Var(\hat{\phi}\hat{\beta}_a) + (0.67)^2 Var(\hat{p}\hat{L}) \\ &= Var(\hat{\phi})Var(\hat{\beta}_a) + E^2(\hat{\phi})Var(\hat{\beta}_a) + E^2(\hat{\beta}_a)Var(\hat{\phi}) \\ &\quad + (0.67)^2 \left[Var(\hat{p})Var(\hat{L}) + E^2(\hat{p})Var(\hat{L}) + E^2(\hat{L})Var(\hat{p})\right] \end{aligned}$$

This is equation (14). Applying the result in equation (41) to (40), the result is as follows:

$$\begin{aligned} Var(\hat{\beta}_a) &= Var(\hat{\beta}_{Ea} + \hat{Q}\hat{\Delta} + \hat{G}) \\ &= Var(\hat{\beta}_{Ea}) + Var(\hat{Q}\hat{\Delta}) + Var(\hat{G}) \\ &= Var(\hat{\beta}_{Ea}) + \left[Var(\hat{Q})Var(\hat{\Delta}) + E^2(\hat{Q})Var(\hat{\Delta}) + E^2(\hat{\Delta})Var(\hat{Q})\right] + Var(\hat{G}) \end{aligned}$$

This is equation (15).

APPENDIX 7

This appendix examines the implications of departures from normality in the $W\hat{A}CC$ distribution. Since $W\hat{A}CC$ involves the product of the estimated market risk premium and the estimated asset beta, some rightward skewness in the distribution is to be expected, and this is inconsistent with the use of a normal distribution. In addition, $W\hat{A}CC$ should be at least zero and the density function should go to zero as $W\hat{A}CC$ does. Two distributions that satisfy these properties are the lognormal and gamma distributions, and are therefore examined.

In respect of the lognormal distribution, this is as follows

$$Ln(W\hat{A}CC) = a + bZ$$

where a is the expectation of $Ln(W\hat{A}CC)$, b is the standard deviation and Z is the standard normal random variable. So

$$W\hat{A}CC = e^{a+bZ} \tag{42}$$

Consequently (see Mood et al, 1974, Chapter 3)

$$E(W\hat{A}CC) = e^{a+.5b^2}$$

$$Var(W\hat{A}CC) = E(W\hat{A}CC^2) - E^2(W\hat{A}CC)$$

$$= e^{2a+2b^2} - E^2(W\hat{A}CC)$$

The values for $E(W\hat{A}CC)$ and $Var(W\hat{A}CC)$ have already been determined as .078 and $.015^2$ respectively. So

$$.078 = e^{a+.5b^2}$$

$$.015^2 = e^{2a+2b^2} - .078^2$$

Simultaneous solution yields a = -2.5692 and b = .1906.[144] Substitution into equation (42) yields

$$W\hat{A}CC = e^{-2.5692+.1906Z} \qquad (43)$$

This lognormal distribution is now used to generate percentiles of the $W\hat{A}CC$ distribution, and compare them with the earlier results from assuming that $W\hat{A}CC$ is normal rather than lognormal. The results are shown in Table 12 below. For example, the 50th percentile of the $W\hat{A}CC$ distribution corresponds to Z = 0, and substitution of this into equation (43) yields $W\hat{A}CC$ = .077. This is slightly less than for the normal distribution. However, as the percentile increases, the $W\hat{A}CC$ value under the lognormal distribution increases more rapidly than for the normal distribution, and overtakes it at around the 90th percentile. However, within the region from the 50th to the 95th percentiles, the results are virtually identical[145].

Table 12: Percentiles of the $W\hat{A}CC$ Distribution

Percentile	50th	60th	70th	80th	90th	95th
$W\hat{A}CC$ (Normal)	.078	.082	.086	.091	.097	.103
$W\hat{A}CC$ (Lognormal)	.077	.080	.085	.090	.098	.105
$W\hat{A}CC$ (Gamma)	.077	.080	.085	.090	.098	.105

The gamma distribution is now considered. This has two parameters, λ (scale) and r (location). The expectation and variance of the gamma distribution are as follows (Mood et al, 1973, Chapter 3)

$$E(W\hat{A}CC) = \frac{r}{\lambda}$$

$$Var(W\hat{A}CC) = \frac{r}{\lambda^2}$$

[144] This process is called “method of moments” (Mood et al, 1974, pp. 274-276).

[145] By contrast, at the 99.75th percentile (Z = 2.8), the $W\hat{A}CC$ value under a normal distribution is .120 whilst that under a lognormal distribution is .131.

Matching this mean and variance to the previously determined values of .078 and $.015^2$ respectively yields r = 27.04 and λ = 346.67. With these parameter values, the percentiles of the gamma distribution are then determined and reported in Table 12. To the third decimal point reported, they match the lognormal distribution.

In summary, for given mean and variance, $W\hat{A}CC$ distributions that are skewed rightwards generate essentially the same $W\hat{A}CC$ values as the normal distribution in the region of the 50^{th} to the 95^{th} percentiles.

APPENDIX 8

This Appendix elaborates upon the use of an asymmetric linear loss function to guide the choice of the percentile chosen from the WACC distribution. Let W denote the actual (but unobservable) value for WACC and $\hat{W}_X$ the value chosen by the regulator. Suppose that the loss L suffered in the event that W is underestimated is b times that of the loss suffered in the event that W is overestimated, i.e.,

$$L = -(W - \hat{W}_X) \quad for \quad W \le \hat{W}_X$$
$$L = b(W - \hat{W}_X) \quad for \quad W \ge \hat{W}_X$$

In addition, $\hat{W}_X$ is the sum of the point estimate for WACC (denoted $\hat{W}$) and a margin m, and $\hat{W}$ is normally distributed (about the true value W) with standard deviation denoted σ, i.e.,

$$\hat{W}_x = W + \sigma Z + m$$

where Z is the standard normal random variable. Substitution of this into the preceding two equations yields

$$L = \sigma Z + m \quad for \quad Z \le -\frac{m}{\sigma}$$
$$L = -b(\sigma Z + m) \quad for \quad Z \le -\frac{m}{\sigma}$$

It follows that the expected loss is as follows:

$$E(L) = -b\int_{Z=-\infty}^{Z=-m/\sigma} (\sigma Z + m) f(Z) dZ + \int_{Z=-m/\sigma}^{Z=\infty} (\sigma Z + m) f(Z) dZ$$

In choosing a value for the margin (m), the natural criterion here is the minimisation of the expected loss. So, m is chosen so that

$$\frac{\partial E(L)}{\partial m} = 0 = -b\int_{Z=-\infty}^{Z=-m/\sigma} f(Z)dZ + \int_{Z=-m/\sigma}^{Z=\infty} f(Z)dZ$$

It follows that *m* must satisfy the following equation:

$$b = \frac{\int_{Z=-m/\sigma}^{Z=\infty} f(Z)dZ}{\int_{Z=-\infty}^{Z=-m/\sigma} f(Z)dZ}$$

Thus, for example, if *b* = 3, then $-m/\sigma$ must be the 25th percentile of the Z distribution (Z = -.6745) and accordingly *m* = .6745*σ*. With *σ* estimated at 1.5%, it follows that *m* is 1.01%. Table 13 presents the margins arising from various values of *b*.

Table 13: Margins Arising from Various Loss Ratios

b	*Z*	*m*
1	0	0
3	.675	1.01%
6	1.07	1.60%
9	1.28	1.92%
12	1.43	2.14%
15	1.53	2.30%

The table reveals that the margin *m* grows much less slowly than the loss ratio *b*.

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