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The Equity Beta of an Electricity Distribution Business

REPORT PREPARED FOR

ETSA Utilities

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CONTENTS

GLOSSARY

ACCC: The Australian Competition and Consumer Commission – the federal regulator.

Asset Beta: The risk of owning all of the assets of the firm.

CAPEX: Capital expenditure – the purchase of assets.

Capital Asset Pricing Model (CAPM): A model that relates the return that investors require from an asset to the risk of that asset. Assets with higher risk require higher returns from investors. The CAPM states that the required return is equal to the return that could be obtained from a risk-free investment (government bonds) plus a premium to compensate for risk. This premium is equal to the average risk premium for all investments (the market risk premium) scaled up or down by the relative risk of the particular investment being evaluated (beta).

Draft Determination: ESCoSA Draft 2005 - 2010 Electricity Distribution Price Determination: Part A - Statement of Reasons.

Diversifiable risk: Risks that affect an individual firm. These risks can be effectively eliminated by holding a diversified portfolio. In a large portfolio of assets, good and bad unexpected firm-specific events tend to balance out.

EPO: The Electricity Pricing Order, which sets out the way in which ESCoSA must compute the regulated return for electricity distribution.

Equity Beta: Schedule 6.1, Clause 3 of the National Electricity Code states that "Beta is a measure of the extent to which the return on a given equity investment moves with the return on the equity market." This represents the risk of owning shares in the firm. The equity beta is affected by the risk of the assets the firm has invested in and the amount of debt the firm has (which ranks prior to equity).

ESC: The Essential Services Commission – the Victorian regulator.

ESC Act: The Essential Services Commission Act, which governs the operation of the South Australian regulator, ESCoSA.

ESCoSA: The Essential Services Commission of South Australia – the South Australian regulator.

Final Determination: ESCoSA 2005 - 2010 Electricity Distribution Price Determination: Part A - Statement of Reasons.

IPART: The Independent Pricing and Regulatory Tribunal – the New South Wales regulator.

Market Risk Premium (MRP): The excess return, over and above the risk-free return, that is expected to be earned by the average investment.

NEC: The National Electricity Code, which governs the regulation of electricity distribution services in Australia.

OLS: Ordinary Least Squares, a basic form of regression analysis.

Productivity Commission: The Australian Government's principal review and advisory body on microeconomic policy and regulation.

QCA: The Queensland Competition Authority – the Queensland regulator.

R-squared statistic (R^2): A measure of the goodness of fit of a regression model. Interpreted as an indication of the informativeness of a regression analysis.

Regulatory Asset Base (RAB): The total amount of capital required to finance the assets of an efficient firm providing the services of the regulated entity.

Risk-free Return (r_f): The return that can be earned by bearing no risk at all. For example, the return that can be earned on government bonds.

RMS: The Risk Management Service at the Australian Graduate School of Management. RMS provides a set of mechanical equity beta estimates for all listed Australian firms every quarter.

Systematic Risk (also Beta Risk or Market Risk): Risks that have an impact on the broad market so cannot be eliminated by holding a diversified portfolio.

Weighted Average Cost of Capital (WACC): The percentage return that investors would need to expect the firm to generate before committing their funds. The WACC is a weighted average of the firm's cost of debt and equity capital – the interest that must be paid to lenders and the returns that must be paid to attract shareholders.

1. EXECUTIVE SUMMARY AND RESPONSE

Objective of Report

1.1 We have been retained by ETSA Utilities to conduct analyses and to comment on the appropriate equity beta to be used in determining the weighted-average cost of capital of an efficient benchmark Australian energy distribution business.

1.2 This report supersedes an earlier report that we prepared for ETSA Utilities. In that report, we were asked to comment on whether a basic and mechanical analysis of data, such as that relied upon by ESCoSA, could produce equity beta estimates that are statistically and economically reliable. The conclusion of our earlier report was that mechanical estimates of the equity betas of listed Australian comparables are based on scant, unreliable, and contaminated data and that they are not reflective of current market conditions as they imply that equity investors are willing to accept unreasonably low returns. In the Final Determination[1], ESCoSA notes that it is “cognisant of the statistical error” in equity beta estimates.

1.3 In this report, we have been asked to address how the available data can best be used to estimate equity betas that are as statistically and economically reliable as possible. The approach we have adopted is to conduct a range of analyses using different methods and data sets. To the extent that the different approaches corroborate one another, and are consistent with economic reasonableness and commercial common sense, they can be considered to be reliable and representative of current market circumstances. It is wrong to rely exclusively on any single approach, especially when that approach is applied mechanically to a very small data set and produces statistically unreliable estimates that defy commercial common sense.

Response to the Discussion of our Previous Report in ESCoSA’s Final Determination

1.4 In the Final Determination[2], ESCoSA addresses a number of issues that were raised in our earlier report. In general, ESCoSA states that it is “cognisant of the statistical error” in the equity beta estimates it seeks to rely upon. This recognition is consistent with our conclusion that mechanical estimates of the equity betas of listed Australian comparables are based on scant, unreliable, and contaminated data and are not reflective of current market conditions. In the remainder of this section, we specifically address the particular points that ESCoSA raises in relation to our earlier report.

1.5 In the Final Determination (p.134) ESCoSA states that our previous report did not conclude that "*there are well established or standard techniques*" to deal with the statistical imprecision of the data. This is correct, as consideration of the appropriate range of analyses to be applied to the available data was beyond the scope of our previous report. Our earlier report simply warns against giving weight to recent mechanical beta estimates where it is not due. In the present report, we express our detailed views and conclusions as to the application of appropriate well-established or standard techniques to allow a credible and reliable equity beta to be derived from the data.

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[1] ESCoSA, 2005-2010 Electricity Distribution Price Determination, Part A – Statement of Reasons, p.135.

[2] ESCoSA, 2005-2010 Electricity Distribution Price Determination, Part A – Statement of Reasons, p.134-135.

1.6 In the Final Determination (p.134) ESCoSA quotes from our previous report that *"there is no single consensus approach for estimating equity betas"* as evidence that there is no standard technique or adjustment for deriving statistically reliable estimates from market data. This is both an incorrect conclusion and an incorrect application of the quoted section from our previous report. What we do conclude is that an appropriate equity beta cannot be determined by applying one single mechanical empirical technique to a single data set. An appropriate equity beta can only be determined by applying a range of empirical techniques to all of the relevant data and taking account of considerations such as economic reasonableness, commercial common sense, and the purpose for which the equity beta is to be used.

1.7 In the Final Determination (p.135) ESCoSA quotes from our previous report that the statistical imprecision of mechanical beta estimates "*goes to further reinforce the unreliability of statistical estimates of equity betas.*" This conclusion is identifying why using the data in a mechanical way *without* applying appropriate adjustments to address the unavoidable shortcomings in the data will not generate reliable outcomes. It is not suggesting that there are no techniques, adjustments, or considerations that can be jointly used to produce reliable outcomes. In this report we express our view as to the appropriateness and application of those techniques, adjustments, and considerations.

1.8 In the Final Determination (p.135) ESCoSA quotes from our previous report regarding the length of the data period which we said "*serves to further illustrate how fickle and unreliable standard beta estimates can be.*" Again, this conclusion applies to the use of mechanical analysis of the data *without* applying appropriate techniques, adjustments, and considerations to address the inherent nature of that data. It is not suggesting that there are no such techniques, adjustments, or considerations. As noted above, in this report we identify and apply those techniques, adjustments, and considerations.

1.9 In the Final Determination (p.135) ESCoSA quotes the conclusion from our previous report in relation to the effect that outlier data points have on beta estimates. In the earlier report, we demonstrated that one or two influential outliers (caused by the chance timing of firm-specific announcements and having nothing at all to do with the systematic risk that the beta estimate seeks to measure) can dramatically alter mechanical beta estimates. We simply noted the impact that outliers can have (consistent with the scope of our earlier report) and concluded that this "*demonstrates just how tenuous these beta estimates can be.*" It is incorrect to conclude from our earlier demonstration of the impact of outliers that there are no statistical techniques to address this problem. Our earlier report demonstrates the importance of this issue. In the present report we apply statistical analyses to identifying outliers and to adjust for those outliers in an appropriate manner. We also report the outcomes achieved when those appropriate adjustment techniques are applied.

1.10 In the Final Determination (p.135) ESCoSA concludes that our previous report did not "*identify any direct estimates of betas for Australian firms that they would propose that the Commission adopt*". This is correct, but it is incorrect to assume that this was the purpose or within the scope of our previous report. In the present report we have provided direct estimates of betas for Australian firms and demonstrate how these should be used to determine an appropriate equity beta that reflects current market conditions, consistent with the Electricity Pricing Order (EPO). These use "*well established or standard statistical techniques and practical adjustments*" to address the data problems identified in our earlier report and by ESCoSA in the Final Determination.

Nature and Purpose of Equity Betas

1.11 Equity beta measures the degree of risk associated with an equity investment in a particular business. It is therefore the main determinant of the return that equity investors require before committing capital to the firm.

1.12 Schedule 6 of the NEC notes that “beta is a measure of the extent to which the return on a given equity investment moves with the return on the equity market.” The reason for this is that if a firm’s shares move closely in line with movements in the broad market index, those shares provide the investor with little protection against a market correction.

1.13 The reason for computing an equity beta is to provide an estimate of the risk of owning shares in a particular firm over some future period. This risk estimate can then be used to determine the return that will be demanded by equity investors. Therefore, what is needed is a determination of the likely relationship (over the relevant future period) between the returns of those shares and the returns on the broad market.

Use of Historical Data

1.14 To the extent that the past relationship between stock returns on a firm (and other similar firms) and the market index is likely to be representative of the future relationship, historical data can help in determining the appropriate equity beta.

1.15 In some cases, there are reasons to suggest that some of the historical data do not reflect the likely future relationship between stock returns and market returns. This may be due to stock market bubbles or crashes or the existence of extreme outlier data points. If these events have occurred in the historical data with greater frequency than would be expected in future periods, they do not reflect the likely future relationship between stock and market returns and therefore are inconsistent with the purpose for which equity betas are employed. For example, if a four-year historical data period was contaminated by an unprecedented two year stock market bubble driven by technology stocks, using a beta determined from that four-year data set is equivalent to assuming that unprecedented stock market bubbles will occur in two out of every four years in the future.

1.16 If there is reason to suggest that some of the historical data does not reflect the likely future relationship between stock returns and market returns, a range of statistical techniques can be employed to account for this. For example, unrepresentative outlier data points or periods of stock market bubbles or crashes can be removed. Also, alternative data sets and data periods can be examined for consistency.

Range of Empirical Techniques

1.17 A range of statistical techniques and data sets can be used to determine an appropriate equity beta. No single approach is capable of producing a precise and statistically reliable beta that provides the optimal indication of the likely future relationship between stock and market returns. The appropriate approach, therefore, is to use a range of empirical techniques and data sources and to draw conclusions from the totality of the evidence. For example, suppose that one were seeking to predict the weather over the coming quarter. One strategy would be to assume that weather from the last quarter will simply be repeated. However, one might eliminate from the forecast the one-in-a-hundred-years flood that happened to occur last quarter – otherwise this is predicted to repeat every three months. One might also use a longer data set (over many years) to recognize that the next quarter is a different season. Another relevant consideration is the forecasts for next quarter that have been made by other meteorologists. The purpose of the forecast is also relevant – tide times are an important consideration if the forecast is to plan a fishing trip, but temperature is more relevant to organizers of a marathon race. The appropriate forecast will be based on a consideration of all of this information. A mechanistic extrapolation of last quarter's weather is clearly inappropriate.

Our Conclusions

1.18 We have applied a range of statistical methods to several different data sets with a view to determining the equity beta that best characterizes the likely future relationship between stock and market returns for an Australian energy distribution business.

1.19 All of the empirical techniques we examine, when properly applied to a range of market data sources, lead us to the conclusion that the appropriate equity beta for an Australian energy distribution business (with 60% gearing) is at least one. An equity beta estimate of 0.8 is unreasonable in light of the empirical evidence and the purpose for which it is to be used.

ESCoSA's Final Determination

1.20 In the Final Determination[3], ESCoSA says that it has "mainly considered beta values from three different sources: historical proxy betas, betas from overseas data, and betas used by other jurisdictional regulators," but relies primarily on betas for Australian energy companies that are computed in a mechanical way from raw data without applying any of the standard statistical corrections that are designed to improve the informativeness and reliability of those estimates. ESCoSA states that "the difficulty of making comparisons of beta estimates across countries suggests Australian regulated entities are likely to provide the most reliable source of beta estimates."[4] ESCoSA places relatively less weight on overseas data and regulatory precedent – it describes overseas evidence as "a secondary source" and the final beta estimate that is used is substantially lower than the estimates that have been accepted by other Australian regulators.

1.21 To summarise its analysis of Australian proxy betas, ESCoSA presents average relevered equity beta estimates for a small sample of energy firms in its Figures 10.2 and 10.3. These figures are based on mechanical beta estimates. There are no statistical adjustments for the effects of outlier data points or what ESCoSA refers to as the "technology bubble." Moreover, only one firm, AGL, has sufficient data to populate the entire duration of these figures – and the beta estimates used for this firm over the last year of analysis are negative. That is, these figures are based on estimates that imply that shareholders in the largest proxy firm, and the only one that has existed for the whole sample period, require a return less than the yield on government bonds. If used to compute a forward-looking cost of equity, the implicit assumption is that AGL shareholders will continue to require less than the yield on government bonds. There is also an implicit assumption that a technology bubble will repeat every four years and that statistical outliers will repeat with the unprecedented frequency with which they have occurred in recent times.

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[3] ESCoSA, 2005-2010 Electricity Distribution Price Determination, Part A – Statement of Reasons, p.138.

[4] ESCoSA, 2005-2010 Electricity Distribution Price Determination, Part A – Statement of Reasons, p.140.

1.22 The conclusion of our earlier report is that the type of analysis of Australian proxy firms that ESCoSA has performed provides little, if any, information about the returns that shareholders currently require from energy distribution firms. ESCoSA states that it is "cognisant of the statistical error" in these beta estimates, but concludes (based on a mechanical analysis of the scant data that is available) that "*this data* does not support a beta of 1.0."[5] In this report, we use a range of statistical techniques to account for outliers, the technology bubble, other statistical issues, and qualitative considerations such as economic reasonableness and commercial common sense. We show that the available data, when properly analysed and considered in its totality *does* support an equity beta of at least one.

[5] ESCoSA, 2005-2010 Electricity Distribution Price Determination, Part A – Statement of Reasons, p.135, emphasis added.

2. CONTEXT

2.1 THE ROLE OF EQUITY BETAS IN THE REGULATORY PROCESS

Weighted average cost of capital

2.1.1 The regulatory system applicable to ETSA Utilities allows regulated entities to earn a fair and reasonable return on capital, being the weighted average cost of capital (WACC). Schedule 6 of the NEC defines the WACC as follows: "The weighted-average cost of capital is a 'forward looking' weighted average cost of debt and equity for a commercial business entity. Accordingly, the Network Owner's weighted average cost of capital will represent the shadow price or social opportunity cost of capital as measured by the rate of return required by investors in a privately-owned company with a risk profile similar to that of the network company."

Capital Asset Pricing Model

2.1.2 Schedule 6 of the NEC states that "There is a variety of methods which can be applied to estimate the cost of capital of equity capital of a business enterprise. The Capital Asset Pricing Model (CAPM) remains the most widely accepted tool applied in practice to estimate the cost of equity. The CAPM is a model based on the proposition that the required rate of return on equity is equal to the risk-free rate of return plus a risk premium. The theory underlying the CAPM is rigorous. However, in applying the CAPM, there should be a recognition of the limitations of the model. The limitations of the CAPM, as with any model, relate mainly to the measurement and estimation of relevant input variables. Consequently, the CAPM should be regarded as providing an indication of the cost of equity, rather than a firm and precise measurement." Accordingly, when determining the value of parameters to be used in the CAPM, consideration should be given to their statistical reliability, their economic reasonableness, and the purpose for which the model is to be used.

2.2 THE AUSTRALIAN REGULATORY FRAMEWORK

Regulation of Natural Monopolies

2.2.1 Many infrastructure assets such as electricity networks, rail networks, ports, and water supply are natural monopolies. Customers can either purchase these infrastructure services from the monopoly provider or not at all.

2.2.2 Because it is a natural monopoly, an electricity distribution business may have an incentive to increase prices, at least in the short term – customers have no alternative source of supply. Thus, the monopoly electricity distribution business could charge excess prices for their services as there is no competition and very limited substitutes for their services.

2.2.3 For this reason, a regulatory regime has been introduced in Australia to control the prices charged by monopoly infrastructure businesses. The Australian Competition and Consumer Commission (ACCC) regulates businesses for which the Commonwealth has jurisdiction. Similar bodies exist in each state and territory for businesses that operate under state jurisdiction. The Essential Services

Commission of South Australia (ESCoSA) regulates the activities of South Australian infrastructure businesses, including the electricity distribution business ETSA.

The Role of the Regulator

2.2.4 The role of the regulator, in these cases, is to ensure that the particular infrastructure business does not exploit its position as a monopolist by charging excessive prices. The regulator's role is to ensure that prices are appropriate – neither excessive nor too low. The Australian regulatory regime is based on the notion that competition is the best means for ensuring the most efficient possible outcomes. Thus, the regulator seeks to replicate a commercial outcome – the outcome that would have occurred had the business been subject to competition, as provided in Clause 6.1.1(b)(3) of the NEC.

2.2.5 In addition, and to a similar effect, the ESC Act (s. 6) requires the regulator to "have regard to the need to promote competitive and fair market conduct, to prevent misuse of monopoly or market power,…and to facilitate maintenance of the financial viability of regulated industries and the incentive for long term investment." Clause 6.1.1(b)(2) of the NEC states an intention to "facilitate a commercial environment which is transparent and stable." Clause 6.10.2 of the NEC states the objective of providing for "on a prospective basis, a sustainable commercial revenue stream which includes a fair and reasonable rate of return."

Revenue Requirement

2.2.6 In the Australian regulatory environment, the regulator first estimates the revenue that the particular business would receive if it operated in a competitive market. This is known as the firm's "revenue requirement" and is designed to mimic a commercial outcome. The regulated firm's revenue requirement is constructed using what is known as a building block approach. This means that the firm's revenue must be sufficient to (i) meet the firm's operating expenses, (ii) meet the firm's capital expenditure requirements, (iii) provide the firm with a return *of* capital (depreciation), and (iv) provide the firm with a fair return *on* capital.

Return on Capital

2.2.7 The return on capital is an attempt to replicate the return that investors would require in order to commit funds to the firm. This often represents more than 40% of the regulated firm's revenue requirement. The return on capital is computed as the product of the regulatory asset base (RAB) and the weighted-average cost of capital (WACC).

2.2.8 The RAB is, in general terms, an estimate of the total value of the assets required by an efficiently operating firm to provide the required services to the required standard. This being so, the RAB also represents the total amount of capital invested in the assets of an efficient firm providing the services of the regulated entity.

2.2.9 The WACC is an estimate of the percentage return that investors would need to expect the firm to generate before committing their funds. Thus, if the firm has assets of $1 billion and investors require a 10% p.a. return to provide capital to such a firm, a return on capital of $100 million per year is included in the firm's revenue requirement. This replicates a commercial outcome – investors will only provide the necessary capital if they expect to receive an appropriate return.

2.2.10 The WACC is a weighted average of the firm's cost of debt and equity capital. That is, the regulated firm essentially raises two types of capital – it borrows from lenders (debt capital) and it sells ownership interests in the firm (equity capital). Providers of debt capital require a return to compensate them for the risk of lending money to the firm and providers of equity capital require a return to compensate them for the risk of holding an ownership interest in the firm. The weighted average of the return required by debt and equity holders is known as the WACC and this represents the firm's cost of funds.

Regulatory Incentives

2.2.11 Any business is only viable in the long term if it is able to generate returns at least equal to its WACC. Therefore, a firm will only undertake new investment if that investment is likely to generate a return that is at least equal to its WACC. To the extent that regulators have the responsibility of ensuring the ongoing viability of the industry and for creating the appropriate incentives for future investment, proper computation of the WACC is vital.

The regulator does not set the entity's cost of funds, but merely sets the allowed return.

2.2.12 It is important to note that a regulator cannot, and does not, precisely determine a firm's true cost of capital. Rather, the regulator uses market data to make some inferences about what the firm's cost of funds is likely to be and then sets a regulated return. Thus, there is a difference between the firm's true cost of funds (true WACC) and the regulated return (regulated WACC).[6]

2.2.13 To construct the regulated WACC, the regulator requires estimates of the return required by lenders (the cost of debt) and the return required by equity holders (the cost of equity).

2.2.14 The cost of debt is (relatively) easier to compute. The risk of lending to the firm is essentially measured in terms of a credit rating. Having established a likely credit rating, one can observe the returns that are currently available on corporate bonds (loans) to firms with that credit rating.

2.2.15 Estimating the cost of equity is undertaken by applying the Capital Asset Pricing Model (CAPM). Under the CAPM, investors require a higher return to invest in firms that are more risky. In particular, the return required on any investment is equal to the return that could be earned on risk-free government bonds plus a premium to compensate the investor for bearing risk. The greater the risk, the greater the premium that is required. Under the CAPM, risk is measured relative to the average investment and is known as "beta." The average investment has a beta of one. Assets that are riskier than average have betas higher than one and are required by investors to earn higher returns on average. Assets that are less risky than average have betas lower than one and are not required to earn such high returns on average.

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[6] ESCoSA has recognized this in the Draft Determination (p.159): "While there is a 'true' cost of capital for any activity in theory, any estimate of the cost of capital is subject to a large degree of statistical uncertainty or imprecision." This is confirmed in the Final Determination (p. 125). ESCoSA also implicitly recognizes the consequences of setting a mis-estimated regulated WACC below the firm's true cost of capital, noting that it must "provide investors with a return that is sufficient to motivate the investment and attract the capital away from alternative investments."

3. THEORETICAL BASIS FOR EQUITY BETAS AND CAPM

Market Risk Premium

3.1 The risk premium for the average investment is known as the market risk premium (MRP). Australian regulatory practice has been to set this market risk premium at 6%. This suggests that the average investment is expected to generate a return of 6% p.a. above the return that could be earned on risk-free government bonds, on average.

Beta and risk

3.2 A particular investment may be more or less risky than the average investment. More risky investments will require a greater risk premium than average, and conversely for lower risk investments. The beta of an investment gives an indication of the extent to which that investment is anticipated to be more or less risky than the average investment.

Diversifiable and systematic risk

3.3 Modern portfolio theory, on which the CAPM is based, considers two types of risk.

3.4 *Diversifiable risk* refers to events (both positive and negative) that may affect an individual firm. For example, the CEO may unexpectedly resign, an explosion may occur at a major pumping station, the firm may win a lucrative contract or discover a large ore deposit. These risks apply to an individual firm and do not affect the broad market. They are known as diversifiable risks because they can be eliminated if an investor holds a diversified portfolio of assets, rather than a single investment.[7]

3.5 *Systematic risk* refers to events that have an impact (positive or negative) on the broad market and so cannot be eliminated even in a broadly diversified portfolio. For example, the Reserve Bank may increase or decrease interest rates, oil prices may rise or fall unexpectedly, or the Federal Government may announce details of a significant tax reform package. Because it has an impact on the broad market, systematic risk is also known as *market risk*. Because this risk cannot be easily diversified away, investors will require a return premium to compensate them for bearing it.[8] Thus, systematic risk depends on the relationship between the returns of a particular investment and those of a broad market index (such as the All Ordinaries Index or ASX 200 Index). Under the CAPM, a firm's systematic risk is quantified in terms of its beta. Thus, under the CAPM beta measures the systematic risk of the firm's shares and determines the risk premium that investors require.

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[7] In a diversified portfolio, some assets will be the subject of unexpected good news and some the subject of unexpected bad news. The more diversified the portfolio, the more the good will tend to cancel the bad, leaving the investor with no net exposure to these diversifiable risks. These diversifiable risks are not relevant to asset returns under the CAPM, since investors are considered to hold diversified portfolios and therefore have no net exposure to such risks.

[8] Some firms are relatively more exposed to systematic risk and therefore require higher return premiums. Firms whose returns increase sharply in response to positive market news and decrease sharply in response to negative market news have high systematic risk. Firms whose returns are largely insensitive to market news have low systematic risk.

The CAPM

3.6 Under the CAPM, the required return on an investment is:

$$\begin{bmatrix} \text{Required} \\ \text{Return} \end{bmatrix} = \begin{bmatrix} \text{Risk - free} \\ \text{Return} \end{bmatrix} + \begin{bmatrix} \text{Premium for} \\ \text{Systematic Risk} \end{bmatrix}$$

The premium for systematic risk for the average stock is the market risk premium (an average over all stocks in the market). To the extent that the systematic risk, or beta, of an individual stock is higher or lower than for the average stock, the return premium that is required will be correspondingly higher or lower. The CAPM, therefore, characterises the return premium that investors require to compensate them for bearing systematic risk as equal to the market risk premium (for the average stock) adjusted up or down by the firm's beta.

3.7 By definition, the market portfolio is an aggregate of all investments available in the economy. The market portfolio has a beta of 1.0, which serves as a reference point. Investments with betas above 1.0 are of above average risk and are more sensitive to market movements and require returns above that expected on the broad market portfolio.[9]

Equity and asset betas

3.8 For the same reason that equity in a house that is heavily mortgaged is more risky than equity in a house that is owned outright, the risk of owning shares in a firm depends on (i) the type of business the firm operates and (ii) the amount of corporate debt that ranks ahead of the equity investment. The former risk can be termed *asset risk* and the latter *leverage risk*.

3.9 If a firm had no debt financing at all, the shareholders would only be exposed to asset risk. A firm's asset risk is quantified as an *asset beta*. This reflects the risk of operating a particular type of business (in relation to a broad market index).

3.10 If a firm does have some debt financing, there is leverage risk which must also be reflected in the risk of owning shares in the firm. The firm's *equity beta* incorporates both the risk of operating that type of business (the asset risk, as measured by the asset beta) and the risk of having debt finance that ranks ahead of equity (leverage risk). The process of adding the leverage risk to the asset beta in order to determine the equity beta is known as *levering* the asset beta. Throughout this report, we use the levering procedure that has been adopted by ESCoSA.[10]

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[9] This is because a high-beta stock does well when the broad market is up and poorly when the broad market is down. This is unattractive to investors – such a stock provides a good payoff when all other assets are doing well and does poorly when all other assets are down. An investor would only buy this kind of stock if it offered a high return. Conversely, investments with a beta below 1.0 are of below-average risk and have lower than average sensitivity to market movements and require lower returns than the broad market portfolio.

[10] ESCoSA, Draft 2005-2010 Electricity Distribution Price Determination, Part A – Statement of Reasons, p.168; ESCoSA, 2005-2010 Electricity Distribution Price Determination, Part A – Statement of Reasons, p.132. We also use the parameter estimates adopted by ESCoSA for this purpose, other than to use a debt beta above zero for Envestra for the reasons discussed in Section 5.4.

Proper basis for comparison of betas

3.11 A particular firm may have a beta different from 1.0 if the business in which it operates has low systematic risk or if it has different gearing than the average firm. In many cases, these effects work in opposite directions since lower-risk firms are often able to support higher amounts of debt. For example, regulated energy distribution firms are likely to have lower than average systematic risk but much higher than average (assumed) gearing. Thus, an estimated equity beta of 1.0 for an energy distribution company reflects the extent to which such a company is in an industry with below average systematic risk but above average gearing. It is inappropriate to suggest that an energy distribution company should have an equity beta below 1.0 simply because that type of business has below-average risk because this ignores the offsetting effect of high gearing.

3.12 The average firm in the Australian market has approximately 30% debt financing. Australian regulatory precedent is to use 60% debt financing as the appropriate level of gearing for energy distribution businesses and to apply an equity beta of 1 reflecting both the type of business and high leverage. If the 60% gearing assumption is replaced with 30%, consistent with the average firm in the Australian market, the appropriate equity beta falls from 1 to 0.57. Australian regulatory precedent is consistent with assuming that energy distribution businesses have a little more than half the risk of the average Australian firm, ignoring the effect of high gearing.[11]

Changes in betas over time

3.13 A firm’s equity beta reflects the extent to which returns on its shares vary in relation to the returns on a broad stock market index. This relationship between stock and market returns can vary over time, and therefore the firm’s equity beta can vary over time. However, any large change in a firm’s systematic risk over a short period of time must be attributable to specific economic events. For example, a firm may acquire a new business unit that operates in an industry that is riskier than the firm’s current operations. In this case, the average risk of the firm’s operations, and therefore its equity beta, would increase. Similarly, if a firm divests a business unit, the average systematic risk of its operations may change.

3.14 To the extent that empirical estimates of a firm’s equity beta change substantially over a short period of time and cannot be tied to any relevant economic event, it is more likely due to statistical aberrations in the data set being used than any true fundamental change in systematic risk and required returns. The smaller the data set and the more mechanical the estimation technique, the more likely it is that, absent a relevant economic event, any observed change in beta estimates is due to estimation error rather than a fundamental economic change in the firm’s systematic risk.

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[11] An alternative like-with-like comparison can be made by computing the equity beta of the average firm if it were geared to 60%, consistent with the regulatory gearing assumption for energy distribution firms. This involves beginning with the average firm’s equity beta of 1.0 and adjusting the effects of leverage from 30% to 60%. This process increases the equity beta of the average firm to 1.75. That is, Australian regulatory precedent is to assume that energy distribution firms have 60% debt finance. If the average firm were assumed to have this same level of gearing, its equity beta would be 1.75. This is the appropriate benchmark when comparing the asset risk of different businesses while holding leverage risk constant.

4. USING MARKET DATA TO ESTIMATE EQUITY BETAS

4.1. CONSIDERATIONS WHEN DETERMINING EQUITY BETAS

4.1.1 When determining an equity beta, one must have regard to the following considerations:

(i) The equity beta cannot be observed like a share price or interest rate, but must be inferred from the available data;

(ii) Many different empirical techniques are commonly used to estimate equity betas;

(iii) Many different data sets are commonly used to estimate equity betas;

(iv) The estimate from any single empirical technique applied to a single data set is not likely to be sufficiently statistically reliable to be the sole basis for the determination of an equity beta;

(v) To the extent that a particular data set is contaminated by observations that can be statistically identified as outliers, betas should be re-estimated after removing these outliers.

(vi) To the extent that a particular data set contains a significant market event (such as a stock market crash or bubble), betas should be re-estimated after removing this period. Failure to remove such a period is equivalent to assuming that the significant market event will repeat in the future, with the same frequency as in the data set being analyzed. For example, if a two-year bubble is included in a four-year data set, betas estimated using that data set effectively assume that such a stock market bubble will repeat, on average, in two of every four years in the future.

(vii) Regard must be had to the purpose for which the equity beta is to be used. For example a different set of considerations would apply if the beta is to be used to provide an estimate of the forward-looking required return on equity capital, than if it were to be used to measure the historical performance of a mutual fund manager – one is forward-looking and the other is backward-looking.

(viii) Regard must be had to the consequences of mis-estimating the equity beta. In some settings, the consequences of over-estimating the equity beta may be less severe than if the equity beta were underestimated. In other cases, the reverse is true.

(ix) Every beta estimate should be examined for economic reasonableness in light of commercial common sense.[12]

4.1.2 The equity beta should be determined after a thorough analysis of all relevant data using all appropriate empirical methods. The aggregate results should be tested for economic reasonableness and examined in light of the purpose for which the equity beta is to be used. That is, the determination of an appropriate equity beta involves a comprehensive quantitative analysis informed by a number of qualitative considerations.

4.2. USING QUANTITATIVE TECHNIQUES FOR DETERMINING EQUITY BETAS

Use of historical data

4.2.1 Since the equity beta is to be used to provide an estimate of the forward-looking cost of equity capital, historical data should only be used to the extent that it provides a useful indication of the future relationship between stock and market returns. Indeed, historical data should be used in a manner that provides the best indication of the likely future relationship between stock and market returns, i.e. establishes the "prevailing conditions in the market" required by Schedule 10 of the EPO. If this requires the elimination of outliers or stock market bubbles or crashes, then this should be done. It is important to consider the purpose for which the equity beta is to be used, and not to place too much reliance on estimates that are constructed by mechanically processing small data sets.

Using a range of methods

4.2.2 Due to the nature of the data that is used, no single statistical method applied to a single data set is capable of producing a unique precise, robust, and statistically reliable estimate of beta. The appropriate approach, therefore, is to use a range of empirical techniques and data sources such that various approaches may corroborate one another. These various approaches form the basis for the quantitative determination of the equity beta, in light of a consideration of the purpose for which it is to be used.

4.3. ORDINARY LEAST SQUARES REGRESSION

The starting point: OLS regression

4.3.1 The starting point when estimating equity betas is an ordinary least squares (OLS) regression of stock returns on market returns. This usually involves using four or five years of monthly stock returns and monthly returns on a broad stock market index portfolio. The slope coefficient from a standard OLS regression of stock returns on market returns is then used as an estimate of the equity beta.

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[12] For example, it is unlikely that one firm's true equity beta should differ markedly from the equity betas of comparable firms without some identifiable economic or market-related explanation. It is also unlikely that a firm would have a negative equity beta as this would imply that investors would be happy to buy shares in the firm even though they expect it to earn a return less than the yield on risk-free government bonds.

Regulatory fears about the lack of precision

4.3.2 The OLS regression approach does not produce precise and robust results, especially in the Australian context where data is scant due to the very small numbers of comparable proxy firms. As with any regression, the estimated coefficient is not a precise calculation, but simply an estimate. The standard statistical (and legitimate) interpretation of the estimated coefficient from any regression is that the true value of this parameter comes from a normal distribution with mean equal to the parameter estimate and standard deviation equal to the standard error of the estimate. That is, the regression approach does not compute the true forward-looking beta, it merely narrows down the historical proxy for the true beta to within some probabilistic range.[13]

4.3.3 Australian regulators generally recognize the statistical imprecision of these OLS beta estimates. The Victorian Essential Services Commission (ESC), for example, have noted their concern for the reliability of beta estimates in its Electricity Distribution Price Review Preliminary Issues Paper stating that "given the lack of reliability of, and imprecision associated with, capital market information the Commission is reluctant to move too far from the range of proxy betas that have been adopted in comparable regulatory decisions. In order to reduce uncertainty across regulatory periods the Commission considers it appropriate to exercise its judgment in a conservative manner."[14]

4.3.4 ESCoSA has also recently expressed concerns about the reliability of beta estimates[15] stating that, "it is concerned at the apparent lack of precision with the current market evidence" and stating a view that current statistical beta estimates "may reflect a short-term aberration." ESCoSA also noted in their Preliminary Views Paper (2004, p. 53) that, "beta estimates are also subject to substantial statistical uncertainty" and that, "other regulators have expressed concern about the degree of statistical imprecision with the available beta estimates for the comparable Australian listed entities (p. 54)." This has been confirmed in the Final Determination, where ESCoSA states (p. 135) that it is "cognisant of the statistical error" in beta estimates and that (p.140) its results "show the statistical imprecision in the current beta estimates."

4.3.5 Similar concerns have also recently been expressed by the Queensland Competition Authority (QCA)[16] who note that, "Australian regulators have expressed concern about the degree of statistical imprecision associated with available beta estimates for comparable Australian listed entities."

4.3.6 Importantly, the ACCC has recently stated that "current statistical methods for estimating the equity beta from market data tend to produce varying confidence interval (and sample average) estimates. The ACCC also notes that the time period of the market data is not long enough to satisfy

[13] The width and range of this distribution depends on how precisely the coefficient can be estimated. It is the standard error of the regression estimate that measures the precision with which it has been estimated. Typically equity beta estimates, computed by regressing stock returns on market returns, have large standard errors. This means that they are imprecisely estimated and cannot be relied upon with any great confidence.

[14] ESC, Electricity Distribution Price Review 2006-10 Issues Paper, 2004, p.93.

[15] ESCoSA Draft 2005 - 2010 Electricity Distribution Price Determination: Part A - Statement of Reasons, p. 171.

[16] QCA Draft Determination Regulation of Electricity Distribution. December 2004. p. 99.

the ACCC that market derived equity betas would not systematically under-estimate the [transmission network service providers]. That is, the current decline in the measures of market derived equity betas may reflect a short-term deviation from normal trend…In recognition of these shortcomings, the ACCC proposes to continue with exercising judgement in its application of empirical evidence from the market…The ACCC will apply an equity beta of 1."[17]

Mechanistic application

4.3.7 A number of commercial data services provide equity beta estimates that are mechanically computed by applying OLS regression to data sets comprising 4-5 years of monthly stock and market returns. These beta estimates are computed mechanically without any adjustment for statistical outliers, non-representative data points, or market episodes such as crashes or bubbles. To the extent that these events are unlikely to be representative of future outcomes, these beta estimates do not provide an appropriate estimate of the expected future relationship between stock and market returns.

4.3.8 For example, in the most recent beta report from the Risk Measurement Service at the AGSM (December 2004) more than 10% of the reported OLS beta estimates are negative.[18] This implies that one in ten Australian firms can raise equity capital by promising returns lower than the yield on risk-free government bonds. Clearly, this is more a reflection of statistical problems in the mechanical analysis than prevailing market conditions. For this reason, OLS equity beta estimates from commercial data services should only ever be the starting point when determining a forward-looking equity beta and should always be subjected to and compared with the results of a much broader analysis.

Recent Beta estimates from commercial data services

4.3.9 The fears that have been expressed by a number of Australian regulators, in relation to the statistical reliability of the mechanical beta estimates that are produced by data services, are clearly borne out by recent beta estimates of Australian energy distribution firms. Consider, for example, the most recent beta estimates published by the Risk Management Service (RMS) at the Australian Graduate School of Management. RMS betas are based on 48 monthly observations of the return of the stock being evaluated and the return on a broad market index. They are computed mechanically with no adjustments for statistical outliers or unique market events such as crashes or speculative bubbles.

4.3.10 The RMS publishes betas computed using Ordinary Least Squares Regression (OLS)[19] and after applying the Scholes-Williams procedure. The Scholes-Williams procedure provides a statistical correction for non-synchronous trading.[20] This correction is designed to correct for the fact that a particular stock may trade more or less frequently than the average stock in the index. It is not

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[17] ACCC, Statement of Principles for the Regulation of Electricity Transmission Revenues – Background Paper.

[18] In addition, for 20% of firms listed on the ASX, betas could not be computed due to lack of data.

[19] See Technical Appendix 1 for a description of this technique.

[20] Whereas OLS betas are computed by regressing stock returns on contemporaneous market returns, the Scholes Williams procedure includes market returns from the prior and subsequent periods as well. That is, the Scholes-Williams approach is a mechanical regression procedure, simply with more explanatory variables.

designed to correct for outliers, unique data periods, or statistical imprecision. It is really only required only for small firms that trade infrequently. We report them here only for completeness and because they are available from a commercial data source. The standard 95% confidence intervals for equity betas of Australian energy distribution firms, as published by the RMS, appear in Table 1.

Table 1: Point Estimates and 95% Confidence Intervals for Australian Proxy Firms, Re-geared to 60%.

Company	OLS			Scholes-Williams		
	Lower 95% Confidence Interval	Point Estimate	Upper 95% Confidence Interval	Lower 95% Confidence Interval	Point Estimate	Upper 95% Confidence Interval
AGL	-0.83	0.05	0.94	-1.69	-0.20	1.30
Alinta	-0.36	0.71	1.78	-1.31	0.67	2.66
Envestra	0.02	0.28	0.53	-0.47	0.03	0.53
APT	0.02	0.52	1.01	-0.02	0.92	1.86
GasNet*	-0.20	0.15	0.50	-0.75	-0.16	0.44

Source: Risk Measurement Service Beta Report, December 2004, RMS, AGSM. The table reports the upper and lower 95% confidence bounds from the AGSM beta report, each re-levered to 60% gearing using gearing estimates from ESCoSA's Draft Determination Table 10.2 and a debt beta of zero.

*Due to its recent listing, estimates for GasNet are based on an incomplete data set.

Problems with these mechanical estimates

4.3.11 There are many reasons why the mechanical beta estimates reported in Table 1 should not be relied upon: the degree of statistical imprecision is so large as to make the estimates uninterpretable, the estimates change substantially if a small number of influential outliers are removed, the estimates are substantially affected by the data from the period of the stock market technology bubble, and in many respects the estimates fail the tests of economic reasonableness and commercial common sense. These problems are dealt with in turn in the remainder of this section.

Problem 1: Statistical imprecision makes the estimates uninterpretable

4.3.12 It is standard statistical practice to compute a 95% confidence interval around estimated coefficients, as displayed in Table 1. The proper interpretation then, is that the true value of the parameter that is being estimated is likely to lie within this range. Alternatively, one can test the hypothesis that the true value of the parameter is *x*, by examining whether *x* lies within this confidence interval.

4.3.13 The huge width of the confidence intervals reported in Table 1 illustrates just how imprecise these individual estimates are.[21] The appropriate statistical interpretation of Table 1 is that the true beta comes from somewhere within the indicated range. These confidence intervals are very wide and the true beta can only be narrowed down to being somewhere within this wide range.

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[21] Recall that the Scholes-Williams estimates correct for thin trading in the stocks being examined and in the benchmark index of stocks. This technique is not designed to improve statistical precision.

4.3.14 In many cases, it is impossible to reject the hypotheses that the beta estimate is below zero and it is also impossible to reject the hypothesis that it is well above one. The statistical precision of these estimates is so poor that they are of little use.

Problem 2: Inconsistency among sample firms

4.3.15 There is dramatic variation among the beta point estimates in Table 1. This inconsistency arises even though the firms were carefully selected by ESCoSA to be comparable to each other, and even after differences in gearing have been controlled for. It is unsettling that such dramatic variation among the sample firms should exist. There is even considerable variation in the estimates for the same firms produced by the two different methods. According to the estimates in Table 1, the return required on an Australian energy distribution firm, re-geared to 60%, could be more than 1% p.a. less than the yield on government bonds, or more than 5% above.

4.3.16 If such dramatic variation exists, after business risk and gearing have been controlled for, it is standard to investigate possible reasons for this inconsistency. It is wrong to simply ignore the inconsistency and take the mean of this range of dramatically inconsistent estimates to determine the forward-looking cost of equity.

Problem 3: The effects of unrepresentative outliers

4.3.17 One potential reason for the wide confidence intervals and economically unreasonable estimates is that the particular data period that is being examined is characterized by an unusually large number of extreme outlier data points. The removal of these outliers is likely to increase the precision of OLS beta estimates and reduce the width of the standard confidence interval. To the extent that these observations are not representative of likely future outcomes, there is an additional reason to omit them from the analysis.

4.3.18 Because so few data points are usually used to estimate equity betas (e.g., RMS betas are based on just 48 return observations) a single outlier can significantly influence the final estimate. In particular, outliers in which the firm's stock moves in a direction opposite to the market can cause a significant reduction in the beta estimate. For example, AGL produced a +5% stock return on the back of positive results announced in September 2001. The fact that this occurred in a month in which the broad market was down 6% (primarily due to terrorist activities in the U.S.) causes the estimated beta to be significantly lower than it would otherwise have been. Also, the AGL stock price fell by 12% in January 2001 amid power rationing and systematic billing problems. These events just happened to occur in a month in which the broad stock market rose. The questions here are (i) whether these events are one-off chance events or representative of likely future outcomes, and (ii) how much they influence beta estimates.

4.3.19 To examine the sensitivity of beta estimates to a single influential data point, we choose a single observation and ask—how much would the beta estimate change if this observation had occurred in a month in which the market rose instead of falling (or vice versa). Consider September 2001, for example. If AGL had announced positive results and risen 5% in a month in which the market advanced (instead of declining due to terrorist activity) how much would the beta estimate change? In Table 2, we show how much the standard OLS beta estimate changes, computed with four years of monthly data, if one or two outlier observations were changed as described above.

Table 2: Impact of Outliers on OLS Equity Beta Estimates, Re-geared to 60%.

Company	OLS Estimate	One Observation Changed OLS Estimate	Two Observations Changed OLS Estimate
AGL	-0.04	0.55	0.98
Alinta	0.64	0.83	1.01
APT	0.33	0.58	0.72
Envestra	0.22	0.29	0.41

Source: AGSM monthly data file, using 4 years of monthly data 2001-2004. Beta estimates are re-levered to 60% gearing using gearing estimates from ESCoSA's Draft Determination Table 10.2 and a debt beta of zero.

4.3.20 The results of this exercise are clear. Had one or two stock observations occurred in a different month, the beta estimate would have been dramatically different. Given the pronounced effect that a small number of outliers can have on beta estimates, it is wrong to simply ignore the existence and effect of outliers when determining an equity beta to indicate the forward-looking cost of equity.

4.3.21 Another way of quantifying the impact of outliers is via the R^2 statistic from the regression that is used to compute the beta.[22] This statistic measures the proportion of the variation in stock returns that is explained by variation in market returns. The remainder of the variation in stock returns is explained by firm-specific factors such as earnings announcements and the like. Beta seeks to measure the relationship between stock and market returns. When most of the variation in stock returns is explained by variation in market returns, the R^2 statistic is high and the regression is highly informative about beta. Conversely, when most of the variation in stock returns is driven by firm-specific factors, the R^2 statistic is low and the regression is less informative about beta – even though stock returns might be highly sensitive to market returns, this may be swamped in the data set by a series of important firm-specific events making it difficult to detect the true relationship. By analogy, it is difficult to measure the ripples that are caused when a stone is thrown into two metre waves, even though the stone does indeed cause ripples. Bowman and Bush (2004) recommend that beta estimates for comparable firms should be used only if the R^2 statistic is above 10%.[23] They argue that in cases where more than 90% of the variation is caused by firm-specific diversifiable risk factors, estimates of systematic risk (beta) is too unreliable to be of any use.

4.3.22 The R^2 statistics for the OLS beta regressions reported by the AGSM Risk Management Service in its most recent report (re-geared and set out in Table 1 above) appear in Table 3. This is the same type and source of data that ESCoSA uses in its Figure 10.2.[24] These R^2 statistics are all less than 10% and would therefore all be eliminated by the Bowman-Bush criteria. The mean is less than 5%. This means that we are seeking to measure the relationship between stock and market returns, but that only 5% of the variation in stock returns is explained by market returns. The other 95% of the variation in stock returns is driven by firm-specific factors and swamps any attempt to reliably estimate beta. Finally, we note that for the largest proxy firm, AGL, the RMS reports a beta estimate that is based on

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[22] The R^2 statistic is defined and discussed in more detail in Technical Appendix 1.

[23] They state that in their analysis "Firms are excluded from the sample if their beta estimate, obtained from Bloomberg, had an R^2 below a threshold of 10%. The purpose of this threshold is to curb the downward bias in the beta estimates that results when there is little explanatory power.

[24] ESCoSA 2005 - 2010 Electricity Distribution Price Determination: Part A - Statement of Reasons, pp. 139.

a regression that explains a negligible amount of the variation in stock returns. This is consistent with our analysis of outliers below and helps to explain why the data may have produced an economically unreasonable beta estimate of essentially zero. That is, these regression estimates are swamped twenty-fold by non-market noise, they are statistically unreliable, and should not be used without first trying to improve their statistical reliability.

Table 3: Informativeness of OLS Beta Regressions: Monthly Data

Company	**R^2 statistic**
AGL	0%
Alinta	4%
APT	9%
Envestra	9%
GasNet	2%

Source: RMS Beta Report, December 2004.

4.3.23 In the Final Determination, ESCoSA also considers beta estimates computed by applying OLS regression to rolling samples of 60 weekly observations of stock and market returns.[25] This involves data for only a little over a year and is therefore too short a period to provide any sort of meaningful analysis. Commercial data services do not report beta estimates over such a short period.[26] Moreover, when stock and market returns are measured over shorter periods, the statistical problem of non-synchronous trading becomes more pronounced. For this reason, it is wrong to rely upon betas estimated using weekly data over the course of a single year. Nevertheless, for purposes of comparison, we report in Table 4 the R^2 statistics from regressions of 60 weekly observations of stock and market returns ending in December 2004. As expected, these results are even more alarming than for the regressions based on four years of monthly data. None reach the Bowman-Bush threshold of 10% and the average is less than 3.5%.[27] In summary, the weekly data set produces beta estimates that are also unreliable.

Table 4: Informativeness of OLS Beta Regressions: Weekly Data

Company	**R^2 statistic**
AGL	1.8%
Alinta	9.2%
APT	0.5%
Envestra	0.1%
GasNet	5.9%

Source:SIRCA Core Research Data, SFG Analysis using 60 weekly observations ending in December 2004.

[25] See, for example, the material underlying Figure 10.3, ESCoSA 2005 - 2010 Electricity Distribution Price Determination: Part A - Statement of Reasons, pp. 139.

[26] Using weekly rather than monthly returns does not increase the amount or informativeness of the data. If we wish to estimate a city's average annual rainfall, for example, we would require rainfall data from a number of recent years. We could tell little by simply observing the rainfall from last year. Taking last year's data and dividing it up into monthly or weekly observations does not help at all – we simply need more data.

[27] To extend our earlier analogy, this is equivalent to trying to measure a 3mm ripple in one metre waves.

Problem 4: The effects of the technology bubble

4.3.24 Whenever historical data is used to estimate equity betas, the features of the dataset that is used are effectively assumed to recur in the future, with the same frequency with which they occur in the data set. For example, if a four-year data set is used, and this period happens to contain a stock market crash, a beta estimated with reference to this data implicitly assumes that such a crash will occur once every four years on average. Similarly, if a two-year bubble is included in a four-year data set, betas estimated using that data set effectively assume that such a stock market bubble will repeat, on average, in two of every four years in the future. In the Final Determination, ESCoSA recognizes that such significant market events can have a pronounced effect on beta estimates.[28] Consequently, such events must be carefully considered when determining an equity beta to indicate the forward-looking cost of equity.

Problem 5: Commercial common sense and economic reasonableness

4.3.25 The set of equity beta point estimates in Table 1, which are from the same source as those relied upon by ESCoSA, violates the tests of commercial common sense and economic reasonableness in a number of respects.

4.3.26 First, the results are disparate and inconsistent. Some are negative, some are close to zero and others are close to one. This implies that equity investors require dramatically different returns from different firms even after controlling for differences in leverage. Recall that these firms were chosen on the basis of their comparability to each other and to ETSA Utilities. If the beta estimates in Table 1 are to be believed, however, the firms are not at all comparable to each in the minds of equity investors. The alternative explanation, of course, is that these firms are indeed comparable but that the equity beta estimates in Table 1 are imprecise and statistically unreliable. If one believes that these firms are comparable to one another, and to ETSA Utilities, the wide range of beta estimates is not economically reasonable. In this case, the proper approach is to explore the statistical reasons for how the data and methodology that is used could lead to the mis-estimation of equity betas.

4.3.27 Second, some of the point estimates and most of the confidence intervals contain negative beta estimates. This suggests that equity investors require a return less than the yield on risk-free government bonds, which defies commercial common sense.

4.3.28 Third, some of the confidence intervals contain beta estimates near, and above, two. This implies that equity investors require a return around 12% p.a. in excess of the yield on risk-free government bonds, which also defies commercial common sense.

Proper use of historical data to estimate equity betas

4.3.29 The point here is that it is wrong to determine an equity beta by simply taking the mean from a small set of disparate and inconsistent beta estimates mechanically computed by a commercial data service. This approach does not produce a beta estimate that can be relied upon with any reasonable degree of confidence. To properly determine an equity beta, it is necessary to examine a series of techniques to improve upon mechanical beta estimates and to examine other data. This may include an

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[28] ESCoSA, 2005-2010 Electricity Distribution Price Determination, Part A – Statement of Reasons, p.138.

expansion of the period of data being examined, an increase in the number of firms, the elimination of outlier data points and periods, a method of averaging the beta estimates of comparable firms, or examining other sources of data. All of these possibilities, and a range of qualitative considerations such as commercial common sense and economic reasonableness, should be examined in the process of determining an appropriate equity beta.

Reliance on mechanical beta estimates in the Final Determination

4.3.30 In the Final Determination[29], ESCoSA says that it has "mainly considered beta values from three different sources: historical proxy betas, betas from overseas data, and betas used by other jurisdictional regulators," but relies primarily on historical proxy betas from Australian energy companies. ESCoSA states that "the difficulty of making comparisons of beta estimates across countries suggests Australian regulated entities are likely to provide the most reliable source of beta estimates."[30] It describes overseas evidence as "a secondary source." The final beta estimate that is used is substantially lower than the estimates that have been accepted by other Australian regulators.

4.3.31 ESCoSA's analysis of Australian proxy firms is based on beta estimates provided by the Risk Measurement Service at the AGSM. These betas are computed by applying OLS regression to monthly stock and market returns over a minimum of two and a maximum of four years. There are no statistical adjustments for the effects of outlier data points or what ESCoSA refers to as the "technology bubble." There are no checks for economic reasonableness or for consistency with like firms. ESCoSA has not disclosed, discussed or addressed the R^2 statistics in relation to these beta estimates.

4.3.32 The Final Determination also considers betas estimated from samples of 60 weekly observations of stock and market returns.[31] For the reasons described in 4.3.23, these estimates are even less reliable than the mechanical estimates based on four years of monthly observations in several respects. First, the weekly data cover little more than one year which is too short a period to provide any meaningful analysis. Second, no adjustments have been made for statistically-identified outliers or estimation error. Third, the R^2 statistics from these types of regressions are almost negligible and fail the Bowman-Bush threshold, which indicates that they are unreliable and uninformative about the true systematic risk of the companies. Fourth, when stock and market returns are measured over shorter periods the statistical problem of non-synchronous trading becomes more pronounced, yet no adjustment (such as computing Scholes-Williams betas) is made.

4.3.33 For the reasons outlined above, we conclude that mechanical beta estimates, whether based on weekly or monthly data sets, are so unreliable as to not justify the drawing of any conclusion as to an equity beta that could be used in the CAPM.

4.3.34 If the period of the technology bubble is removed, only one firm (AGL) has sufficient data to estimate an equity beta using five years of monthly data – and the beta estimates used for this firm over the last year of analysis are negative. That is, these figures are based on estimates that imply that

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[29] ESCoSA, 2005-2010 Electricity Distribution Price Determination, Part A – Statement of Reasons, p.138.

[30] ESCoSA, 2005-2010 Electricity Distribution Price Determination, Part A – Statement of Reasons, p.140.

[31] ESCoSA 2005 - 2010 Electricity Distribution Price Determination: Part A - Statement of Reasons, pp. 139.

shareholders in the largest proxy firm, and the only one that has existed for the whole sample period, require a return less than the yield on government bonds. If used to compute a forward-looking cost of equity, the implicit assumption is that AGL shareholders will continue to require less than the yield on government bonds. There is also an implicit assumption that a technology bubble will repeat every four years and that statistical outliers will repeat with the unprecedented frequency with which they have occurred in recent times.

Improving on mechanical beta estimates

4.3.35 In the remainder of this section, we describe a range of techniques that are often used to improve upon mechanical beta estimates.

4.4. STATISTICAL TECHNIQUES TO IMPROVE OLS BETA ESTIMATES

4.4.1 A number of statistical techniques have been proposed to improve simple OLS beta estimates.

The Blume Adjustment for Non-Persistent Estimation Error

4.4.2 Commercial providers of beta estimates, including Bloomberg and ValueLine, apply a statistical adjustment that is designed to correct for the type of estimation error that pervades simple OLS regression estimates. This adjustment is based on the work of Blume (1975) who shows that beta estimates exhibit mean reversion over time. That is, a firm's OLS beta estimate is more likely to move towards one from one period to the next.[32]

4.4.3 Blume (1975) recommends that a statistical adjustment should be applied to simple OLS beta estimates to incorporate this observed mean reversion. The Victorian regulator (the Essential Services Commission or ESC) has rejected the use of the Blume adjustment and ESCoSA has followed the Victorian ESC decision in this regard.

4.4.4 In outline, the Victorian ESC observed that one reason for the observed mean reversion in beta estimates is that the true beta (the firm's systematic risk) really does tend to move towards one over time. This would occur, for example, if firms pursued a policy of diversification across different business units over time. Thus, a firm with a low beta (less than one) would seek investments in other industries. These new investments would more likely have higher systematic risk than the existing firm (since the average investment has a beta of one, which is higher than that of the existing firm). Therefore a policy of corporate diversification leads the firm's systematic risk towards one. At the extreme, of course, the firm would be diversified across all industries in the economy and would have a beta of exactly one. Another explanation put forward was that a low-beta firm may be more likely to increase its gearing in the future as low-risk firms are relatively more able to attract debt finance on attractive terms. Higher gearing increases the risks of holding equity in the firm and therefore the equity beta.

4.4.5 The Victorian ESC argued that, in effect, if these were the reasons for the observed mean reversion of beta estimates, it would be inappropriate to apply the Blume adjustment in the Australian

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[32] Suppose a firm has a low OLS beta estimate (less than 1.0) based on current data. When re-estimated a year later using an updated data set, the same firm's OLS beta estimate is more likely than not to be higher.

regulatory setting.[33] After acknowledging the empirical support for the phenomenon, the ESC attributed it "to the conscious behaviour of managers – such as by undertaking projects with less extreme risk characteristics or by manipulating capital structures."

4.4.6 However, the ESC's argument that conscious diversification or gearing strategies cause the observed mean reversion is flawed. There is no evidence that firms in general pursue a policy of diversification, so this is not the cause of the observed mean reversion. In recent decades, firms have been more likely to divest non-core assets to focus the firm on its key strengths. There is also no evidence that low-beta firms tend to increase gearing in future periods. Low-beta firms do tend to have higher gearing on average, but what is relevant here is not the *level* of gearing but the likely *change* in gearing in future periods. Thus, the ESC has rejected the correction for mean reversion under the assumption that the observed mean reversion is caused by the conscious actions of managers in diversifying or increasing gearing. But there is no evidence to support this.

4.4.7 There is an alternative (and more likely) explanation for the observed mean reversion in OLS beta estimates. Recall that the observed phenomena is that simple OLS beta *estimates* revert toward one. The above explanation assumes that true betas (the firm's actual systematic risk) revert towards one over time. It is, however, possible that beta *estimates* may revert toward one even though *true* betas are stable. The fact that beta estimates are potentially contaminated by significant measurement error is well accepted. A very low beta estimate is more likely to be contaminated by negative measurement error and a high beta estimate is more likely to be contaminated by positive measurement error. If measurement error is random over time, this would manifest itself as beta *estimates* regressing toward one over time even if true betas are constant. That is, Blume-type adjustments should be interpreted in the context of measurement error rather than a conscious decision undertaken to move the firm's true beta toward one.[34]

4.4.8 Given that the observed mean reversion in equity beta estimates is more likely caused by random measurement error in beta estimates rather than by conscious managerial decisions, it is appropriate to apply the Blume adjustment.

The removal of influential outlier observations

4.4.9 Because so few data points are usually used to estimate equity betas (e.g., RMS betas are based on just 48 return observations) a single outlier can significantly influence the final estimate. In particular, outliers in which the firm's stock moves in a direction opposite to the market can cause a

[33] Review of Gas Access Arrangements: Final Decision (p. 341).

[34] An analogy may help to further illustrate this point. Consider the exercise of measuring the duration of television commercials, and suppose that every commercial actually lasts for exactly thirty seconds. Also suppose that we use an unreliable watch to measure the duration such that times are randomly under- or over-estimated. That is, our estimates will be contaminated by random measurement error. If we measure the duration of a particular advertisement to be 25 seconds, this is contaminated by negative measurement error. If we re-measure the duration the next time that advertisement appears, we will likely record a higher measurement given that the actual duration is 30 seconds and measurement error is equally likely to be positive or negative. Thus, even though there is no change in the *actual* duration of the commercial, random measurement error causes the *estimated* duration to revert toward one, on average.

significant reduction in the beta estimate.[35]

4.4.10 The questions here are (i) whether these events are one-off chance events or representative of likely future outcomes, and (ii) how much they influence beta estimates. The former question is analyzed by determining the number of outliers in the data set that is used to construct the beta estimate. If that data set contains an unusually high number of outliers, the beta estimate produced by analyzing that data is unlikely to be representative of future periods – its predictive ability is likely to be poor. Using that beta estimate is equivalent to assuming that the frequency and type of outliers in the data set that was analyzed is representative of what is expected in future periods. Alternatively, statistical techniques can be used to eliminate outliers or at least to measure their impact on beta estimates.

4.4.11 To quantify the extent to which any bias caused by outliers may affect beta estimates, we conducted a series of simulation experiments calibrated to actual market data. The full detail of these experiments is contained in Technical Appendix 2. In that appendix, we demonstrate how outlier data points can cause a bias in beta estimates, upwards or downwards.

4.4.12 It is clear that outliers can cause a substantial bias in equity beta estimates. The size and direction of this bias depends on (i) the relative frequency of outliers in the data set being analysed, (ii) the magnitude of these outliers, and (iii) the correlation between these outliers and market returns. A complete determination of equity beta requires that all of these issues be examined and taken into account. If there is potential for equity beta estimates from a particular sample to be biased by outliers, accepted statistical techniques for the identification and removal of outliers should be employed. These more robust outlier-resistant estimates would then form part of the information set that is used to determine the appropriate equity beta for a particular purpose. As with all empirical estimates of beta, they should always be subjected to and compared with the results of a much broader analysis.

The removal of unrepresentative market events such as stock market crashes and bubbles

4.4.13 Annema and Goedhart (2003) use U.S. data to examine the impact on beta estimates of the telecom-media-technology (TMT) stock market bubble of 1998-2001. They note (p. 1) that, "despite volatility in the market during the 20 years before 1998, industry-specific betas were remarkably stable. But during the bubble, betas for many industries appeared to decline significantly…these apparent decreases actually reflect the influence of telecom, media, and technology share prices on the indexes during the 1998-2001 bubble and distort the real change in the relative risk borne by companies in other industries." They also note (p. 3) that, "recent beta estimates are also more closely in line with pre-1998 values."

4.4.14 Annema and Goedhart (2003) suggest that these issues can be best handled by re-estimating betas after excluding the 1998-2001 period. This has the effect of substantially increasing the estimates of utility betas to pre-bubble levels. The conclusion from this is that the recent low estimates of beta for energy distribution companies are more an aberration caused by the dramatic and unusual behavior of companies in other industries and are not due to sudden and dramatic changes in the systematic risk of utilities. Since such unusual behavior is not predicted to re-occur in every future four-year

[35] For example, AGL produced a +5% stock return on the back of positive results announced in September 2001. The fact that this occurred in a month in which the broad market was down 6% (primarily due to terrorist activities in the U.S.) causes the estimated beta to be significantly lower than it would otherwise have been. Also, the AGL stock price fell by 12% in January 2001 amid power rationing and systematic billing problems. These events just happened to occur in a month in which the broad stock market rose.

regulatory cycle, the contaminated period should be removed when determining the equity beta that is to be used to estimate the forward-looking cost of equity.

4.4.15 In the Review of Gas Access Arrangements: Final Decision (p. 348), the ESC (2002) presented a figure to suggest that the impact of this bubble was larger in the U.S. than in Australia. This would seem to lessen the influence of U.S. comparables and focus more reliance on the tiny set of Australian comparables.

4.4.16 However, the Australian regulators who have had detailed analysis carried out, now generally accept that this unique market event is likely to have downwardly biased equity beta estimates for utility stocks, even in Australia[36].

4.4.17 ESCoSA[37] devotes a subsection to this issue in its recent Draft Decision, noting that, "betas estimated using four or five years of observations will include the period over which the 'bubble' in technology related shares took place. It has been argued by a number of commentators that the 'bubble' has substantially reduced the measured betas for U.S. utility firms over the period, making those betas an unreliable guide to the future." ESCoSA[38] concludes that, "the results suggest that there is a material risk that the beta estimate provided by the use of observations over the past five years (which include the 'bubble') may materially understate the expected (future) beta for this activity." In the Final Determination, ESCoSA confirms that "the Commission recognizes that the technology bubble may have had an impact in the historical proxy beta values."[39]

4.4.18 In the QCA's case, these views are based on work performed by the Allen Consulting Group and contained in the recent ACG Report[40] to the QCA. After a substantial analysis of the issue and consideration of a whole range of empirical estimates, the conclusion is that, "the Allen Consulting Group considers that the empirical evidence, together with the desirability of maintaining stability in regulatory decisions across time and consistency in regulatory decisions across companies justifies the use of an equity beta of 1.00 (for a gearing level of 60%) for the average regulated electricity distributor."

4.4.19 If there is some possibility that the data used to estimate an equity beta is contaminated by a unique market episode such as a stock market bubble or crash, the practice is to re-estimate the equity beta having omitted the contaminated data period forming part of the information set that is used to determine the appropriate equity beta for a particular purpose. As with all empirical estimates of beta, they should always be subjected to and compared with the results of a much broader analysis.

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[36] For example, the QCA has recently expressed the view that, "The Authority accepts that the dot-com bubble may have affected the measurement of betas over recent years, and that measures of beta using data from this period may underestimate the true value of beta, including the 0.71 equity beta adopted by the Authority in its 2001 Final Determination."

[37] ESCoSA Draft 2005 - 2010 Electricity Distribution Price Determination: Part A - Statement of Reasons, p. 171.

[38] ESCoSA Draft 2005 - 2010 Electricity Distribution Price Determination: Part A - Statement of Reasons, p. 172.

[39] ESCoSA, 2005-2010 Electricity Distribution Price Determination, Part A – Statement of Reasons, p.135.

[40] The Allen Consulting Group: Queensland Distribution Network Service Providers - Cost of Capital Study. December 2004 Report to Queensland Competition Authority.

Increasing Statistical Precision by Using Longer Data Sets

4.4.20 A number of academic papers have examined the appropriate frequency and length of data that should be used to estimate equity betas. A longer data period provides more observations, but it also increases the likelihood that the nature of the business has changed. If, for example, betas were estimated using 20 years of data, it is likely that the business in the early part of the data period varies considerably from the business in the later part. This may occur due to mergers, acquisitions, spin-offs or even expansion of one division at a faster rate than others. All of these things may change the risk profile of the business and therefore the equity beta.

4.4.21 In addition, the number of data points in a standard beta regression approach can be increased by sampling more frequently. For example, if stock and index returns are sampled weekly, rather than monthly, the number or data points increases fourfold. The ESC recognizes this in their 2001-05 Electricity Distribution Price Determination (2000, p. 276). However, this exacerbates any thin trading problem. For example, if a stock does not trade on a particular day, this represents 20% of the weekly return period but less than 5% monthly return period.

4.4.22 These tradeoffs tend to be balanced by using four or five years of monthly data to estimate equity betas. However, a number of academic and practitioner publications suggest that longer periods (up to 10 years) of data should be used (e.g., Gonedes 1973; Baesel 1974; Alexander and Chervany 1980; Elgers, Hill et al. 1982; Brailsford et al. 1997).

4.4.23 The theory behind the CAPM provides no guidance about the appropriate data period to be used to estimate equity betas. Commercial practice is to use four or five years of monthly data. This appears to be based more on commercial convenience than empirical evidence, which suggests that longer data sets provide more reliable estimates. Therefore, it is appropriate to use data sets of different lengths when determining an appropriate equity beta. The results should then be considered collectively in light of the purpose for which the equity beta is to be used and with reference to the results from a range of other estimation techniques.

4.5. REDUCING ESTIMATION ERROR BY COMPUTING PORTFOLIO BETAS

4.5.1 In practice, it is widely recognized that beta estimates for individual firms are too imprecise to be relied on with any confidence. A particular concern in this regard is the influence of firm-specific outlier observations. To reduce the impact of such outliers, it is common to compute an average beta for an industry group.

4.5.2 Often this is done by separately estimating individual betas for each firm and then taking a simple or weighted average. While common, this procedure should be treated with caution because it ignores the correlation between the beta estimates of each firm which means a reliable standard error of the estimate cannot be obtained. Technically, each beta estimate is a random variable (not a precise number) and they are not independent. Therefore, averaging them without consideration of the correlation structure can produce mis-leading estimates and certainly produces a mis-specified and meaningless standard error. Consequently, any use of such averages should be tested against other quantitative results and qualitative considerations in light of the purpose for which the equity beta is to be used.

4.5.3 One sound method to account for these statistical problems is to construct an index of industry returns and then regress those industry returns on market returns.

4.5.4 It is widely accepted practice to examine a range of equity beta estimates from a sample of comparable firms when determining the appropriate equity beta for a particular firm. No analysis of equity beta is complete without a full consideration of the evidence relating to a set of comparable firms.

4.6. EXPANDING THE DATA SET TO INCLUDE FOREIGN COMPARABLE FIRMS

4.6.1 As a general rule, one cannot directly use as an estimate of a domestic company's beta, the beta of a comparable company from another market or economy. The different composition of the markets is likely to lead to different estimates of beta and the assumptions required to make them equivalent are usually violated. However, given the lack of domestic comparables for energy distribution firms, it would be improper to pay no attention at all to the foreign comparables. Moreover, it may be possible to draw inferences about an appropriate domestic beta from foreign comparables by making adjustments for the differences between the markets.

4.6.2 It is accepted practice to examine evidence from foreign comparable firms when determining an appropriate equity beta for a particular firm. This is particularly so when the number of domestic comparables is low, as is the case for Australian energy distribution firms. Because beta estimates for foreign firms are assessed against a market index whose composition differs from the domestic Australian index, beta estimates from foreign firms should be considered to be informative as part of a range of information, but sole or primary reliance should not be placed on them.

4.6.3 In the Final Determination, ESCoSA conducts an analysis of foreign comparables, but states that "the difficulty of making comparisons of beta estimates across countries suggests Australian regulated entities are likely to provide the most reliable source of beta estimates, although overseas entities are often relied upon as a secondary source of information."[41]

4.7. QUALITATIVE CONSIDERATIONS WHEN DETERMINING EQUITY BETAS

4.7.1 When determining an appropriate equity beta, the first stage is always to conduct a comprehensive quantitative empirical analysis of all relevant data. When comparing and contrasting the various results, adjustments must be made to account for differences in leverage between firms so that the risk of comparable assets can be compared on a like-with-like basis. The aggregate results should then be tested for economic reasonableness and examined in light of the purpose for which the equity beta is to be used. That is, the determination of an appropriate equity beta involves quantitative analysis informed by a number of qualitative considerations. In a regulatory setting, these qualitative considerations include (i) the consequences of mis-estimating the equity beta; and (ii) economic reasonableness and commercial common sense.

[41] ESCoSA, 2005-2010 Electricity Distribution Price Determination, Part A – Statement of Reasons, p.140.

4.8. ASSET BETAS AND RE-LEVERED EQUITY BETAS

4.8.1 The ESC reports in their 2001-05 Electricity Price Determination (p. 275-8) that the great majority of Australian, U.S. and U.K. comparable firms have significantly lower leverage than the benchmark 60% that is used in the Determination. ESCoSA reports[42] that the average gearing of the five Australian comparables on which it relies for empirical evidence is only 50%. This means that even though these firms may have the same asset beta as the benchmark firm, they will have lower equity betas because their shareholders do not bear the same amount of risk from leverage.

4.8.2 Differences in leverage can be controlled through a procedure known as de-levering and re-levering. First, the effects of leverage are removed from the estimated equity betas to produce an estimate of the asset beta. This asset beta is then re-levered using the assumed benchmark gearing of 60% to give an estimate of what the equity beta of the comparable firms would have been with 60% debt financing. ESCoSA notes that "To allow equity betas to be compared across firms with different capital structures, the estimated equity beta must be converted into an equivalent asset beta…As an asset beta is purged of the financial risks associated with gearing, it can be compared with other asset betas derived from different capital structures. The asset beta can then be adjusted into an equity beta that is consistent with the target firm's level of gearing. The process of adjusting equity betas for different levels of gearing is known as de-levering and re-levering."[43] A number of methods have been proposed for de-levering and re-levering. In this report, the same de-levering and re-levering procedures as used by ESCoSA in the Draft and Final Determinations is generally adopted.[44]

4.9. THE CONSEQUENCES OF REGULATORY ERROR

The impact of regulatory error

4.9.1 If a regulator errs by adopting an estimate of the equity beta that is higher than the true value, the result is that regulated prices will be higher than commercial outcomes and the firm will earn returns that are higher than would be achieved in a competitive commercial setting. Conversely, if the regulator adopts an estimate of the equity beta that is lower than the true value, the result is that regulated prices will be lower than commercial outcomes and the firm will earn returns that would be insufficient to attract capital investment in a commercial setting. Setting the regulated return (regulated WACC) lower than the true cost of funds (true WACC) has implications for the viability of the business and for the incentives for appropriate levels of future investment.

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[42] ESCoSA Draft 2005 - 2010 Electricity Distribution Price Determination: Part A - Statement of Reasons, p. 172.

[43] ESCoSA Draft 2005 - 2010 Electricity Distribution Price Determination: Part A - Statement of Reasons, pp. 167.

[44] ESCoSA Draft 2005 - 2010 Electricity Distribution Price Determination: Part A - Statement of Reasons, pp. 167-169, ESCoSA, 2005, 2005-2010 Electricity Distribution Price Determination, Part A – Statement of Reasons, p.132. We use the procedure that ESCoSA has adopted throughout this report. We also use ESCoSA's gearing estimates throughout. We use a debt beta of 0.2 for Envestra, to reflect the risk that results from its very high gearing. For all other firms, we use a debt beta of zero, consistent with the values used by ESCoSA.

Regulatory recognition

4.9.2 The effects of estimation error have been addressed by Australian regulators.[45] ESCoSA notes that "an important issue" is that "any estimate of the cost of capital is subject to a large degree of statistical uncertainty or precision." Also, "A key objective when determining the regulated rate of return…is to provide investors with a return that is sufficient to motivate the investment and attract the capital away from alternative investments."[46] These views are confirmed in the Final Determination.[47]

Legislative Recognition

4.9.3 This point is also well recognized in the relevant legislation. For example, s.6 of the ESC Act requires ESCoSA to "facilitate maintenance of the financial viability of regulated industries and the incentive for long term investment." Chapter 6 of the NEC requires the regulator to seek to achieve "on a prospective basis, a sustainable commercial revenue stream which includes a fair and reasonable rate of return," and "an environment which fosters an efficient level of investment within the distribution sector."

Recognition by the Productivity Commission

4.9.4 The Productivity Commission has examined the competing objectives of (i) ensuring the ongoing viability of the business and creating the right incentives for future investment and (ii) ensuring that consumers do not pay unreasonably high prices for the regulated service. If the regulated WACC is set at a level that is lower than the firm's true cost of funds, there are clear implications for the incentives to make future capital investments. Moreover, if the regulated price is set at a level below that required to generate an appropriate return on investment, consumers will be encouraged to over-use. Whenever any commodity price is artificially depressed, the result is over-use and a lack of incentive to manage the demand for that commodity. The lower the price, the less the incentive for customers to invest in demand management and technological innovation and improvements to reduce demand. In the case of electricity, this also has environmental and social consequences.

4.9.5 This issue has recently been addressed in some detail by the Productivity Commission (PC) – see the Productivity Commission's Review of the National Access Regime which recognizes that the effects of too little infrastructure investment are far more severe than those associated with too much (or too early) investment. The PC states (p. xxii) that "Given that precision is not possible, access arrangements should encourage regulators to lean more towards facilitating investment than short term consumption of services when setting terms and conditions" and that "given the asymmetry in the costs of under- and over-compensation of facility owners, together with the informational uncertainties facing regulators, there is a strong in principle case to 'err' on the side of investors".

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[45] In relation specifically to equity betas, the Victorian Essential Services Commission has stated that "given the lack of reliability of, and imprecision associated with, capital market information the Commission is reluctant to move too far from the range of proxy betas that have been adopted in comparable regulatory decisions. In order to reduce uncertainty across regulatory periods the Commission considers it appropriate to exercise its judgment in a conservative manner." ESC, Electricity Distribution Price Review 2006-10 Issues Paper, 2004, p.93.

[46] ESCoSA Draft 2005 - 2010 Electricity Distribution Price Determination: Part A - Statement of Reasons, pp. 159.

[47] ESCoSA 2005 - 2010 Electricity Distribution Price Determination: Part A - Statement of Reasons, pp. 125.

4.10. ECONOMIC REASONABLENESS AND COMMERCIAL COMMON SENSE

4.10.1 One obvious and important consideration when examining any equity beta estimate is whether that estimate is economically reasonable and accords with commercial common sense. For example, in the most recent RMS beta report (December 2004) more than 10% of the reported OLS beta estimates are negative.[48] When used in the CAPM, these beta estimates would suggest that the required return on equity is less than the yield on risk-free government bonds. It is simply implausible that one in ten Australian companies could attract equity funds from investors who expect a return less than what could be obtained from risk-free government bonds. That is, these estimates should not be simply taken at face value and mechanically inserted into the CAPM to estimate the cost of equity capital without any consideration of the perverse economic implications and violation of simple common sense. Symmetrically, the RMS reports several beta estimates above 3. This implies a very high required return and such estimates should also be treated skeptically.

4.10.2 In the Final Determination, ESCoSA states that "the regulatory rate of return should reflect an opportunity cost of capital – the return on capital available to investors in the next-best investment opportunities, adjusted for the relative risk of the projects."[49] When assessing the relative risk of projects, economic reasonableness and commercial common sense are important considerations. It would make no sense, for example, to evaluate risk estimates that imply some assets have negative risk without first establishing whether such counter-intuitive estimates are the result of statistical, rather than economic, issues.

[48] In addition, for 20% of firms listed on the ASX, betas could not be computed due to lack of data.

[49] ESCoSA Draft 2005 - 2010 Electricity Distribution Price Determination: Part A - Statement of Reasons, pp. 125.

5. COMPREHENSIVE ANALYSIS OF THE EQUITY BETA OF AN AUSTRALIAN ELECTRICITY DISTRIBUTION BUSINESS

5.1. OVERVIEW

5.1.1 The previous section outlines the range of statistical techniques and qualitative considerations that would usually be employed when determining an appropriate equity beta to use when computing the forward-looking cost of equity capital. These techniques are documented in the academic and practitioner literatures, are employed in practice, and have been adopted by other Australian regulators. This section demonstrates the application of these empirical techniques and qualitative considerations to the case of an Australian electricity distribution firm.

5.2. CHANGING THE DATA ESTIMATION PERIOD

Application of commonly-used data periods

5.2.1 In our analysis of historical data, we use monthly observations over three periods. We use four and five-year periods as these are the periods most commonly used by commercial data providers. We also examine a 3.5 year period, as this is the period since the end of the technology bubble. We examine the results computed over various periods for consistency and corroboration of one another.

5.3. THE BLUME ADJUSTMENT

5.3.1 A number of reputable data services report beta estimates after application of the Blume adjustment. Bloomberg and ValueLine, two of the leading commercial beta services, both use the Blume adjustment. They do this because when the CAPM is applied with Blume-adjusted betas (rather than mechanical OLS betas) it provides a better fit to observed stock returns. That is, Blume-adjusted betas work better. This is likely due to the fact that the observed mean reversion in beta *estimates* will result if estimation error is non-persistent, even if true betas are constant. That is, the Blume adjustment can be motivated on statistical grounds.

5.3.2 As the Blume adjustment corrects for statistical error, not conscious managerial choices in relation to diversification and gearing, it is wrong to reject this adjustment on the basis that mean reversion in beta estimates can be caused only by conscious managerial diversification and gearing choices.

5.3.3 The Blume adjustment is warranted as a statistical correction and is consistent with accepted commercial practice. Accordingly, we report Blume-adjusted betas.

5.4. RE-GEARING AND RISKY DEBT

ESCoSA's re-gearing procedure

5.4.1 Throughout the Draft and Final Determinations, ESCoSA applies a consistent procedure for re-gearing beta estimates to reflect the differences between the gearing of the proxy firm and the assumed 60% gearing of the benchmark firm. The procedure that ESCoSA uses assumes that all debt is free of systematic risk. That is, ESCoSA assumes that all debt betas are zero. This implies that the value of the firm's debt is insensitive to movements in the broad market index.

Envestra's Gearing

5.4.2 The assumption of a debt beta of zero may be reasonable for the efficient benchmark firm when the level of gearing is low and we are prepared to accept this assumption where it is reasonable. This assumption may be similarly reasonable for APT, AGL, and Alinta, all of which have substantially less debt than the assumed 60% gearing of the efficient benchmark firm. It is, however, not reasonable to assume that Envestra also has a debt beta of zero, since this firm has substantially higher gearing than the benchmark firm.

5.4.3 The most recent credit rating report from Standard and Poors[50] states that Envestra has an "aggressive financial policy…and an aggressive debt appetite" with a "high level of indebtedness." Moreover "total debt to regulatory asset base as at fiscal 2004 is about 104% higher than a number of its rated peers." Importantly, the S&P report also states that Envestra has "limited room to absorb underperformance. Any unfavorable regulatory outcome or underperformance will put downward pressure on its ratings. There remains no room in the ratings for additional debt."

5.4.4 Thus, it is unreasonable to assume that Envestra's debt beta is zero and consequently some method must be used to compute it. We use the procedure that has been adopted by most Australian regulators for this purpose, including the Victorian ESC, QCA, and IPART. This involves reverse-engineering the implied debt beta from the CAPM. That is, we take the yield on debt, risk-free rate, and market risk premium and then use the CAPM to solve for the implied debt beta. This produces an estimate of 0.2 for the debt beta of Envestra and we use this estimate when re-gearing equity beta estimates for Envestra. In all other respects, and for all other firms, we use exactly the same re-gearing procedure as does ESCoSA.

5.5. THE EFFECT OF OUTLIER OBSERVATIONS AND THE TECHNOLOGY BUBBLE

The basis for the statistical adjustment for outliers

5.5.1 Since the equity beta is to be used to estimate the forward-looking cost of equity capital, we require a forward-looking estimate of the likely future relationship between stock and market returns. Therefore, outlier data points should only be removed if considered to be unrepresentative of likely future market conditions. One way of making this determination is on the basis of the frequency of outliers. To the extent that a recent period contains an unprecedented number of outliers or can otherwise be characterized as "unusual," a statistically based removal of outliers may be appropriate.

5.5.2 We have examined the frequency of outliers and the "representativeness" of recent data periods using AGL as an illustration as set out in Technical Appendix 2. We use AGL because other listed comparables have inadequate histories and are small relative to AGL. That is, AGL is used here as an illustrative example on the basis of data availability, not because of its particular similarity to ETSA Utilities. We have undertaken a standard statistical bootstrap analysis to determine whether data for the most recent four year period is unusual in the context of the last 10 years of data in Technical Appendix 3.

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[50] Standard and Poors, Envestra Ltd. Corporate Credit Rating, 3 November 2004.

5.5.3 The conclusion of the bootstrap analysis is that, in the context of the last 10 years, the most recent 4 year period is unique and extreme in terms of the beta estimate it produces. There are two possible explanations for this dramatic result:

1. The true systematic risk of AGL has reduced dramatically over the last four years and the statistical beta estimate reflects this economic truth, or

2. The true systematic risk of AGL has not materially changed over the last 10 years, and the presently low statistical beta estimate is the result of chance outliers and statistical aberrations (such as a technology bubble) that are known to be able to contaminate least squares estimates in small samples.

5.5.4 There are many reasons to reject the first explanation including:

1. The present beta estimate for AGL implies that investors require a return less than the yield on risk-free government bonds, which is clearly economically implausible.

2. If we use the most recent two or six year period instead of using four years, the beta estimate is substantially higher. This is not consistent with a sustained reduction in systematic risk.

3. Replacement of two extreme observations in the last four years of data results in the AGL equity beta estimate increasing by more than one, when re-levered to 60%.

5.5.5 All of these reasons suggest that the true systematic risk of AGL has not materially changed over the last 10 years, and the presently low statistical beta estimate is the result of outliers and statistical aberrations. If this is the case, it should be recognized when considering how best to estimate equity betas for use in the CAPM.

Elimination of outliers and unrepresentative periods

5.5.6 The objective of the outlier elimination procedure is to eliminate a small number of observations that are so extreme and influential as to bias the beta estimate. The technique is designed to detect influential outliers caused by significant one-off events. For example, firm-specific announcements such as takeover or divestment activity, a share buyback, or a revised profit forecast. If the particular data period being analyzed contains an unusually large number of these events, and they happen to cause stock returns that are positively (negatively) correlated with market returns, the result is a beta estimate that is upwardly (downwardly) biased. The outlier elimination procedure is not designed to correct for the impact of a more persistent unusual market event such as the technology bubble, so this issue must be addressed separately. During this period, the estimated correlation between stock and market returns was affected by the movement of funds into and out of the technology sector. This caused a series of observations over 2-3 years to behave quite differently from previous and subsequent data.

Beta estimates after removal of outliers and the technology bubble

5.5.7 Because there is strong evidence that the recent beta estimates of Australian energy distribution firms have been affected by the technology bubble and an unusually high number of outlier data points, we adopt a two-step procedure in our analysis. First, we eliminate the technology bubble from our data set. This involves eliminating data from July 1998 to June 2001. This period is consistent with the period identified recently by ESCoSA and the QCA.[51] Second, we employ the statistical outlier elimination procedure to data sets that do not include the technology bubble.

5.5.8 We first fit a regression line through the data points in the sample period. We then measure the residuals for each observation.[52] Next, we measure the standard deviation of the residuals – a measure of their dispersion. Finally, any residual that is more than *x* times the standard deviation is removed as an outlier. We allow *x* to take the values 1.0, 1.5, and 2.0. After removing outliers, we use regression analysis to estimate the equity beta. We then apply the Blume adjustment and re-lever to 60% gearing. The results of our analysis are contained in Table 5.

Table 5: Re-levered OLS Beta Estimates After Removal of Technology Bubble and Outliers: Blume-Adjusted.

Outlier Removal Criteria (Standard Errors)	**2.0**	**1.5**	**1.0**
	Beta (R^2)	**Beta (R^2)**	**Beta (R^2)**
3.5 years: 7/2001-12/2004			
AGL	0.80 (0.03)	1.06 (0.12)	1.25 (0.33)
Alinta	1.46 (0.17)	1.50 (0.22)	1.97 (0.60)
APT	0.95 (0.21)	1.03 (0.35)	1.14 (0.67)
Envestra	0.77 (0.11)	0.87 (0.22)	0.89 (0.41)
Mean	**1.00**	**1.11**	**1.31**
4 years: 1/1998-6/1998 7/2001-12/2004			
AGL	1.06 (0.09)	1.15 (0.15)	1.34 (0.35)
Envestra	0.83 (0.17)	0.96 (0.31)	0.91 (0.40)
Mean	**0.95**	**1.05**	**1.12**
5 years: 1/1997-6/1998 7/2001-12/2004			
AGL	1.23 (0.16)	1.30 (0.20)	1.41 (0.33)
Mean	**1.23**	**1.30**	**1.41**
GRAND MEAN	**1.06**	**1.15**	**1.28**

Source: AGSM monthly data file, SFG regression analysis, gearing estimates from ESCoSA's Draft Determination Table 10.2, debt beta of 0.2 for Envestra and zero for other firms, consistent with the procedure used in the Draft Determination p. 168, equity betas are re-levered to 60% gearing, outliers and the technology bubble are eliminated. Raw beta estimates are Blume-adjusted before being re-levered.

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[51] ESCoSA 2005-2010 Electricity Distribution Price Determination, Part A – Statement of Reasons; QCA (2004). Draft Determination Regulation of Electricity Distribution.

[52] The residuals are the distance between the actual data point and the regression line, as explained in Technical Appendix 1.

5.5.9 The three columns in Table 5 relate to the standard approach of adopting different critical values for the removal of outliers from within each data set (different values of *x*). A lower critical value means that more observations are considered to be outliers and are removed. When a smaller critical value is used for the outlier elimination procedure, more outliers are eliminated and the remaining data points provide a better fit to the model, as measured by the *R*-squared statistic.

5.5.10 We discuss the interpretation of the R^2 statistic in Technical Appendix 1 and in Section 4.3 above. When the R^2 statistic is low, the relationship between stock returns and market returns is swamped by noise in stock returns caused by various firm-specific factors that have nothing to do with systematic risk or beta. Recall that this is akin to trying to measure the ripples that are caused when a stone is tossed into two metre surf – although they are there, their effect is swamped by other factors. It is for this reason that Bowman and Bush (2004) recommend ignoring any beta estimate that comes from a regression analysis with an R^2 statistic less than 10%.

5.5.11 Using the Bowman-Bush criterion, raw beta estimates for all of the proxy firms used by ESCoSA would be ignored due to the uniformly low R^2 statistics. Table 5 demonstrates that after eliminating outliers, the R^2 statistics increase. Extending our analogy, this is equivalent to trying to measure ripples from a stone thrown between waves, when the water surface is relatively still – we are more likely to be able to detect the effect we are tying to measure as we begin to eliminate some of the extraneous noise.

5.5.12 We begin by eliminating the most extreme outliers; those that are more than two standard deviations in magnitude. This improves the reliability and informativeness of the regression analysis somewhat, but two of the seven R^2 statistics remain below the 10% threshold used by Bowman and Bush (2004), which we consider to be significant. Moreover, in only one case does the R^2 statistic reach 20%. Thus, even after eliminating one or two extreme outliers from each regression, there are still doubts about the reliability and informativeness of the regression analysis. Therefore, we also apply stronger criteria in the remaining columns of Table 5. In these columns, the R^2 statistics improve, the "signal-to-noise" ratio is higher, and the beta estimates are more reliable.

5.5.13 Collectively, the results in Table 5 illustrate that when the technology bubble and statistical outliers are removed from the analysis, there is no support for an equity beta estimate less than one. Indeed, as longer data periods are used and statistical reliability is increased, beta estimates are much higher. When a standard five-year data set is used, even AGL has beta estimates at and above one. Recall that the current mechanical OLS beta estimate of AGL (even after re-levering to 60%) is close to zero. Thus, to ignore the technology bubble and the effects of a small number of statistical outliers is to dramatically mis-estimate the relationship between stock and market returns for these proxy companies.

Summary and conclusion

5.5.14 When standard OLS regression analysis is mechanically applied to recent data, the beta estimates for Australian energy distribution firms are much lower than they have historically been. The analysis above indicates that this decrease in beta *estimates* is due to the technology bubble and the effects of statistical outliers. When these are removed, the results indicate that an appropriate estimate for an equity beta re-levered to 60% is at least one.

5.5.15 Moreover, this analysis corrects the problems with the mechanical beta estimates, on which ESCoSA relies, that are identified in Section 4.3 above. In particular, the regression analyses in Table 5 all have higher R^2 statistics than is the case for mechanical beta estimates. This indicates higher reliability and less chance that the true effect is distorted by extraneous noise. Also, the results for the various proxy companies in Table 5 are consistent with one another, and with commercial common sense. They are also consistent with the view taken by the ACCC in recent determinations[53] that even though recent mechanical beta estimates indicate a reduction in the systematic risk of Australian energy distribution companies, it is appropriate to use an equity beta of one (assuming 60% gearing).

5.6. AVERAGE BETAS AND PORTFOLIO BETAS

Portfolio Formation

5.6.1 The easiest way to account for the statistical problems of beta estimates for individual firms is to construct an index of industry returns and then regress those industry returns on market returns. We have done this by forming a portfolio consisting of close comparables (AGL, Alinta, APT, and Envestra) for the periods over which they were listed. We compute portfolio returns in two ways. First, we take the mean return of the comparable firms. However, given the unusually small set of comparables that is available here, an extreme return for one firm can substantially affect the mean. Therefore, we also examine portfolio returns constructed as the median of the returns of the comparable firms. In each case, we use OLS regression techniques to estimate the portfolio beta, re-levered to 60%. We continue to examine the data periods that were used in Table 6 in order to eliminate the effects of the technology bubble, we employ the statistical outlier elimination technique, and we apply the Blume adjustment.

5.6.2 In the Final Determination, ESCoSA reports average beta estimates for a small group of proxy firms. These results are obtained by simply averaging the beta estimates of the proxy firms in each time period and are reported in Figures 10.2 and 10.3.[54] Most of the data points in these figures are obtained by averaging beta estimates over two or three companies, which would ordinarily be considered too small a set of comparables to provide any sort of meaningful analysis. The beta estimates that are averaged are also not adjusted for statistical outliers or the effects of the technology bubble. Also, negative beta estimates, which defy commercial common sense, are included in the analysis. The simple averaging process treats the each beta estimate as independent and does not properly reflect the correlation between the beta estimates for different firms. Our process of constructing an index of returns of comparable firms and computing an outlier-resistant beta for this index does incorporate all of these important statistical issues.

Results

5.6.3 The results of our analysis of portfolio betas are reported in Table 6. As in Table 5, we note that the fit of the model (as measured by the R^2 statistic) improves as we reduce the critical value for the outlier removal procedure. In general, as the goodness of fit of the model improves, the reliability of

[53] ACCC (2003) South Australian Transmission Network Revenue Cap 2003-2007/8, Final Determination; ACCC (2003) Victorian Transmission Network Revenue Cap 2003-2008, Final Determination; ACCC (2004) Tasmanian Transmission Network Revenue Cap 2004-2008/9, Final Determination.

[54] ESCoSA 2005 - 2010 Electricity Distribution Price Determination: Part A - Statement of Reasons, pp. 139.

the beta estimate increases. Also, as the length of the data set increases and statistical reliability improves, beta estimates also generally increase.

Table 6: Re-levered OLS Portfolio Beta Estimates After Removal of Technology Bubble and Outliers: Blume-Adjusted.

Outlier Removal Criteria (Standard Errors)	**2.0**	**1.5**	**1.0**
	Beta (R^2)	**Beta (R^2)**	**Beta (R^2)**
3.5 years: 7/2001-12/2004			
Mean Portfolio	0.96 (0.27)	1.04 (0.31)	1.18 (0.45)
Median Portfolio	1.02 (0.34)	1.07 (0.45)	1.27 (0.52)
4 years: 1/1998-6/1998 7/2001-12/2004			
Mean Portfolio	0.97 (0.18)	0.96 (0.23)	1.22 (0.40)
Median Portfolio	1.07 (0.22)	1.02 (0.29)	1.26 (0.46)
5 years: 1/1997-6/1998 7/2001-12/2004			
Mean Portfolio	1.01 (0.25)	1.07 (0.31)	1.26 (0.54)
Median Portfolio	1.03 (0.26)	1.10 (0.36)	1.37 (0.58)

Source: AGSM monthly data file, SFG regression analysis, gearing estimates from ESCoSA's Draft Determination Table 10.2, debt beta of zero, consistent with the Draft Determination p. 168, equity betas are re-levered to 60% gearing, outliers and the technology bubble are eliminated. Raw beta estimates are Blume-adjusted before being re-levered.

Summary and conclusion

5.6.4 The analysis in Table 6 indicates that recent beta estimates for Australian energy distribution firms are substantially affected by the technology bubble and statistical outliers. When these are removed, beta estimates return to long-term levels, at or above one (assuming 60% gearing). This must be an important consideration when determining a beta estimate to be used for a future period.

6. QUALITATIVE CONSIDERATIONS

6.1 Having conducted a thorough empirical analysis of the available data, the results should then be tested against a number of qualitative considerations before finally determining the equity beta that is used to estimate the cost of equity capital. We have not been asked to conduct such an examination of the various qualitative considerations. In a regulatory setting, such an examination would consider:

1. Whether the beta estimate from the empirical analysis conforms with commercial common sense – whether the implied return to shareholders is economically reasonable in the circumstances;

2. The estimates of equity beta that have been used by other jurisdictional regulators; and

3. The estimates of equity betas from foreign comparable firms.

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Date: 18/4/05 | 17/04/05

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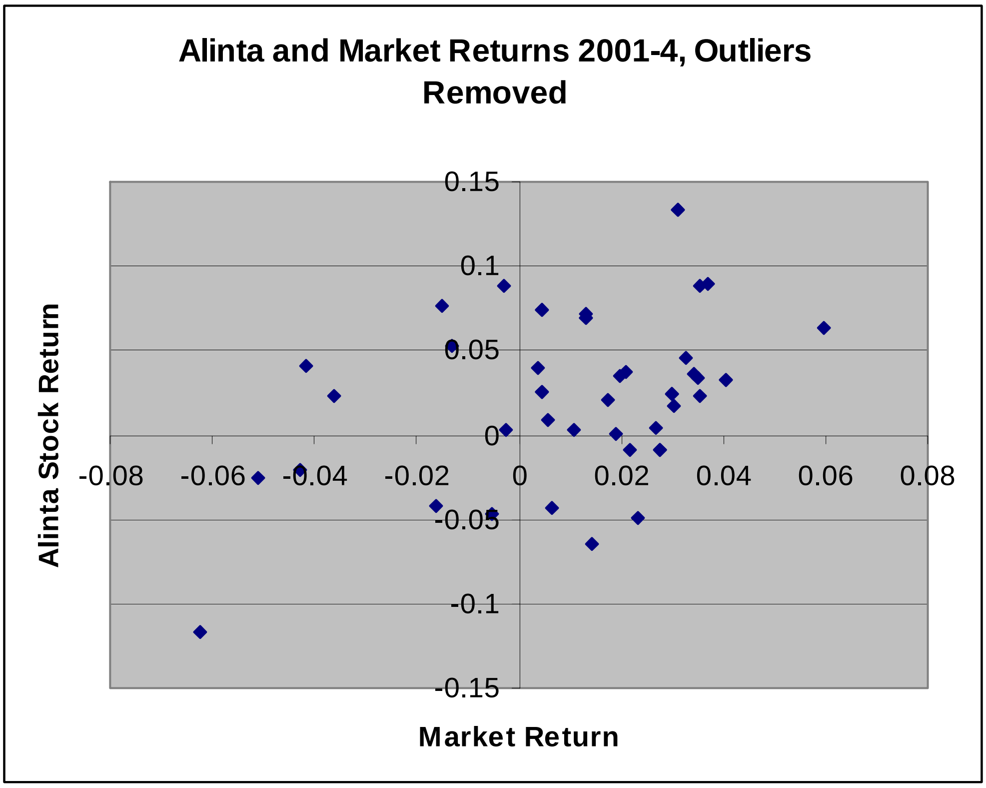
TECHNICAL APPENDIX 1: ORDINARY LEAST SQUARES REGRESSION

A.1.1 Ordinary least squares (OLS) regression is a statistical technique that is used to assess the strength of the relationship between two variables. The technique requires a number of observations of each variable. The regression technique then computes the best linear (straight line) relationship between the two variables. This can be best illustrated via an example. Consider a sample of monthly returns on (i) Alinta shares and (ii) a broad stock market index like the All Ordinaries index. A sample of these returns appears in Figure A.1.1

Figure A.1.1

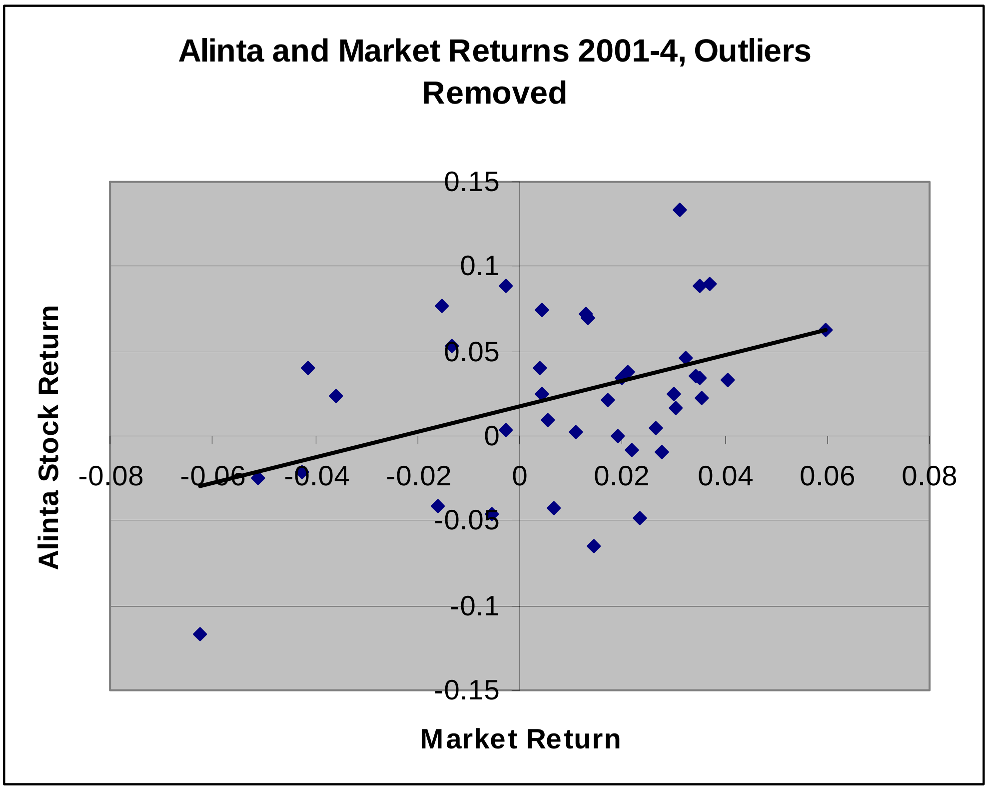


Source: AGSM monthly data file.

A.1.2 Each point in the figure represents the returns in a particular month. For example, the data point in the lower left corner represents September 2001. In that month, the broad stock index declined by 6% and Alinta shares fell 11%.

A.1.3 OLS regression fits the best linear relationship between these two variables. The result of this regression analysis is illustrated in Figure A.1.2.

Figure A.1.2



Source: AGSM monthly data file, SFG analysis.

A.1.4 The regression line is illustrated graphically in Figure A.1.2. It can also be written in the form of an equation:

$$r_e = 0.017 + 0.75 r_m .$$

In this equation, r_e represents the return on Alinta shares and r_m represents the return on the market index. This equation suggests that if the market rises by 1% in a particular month, we would expect the return on Alinta shares to be

$$r_e = 0.017 + 0.75 \times 0.01 = 2.45\%.$$

A.1.5 In this setting, the equity beta estimate for Alinta is the slope of this regression line, 0.75. This is, of course, a beta estimate that reflects the actual level of gearing of Alinta, and must be re-geared to 60% before being used in a regulatory cost of capital estimate. This process produces a re-geared equity beta estimate of 1.31.

A.1.6 The OLS regression line and equation are constructed by minimizing the sum of squared errors. The error for each data point is the vertical distance between that data point and the regression line. For September 2001, the actual return on Alinta shares was -11%. The regression line suggests that the expected return, given that the market declined 6%, is

$$r_e = 0.017 + 0.75 \times (-0.06) = -2.8\%.$$

Thus, the error for this observation is the difference between the actual data point (6% decline) and the regression line (-2.8% decline), or 3.2%.

A.1.7 An error term is computed for each observation. All these errors are then squared. In our example, we would have $(0.032)^2$ =0.001024. These squared errors are then added together. The

OLS regression line is that which minimizes the sum of squared errors. It is in this sense that among all linear relationships between the two variables, the OLS regression line provides the best fit.

A.1.8 The statistic that measures how well the regression line fits the data is the R^2 (r-squared) statistic. In the example in Figure A.1.2, the R^2 statistic is 15%. This means that 15% of the month-to-month variation in Alinta stock returns is explained by variation in market returns. The remaining 85% is due to other (non-market) factors. A higher R^2 statistic means that more of the variation is explained by the regression model and the regression line better fits the observed data. That is, a low R^2 statistic means that much of the variation in the firm's stock returns are driven by firm-specific (non-market) factors. This is consistent with the existence of many outlier data points due to firm specific announcements that have nothing to do with broad stock market movements, for example. Conversely, a high R^2 statistic means that little of the variation in the firm's stock returns are driven by firm-specific factors.

A.1.9 A low R^2 statistic does not imply that the firm should have a low beta. For example, a firm's stock returns may be highly sensitive to market movements, but the data may also contain several outlier data points associated with firm-specific announcements. This would lead to a high beta and a low R^2 statistic. That is, a low R^2 statistic does not imply that the firm's beta is low, just that it is estimated from relatively uninformative and noisy data and is therefore unreliable.

A.1.10 If the R^2 statistic is very low firm specific factors may dominate any relationship between stock and market returns. That is, the equity beta becomes very difficult to estimate and statistical reliability is low. There is also the risk that outliers caused by firm-specific announcements may be correlated with market returns in the sample of data, just by chance. This can lead to biased beta estimates. Consequently, when the R^2 statistic is very low, caution must be exercised when interpreting the results, and it is important to analyze the impact of statistical outliers in the data set. For this reason, Bowman and Bush (2004) recommend that any beta estimate from a regression with an R^2 statistic less than 10% should be ignored.

TECHNICAL APPENDIX 2: HOW OUTLIERS MAY CAUSE A BIAS IN EQUITY BETA ESTIMATES

A.2.1 Under a standard market model regression, equity betas are estimated as the slope of a regression line:

$$r_{it} = a_i + b_i r_{mt} + \varepsilon_{it}. \qquad \text{(A.2.1)}$$

where:

- r_{it} is the return on stock *i* in period *t* ;
- r_{mt} is the return on the market portfolio in period *t* ;
- *a* and *b* are coefficients to be estimated with *b* being used as an estimate of the equity beta; and
- ε_{it} is assumed to be normally distributed with constant variances.

A.2.2 Outliers tend to be caused by firm-specific announcements that shock the stock price, and therefore r_{it}. These can be positive (good news) or negative (bad news). If we represent these shocks as ν_{it}, the true model is:

$$r_{it} = \alpha_i + \beta_i r_{mt} + \eta_{it} + \nu_{it}. \qquad \text{(A.2.2)}$$

A.2.3 That is, we assume that in truth stock returns are generated by Model (A.2.2) where η_{it} is normally distributed with constant variance (i.e., a well-behaved error term) and ν_{it} equals zero for most observations, but can be large and positive (when the firm announces good news in period *t*) or large and negative (when the firm announces bad news in period *t*). In Model (A.2.2), α_i and β_i represent true parameter values.

A.2.4 The issue is then whether the least squares slope estimate b_i in Model (A.2.1) is an unbiased estimate of the true parameter β_i. Note that (A.2.1) can be thought of as omitting a parameter (ν_{it}) or mis-specifying the error term (assuming ε_{it} is normal, when it is really a mixture of η_{it} and ν_{it}). Either way, the estimation equation (A.2.1) differs from the true model (A.2.2), and the question is whether b_i estimated from (A.2.1) provides a good estimate of the true parameter value β_i.

A.2.5 In statistics, this is known as an errors-in-variables problem. It is well-known that if ν_{it} is correlated with r_{mt}, the regression model (A.2.1) is mis-specified and the most basic property of consistency is lost. That is, even in very large samples, the estimate b_i will not converge to the true parameter β_i.

A.2.6 Much of the analysis of this issue addresses asymptotic results--results that apply as sample sizes become very large. For this reason, we perform a simulation analysis to examine the impact of this issue using sample sizes and parameter values that are typically encountered in beta estimation.

A.2.7 We assign parameter values to the true model (A.2.2) as summarized in Table A.2.1. These parameter values are simply assigned for the purposes of demonstrating the potential impact of outliers. We cannot assign values from any particular firm, because the true parameter values are, of course, unobservable. The purpose of this exercise is to demonstrate the effect of outliers for a firm to which these assumed parameters applied. We demonstrate in A.2.13 below that our choice of parameters appears conservative in light of the observed returns for AGL during the most recent four-year period.

Table A.2.1
Parameter values for true market model: $r_{it} = \alpha_i + \beta_i r_{mt} + \eta_{it} + \nu_{it}$.

Parameter	Value/Distribution
Number of Observations	48 (monthly)
α	0
β	1
η_{it}	$N(0, \sigma_\mu^2)$
σ_μ	0.005[a]
r_{mt}	$N(\mu_m, \sigma_m^2)$
μ_m	0.007[a]
σ_m	0.03[a]
ν_{it}	0 for 43 observations $\begin{cases} 0.10 \ w.p. \ 0.5 \\ -0.10 \ w.p. \ 0.5 \end{cases}$ for 5 observations

[a] consistent with observed monthly data 1994 - 2003.

A.2.8 That is, the monthly market return is assumed to be normally distributed with mean 0.7% and standard deviation 3%, consistent with data from 1994 - 2003. We assume that in any sample of 48 observations, 43 are not contaminated by outliers. Five observations in each sample are affected by shocks of $\pm 10\%$, again consistent with data from 1994 - 2003.

A.2.9 We then randomly generate 48 observations consistent with Model (A.2.2), estimate b_i as in Model (A.2.1), and repeat 10,000 times. Table A.2.2 summarizes the results for three cases, depending on the correlation between the outlier observations and market returns.

Table A.2.2
Relationship between standard beta estimates and in-sample correlation between outliers and market movements.

	Outliers Positively Correlated with Market ($\rho \geq 0.5$)	**Outliers Uncorrelated with Market (- 0.5 < ρ < 0.5)**	**Outliers Negatively Correlated with Market ($\rho \leq$ - 0.5)**
Distribution of b_i estimates			
5th Percentile	0.71	0.51	0.32
10th Percentile	0.81	0.61	0.42
25th Percentile	0.98	0.77	0.59
50th Percentile	1.15	0.94	0.77
75th Percentile	1.33	1.12	0.95
90th Percentile	1.51	1.27	1.13
95th Percentile	1.62	1.36	1.25

A.2.10 The results of this analysis clearly demonstrate the statistical effect of outliers. Our simulation results are divided into three classes. In all cases, every sample contains 48 observations, five of which are outliers. The outliers are randomly assigned to be positive or negative and may occur in months in which the market rises or falls. Thus, the correlation between the outlier stock returns and market returns, in a particular sample, may be:

- Positive, if positive outliers happen to occur when the market is up and negative outliers happen to occur when the market is down, in that sample;
- Negative, if positive outliers happen to occur when the market is down and negative outliers happen to occur when the market is up, in that sample; or
- Uncorrelated, if there is little relationship between outliers and market movements.

A.2.11 We break our analysis into three classes, strong positive correlation ($\rho \geq 0.5$), strong negative correlation ($\rho \leq -0.5$), and no substantial correlation ($-0.5 < \rho < 0.5$). In each case, we ignore the presence of outliers and estimate the equity beta using the simple least squares approach as in Model (A.2.1). For some of our samples, the outliers happen to be positively correlated with market returns (just by random chance, like the person who threw heads on all four turns). Other samples exhibit negative correlation. The third group exhibit low correlation (some outliers correspond with the direction of the market and others do not). If the outliers happen to be positively (negatively) correlated with market returns, the OLS beta estimate is upwardly (downwardly) biased by around 20%. Thus, a handful of outliers can cause a 20% bias in equity beta estimates.

A.2.12 The results demonstrate that the in-sample correlation between outliers and market movements can have a substantial impact on standard beta estimates, If, in a particular sample, the outliers tend to be negatively correlated with market returns, the median least squares beta estimate is 23% below the true value, given our assumed parameter values. That is, there is a clear and significant downward bias in standard beta estimates if the sample on which they are based contains outliers that happen to be negatively correlated with market returns. If, in the particular sample period, bad news happens to be released in months when the market is up, and vice versa, the standard beta estimate is a downwardly biased estimate of the true value. We also note that the result is symmetrical in the sense that when outliers happen to be positively correlated with market movements, standard beta estimates are upwardly biased.

A.2.13 Note that our simulation exercise is calibrated to recent market data. To illustrate that our choice of parameter values is reasonable, we note that in the last four years, AGL has experienced two monthly stock returns of -12% and one of -19%, all in months were the market is up. Thus, our calibration errs on the side of conservatism. In all of our analyses, shocks were limited to a magnitude of 10%. Increasing the magnitude of shocks increases the bias in the results in Table A.2.2.

TECHNICAL APPENDIX 3: BOOTSTRAP ANALYSIS

A.3.1 Bootstrap analysis is a statistical technique that is used to assess the statistical significance of an event using a re-sampling procedure. It is a non-parametric technique based on the actual data set being analyzed. Thus, no parametric distributional assumptions are required. Rather, the features of the actual data are incorporated in the statistical test. The bootstrap analysis allows us to determine whether the most recent 4-year period is substantially different from all previous data and to quantify the extent of any such difference. In particular, the most recent 4-year period may contain a disproportionately large number of outliers that cause standard beta estimates to be biased downwards. The bootstrap analysis will determine if this is the case and quantify the effect on beta estimates.

A.3.2 We apply this bootstrap analysis to AGL because it is the only comparable firm with sufficient data. The point of this bootstrap analysis is simply to examine whether the most recent four-year period is unique in the context of the last ten years. Since the other comparable firms have only two, four, or six years of data available, they cannot be used for this purpose.

A.3.3 The bootstrap analysis is conducted as follows. First, we collect 10 years of monthly returns for AGL and the broad market index from the last ten years. This yields 120 pairs of monthly observations. Next, we randomly select 48 of these 120 observations. We select 48 observations as this is the sample size that is used by RMS/AGSM to compute beta estimates. We then perform a standard least squares regression of stock returns on market returns using the 48 observations that have been selected. We record the beta estimate from this regression. Then we randomly select another 48 of our 120 observations and repeat this process 10,000 times.

A.3.4 The result of this procedure is 10,000 beta estimates, each computed from a different random sample of 48 monthly observations drawn from the last 10-years of available data. The results of this analysis are stark. The most recent four years of available data produce an OLS beta estimate well inside the first percentile. That is, if 48 monthly observations are randomly selected from the last 10 years, there is a less than 1% chance that the least squares beta estimate from this sample would be less than the estimate from the last four years. The probability of selecting a sample that produces a beta estimate as low as that obtained from analyzing the last four years of data is less than remote.