Methodological issues in estimating the equity beta for Australian network energy businesses

Report prepared for

Australian Competition and Consumer Commission and Australian Energy Regulator

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EXECUTIVE SUMMARY

Matters to be addressed

This report focusses on three matters identified by the AER in relation to determining a relevant equity beta suitable for inclusion in the standard Sharpe-Lintner Capital Asset Pricing Model (hereafter SLCAPM) in the economic regulation of network energy businesses in Australia.

The matters to be addressed are:

- The relevant period for estimating the equity beta and implications of recent developments including: impacts in relation to inflation, the risk free rate and the impact of COVID and similar events that may justify excluding certain periods;
- The proxy firm comparator set including *inter alia*: characteristics, relevance of overseas firms, sample size, impact of regulation, and weights for comparators; and
- Where relevant any other issues related to the equity beta that are considered important having regard to the overarching objective.

The report is not required to make recommendations but rather to provide key considerations and advantages and disadvantages of different methodology choices. In answering these questions we consider it is relevant to understand the assumptions of the CAPM, its empirical performance and variants of the model that may be relevant to answering the questions about the period for estimation and the comparator set.

CAPM assumptions, performance and relevance

The SLCAPM is a highly parsimonious and readily usable and useful model. Note, however, that the standard model is a one period model where the period is not defined, beta is not dependent on the time period, inflation is implicitly assumed to be zero and investors are only concerned with the mean and variance of returns. In practice inflation is captured by using nominal variables and the period is defined by the period of interest or application.

In practice the model has not performed well in terms of predicting returns but academic attempts to overcome that problem have tended to produce models that are complex, difficult to use and prone to over-fitting. Despite these problems we consider that the SLCAPM is still the most popular and most suitable model in commercial and regulatory applications – it is still invariably used at least as a starting point by the majority of practitioners and it is widely used in regulatory contexts.

In the case of the regulated network energy businesses in Australia we consider that the natural monopoly, essential service characteristics of these businesses and the regulatory arrangements in effect greatly reduce the firm-specific, non-diversifiable risk as measured by the equity beta. They also support the use of the SLCAPM by achieving reasonable consistency with the underlying behavioural assumptions of investor concern with only the mean and variance of returns, and by providing high protection against inflation.

The regulatory arrangements

The regulatory arrangements that apply to the network energy businesses are considered to substantially limit the risk that these businesses face. There is in effect no revenue risk (for revenue caps) or revenue risk that does not appear to be of concern (for price caps or average revenue yield) for the regulatory period. In addition, cost risk is greatly reduced with indexing of the RAB with actual inflation each period and in effect a guarantee of specified expected real rate of return to be applied to the indexed RAB for each period, cost pass through mechanisms and regular re-setting of prices to reflect approved costs as well as other measures for sharing unders and overs for operating and capital expenditure.

As far as cash flow risk is concerned, the main risk relates to under or over spending on operating and capital expenditure relative to approved forecast estimates, although variability of these expenditures is greatly mitigated by the efficiency benefit sharing scheme for operating expenditure and the capital efficiency sharing scheme for capital expenditure and re-setting of prices every five years.

We consider that it is reasonable to conclude that collectively these regulatory arrangements mean that cash flow risk for regulated network energy businesses is very low relative to the average that applies to firms in the broader market. In addition, the regulated network energy businesses are natural monopolies where there is by definition no competition and the service is essential with a low income elasticity of demand providing further fundamental protection from business and financial risk.

Choice of Estimation Period

Theory and evidence

When the CAPM is estimated it is assumed that it holds period by period and this requires returns to be independently and identically distributed over time. However, this assumption is unlikely to hold which implies that beta is likely to be time dependent although the extent of any impact is uncertain.

A popular approach to taking account of time dependent effects is to specify a conditional CAPM that allows for time dependent effects to impact on the beta parameter or to specify a model with multiple betas relating to different measures of risk. There are mixed results with these models and they are prone to over-fitting and complex to apply in practice. An interesting finding from two studies with these models though was that time variation in the market risk premium was relatively more important than time variation in betas. The evidence also tends to support some variability in betas in up and down markets. However, much of the apparent instability of betas may be attributable simply to measurement using historical returns whereas the true beta is a function of expected returns. Commercial practice tends to focus on the scope for changes in the market risk premium rather than the beta. And finally empirical testing of the AER betas does not find material statistical evidence of beta instability for longer time periods.

The time interval

In choosing the time period for estimation there is a need to consider the return interval (frequency of the data) and the length of the estimation period. This is because of the need to obtain a sufficiently large sample to provide statistically reliable beta estimates while recognising that changes in circumstances facing firms can mean changes in betas.

Considering frequency first, if stock price returns are serially uncorrelated and the return on the individual stock is the same for all frequencies then OLS estimates based on the highest frequency would be optimal as it would provide more observations and estimates would not be biased. However, there tends to be high serial correlation for daily returns and there are more likely to be thin trading and related outcomes affecting the beta estimates for high frequency data. There is also literature indicating that interval choice can be a major factor influencing beta and the problems are less if monthly data are used. The literature includes thin trading issues, mis-match between the estimation period and the holding period and gradual recognition of information over a longer interval. However, we note the extensive statistical tests undertaken by Henry (2014, 2009) provide support for the continued use of weekly data for the existing AER comparator set although we consider it is worth using both monthly and weekly data.

The estimation period

Turning to the period of estimation, assuming beta is constant over time, increasing the number of observations will reduce the standard error of the estimate of beta thereby providing a more precise statistical estimate. However, increasing the estimation period increases the probability that the true beta will have changed as a result of changes in the determinants of beta. It is a common practice in the finance sector to use five years of monthly data.

The characteristics of regulated energy network service businesses in Australia that are relevant for impacting on beta, including in particular the regulatory arrangements, are not expected to change materially over reasonably long time periods and Henry's studies find strong evidence of beta stability in the AER comparator set including for the longest period available that includes the tech shock and the global financial crisis.

Stability of equity beta

If one were to use historical data over a long time period, say ten years, it is reasonable to hypothesise that in general there would more likely be a change in beta estimates then for a more recent period. Thus there is *ceteris paribus* an advantage in using a more recent period rather than a very long historical period. However, as noted, for the regulated network energy businesses we consider that the regulatory arrangements contain a number of features that greatly limit the systematic risk that would otherwise apply in the absence of the regulatory protection and the natural monopoly type, essential service type characteristics and are most likely to lead to a high degree of stability for the equity beta.

With cash flow systematic risk being very low the other main factor that could impact on realised share returns and impact on the equity beta would be changes in investor discount rates. This consideration recognises that realised equity market returns depend on investor assessments of cash flows as well as the discount rates investors use to determine the present values of investments. However, we consider that the market risk component of the discount rate (which is the market price for relevant risk) would be the predominant factor that would change over time relative to a measure of systematic risk (measured by the equity beta) which captures the non-diversifiable risk of the entity under consideration relative to the market as a whole.

Given these features and recognising that economy-wide shocks are in general likely to impact on the market risk premium much more than industry betas, we consider that the betas of network energy businesses would not change much over time and particularly in the period since the regulatory arrangements described in this report have applied.

Although we consider that in general it is reasonable to give more weight to recent periods we consider that reliance exclusively on recent information should be avoided.

Use of equity betas for firms no longer listed

The appropriateness of using equity betas for firms no longer listed depends on the likely stability of beta for if beta is considered stable the historical use of estimates of beta for firms that are no longer listed would contribute to lowering the standard errors for the beta estimates meaning more statistically precise estimates would be obtained.

Exclusion of data

In relation to the exclusion of data relating to the treatment of outliers or highly influential data points, the appropriate response depends on whether they are believed to reflect the data generation process or are inconsistent with it. For significant events excluding them may bias estimates of the actual risk that the businesses carry. A key consideration, in relation to both outliers and the impact of significant events is the use of the estimated beta and whether the outlier is likely to be relevant given the designated use of the beta in the economic regulation context and the impact of the regulatory arrangements in muting economy-wide shocks for the revenues of the regulated businesses.

Reduction of ex ante returns and impact on systematic risk

The reduction in *ex ante* returns set in the allowed WACC by the AER, in recent years, is largely related to recognising a lower risk free rate in the CAPM and a lower allowed cost of debt. Beta measures the non-diversifiable risk of the entity relative to the market as a whole. Again, we consider that regulatory arrangements for regulated network businesses greatly limit their non-diversifiable risk in terms of the variability of their returns relative to the returns for market as a whole. This means there is very high cash flow stability that should in turn be reflected in the measure of systematic risk. We would expect that if there was an impact of *ex ante* returns on the systematic risk of energy networks through time it would be reflected in the market price for risk rather than the relative risk (beta) of the regulated entity. In other words investors may demand a higher MRP given a lower risk free rate.

To reiterate, we consider that the very high protection to returns afforded the regulated entities with the existing regulatory arrangements is a dominant factor limiting the scope for changes in systematic risk for regulated energy networks. So we do not see a clear theoretical or empirically based argument for the lower *ex ante* returns set by the AER to have materially changed the systematic risk for regulated energy networks through time. However, there is a separate issue of whether the reduction in *ex ante* returns means that there is a material impact on incentives to ensure efficient investment. In this respect we suggest the focus of attention should be on the level of the market risk premium and the issue of whether overall expected returns for the market as a whole are lower now than a decade or more ago.

Reduction in risk free rate or inflation rate and impact on systematic risk

Key considerations just discussed above are relevant to the question of the potential impact of a reduction in the risk free rate or inflation rate on systematic risk. We also note these are economy-wide developments that are affecting all firms and investors and conceptually we do not see there is theory to support a significant impact on the systematic risk of regulated energy network businesses. We also reiterate our view of the strong protection that the regulatory arrangements provide for interest rate risk and inflation outcomes and consider that this inflation protection is most likely to be much higher than exists on average in the market economy. We also note that both the level of inflation and its variability have been relatively low for some time and that this should generally contribute to limiting the impact of inflation on systematic risk.

We also recognise that the AER in its 2018 explanatory statement for the rate of return instrument noted that its regulatory treatment was to deliver "the initial real rate of return plus ex-post inflation outcomes" and that this approach would reduce systematic risk exposure because firms are insulated from inflation risk. The AER noted that, with this approach, the effects of (CPI) inflation are already incorporated in the observed financial market data and so the equity beta based on that financial data would reflect this treatment of inflation. In addition, the trailing average cost of debt provides a natural hedge against movements in interest rates.

We note that the main risk to the cash flows is in relation to under and over expenditure outcomes for operating and capital expenditure but the risk is greatly diminished with efficiency sharing schemes.. Our understanding is that the regulatory arrangements first determine the best nominal forecasts of these expenditures over the regulatory period then convert them to a present value using the allowed WACC and then determine prices indexed by the CPI such that the present value of the total revenue will equal the present value of the total allowed costs (the NPV=0) condition. This means there is both specific price risk and volume risk applying to both operating and capital expenditure. For example, the operating expenditure forecasts contain both a cost price element and a volume element and either could turn out significantly different to what was projected. However, these are risks that are not likely to be linked to general inflation as measured by the CPI. In addition, some of these risks may be specific or unique to the regulated firm and therefore diversifiable and not relevant for pricing in the CAPM.

In relation to consideration of whether changes in the risk free rate or inflation should be treated as cyclic or structural, given the high protection from the regulatory arrangements from actual inflation and interest rate risk and the likelihood that economy wide pricing developments would mainly impact on the market risk premium we don't consider there would be a materially different effect if changes in the risk free rate were cyclic or structural.

We would expect that if there was an impact of a reduction in inflation or the risk free rate on the cost of capital it would be reflected in the market risk premium which is the price of relevant risk rather than the systematic risk as measured by the beta for regulated energy network businesses. We also understand that commercial practice tends to focus on changes in the market risk premium rather that changes in beta in the context of changes in macroeconomic parameters.

Conclusion on choice of period

Reliability is the main criterion for evaluation of the time period and the following observations apply for the energy network businesses regulated by the AER:

- Provided there is not statistical evidence of beta instability the longest time period would provide the most reliable estimates for beta.
- The exclusion of data is not necessary and could produce less statistically reliable estimates of beta if there is no clear statistical evidence of beta instability. Robust regression methods may be used to diminish the effects of atypical observations that would otherwise have an undue effect on the estimated beta.
- The use of a shorter recent time period will produce less statistically precise estimates of beta, and it is not necessary to exclude earlier data if there is no clear statistical evidence of beta instability. With weekly data there may be sufficient precision with a five-year period. If the average beta is stable over a longer period, then greater precision of the beta estimate can be obtained.
- If there is reasonable evidence of beta instability then more weight should be considered for the recent evidence but longer term estimates are still relevant for the information set given the empirical evidence on beta stability that has been presented to date.
- The reduction in regulatory *ex ante* returns in recent years is unlikely to have a material impact on systematic risk which is a relative measure of risk.
- The reduction in the risk free rate or the inflation rate embedded in regulatory decisions for the CAPM is unlikely to have a material impact on systematic risk but there may be an impact on the market risk premium. This assessment reflects the high protection to the regulated entities for their cash flows, including regulatory protection against general changes in inflation, which is also captured in the risk free rate in the CAPM and the indexing of the RAB.

Choice of Comparator Set

The ideal benchmark

The AER aims to estimate the beta of a benchmark efficient entity defined as ‘a pure play, regulated energy network business operating within Australia’. A ‘pure play’ business is one that only provides the relevant regulated energy services, and is not engaged in other activities. This is an ideal and if strictly applied could limit the comparator set substantially and lead to less precise statistical estimates compared with including comparators that have similar fundamental business and risk characteristics.

The key question is with regard to reliability in forecasting. Further widening the group of comparators means including businesses that have differentiating characteristics, and the importance of those differentiating characteristics for business risk is generally unknown. Set against this drawback there is the advantage of improving the precision of the average beta estimate and, arguably, the resulting average beta is likely to represent a more reliable forecast. The literature suggests that there is a strong portfolio effect on the forecasting accuracy of beta with the benefits of the widening process being substantial for up to around 10 securities.

In considering the forecasting potential of the benchmark beta estimate the mean square error (MSE) of an estimator is relevant as the mean square error is the sum of the variance of an estimator and the square of the bias of the estimator. The MSE is relevant because a larger sample size may reduce the variance of an estimator but introduce more bias depending on the relevance of the sample. Given the information we have reviewed we are only able to assess the impacts in relation to MSE based largely on qualitative information but it is a useful concept for assessment purposes.

Characteristics of good or acceptable comparators

Key characteristics of good or acceptable comparators for the regulated network energy businesses that we consider are important are:

- Operating in the same industry and the same or a similar market or with similar production processes
- Low variability in returns over a business cycle
- Size and diversity that contribute to return stability
- Natural monopoly type characteristics
- Essential service or services with a relatively low income elasticity of demand
- High operating leverage reflected in a relatively high share of fixed costs
- Regulation or contractual arrangements or demand characteristics that contribute to high return stability
- Data that is limited to approximately the last 10 years

Assessments for the comparator set

We have considered these characteristics in broad terms as well as the likely impact on the MSE and assessed five options for consideration. The options and key advantages and disadvantages are summarised below.

Option 1 – retain the existing comparator set: The main advantages are high comparability of the comparators and low variance for the estimator, relevance and simplicity. The main disadvantage is the potential for bias as four delisted firms are considered less relevant given the time since they were delisted.

Option 2 – remove four firms in the existing comparator set given the time since their delisting: The main advantages are high comparability of the comparators, relevance, potential for low MSE and simplicity. The main disadvantage is a potentially higher variance of the beta estimate.

Option 3 – option 2 plus two toll companies listed in Australia and Chorus, a regulated telecommunications infrastructure provider operating in New Zealand but listed in both Australia and New Zealand: The main advantages are potential to contribute to a relatively low MSE, for the beta estimate, and simplicity. The main disadvantage is that the addition of the toll firms and Chorus would not be consistent with the 'pure play' benchmark as defined by the AER.

Option 4 – include overseas regulated energy network businesses with adjustments if required: The main advantage would be the scope to lower the variance of the estimator. The main disadvantages are the beta estimate could be biased and there are no simple adjustments to correct for this.

Option 5 – include unlisted firms with betas estimated using accounting information: The main advantage is additional information that could support the findings from the listed sample. The main disadvantages would be difficulties in implementation, including obtaining sufficient observations and lack of comparability to the estimates obtained from market data for listed firms.

Some further elaboration in relation to specific questions in the terms of reference is set out below.

Use of overseas firms as comparators

Ideally, the beta for each firm will be estimated against a common market index. However, if there is an insufficient number of comparators in the same local market the inclusion of overseas firms may be helpful although it is preferable if they come from nearby markets. In past consultations service providers have supported the use of international energy firms and there are a lot of listed firms in the United States that have been suggested for inclusion in the comparator set. However, US energy utilities are generally vertically integrated with greater risk from generation and retailing activities and their betas are measured against the US market index and subject to different regulation and there are no simple adjustments to take account of different business and regulatory characteristics.

However, consideration of betas from international comparators may help inform a view of a preferred estimate or to better inform specific questions such the impact of different regulatory arrangements on business risk or the effects of different estimation intervals and periods on beta estimates. In this respect we reviewed a large sample of betas from the US and found there was little difference in terms of the impact of different forms or degrees of regulation on electricity and gas betas. There were no significant differences between the betas for electricity and gas utilities, irrespective of whether one is using monthly or weekly data. We also found that the average beta for monthly data is lower than for the weekly data for both gas and electric utilities.

Use of accounting information

The terms of reference also requests consideration of estimating beta for unlisted firms with financial accounts information. This may be possible, but likely to be a difficult exercise and quite experimental in nature. There may be limited accounting data for unlisted businesses and that data may be affected by various non-operating factors and accounting conventions. Further, these estimates would not be directly comparable to the estimates obtained from market data for listed firms which reflect both cash flow assessments and investor discount rates, raising conceptual issues of how such different estimates might be combined.

Weighting comparators

The alternative weighting schemes include equal weights, market capitalisation weights, weights reflecting the statistical precision of beta estimates, and weighting according to relevance of comparators. For an investor, it will be most meaningful to calculate portfolio returns that use market value weights for averaging the returns on the constituent securities, since the result will actually be equal to the return to the investor on the portfolio. However, the purposes of the regulator in averaging betas is quite different. The weights should represent the relevant importance of each of the comparators as a comparator. If there is no information to bring to bear on an assessment of the relative importance of comparators, then a simple average, which gives them equal weight, would be the most useful approach.

Weights can also be developed that reflect the statistical precision of different estimates but these can be complex and may not be necessary if a pooled regression is used for estimating the beta from the comparator set. If a pooled regression is used with an unbalanced panel, it may be appropriate to downweight the firms with a greater number if observations, relative to those with fewer observations, if the firms have equal importance as comparators.

When business functions differ weights can also be developed to take account of the costs of the different functions but this is likely to be a complex and costly exercise and may not be necessary if there are sufficient comparable comparators. Alternatively, weights may be developed to reflect the degree of similarity or proximity of the business' functions to those of the benchmark efficient entity.

1 INTRODUCTION

Economic Insights Pty Ltd has been contracted by the Australian Competition and Consumer Commission (ACCC) and the Australian Energy Regulator (AER) to provide advice on methodological issues in estimating the equity beta for regulated network energy businesses.

1.1 Scope of Work

The AER applies a building block model to set regulated revenues for electricity and gas network service providers based on costs that would be incurred by an efficient benchmark entity. The regulated rate of return plays two distinct and important roles in determining allowed revenue or price paths within the energy network regulation frameworks:

- It is applied to the regulatory asset base to determine the return on capital component of the building block framework; and
- It is used as the discount rate for discounting forecast revenues and costs to ensure that the allowed revenue caps, or the forecast revenue associated with the approved price caps, are consistent in present value terms with the forecast cost base determined using the building block method.

The regulatory rate of return determined by the AER needs to achieve the National Electricity Objective (NEO) and National Gas Objective (NGO), and the related revenue and pricing principles (RPPs). The NEO is “to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to: (a) price, quality, safety, reliability and security of supply of electricity; and (b) the reliability, safety and security of the national electricity system” (National Electricity Law (NEL), s 7). The NGO is “to promote efficient investment in, and efficient operation and use of, natural gas services for the long term interests of consumers of natural gas with respect to price, quality, safety, reliability and security of supply of natural gas” (National Gas Law (NGL), s 23).

Determining the allowed rate of return entails, *inter alia*, estimating the weighted average cost of capital (WACC) for electricity and gas network businesses, with the return on equity component of the WACC estimated using a domestic capital asset pricing model (CAPM). This report is focussed on methods for estimating the equity beta component of the CAPM. This report does not make recommendations on different methodology choices but rather sets out key considerations and advantages and disadvantages of alternative options.

The following criteria, stipulated by the AER, are employed when evaluating the alternative approaches/choices that might be used when estimating equity beta:

- *Reliability*—produces estimates of the return on equity that reflect economic and finance principles, empirical evidence, and market information; estimates have minimal error, and are free from bias.
- *Relevance to the Australian benchmark*—as the benchmark firm operates in Australia; this may include ability to populate the model with Australian-relevant data.

- *Suitability for use in regulated environment*—this may include transparency, replicability, and consideration of any incentive effects.
- *Simplicity*–avoids unnecessary complexity or spurious precision, is able to be understood by a broad stakeholder set.

In preparing this report we have comformed to the standards set out in the Federal Court Guidelines for expert witnesses (Federal Court of Australia 2016).

Key matters required to be addressed in this report include:

- The relevant period for estimating the equity beta and implications of recent developments including: impacts in relation to inflation, the risk-free rate and the impact of COVID and similar events that may justify excluding certain periods;
- The proxy firm comparator set including *inter alia*: characteristics, relevance of overseas firms, sample size, impact of regulation, and weights for comparators; and
- Other issues related to the equity beta that are considered important having regard to the overarching objectives.

1.2 Organisation of the Report

In chapter 2 we summarise the AER's approach to estimating the return on equity and discuss the effect of regulatory frameworks on the cost of equity. Chapter 3 discusses theory and estimation issues in relation to the Capital Asset Pricing Model and beta. This includes current commercial practices in estimating beta, and alternative methods of estimating business risk. Chapter 4 reviews the theory and evidence relating to the return interval and estimation period for estimating beta. Chapter 5 focusses on answering the specific questions posed by the AER in relation to the choice of the estimation period. Chapter 6 covers the choice of comparators for estimating a benchmark beta. Chapter 7 discusses some broader cost of capital issues that are drawn on in the report.

2 RETURN ON EQUITY IN THE REGULATORY FRAMEWORK

This chapter firstly describes, in section 2.1, the AER's current approach to estimating the return on equity, as established in its *Rate of Return Instrument* (2018b), which is currently under review in the AER's *Pathway to 2022* process. Then section 2.2 discusses the effect of the regulatory framework on the cost of equity.

2.1 AER's 2018 Approach to Estimating Return on Equity

The AER determines the allowed rate of return using a WACC, and particularly the Vanilla WACC. This is a simple average of the cost of debt and the required return on equity (ROE), with weights equal to the benchmark proportions of debt and equity in total financing. Tax effects are accounted for separately in the revenue allowance. The ROE is the risk-free rate plus the product of the market risk premium (MRP) and the equity beta, the latter being the subject of this report.

The AER has adopted the Sharpe-Linter CAPM (SLCAPM) as its 'foundation model' for determining the equity beta. Although this is its central method, a range of other information and cross-checks are brought to bear by the AER in exercising its judgement on the appropriate choice for the forward-looking ROE for regulated energy network assets (AER 2018c).

2.1.1 AER's method of estimating SLCAPM betas

In 2018 the AER made the following decisions on its method for carrying out the SLCAPM analysis, deciding to:

(i) use only Australian energy network businesses as comparators, in an unbalanced sample of currently listed businesses and several delisted energy network businesses (with nine comparators in total);

(ii) use two methods of estimating the market model for each firm: ordinary least squares (OLS) and least absolute deviation (LAD) – the latter as a robustness check for the effects of outliers;

(iii) use weekly data (with monthly data as a cross-check);

(iv) test multiple estimation periods, including: (a) the longest period available for each firm; (b) the same excluding the 'tech bubble' and GFC periods; and (c) latest five years available for each firm. The AER preferred option (a) – the longest available period;

(v) use the Brealey-Myers formula for de-levering and re-levering betas. A benchmark gearing of 60 per cent used for re-levering;

(vi) use two methods of averaging:

- averaging the betas from individual firm regressions (after de-levering);
- constructing a series for returns on a portfolio of comparator firms (using fixed portfolio weights either equal-weighted or value-weighted) and using the portfolio returns in estimating the portfolio beta;

(vii) test seven different portfolios made up of different combinations of the nine firms in the sample;

(viii) use tests for whether thin trading causes bias;

(ix) use tests of the stability of equity beta over the sample period;

(x) *not* use a Blume or Vasicek adjustment.

Concepts such as SLCAPM, the Brealey-Myers formula for de-levering and re-levering betas, and the Blume or Vasicek adjustments are explained briefly in section 3.5.

2.1.2 Other information relied on

The AER also uses other information, in addition to the SLCAPM, to inform its decision-making on the cost of equity. Amongst the other information are two other methods of estimating the cost of equity which the AER has lower confidence in, namely:

(a) the Black CAPM; and

(b) the Wright approach.

These methods are briefly explained in section 3.5. In addition, the AER has regard to various financial indicators, and also has regard to:

- return on equity estimates of other regulators, brokers, and other financial valuation reports. An example of the latter is prospectuses which include explicit assessments of the cost of capital for the purpose of valuing companies;
- comparisons with return on debt, on the expectation that ROE for utilities may represent a reasonably stable premium above the return on debt. Specifically, the AER compares the equity premium (ERP), which is the ROE minus the risk-free rate, to the debt risk premium (DRP), which is the spread between BBB+ rated corporate debt and the risk free rate. The AER notes that in its 2013 decision the ERP was about 115 points above the DRP, and in its 2018 decision the ERP was about 170 basis points above the DRP (AER 2018a, p.54).

2.1.3 Summary conclusion

When determining the allowed rate of return in in any given regulatory application, for the purpose of determining the return on equity, the AER relies primarily on the SLCAPM as the foundation model for determining the beta. Econometric estimation of this model is carried out to derive a point estimate and a range for beta. Other models, data and evidence are used to yield other estimated ranges or directional information to inform beta and ROE. The AER's approach to using these estimates and information is evaluative and involves judgement in reaching a decision on its preferred beta estimate which it chooses from within the range determined using the foundation model.

2.2 Effect of the Regulatory Framework on the Cost of Equity

One determinant of beta, of particular importance is the existence and form of regulation. It is generally recognised that economic regulation usually buffers risk, thereby reducing the business risk of regulated businesses, and that different forms of regulation may impact on risk differently. Thus, the form of regulation can affect the level and variability of a firm's returns, and their degree of correlation with market returns, and thus influence beta.

2.2.1 Current regulatory frameworks for energy networks

The regulatory frameworks that currently apply to regulated network energy businesses in the NEM differ in some respects between electricity networks and gas distribution and transmission networks. Typically, they are either a weighted average price cap or a revenue cap for standard regulated services.

Under the National Electricity Rules the AER decides, for each regulated business, on a control mechanism to apply to standard control services (NER, r. 6.2.5). It must be of the prospective CPI–X form, or some incentive-based variant (r. 6.2.6), such as revenue yield control. The control mechanism is specified in the AER's framework and control paper (r. 6.8.1). The form of control mechanism for standard control services of electricity distribution and transmission businesses is a revenue cap. The annual pricing proposals of regulated businesses must demonstrate compliance with the standard control services revenue cap.

Under the National Gas Rules (NGR), an access provider proposes a reference tariff variation mechanism (NGP, r. 97). A formula for varying reference tariffs may (for example) provide for variable caps on the revenue to be derived from a particular combination of reference services; or tariff basket price control; or revenue yield control; or a combination of all or any of these factors.

- Gas distribution networks are currently regulated using a CPI – X tariff basket price control formula. The tariff smoothing mechanism may have some rebalancing side constraints, and there may be provision for adjustments in response to certain specified cost-pass-through events.
- APA's Victorian Transmission System (VTS) uses an 'average revenue yield' formula, which includes annual updates for the return on debt and also includes a cost-pass-through mechanism for specified types of events. The price control formula adjusts for the effect of differences between actual and forecast volumes over the regulatory period, to ensure that the net present value of building block revenues equals the revenues forecast to be achieved in the current regulatory year and future regulatory years of the regulatory period.

With particular relevance to the business risk of regulated businesses, the key features of the AER regulatory arrangements for regulated network energy businesses are set out below. Many of them were in place in 2013 (AER 2013, p.40, AER 2018b, pp.21–22). The 2018 Draft Guidelines provide a useful summary of all the key clauses in the NGR and NER that mitigate systematic risk (AER 2018, p.108 Table 10). Our interpretation of these and other relevant features is as follows:

- a total revenue cap ensures the estimated revenue over the regulatory period will be recovered in present value terms and that the regulated entity incurs no demand risk (except to the extent assets would be stranded which is highly unlikely for electricity distribution and transmission networks and gas transmission networks – see below);
- the total revenue cap is calibrated to recover estimated costs over the regulatory period with resetting of prices at the next regulatory period thereby limiting cost risk;
- the historical asset base rolls forward from one regulatory control period to the next and from year to year within each regulatory control period with indexation for actual inflation and guarantees the recovery of historical asset costs through deprecation, a real return on the asset base and indexation and recovery of future efficient capital expenditure;
- the allowed revenue for the regulatory period includes a component to recover the initial real rate of return plus ex-post inflation outcomes (but note that the expected nominal rate of return may vary because of inflation outcomes[1] and it and the real rate of return that is realised for the regulatory period can vary depending on under and over outcomes for operating expenditure and capital expenditure which are limited by sharing schemes – see below and AER (2020a, pp. 9-11);
- application of a trailing average cost of debt that provides effective protection against interest rate changes and recognises gradual refinancing of debt;
- cost pass through mechanisms for certain costs to be fully passed on to consumers (with some potentially relating purely to business specific risk that should not be recognised for compensation in the CAPM and some relating to unforeseen market wide influences that would mean a reduction in systematic risk exposure). For example, costs that arise through regulatory change can be fully passed on, and there is provision for re-opening a determination for capital expenditure relating to an event that is beyond the reasonable control of the service provider, and unforeseen at the time of making the determination;
- provision for tax in determining total revenue regardless of whether the service provider pays tax;
- tariff adjustment mechanisms that adjust for inflation, providing real price certainty over the regulatory period;
- tariff structures that include fixed charges, further reducing the impact of any change in aggregate demand;
- resetting the allowed weighted average cost of capital for each regulatory period

[1] The nominal WACC contains expected inflation which can differ from actual inflation so the ex ante nominal WACC, which is recognised, can differ from the ex post nominal WACC but the ex ante and ex post real WACCs are the same and **in effect** applied to a depreciated asset base indexed for actual inflation so real magnitudes are recognised in the regulatory framework. The expected inflation component in the nominal WACC is removed in the calculation of regulatory depreciation which reflects the need to avoid double counting as a nominal WACC is applied to an indexed asset base in an intermediate step.

thereby reducing interest rate risk and relevant economy wide risks captured in the market risk premium;

- an efficiency benefit sharing scheme that provides an approximate 30/70 sharing in present value terms to the firm and consumer respectively of under and over expenditure against operating expenditure benchmarks;
- a capital efficiency benefit scheme that provides an exact 30/70 sharing in present value terms to the firm and consumer respectively of under and over expenditure with over expenditure required to be confirmed as efficient;
- service standard performance measures with financial incentives; and
- protections from asset write-downs through provision for accelerated depreciation where warranted.

In relation to inflation we note some recent changes to the AER's approach (AER 2020, Lally 2020) to forecasting expected inflation which are considered to be more reliable. The changes mean that the expected inflation components in the regulated revenues will change but the RAB will still be indexed by actual inflation and the expected real return on assets will be realised as per the previous arrangements. However, there can be changes to the realised nominal return due to variations between expected inflation and actual inflation as explained above and in footnote 1.

Some of the changes were motivated by a mismatch between using the expected inflation consistent with a 10-year expected nominal rate of return and actual inflation realised over the five-year regulatory period. The changes mean that both expected inflation and actual inflation for a five-year term consistent with the regulatory period will be used to adjust revenues in the regulatory period. The AER (2020a, p.18) notes that this does not result in incorrect compensation as real returns and real prices are not affected, and nominal outcomes will be reflected in the market data used for estimating beta and the market risk premium.

However, we note there is still an issue of whether a 10-year WACC or a five-year WACC should apply when prices are reset on a five yearly basis. With an upward sloping term structure Lally (2020) maintains the NPV=0 condition will be violated to the extent that the relevant discount rate for the five-year period is less than the 10-year discount rate used to determine the WACC and used for setting prices and allowed revenues. In this situation an NPV>0 would usually be realised because an upward sloping term structure tends to apply most of the time, and this should provide additional benefit to the regulated entities.

2.2.2 Effects of regulation on business risk

It is generally accepted that regulation specifying a pure price cap regulation entails greater risk for investors than a pure revenue cap as demand risk is solely borne by the firm for pure price cap regulation but by consumers for a pure revenue cap. The differences may however be reduced in practice depending on adjustments to allow specifically for certain risks or to share risks. Currently revenue cap regulation applies for electricity network service businesses regulated by the AER, whereas previously a form of price cap regulation applied to electricity distribution businesses which provided strong incentives to under-estimate demand. As discussed, there are numerous other aspects of the regulatory arrangements that insulate energy network businesses from systematic risk (AER 2013, pp.40–41, AER 2018c, p.21). The importance of differences in risk between these forms of regulation is an empirical question.

The impact of setting a revenue cap has a particularly strong effect on cash flow risk. If the revenue cap strictly holds in a present value form then investors can be assured that they will be compensated for any total revenue variability within a regulatory period. For firms with large fixed costs relative to variable costs, revenue variability is normally likely to be a major source of return variability. However, changes in discount rates also affect returns (Lally 2000, pp.35–36). This is because the returns realised in the market, reflect assessments of cash flows as well as an investors discount rate for evaluating the present value of those cash flows.

The impact on beta can be shown as follows. Returns can be decomposed into revenue and cost elements. In their widely used textbook on the theory and practice of corporate finance, Brealey and Myers (1991, pp.199–200) defined the present value of an asset as equal to the present value of revenue less the present value of fixed cost (including debt costs) and the present value of variable cost. They express the relationship in terms of betas as follows:[2]

$$\beta_A = \beta_R \frac{R}{A} - \beta_{FC} \frac{FC}{A} - \beta_{VC} \frac{VC}{A} \qquad (2.1)$$

where β_A is the asset beta, A is the present value of the forward-looking value of the asset, R, FC, and VC are the present values of the forward-looking revenues, fixed costs, and variable costs of the firm respectively. The 'beta' for each of the latter three streams reflects the sensitivity of that component to the returns on the market portfolio of risky assets.

The intuition of this equation is that, just as an asset beta is a weighted average of equity and debt betas (with the weights being the shares of equity and debt in the total value of the asset), the asset beta can also be expressed as a weighted average of its underlying revenue and cost components. The weight for each of the betas for the revenue and cost components reflects the importance of that component in terms of its contribution to the present value of the underlying asset. Brealey and Myers (1991) note that the fixed cost beta is zero by definition and that the betas of the revenue and variable costs should be approximately the same because they respond to the same underlying variable. With a fixed cost beta of zero, the above equation becomes:

$$\beta_A = \beta_R \frac{R}{A} - \beta_{VC} \frac{VC}{A} \qquad (2.2)$$

The relative importance of cash flow variability and discount rate variability has been examined in an alternative approach developed by Campbell and Shiller (1989) and Campbell and Voulteenaho (2004) who decompose beta into a cash flow component and a discount rate component, and find that the latter is more important. However, Chen and Zhao (2009) argue that this approach has a serious limitation because the discount rate component is directly estimated while the cash flow component is a residual and could be a catch-all for modelling noise. The cash flow component inherits the impact of omitted variables that could explain the

[2] See also QCA (2012, pp.14–15) and Appendix A of this report.

discount rate component. They illustrate their point by applying the decomposition approach to Treasury bond returns with fixed cash flows so that the cash flow betas should be zero but they find the cash flow betas are larger than the discount rate betas. They conclude that omitted state variables[3] in the discount rate forecast can induce misleading patterns and lead to drawing wrong conclusions regarding the relative magnitude of betas. They also confirm that the results for equity betas are sensitive to the choice of state variables.

With a revenue cap, the revenue beta in (2.2) is in effect zero over the whole regulatory period. With a positive variable cost beta and no changes in weights and a relatively small variable cost share this implies a small negative asset beta. This relationship suggests that a revenue cap has fundamental implications for an asset beta. However, as noted, changes in discount rates can also affect returns and this would be reflected in the present value components for calculating the shares.

As best we know there is no settled position on this but it seems reasonable to conclude that that revenue cap will have an important impact on the stability of the asset beta and supports the proposition that it is relatively low (over the full regulatory period), particularly if the main components of a discount rate (the real interest rate, inflation and the market risk premium) are relatively stable. Other aspects of the regulatory arrangements are also considered to greatly mitigate equity risk for regulated network energy businesses and these are discussed further below.

Conceptually a pure price cap entails demand risk that is not present in a pure revenue cap. However, whether the demand risk is material for the regulatory arrangements that apply depends on mechanisms the regulated gas businesses with a price cap have for managing demand risk. If they have long contracts with large well established customers with secure demand then the risk is mitigated and we understand that long term contracts are a prevalent feature for gas network businesses. In addition, as noted by the AER (2013, p.41), under a price cap, service providers may restructure tariffs such that higher fixed charges are set to offset demand volatility and importantly under the national electricity and gas rules electricity distribution and gas service providers are able to propose the form of price control – revenue cap, price cap or any variation thereof – they employ. As noted by the AER (2013, p.42), if a service provider chooses a form of price control that maximises wealth and chooses a price cap over a revenue cap it implies that any expected increase in cash flows must outweigh an expected increase in risk. The AER has also considered this issue, and having regard to the empirical evidence, is "of the view that the systematic risk differences between gas pipeline and electricity network businesses are not material enough to reasonably justify different benchmarks" (AER 2018c, pp.53–56).

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[3] A state variable is a variable that reflects the state of a system at a point in time. For the variance decomposition of the Treasury bond returns Chen and Zhao (2009, p. 5225) use the following state variables different combinations of the term spread (the difference between the long-term and short-term bond yields), real interest rate, inflation, and credit spread (Baa over Aaa bond yield). Additional financial variables are included for the variance decomposition for the equity market (p. 5228).

We consider that regulatory arrangements for regulated network businesses greatly limit their non-diversifiable risk in terms of the variability of their returns relative to the returns for market as a whole. In summary, key features include revenue caps and scope to structure charges to recover fixed costs, cost pass-through arrangements, regular re-setting of prices to reflect efficient costs, annual indexing of the asset base and efficiency sharing schemes.

In terms of realised earnings, the main potential variability seems to relate to over and under expenditure on approved operating and capital expenditure where there are sharing schemes in place that allocate approximately 30 per cent of the under or over amount in present value terms to the regulated business for operating expenditure and exactly 30 per cent in present value terms for capital expenditure. This means there is very high cash flow stability that should in turn be reflected in the measure of systematic risk.

3 RETURN ON EQUITY: THEORY AND ESTIMATION ISSUE

This chapter firstly outlines, in section 3.1, the conceptual meaning of the equity beta, key underlying assumptions of the CAPM and some reservations about the CAPM. Section 3.2 describes commercial practice in estimating the equity beta. Section 3.3 discuss methods for estimating equity betas and asset betas. Section 3.4 discusses econometric estimation issues. Some of the methodological issues relating to estimating betas which have been matters of contention in previous AER consultation processes are briefly noted in section 3.5.

3.1 Meaning of Equity Beta

3.1.1 The Beta Value of a Company

The capital asset pricing model (CAPM) reflects the fundamental trade-off between return and risk for investors, due to risk aversion. The greater the risk of an investment, the greater the return needed to attract capital to that investment. The return of investment j is measured by the expected rate of return $E[R_j]$, and the risk is measured by the variance $Var[R_j]$ or by the standard deviation.

When the correlation coefficients between securities are less than one it is possible to improve the balance between risk and return by forming a diversified portfolio. An optimal portfolio is one with the highest expected return for a given variance, or the lowest variance for a given expected return. A portfolio is optimal when all securities with the same marginal variance have the same expected returns. That is, "if a portfolio is optimal, then all securities with the same beta value relative to the portfolio must have identical expected returns" (Berndt 1990, p.27).

The beta value of security *j* is defined as:

$$\beta_j = \frac{\sigma_{jp}}{\sigma_p^2} = \rho_{jp}\left(\frac{\sigma_j}{\sigma_p}\right) \tag{3.1}$$

where:

- σ_p^2 is the variance and σ_p is the standard deviation of optimal portfolio p;
- σ_j is the standard deviation of security *j*; and
- σ_{jp} is the covariance and ρ_{jp} is the correlation coefficient between security j and portfolio p.

The market portfolio is taken to be an optimal portfolio. The beta value of security *j* depends on the inherent riskiness of security *j* relative to the riskiness of the market portfolio, and the degree of correlation between movements in the returns on security *j* and those of the market portfolio.

3.1.2 The Standard Market Model

Statistical techniques can be used to measure the equity beta, and since it is formally defined as the covariance over time between returns on the specific investment and returns on the market as a whole divided by the variance of returns for the market as a whole, it is measured by the beta parameter in the following regression models.

The most accepted form of the CAPM is the Sharpe-Lintner CAPM (SLCAPM), in which:[4]

$$E(R_j) = R_f + \beta_j[E(R_m) - R_f] \quad (3.2)$$

where:

- R_f is the risk free rate of return
- $E(R_m)$ is the expected return on the market portfolio of risky assets
- $\beta_i = \sigma_{jm}/\sigma_m^2$ is the measure of business risk of company j.

This can be formulated as a regression equation in the form:[5]

$$Z_j = \alpha_j + \beta_j Z_m + \varepsilon \quad (3.3)$$

where $Z_j = R_j - R_f$ and $Z_m = R_m - R_f$ are the excess returns above the risk-free rate of security j and the market portfolio respectively; and ε is a normally distributed stochastic variable. In theory, α_j should equal zero, but in practice it may be above or below zero for a given security over a particular period. Nevertheless, in most cases the OLS estimate of α_j is found to be statistically insignificantly different from zero (Berndt 1990, p.36).[6]

A simpler and also common way of estimating beta is to use the following regression:

$$R_j = \alpha_j' + \beta_j R_m + \varepsilon' \quad (3.4)$$

Note that in principle both betas should be the same because $\alpha_j' = \alpha_j + (1 - \beta_j)\bar{R}_f$, and $\varepsilon' = (1 - \beta_j)(R_f - \bar{R}_f) + \varepsilon$. Generally speaking, $\hat{\beta}_j$ estimates using (3.3) and (3.4) are not identical but are typically quite close to one another. Equation (3.3) should yield a best unbiased linear predictor (BLUE) of β_j. Patterson argues that if R_f is correlated with R_m, then in equation (3.4) the omission of R_f may cause ε' to be correlated with R_m, causing bias in the estimated beta in that model (Patterson 1995, p.119).

Note that *j* need not be a single security. It can be a portfolio of securities where R_j is defined as: $R_j = \sum_k w_k R_k$, where securities k = 1 … K are in the portfolio with value-weights w_k. In

[4] Returns are generally defined as: $R_t = (P_t + D_t - P_{t-1})/P_{t-1}$. This is equivalent to the rate of change in an accumulation index. Some analysts alternatively define returns as: $r_t = \ln[(P_t + D_t)/P_{t-1}]$.

[5] Equation (3.2) is expressed in *ex ante* terms – i.e., in terms of expectations. Equation (3.3) is in *ex post* terms – i.e., in terms of realised returns.

[6] Note that the R^2 of the estimated market model measures the systematic risk in proportion to total risk.

this case the beta obtained from a market model regression, that is the beta for the portfolio, has the following relationship to the betas for the individual securities that make up the portfolio: $\beta_j = \sum_k w_k \beta_k$.

The econometrics of estimating beta is discussed further in section 3.3.

3.1.3 Non-diversifiable Risk

The equity beta parameter in the CAPM measures the equity risk for the particular investment *relative to* the risk of investing in the overall market of interest. The price of the risk is the market risk premium (Damodaran 2020, p.6, Patterson 1995, pp.10 & 37). This follows since the beta of the market portfolio is by definition equal to 1. The relative amount of systematic risk of the firm is measured by its beta. The product of the equity beta and the market risk premium measures the equity risk premium that is added to the risk free rate to determine the required expected return on equity for the investor.

In the SLCAPM, the beta parameter is the only investment or firm-specific parameter that is recognised in estimating appropriate compensation for risk. The theoretical foundations for the CAPM support the propositions that; (i) a distinction can be made between diversifiable (or unique or non-systematic) risk and non-diversifiable (or systematic) risk from the perspective of investors; and (ii) that diversifiable risk is not priced because it can be eliminated by diversification. The non-diversifiable or systematic risk for the individual firm is the product of the equity beta and the market risk premium that relates to the market as a whole.

The relevance of this theoretical distinction between non-diversifiable or systematic risk, which is compensated through a higher return than the risk-free rate (or equity risk premium), and unsystematic risk which is not compensated, is supported by the following two observations:

- "Tests have proved that alphas exhibit no serial correlation, or tendency to repeat. That is, a stock that outperformed the market over a given period (i.e. had a positive alpha) is no more (or less) likely to outperform the market (i.e. persist in positive alpha) in a subsequent period than a stock that previously had under-performed the market (i.e. had a negative alpha)" (Stewart 1991, p.440); and
- When well-diversified "stock portfolios of as few as 15 companies are constructed, most of the idiosyncratic monthly movements [i.e., the ε's] in individual shares cancel out" so that the variance of ε is diminished (Stewart 1991, pp.440–441).

Thus, using either equation (3.3) or (3.4), where j represents a diversified portfolio, these two observations imply that over time the α's and ε's diminish in importance, and "the risk of holding a well-diversified portfolio is attributable entirely to unpredictable movements in the market as a whole" (Stewart 1991, p.441).

3.1.4 Key assumptions of the CAPM

The validity of the CAPM depends on the extent to which its underlying assumptions reasonably apply in practice. One fundamental assumption is that investors are only concerned with the expected average return and the variance of returns, and not higher order moments, so that potential skewness in the distribution of returns can be ignored. Other assumptions include:

(i) that markets are sufficiently efficient in pricing risk; (ii) that the SLCAPM parameters are not state-dependent; (iii) the model is a one period model that applies to all investors; and (iv) inflation is implicitly assumed to be zero.[7]

It is also relevant to recognise that the equity beta depends on the type of business and assets (business risk) as well as the capital structure or financial leverage of the business (financial risk). Business risk is measured by the unlevered equity beta, also called the 'asset beta', or the 'business risk index' (Stewart 1991). The ratio of the firm's equity beta to its asset beta is a measure of its financial risk.

The unlevered or asset beta is in effect a weighted average of a debt beta and an equity beta, with the weights reflecting the capital structure. Financial leverage affects the equity beta but not the asset beta so that as financial leverage or gearing (the share of debt in total capital) increases the equity beta increases offsetting the impact of increased leverage on the asset beta. Debt beta represents the systematic risk in debt returns, which arises from both default risk and maturity risk. Regulators often assume that debt betas are zero. Empirical evidence suggests they are positive but small (Franks et al. 2008, p.23).[8] They can be positive because some interest rate risk is likely to be systematic, and because default risk can be connected to market risk for some highly geared companies.

The standard model is an unconditional model meaning that the beta is not dependent on the time period. This has implications for the discussion about the period of time over which beta should be estimated and factors that may affect beta differently over different time periods. In econometric studies, beta is generally assumed to be unchanging over the estimation period. Berndt reports that econometric studies of betas of US firms using monthly data over a five-year period find that the betas are usually, but not always, relatively stable over that period. That said, there "are cases, however, in which conditions in an industry or a firm abruptly change, implying that the relevant β_j might also vary" (Berndt 1990, p.35). The stability of beta is an important econometric issue, and may constrain the length of feasible sample periods. Berndt emphasises that analysts should examine the stability of betas over time using statistical techniques such as Chow tests or event study methodologies.

3.1.5 Some reservations about the CAPM

This report on methodological issues in estimating beta has been commissioned on the implicit assumption that the CAPM is a valid model. Nevertheless, reviewing challenges to the validity of the CAPM highlights pertinent aspects of the methodological issues in estimating beta. To be clear, we agree with the prevalent view in industry – as evidenced by widespread application of the CAPM – that the CAPM is the best available model for estimating expected return but that acknowledging the challenges provides a fuller appreciation of the methodological issues in estimating beta and how they are best addressed.

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[7] See Lally (2000, pp.2–3) for a full list of assumptions.

[8] Based on a study by Schaefer and Strebulaev (2004) the debt beta for BBB bonds is estimated to be about 6 basis points (Franks et al. 2008, p.23).

The principal challenge to the CAPM is that a substantial body of research, the most influential if not the first being Fama and French's (1992) paper "The cross-section of stock returns", documents results showing that the association between actual equity returns and expected equity return derived from the CAPM is essentially flat. That is, variation in beta, which drives the difference in expected return across firms, is not effectively predictive of *ex post* outcomes. A range of models incorporating additional factors, including firm size and book-to-market ratio in the Fama-French three factor model plus momentum in the Carhart four-factor model, have been found to yield estimates of expected return more closely associated with actual return. Other studies have documented an empirical association between returns and, respectively, month in the year (i.e., the January effect), past profitability, accounting accruals, and dollar trading volume, to name a few. John Cochrane, in his 2014 Presidential Address to the American Finance Association titled "Discount rates", famously referred to "a zoo of new factors", a turn of phrase that hinted at his discomfort with the lack of a theoretically well-grounded basis for introducing new factors (Cochrane 2011). Indeed, Bartram, Lohre, and Pope (2021) report that research "on cross-sectional stock return predictability has documented over 450 factors".

In the face of so many studies reporting that asset pricing models with multiple factors have a closer association between expected return and actual return than the CAPM, it is striking that the one-factor SLCAPM continues to be widely used in practice to estimate the cost of equity capital. Indeed, the use of the CAPM in industry has grown rather than declined notwithstanding that the essentially flat empirical relationship between beta and actual return was publicised in the early 1990s. This is likely due to the three reasons discussed next.

One, the CAPM is theoretically well supported. The elegant and logically coherent theory on which the CAPM is based provides a basis for practitioners to winnow the "zoo" of factors empirically associated with historical return to a tractable one-factor model. The literature critical of the CAPM has tended to compare how well the CAPM has performed against a miscellaneous assortment of factors with no theoretical support and the alternatives have not proved robustly reliable either. For instance, firm-size, perhaps the most well-known member of the factor zoo ever since Banz (1981) reported a negative relationship between firm size and return, has not been reliably associated with future return for long stretches of time. Indeed, Horowitz, Loughran, and Savin (2000) report findings that lead them to conclude "size should not be considered as a systematic proxy for risk". The point here is that the alternatives to the one-factor SLCAPM are empirically unreliable in addition to being theoretically unsupported which leaves practitioners without a disciplined basis to identify a model of expected return.

The second closely related likely reason for the CAPM's popularity with industry practitioners is that it provides a clear analytical basis to estimate the cost of capital. There are challenges with estimating the model's parameters, hence the need for reports such as the present one, but the conceptual path is clear. The model identifies and justifies the parsimonious set of variables – just three! – whose values need to be determined to arrive at an estimate of the cost of capital.

Finally, and this is perhaps the most significant reason for the CAPM's continued popularity with industry practitioners, relative to multi-factor models, the CAPM more readily facilitates the application of expert judgment in estimating required expected return.

Industry practitioners typically do not apply the CAPM in a mechanistic way but use expert judgement to vary the values of its estimated parameters to take into account aspects of risk not captured by the model but relevant to stakeholders. All models require the application of judgement in estimating parameter values. The parsimony of the CAPM means there are fewer parameter variables that require the use of expert judgement. Having to apply judgement to estimate the values of multiple parameters without well-grounded theoretical guidance about their relative importance is difficult. In essence, having to focus on turning just one dial is easier than turning on many dials without understanding their relative importance.

An understanding that mechanistic application of the CAPM must be supplemented by expert judgement casts a different light on the academic literature showing a flat relationship between beta and expected return. Academic studies using large samples are constrained to rely on estimates of beta based on historical data. The significant methodological issues in identifying, obtaining and using historical data to estimate beta lower the likelihood of finding an empirical association between beta estimated from historical data and future return. Expert judgement is needed to ameliorate the issues. That is, estimates of beta obtained from regression analysis are a starting point, not the end point, for estimating beta. A review of industry practice and academic studies supports the above interpretation. SFG Consulting, in its (2013) report "Evidence on the required return on equity from independent expert reports" observes that independent experts' estimates of expected return for a set of low beta companies were higher than the estimate yielded by a mechanistic application of the model. In other words, the experts estimated that the CAPM-based valuation was too high for the stocks. Strikingly, in their paper "CAPM-based company (mis)valuations", Dessaint, Olivier, Otto, and Thesmar (2021) report findings that suggest the independent experts' judgement is right. The implied valuation of low-beta stocks when beta is estimated mechanistically is too high.

However, it is also important to recognise the context and purpose in using the CAPM. While the CAPM as used in the 'mechanistic way' might not be generally adopted in valuation reports it may still be appropriate in a regulatory context where the monopoly nature of the firm and the regulatory arrangements provide strong stability in the cash flows and low revenue and profit risk, and hence low beta, for the firm.

3.2 Commercial practice

Commercial practice provides a "market test" of the usefulness and relevance of the CAPM. It also shows how market participants address the issues in applying theoretical valuation concepts in particular circumstances.

Identifying commercial practice is difficult since most companies understandably prefer to keep how they arrive their estimates of their cost of capital confidential. However, independent expert reports are often legally required to be commissioned and published for the benefit of shareholders in transactions of publicly listed companies involving schemes of arrangements, mergers and acquisitions, share issues and capital reductions. Pertinently, in these cases the independent experts are required to explain and justify their choice of valuation method, where relevant. Independent expert reports therefore provide an authoritative and credible source of information to assess if and how valuation techniques and concepts, including the CAPM, are used in commercial practice. As seen next, others share this view.

In June 2013, SFG Consulting, whose principal is Professor Stephen Gray, produced a report

"Evidence on the required return on equity from independent expert reports" for the Energy Networks Association to, *inter alia*, review the usefulness of valuation evidence from independent expert reports and to consider the difference between the values for expected return estimated by the experts and values arrived at by a mechanistic application of the model (i.e., without the application of judgement). SFG Consulting's report built on Ernst & Young's (now EY) (2012) review of 889 independent expert reports issued between 1 January 2008 and 10 October 2012. Around 15% of the 889 expert reports included an estimate of the required return on equity. In its update of the EY report, SFG looked at the 12 independent expert reports issued between October 2012 and June 2013 that included a detailed description of how they arrived at a WACC for the purpose of discounting future cash flows.

The principal reasons only a small minority of independent expert reports included a detailed discussion of their WACC valuation methodology were that a valuation was not required and/or the data to estimate the requisite cash flows to apply a DCF analysis were not available.

A striking characteristic of those expert reports that estimated the cost of equity capital using an asset pricing model is that without exception they all selected the single-factor CAPM, usually on the basis that it has the strongest theoretical foundation and is used most frequently. Justifying the CAPM on the basis that it is the most frequently asset pricing model is of course a self-fulfilling rationale and somewhat circular. On the other hand, it does attest that the alternatives to the single-factor CAPM have not found favour in industry, whatever their merits. At the very least it seems we may reasonably conclude that when total costs and benefits of the various CAPMs are considered, the single-factor CAPM is viewed by industry as the most tractable and fit for purpose.

The frequent reference to the single-factor CAPM's strong theoretical foundation in independent experts' reports is not merely a nod to the model's academic standing. The theory from which the CAPM is derived provides the basis for the experts to apply their judgement. For instance, all the independent experts that showed how they arrived their estimate of cost of equity capital used, as their starting point, the estimate of beta obtained by regressing firms' returns against historical market returns. However, as is well recognised, firms change their characteristics so historical relationships may not hold in future. As Damodaran (1999) has noted, the "objective is not to estimate the best beta we can over the last period but to obtain the best beta we can for the future". Bearing this point in mind, the independent experts used their judgement, guided by theory, to adjust the mechanistic estimates of beta to reflect what they believe to be the best beta for the future.

3.3 Methods of Estimating Equity and Asset Betas

There are several methods for estimating the risk premiums (or asset beta) of particular firms. The most well-established is to use historical data on market prices for the securities of those firms and estimate betas using regression analysis. This approach is only available if the firms being analysed are listed. Other approaches include (Damodaran 2011, p.121):

- examining a business's fundamentals to assess the general class of risk which it is likely to belong to;
- bottom-up analysis of the firm's beta; or

- use of accounting data to estimate beta.

3.3.1 Fundamental analysis of beta

The fundamental approach to analysing beta assumes that the risk premium of a firm is driven by observable features of the firms's business. Comparisons of characteristics against other firms may provide useful information about the general risk class that a firm belongs to. This may enable some indicative estimate to be made of the firm's beta.

Damodaran suggests there are three key factors to consider (Damodaran 2011, p.131):

(a) *The type of business or businesses that are firm is in*: The more sensitive are revenues to market conditions, the higher the beta. A firm whose products are discretionary may have a higher beta than one that supplies 'essential' products with inelastic demands.

(b) *Degree of operating leverage*: The higher the ratio of fixed costs to total costs (i.e. 'operating leverage'), the greater will be the variability of operating income for a given degree of variability in revenues. Firms with higher operating leverage will have higher betas.

(c) *Degree of financial leverage*: An increase in financial leverage, all else equal, will increase the equity beta of a firm. This is because higher leverage increases the variance in equity earnings per share, making equity investment in the firm riskier.

For example, Damodaran suggests that the correlation of a firm's sales revenues with cyclical conditions in the market may provide a useful indication of the degree of risk associated with the type of business the firm is in. The degree of operating leverage may be indicated by the average ratio of the rate of change in operating profit and the rate of change in sales (Damodaran 2011, p.132).

Lally (2000, pp.27–29) provides a summary of determinants of beta, many of which have been examined in the regulatory context in Australia (e.g. Incenta 2014 on the Aurizon rail network). Referencing the factor approach in Arbitrage Pricing Theory (APT) Lally notes that differences in betas would arise from differences in the factor coefficients for each risk factor measure. For industrial equities, he considers that sensitivities to inflation, market risk aversion and the long term real interest rates should generally be similar, implying a similar impact on beta. However, there may be significant differences in sensitivities to real GNP.

Lally then provides a summary of key determinants of beta including empirical findings. The determinants of beta include: the nature of the firm's output (e.g. measured by the income elasticity of demand); the duration of the firm's contracts with suppliers and customers; the existence of price or rate of return regulation (see: Rosenberg & Guy 1976); the degree of monopoly power (but results are mixed); real options (that should increase the sensitivity of returns to real GNP shocks but assuming there is uncertainty about growth prospects (see: Dixit & Pindyck 1994); operating leverage (higher fixed to operating costs will mean greater variability of EBIT than the relative variability of sales; a firm's market weight – increasing a firm's weight in the market proxy will draw its beta towards unity (Lally & Swidler 1997); capital structure – greater financial leverage means greater sensitivity of returns to real GNP.

Lally (2000, p.29) notes that, apart from adjusting for financial leverage, correction for other factors affecting beta does not seem promising due to lack of theoretical formulas or to significant controversy about the appropriate formula but that it is common practice to adjust comparator betas subjectively to accommodate for at least some of these other factors. Lally also notes that econometric approaches could allow for pure statistical corrections of the direct recognition of other explanatory variables.

Chapter 6 draws on the relevant key determinants of beta, as identified by Lally, in considering how to choose the comparator set for determining beta.

3.3.2 Bottom-up analysis of beta

Firms often consist of a number of different business activities, and the asset beta of the firm is a weighted average of the asset betas associated with those different business activities. The bottom-up approach involves (Damodaran 2011, pp.137–139):

- identifying the different business activities that the firm is engaged in;
- for each of those activities, identifying a listed firm (or firms) primarily engaged only in that business activity;
- estimate the equity betas of those firms identified as comparators for each of the individual business activities using econometric analysis;
- make the necessary adjustments for levering and for cash holdings;
- calculate the weighted average of the unlevered betas obtained for each business segment, with the weights being the estimated values of those business segments in the firm being analysed.

The result is called the 'bottom-up' beta. An estimate of the standard error of the bottom-up betas can be obtained using a weighted average of the standard errors of the econometrically estimated betas, divided by the square-root of the number of firms over which the average is calculated (Damodaran 2011, p.139).

3.3.3 Accounting Betas

Another way to estimate the beta for an entity is to use accounting information. The accounting beta approach attempts to estimate the asset or equity beta of a firm using accounting earnings, rather than from traded prices. This entails regressing accounting earnings or cash flow on the returns on a diversified portfolio of assets such as an index-based market return. Alternatively, a firm's earnings may be regressed against macroeconomic indicators that are an attempt to measure returns on a much more comprehensive range of assets (Ball et al. 2021).

Ball et al. argue that conventional beta estimates, in which the market return on a firms' equities is regressed against a securities market returns index, rely on a restrictive subset of aggregate assets, resulting in mismeasurement of systematic risk. Their study uses macroeconomic indicators to represent aggregate asset risk: namely, movements in total factor productivity (TFP) to represent supply-side risks and movements in aggregate wealth to represent demand-side risks. They argue that accounting-based betas should be based on macroeconomic indicators, because they are better aligned in time with accounting earnings than are the returns of a market index, which are forward looking.

Ball et al. argue that accounting-based beta estimates should be used in addition to betas derived from market securities. Others are critical of the accounting beta approach. Damodaran suggests that it may be difficult to measure systematic risk using accounting betas because accounting measures of earnings:

1) are measured only quarterly or yearly, resulting in few observations;
2) tend to be smoothed out, dampening the underlying effects of changes in business conditions; and
3) are affected by various changes in non-operating factors such as depreciation (Damodaran 2011, p.148).

Similarly, Lally (2000, p.35) argues that betas measure systematic risk in returns which reflect systematic risk in both cash flows and discount rates whereas accounting betas proxy at best for only systematic risk in cash flows. This may mean that accounting earnings are smoother relative to returns reflecting the underlying value of a company, making accounting beta estimates less well-defined.

We note that these are empirical questions, and whether accounting betas can be adequately estimated is something that can only be tested in practice with accounting data for Australian energy networks.

3.3.4 Concluding comments

The regulated functions of energy networks are viewed as effectively carrying on a single business activity. Although there are some listed businesses that are primarily engaged only in that same business activity, they are few in number. If other firms are to be included in the sample, then either:

(a) Those businesses must have fundamentals similar to those of energy networks. That is, they should be ‘essential’ services for consumers and have a high degree of operating leverage; or

(b) May be diversified businesses that have, as one of their business activities, the operation of energy networks. For these businesses the task is almost the opposite of that described as the bottom-up approach. Since these firms are engaged in several different business activities, it would be necessary to decompose their asset betas, in order to find a specific asset beta applicable to their energy network activities.

3.4 Econometric Estimation Methods

3.4.1 Averaging and Pooling

Once the comparator set has been chosen there is a need to select an appropriate point estimate for the beta. It is well accepted that some type of averaging mechanisms should be used to average out idiosyncratic differences if the objective is to obtain a reliable beta for a single company. Averaging across beta estimates from just a few different companies can greatly reduce statistical error.

There are at least three ways for obtaining an average beta for a group of businesses that form the sample of comparators.

(1) Calculating a simple or weighted average of the individual betas estimated using individual firm OLS regression.

(2) Consolidate assets into a portfolio by calculating a weighted average return for that portfolio and using that as the dependent variable in the market model.

(3) Pool the data for the comparator firms and estimating the market models for the comparator firms jointly as a system using maximum likelihood estimation (MLE). An average estimate for beta can be obtained by imposing a constraint on this model.

The AER has used the first two of these approaches. The last of these options could also be tested by the AER.

3.4.1.1 Averaging betas

Once equity beta estimates have been obtained for a set of comparable firms using individual firm OLS regression, an average beta for those firms can be calculated by a simple average, or a weighted average with weights based on market capitalisation. The AER and industry consultants have commonly calculated arithmetic averages of equity betas obtained from individual firm regressions. Usually, unlevered betas are calculated for each firm using that firm's debt-to-equity ratio, and the average of the unlevered betas is also calculated. The range of reasonable estimates may then be determined based on the highest and lowest of the estimated betas among the comparator group of firms.

Alternative procedures are available for determining the reasonable range and for unlevering. If the equity betas are averaged, then Damodaran notes that the standard error of the average beta can be approximated by the formula (Damodaran 2011, p.139):

$$\bar{\sigma}_\beta = \frac{\text{Average } \hat{\sigma}_\beta}{\sqrt{N}} \tag{3.5}$$

where N is the number of firms in the comparator group, and $\hat{\sigma}_\beta$ is the standard error estimate for the beta of a comparator firm.

Damodaran also observes that we can unlever the betas before averaging, which is a common practice as mentioned, or alternatively we can average the equity betas first, and then unlever the average beta using the average debt-to-equity ratio of the comparator firms. He suggests that this latter approach is preferred as it leads to a lower standard error (Damodaran 2011, p.138).

3.4.1.2 Portfolio models

Another common method of obtaining an average beta for a group of comparator firms is to define a portfolio return: $R_p = \sum_k w_k R_k$, where w_k is a weight, and the weights sum to 1 (Henry 2014, pp.34–35).

Lally (2000, p.26) reports that Eubank and Zumwalt found substantial reductions in errors in moving from one to ten asset portfolios but commented that these benefits are mitigated by biases that can arise from differences across the comparators that cannot be corrected for. Patterson (1995, p.128) reports that Klemkosky and Martin demonstrated that the mean square error of the precisions using OLS estimation was reduced by more than two-thirds when ten securities with similar betas were grouped together rather than being estimated singly.

Individual beta estimates can be pooled by equal weighting, market value weighting, choice of the median, the Vasicek method (taking the simple mean of the comparators' beta estimates and the direct beta estimate of the firm of interest and weighting them in inverse proportion to the variances of the distributions from which they are drawn) and statistical estimation of a pooled sample.

Patterson (1995, p.127) notes that if the error terms are completely independent across securities and if the true beta is the same for all N securities in an equally weighted portfolio the standard error of the aggregate estimated beta for the portfolio SE[$ß_p$] will be equal to $1/\sqrt{N}$ times the mean value of SE[$ß_p$]. This is similar to the reduction in standard error of beta that occurs by simply averaging individual estimates of beta.

Franks, Lally and Myers (2008, pp.24–25) in their review of the cost of capital methodology of the Commerce Commission of New Zealand provided differing views on the benefits of a pooled portfolio or industry regression. Myers supported the estimation of an industry beta if the companies are similar given the reduction in standard errors that could be expected and the overall standard error can be readily obtained. He suggests that then the Commission could assess whether the beta of a single company in the industry differs from the industry average. This could be done by weighting the single company estimate against the industry estimate, taking account of both standard errors and also other information, such as differences in business mix, operating leverage and growth opportunities, to obtain a final estimate for the individual company. Lally was doubtful whether reliable adjustments can be made to industry average asset betas to account for intra-industry variations across firms in factors other than financial leverage (for example, operating leverage and growth options). Lally preferred estimation of the industry average asset beta from the estimates for the individual firms within the industry.

3.4.1.3 Pooling regressions

The pooled SLCAPM model is as follows (Campbell et al. 1997, pp.189–190). For a group of assets $i = 1 \dots N$ and periods $t = 1 \dots T$, the SLCAPM excess-return market model is:

$$\mathbf{Z}_t = \boldsymbol{\alpha} + \boldsymbol{\beta} Z_{mt} + \boldsymbol{\epsilon}_t \tag{3.6}$$

where $\mathbf{Z}_t$ is an $N \times 1$ vector of excess returns on assets, with the *i*th element: $Z_{it} = R_i - R_f$, and $Z_{mt} = R_m - R_f$ is the excess return on the market portfolio (where R_i, R_f, and R_f are the returns on asset *i*, the risk-free rate and the market portfolio respectively);[9] $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$ and $\boldsymbol{\epsilon}_t$ are $N \times 1$ vectors of intercepts, betas and disturbances respectively. A hypothesis implied by the

[9] An asset can be a portfolio, in which case it is the return on the portfolio.

SLCAPM model is that $\alpha_1 = \alpha_2 = \cdots = \alpha_N = 0$; and this can be tested. Although the intercepts should all equal zero in theory, this constraint is not imposed in estimation (because in that case the beta estimates would not be BLUE, and the beta estimates are the objective).

An estimate of the average equity beta for the pool of comparator firms can be obtained by imposing the constraint: $\beta_1 = \beta_2 = \cdots = \beta_N$. The standard error on this estimated beta yields a proper confidence interval for the average beta. The average equity beta can then be unlevered using the average debt-to-equity ratio in accordance with the approach of unlevering *after* calculating the average recommended by Damodaran and discussed above. If weights need to be applied to different businesses in the sample, this can easily be done within the estimation routine.[10] This pooling method, with the constraint of equal betas imposed, yields the same estimate for average beta as the portfolio method discussed above if the panel is balanced, but yields somewhat smaller standard errors of beta because it uses a greater number of observations.

Alternatively, the constraint imposed may be that the asset betas of the group of comparator firms are equal. That is: $\beta_1^A = \beta_2^A = \cdots \beta_N^A$, where β_j^A is the unlevered or asset beta of firm j. Henry (2014, p.12) uses the following de-levering formula: $\beta^A = \beta^E(E/V)$. The values of E/V are obtained from financial accounts. Denoting: $\eta_j \equiv E_j/V_j$, the following linear constraint can be imposed in estimation:

$$\beta_1\eta_1 = \beta_2\eta_2 = \cdots \beta_N\eta_N \quad (3.7)$$

Post-estimation, the value of β^A can be recovered from any one of the beta estimates, with its standard error and confidence interval.[11] This is similar to the approach of de-levering the betas obtained from individual security OLS regressions, and averaging the resulting de-levered betas. This approach clearly has advantages over the portfolio method of estimation.

If one is focussed on estimating the beta for a portfolio of individual securities the weights should be based on market values. However, if one is focussed on obtaining a benchmark estimate for the regulated entitles then each comparator is in effect a valid comparator that should receive an equal weight. This is discussed further in chapter 6.

If the comparator set is sufficiently similar, then portfolio regression with equal weights would seem to be very useful. The pooled approach has further advantages over the portfolio method, in light of the smaller standard error, and the ability to constrain the asset betas or the equity betas to be equal, rather than only the latter.

3.4.2 Dealing with Outliers

The AER uses least absolute deviation (LAD) estimators in addition to using OLS (least squared errors). The LAD estimator is less sensitive to outliers than is OLS, and provides a

[10] In Stata this can be done using the 'frequency weights' option.

[11] In Stata this can be done using the 'lincom' postestimation command.

useful cross-check on the OLS estimators. Another alternative would be to test a 'robust regression' method, which give less weight to outliers (see: Verardi & Croux 2009).

Influential observations can distort parameter estimates, and these include outliers and some observations with high leverage. Ordinary outliers are observations where the dependent variable takes an extreme value relative to the values of the regressors, causing a large standardised residual. The least-squares estimator gives heavy weight to outliers, causing them to have a strong influence, on parameters, especially the intercept. High leverage points are observations where a regressor (or regressors) takes a value far outside the range of its other values. These observations can be good if the dependent variable value for this observation is close to the regression line. They are bad if the dependent variable takes a value far from the regression line. In that case both the intercept and slope are strongly influenced by the bad leverage point. Because of their influence in distorting the slope estimate, bad leverage points need not result in a large outlier residual. The LAD estimator, used by the AER as a cross-check, gives less weight to outliers compared to OLS, but does not necessarily mitigate the effects of bad leverage points.

The term 'robust regression' is used to refer to a set of regression techniques that do not rely entirely on the least-squares principle, and instead involve down-weighting (and in some cases removing) extremely influential observations using algorithms that iteratively re-weight the individual observations in the sample with successive estimations of the model. There are various methods of robust regression, most notably the M-estimator (in Stata, the 'rreg' command); the S-estimator and the MM-estimator (implemented in user-contributed programs 'sregress' and 'mmregress'; Verardi & Croux 2009). The last of these is the most effective. These techniques can be useful in circumstances where it is believed that most of the data in the sample is accurate, but that some of the data is contaminated, and the most extremely influential data points are those most likely to be contaminated.

3.5 Issues of debate

Several issues of disagreement remained among the experts after the 'hot tub' debate in the 2018, which are also potentially issues for the AER's current review of the method for determining the ROE. Among these issues were:

- whether to re-lever raw equity beta estimates. The estimates produced by Henry (2014) used re-leveraging;
- whether there is a feedback loop between the AER's decision and equity beta estimates;
- the appropriateness of the group of comparator businesses used by the AER, including whether: (a) de-listed firms should be excluded;[12] and (b) overseas energy business should be included;

[12] The following energy utilities that were either delisted or ceased being network providers that were included in the sample (up to the date indicated): AGL Energy (Oct 2006); Alinta (Aug 2007); DUET Group (May 2017); Envestra (Oct 2014); GasNet (Nov 2006); Hastings Diversified Utilities (Nov 2012). The following energy network businesses are not delisted: APA Group; Spark Infrastructure Group; AusNet Services.

- whether non-market data should be used to estimate equity betas for some unlisted businesses;
- whether to allow different betas for different types of energy businesses;
- whether lesser weight should be given to businesses that have a significant proportion of assets that are not energy networks, or are not regulated;
- the stability of the equity beta over time; and
- whether there should be any adjustment for low beta bias.

As noted in chapter 2, our focus in this report is on the choice of the estimation period (chapter 5) and the choice of the comparator set (chapter 6). We include some additional comments we consider important in Chapter 7. The following two sub-sections discuss two of the issues that have attracted a considerable amount of debate.

3.5.1 Low beta bias and Black CAPM

The Black CAPM has been advocated by some stakeholders as a means of better dealing with ‘low beta bias’. Empirically it has been shown that low-beta firms have, on average, higher earnings than predicted by the SLCAPM framework and high-beta firms to have lower than predicted earnings (Fama & French 2004). This suggests that estimates of very low betas are more likely to have negative than positive estimation error, and estimates of very high betas are more likely to have positive than negative estimation error (Franks et al. 2008, p.27). The Black CAPM, which does not assume a perfectly liquid borrowing/lending market for a risk free asset, is said to yield a flatter slope for the market line and hence to better address low beta bias (AER 2018c, p.195).

The AER concluded that the SLCAPM is the most widely used and reliable CAPM framework. “The Black CAPM has empirical issues including instability, sensitivity to the choice of inputs, lack of consensus, and nonsensical and counter-intuitive results. Observations of higher actual returns than the Sharpe-Lintner CAPM estimates for low beta stocks do not necessarily imply low beta bias or that the bias should warrant increasing the allowed rate of return. A range of reasons can explain these observations and it is not clear investors expect a higher return from low beta stocks” (AER 2018c, p.196). Nevertheless, the AER does have regard to the Black CAPM as a cross-check to the SLCAPM estimates.

The Black CAPM is estimated without using R_f. It is estimated using the real return market model (Campbell et al. 1997, pp.196–197):

$$\mathbf{R}_t = \boldsymbol{\alpha} + \boldsymbol{\beta} R_{mt} + \boldsymbol{\epsilon}_t \tag{3.8}$$

where $\mathbf{R}_t$ is an $N \times 1$ vector of *real* returns on assets with *i*th element R_{it} (and both R_{mt} and R_{it} are real rather than nominal); again $\boldsymbol{\alpha}, \boldsymbol{\beta}$ and $\boldsymbol{\epsilon}_t$ are $N \times 1$ vectors of intercepts, betas and disturbances respectively. A hypothesis implied by the Black CAPM model is that: $\alpha_1/(1-\beta_1) = \alpha_2/(1-\beta_2) = \cdots = \alpha_N/(1-\beta_N) = \mathrm{E}[R_{om}]$; where R_{om} is the rate of return on a zero-beta portfolio. Although R_{om} is not observed, the other parts of the implied restriction can be tested.

The point of spelling out this model is to show that, from an estimation perspective, it is similar to the simple model represented in equation (3.4), with the main exception being the use of real returns, rather than nominal returns.

3.5.2 Adjusting beta for mean reversion

Betas estimated from past market data are sometimes adjusted for forecasting future betas – often called 'shrinkage adjustment'. One rationale is that empirical studies of changes in beta over time suggest that they appear to regress towards one, the market portfolio beta (Blume 1975). Patterson states that it "is not clear whether this observed tendency is real phenomenon that reflects the likelihood that the true betas of high risk companies tend to drift downward over time, and vice versa, or whether it is a purely statistical effect" (Patterson 1995, p.125). The tendency of betas on average, and especially extreme value betas, to trend toward the mean is the basis of the 'Blume' adjustment made by some services such as Bloomberg.[13] Another related approach, the Vasicek procedure, has a Bayesian justification, where a beta of one is taken to be the Bayesian prior (Vasicek 1973). Such adjustments have similar effect to adjustments for low beta bias.

These shrinkage adjustments use the formula: $\beta' = (1-c) + c.\hat{\beta}$, where $\hat{\beta}$ is the estimated or 'raw' beta and β' is the adjusted beta. In the Blume adjustment: c = 2/3. However, in principle, the rate of mean reversion should not be a 'hard coded' parameter, as is used in the Blume adjustment, but should instead be empirically determined by studying the betas over different time periods. In principle, c "can be interpreted as the slope of the cross-sectional regression of beta estimates on those obtained over a prior non-overlapping period" (Vasicek 1973, p.1237).

The Vasicek approach assumes that priors can be obtained by sampling the cross-sectional distribution of betas, which is assumed to be approximately normal with mean b and standard deviation s_b. Then the adjusted beta is:

$$\beta'' = \frac{b/s_b^2 + \hat{\beta}/\hat{\sigma}_\beta^2}{1/s_b^2 + 1/\hat{\sigma}_\beta^2} \tag{3.9}$$

where $\hat{\sigma}_\beta$ is the standard error of the 'raw' beta estimate. Vasicek used the whole of the NYSE market index to form priors, finding that b = 1, and $s_b = 0.5$. When these parameter values are used for the priors, the Vasicek adjustment can be related back to the shrinkage formula with: $c = \left(1/\hat{\sigma}_\beta^2\right)/\left(4 + 1/\hat{\sigma}_\beta^2\right)$.

Lally argues that "the Blume process disregards the industry from which the firm is drawn, and this induces upward bias in the beta estimates of low-beta firms and downward bias for high-beta firms" (Franks et al. 2008, pp. 26–27). He says that the Vasicek procedure is not subject to this criticism when it uses industry average beta estimates as priors. Myers suggests that "some sort of Bayesian adjustment is sensible. The Vasicek procedure is a good starting point for such an adjustment" (Franks et al. 2008, p.27).

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[13] This sets forward-looking beta as equal to: 1/3 + (2/3)* Estimated beta.

If the Vasicek procedure were used, it is not at all clear why the prior for beta should equal one, rather than being based on a fundamental analysis of the business risk of the sector of interest. Patterson observes that the practice of using the market average beta to determine b in equation (3.9) "may be inappropriate if there is evidence that asset j's return distribution is significantly different from that of the market." He cites a study by Chambers and Wood (1985) who state (at p.27): "If the distributions are statistically different and the industry under examination has a reasonable number of firms, … then an industry sample would be preferred".

4 RETURN INTERVAL AND ESTIMATION PERIOD THEORY AND EVIDENCE

This chapter discusses the various theoretical and empirical literature on the choice of the return interval and estimation period to provide the background material for more specifically addressing the first matter in the terms of reference – the period of estimation.

4.1 Introduction

To estimate a relevant beta there is a need to decide on:

1. the time interval over which returns are calculated to obtain individual observations (hereafter 'return interval');
2. the length of the estimation period over which the time series is analysed;
3. exclusion of data, such as outliers or abnormal trading periods;
4. the choice of suitable comparator businesses; and
5. the method for selecting a preferred point estimate of beta.

The first three of these questions, and related issues, are discussed in this chapter. Although our terms of reference did not mention the return interval, its choice is related to the length of the estimation period and we consider it is relevant for our assessment. The fourth item on the above list is addressed in the following chapter. The last item in part depends on the method of defining a reasonable range of estimates as well as the method for determining a preferred estimate within that range. The AER has emphasised that it looks to the results derived from applying its foundational model for the purpose of determining the reasonable range of estimates, and it takes account of a wider range of information in an evaluative process whereby it selects a preferred central estimate of beta.

4.2 Trade-offs in Sample Selection

It is highly desirable to derive an estimate of beta that has minimal standard error in order to reduce uncertainty in decision-making. Analysts face a dilemma when choosing a return interval and estimation period for estimating beta. By reducing the return interval and lengthening the estimation period, the number of observations is increased. The more observations used, the smaller the standard error of the estimated beta, meaning a more precise estimate of the beta over the relevant period. However:

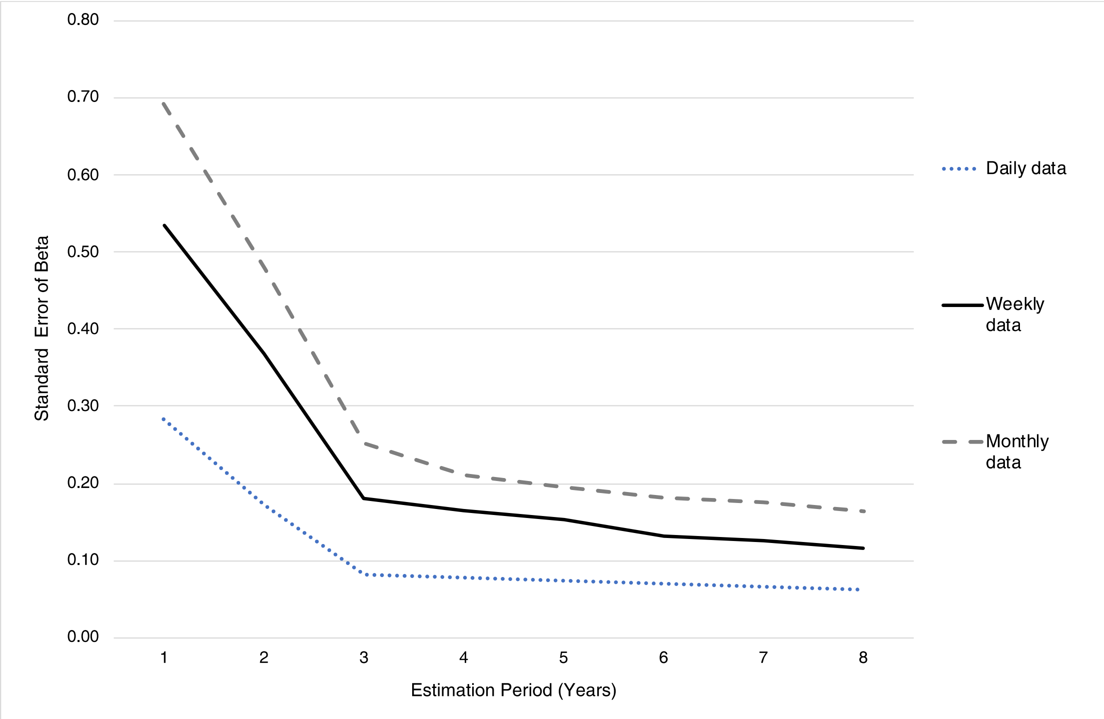
- reducing the return interval can lead to bias in beta estimates, such as 'thin trading bias' and related problems;
- lengthening the calendar time of the estimation period increases the likelihood that structural characteristics of the firm have changed during that period, resulting in the beta estimate being unrepresentative of its current value (Daves et al. 2000, p.7).

Daves et al. (2000) examined the effects of varying the return interval and estimation period on the standard error of beta, by examining a large number of companies drawn from the CRSP NYSE/AMEX databases over the 1980s. In the standard market model, the standard error of the beta estimate is equal to:

$$s_\beta = \frac{(s_\epsilon / s_m)}{\sqrt{N-1}} \tag{4.1}$$

where s_ϵ is the standard error of the regression (ie, of the disturbance term); s_m is the standard deviation of market returns; and N is the number of observations. The effect of varying the return interval and estimation period is depicted in Figure 4.1.

Figure 4.1: Effect of Return Interval and Estimation Period on Standard Error of Beta



Data source: Daves et al (2000).

Daves et al. (2000) also examined the structural stability of beta estimates and found that the likelihood of a structural break increased with the length of the estimation period. Over an eight-year estimation period it was found that 86 percent of firms had a significant shift in beta over that period. Thus, while longer estimation periods give a more precise estimate of beta if the firm's fundamental structure does not change, in fact many firms do experience shifts in their business structure, which changes the firm's systematic risk. Thus, if beta is not stationary, longer estimation periods may lead to biased estimates of beta.

Daves et al. argued for using daily data and a three-year estimation period. Wright et al. (2003, p.86) also suggest that, assuming thin trading is not a problem, the use of daily data is highly favourable in the trade-off between using an estimation window that gives low standard errors and one which comes from a period where beta is likely to be close to its current value. Wright et al. (2003, p.86) report that with daily data going from a 1-year window to a 2-year window the increase in observations from 250 to 500 will reduce the standard error by about 40 per cent and going to a 3-year window will reduce the standard error by about a further 22 per cent and going to a 4-year window by a further 15 per cent. Serial correlation in the error terms can be corrected-for with readily applicable statistical techniques.

However, as is discussed in the next section, many other researchers have concerns about bias when using daily data. Further, structural changes in business may be more frequent in some industries than in others, which supports an approach of testing for structural stability in the particular application in which beta is being estimated, and using as long a period as possible subject to structural stability, rather than using a 'one size fits all' rule of thumb such as a three-year period for estimation.

4.3 Choice of Return Interval

Many researchers have observed that choice of return interval has a substantial effect on estimated betas, and there is a common view that high frequency data such as daily return intervals, can be biased. The bias can be in either direction. Such effects are grouped under the heading 'thin trading bias'. Some of the analysis and reasoning that has been put forward include:

a. *Serial correlation of returns*: If stock price returns are serially uncorrelated and the return on the individual stock is the same for all frequencies then OLS estimates based on the highest frequency would be optimal as it would provide more observations and estimates would not be biased. However, Wright et al (2003, p.80) report that there is evidence of high positive correlation of daily returns and that serial correlation in weekly and monthly returns tends to be somewhat less significant. If beta is time varying the standard model will be mis-specified and there could be heteroscedasticity. Serial correlation and heteroscedasticity are not problems of bias but rather of misleading standard errors which could be corrected using statistical techniques.

b. *Thin trading*: For stocks that are infrequently traded the return on the stock is not likely to be the same for all frequencies. When there is thin trading one could expect an impact on beta, for example if there is no trading for some periods the correlation of returns with the market would likely be lower implying a lower beta. Longer return intervals would overcome this problem. Weekly return intervals are more likely to mean a lower thin trading impact than daily return intervals, and likewise, monthly return intervals are less likely to have thin trading bias than weekly intervals. However, for monthly data a longer estimation period would be needed to have sufficient observations to obtain reliable estimates.

c. *Investor holding periods*: Levy Gunthorpe and Wachowitz (1994) claim that the return interval should match the investors holding period. Patterson (1995, p.121) reports on similar earlier findings of Levhari and Levy (1977) and Levy (1980). According to Patterson (1995, p.122) mismatch between the estimation period and the holding period introduces a mathematical bias. However, the practical importance of such bias is unknown.

d. *Transaction frictions*: Hawawini (1983) develops a model to explain why beta estimates change with return interval. Security prices do not all move in unison as some prices respond more quicky to information than others, and hence some prices lead and some lag the market index. He develops the 'q-ratio', where for security i: $q_i = (\rho_{im}^{-1} + \rho_{im}^{+1})/\rho_{im}$, where: ρ_{im} is the contemporaneous correlation coefficient between security i and the market; ρ_{im}^{-1} is the correlation coefficient between current period's returns on i and the previous period's market return; ρ_{im}^{+1} is the correlation coefficient between the current period's returns on *i* and the next period's market return. He shows that mathematically, beta for a given return interval is a function the firms' q-ratio for that interval. He then observes empirically that q-ratios are systematically related to the ratio of the firm's market capitalisation to the average market capitalisation of firms in the market index. From this analysis he shows that the betas of securities with a smaller market value than the average will decrease as the return interval is shortened whereas the betas of securities with a large market value will increase. In effect the bias in estimating beta when moving to short trading intervals, such as daily data, depends on the firms' market capitalisation relative to the average in the market index. Brailsford and Josev (1997) apply the same method to Australian data and find that Hawawini's results are generally supported in this market. We understand that the AER uses the ASX All Ordinaries Index in its MRP and beta calculations. This index includes the 480 largest firms listed on the ASX, and currently the average market capitalisation is just over $5 bn. The businesses included as comparators for energy networks the AER, and other potential comparators discussed in chapter 6, have a considerably higher average market capitalisation. Hence, moving from a weekly to a daily return interval would be likely to upwardly bias the estimated beta.[14]

e. *Opacity*: More recently Gilbert et al (2014) show that differences in betas estimated using higher (daily or weekly) and lower (monthly) frequency may reflect differences in the relative "opacity" of information about the prospects of those firms and how their returns will be affected by market movements (see also: Incenta 2019, p.16). Gilbert et al. distinguish between opaque firms and transparent firms. For opaque firms the effect of systematic news is revealed with a delay while the revelation of the impact of systematic news is immediate for transparent firms. The opacity measures are a survey-based measure of managerial discretion and the variance of abnormal accruals. They examine daily, monthly and quarterly data for the US spanning the period 1969 to 2010. They show that beta differences across frequencies occur even in large and liquid stocks and cannot be explained by microstructure and trading frictions. They find a robust relationship between the frequency dependence of betas and proxies for opacity with higher opacity being associated with a lower beta. They conclude that opacity poses significant challenges to using betas estimated from high-frequency returns. This suggests that while the CAPM may be an appropriate asset pricing model at low

[14] Note that the average market capitalisation of the potential comparators listed in Tables 6.1, 6.3 and 6.4 is close to the average for the S&P/ASX 200 index, which is just above $11.5 bn. This suggests a strategy of testing the estimation of betas relative to the S&P/ASX 200 index over alternative return intervals, including daily data, to see whether there is a bias when daily data is used. A limitation of this approach is that the market index used for estimating beta should be the same as that used for estimating the MRP.

frequencies, additional factors (i.e., explanatory variables) as proxies for opacity, are necessary at high frequencies.

f. *Other market factors*: Incenta (2019, p.16) reports on further analysis by Gregory, Hua and Tharyan (2018) who repeated and extended the Gilbert et al. analysis using UK data. They report that the differences in beta estimates that are obtained by using high frequency versus low frequency data can be explained by factors that are widely used proxies for risk, which include opacity (proxied by a measure of abnormal accruals), size, illiquidity, and Book-to-Market ratio. Gregory et al. also showed that when the standard CAPM tests are done using monthly data they perform in a superior manner to when performed using weekly data.

The intervalling effect has been found to be an important consideration. Cohen *et al* (1983) also demonstrated a significant intervalling effect and that it primarily affected betas using daily data and was small for intervals between 20 and 30 days (Patterson 1995, p.122). Reilly and Wright (1988) also confirmed that interval choice was a major factor affecting beta. Patterson (1995, p.123) concludes that use of return intervals less than one month to increase the number of observations is likely to induce a size related bias into beta estimates and considers that monthly intervals are a practical compromise and are most commonly used but that one month is likely to be less than the true average holding period so that the possibility of bias still remains.

For the existing AER comparator set, Henry (2014, pp.28–48) concludes that there is a paucity of evidence of thin trading bias for the individual firm and portfolio regressions using a weekly return interval. Although there may be a theoretical concern about using return intervals that do not match the typical holding period, the extensive statistical tests undertaken by Henry provide support for the continued use of weekly data for the existing AER comparator set.

In summary, the foregoing review of relevant literature suggests a lack of confidence in using daily return intervals. For several reasons this may lead to thin trading bias in the estimated betas. If there are sufficient resources, there may be merit to complementing the existing analyses using weekly and monthly return intervals, by estimating betas also using daily data, and testing for ‘thin trading’ bias.

4.4 Choice of Estimation Period

As previously indicated, assuming beta is constant over time, increasing the number of observations will reduce the standard error of the estimate of beta thereby providing a more precise estimate. However, increasing the estimation period increases the probability that the true beta will have changed as a result of changes in the determinants of beta. Alexander and Chervany (1980) suggest that, in the absence of specific information that might indicate a shift in beta, the optimum period that balances reduction of standard errors against the risk of structural change in beta is four to six years. This period conforms to that used by most analysts and commercial beta services (Patterson 1995, p.121).

There is reasonable evidence that betas vary over time (see: Wright et al. 2003, p.63 and the discussion in section 7.1 on the conditional CAPM). Brailsford et al (1997, p.15) report that it is generally accepted that at least 50 data points are required to obtain reliable OLS estimates and that beta estimates appear to be reasonably stable over a four to five year period. This has led to a common practice of using five years of monthly data. For example, Wright, Mason and Miles (2003) report that the London Business School Risk Management Service uses the most recent 60 months of returns.

In the Australian energy network context, Henry (2014, pp.31–33) finds no systematic evidence of parameter instability in the OLS estimates for individual firms using recursive regression and individual parameter tests, although he does find some evidence for instability in the residual variance. He reports that on only three occasions in 27 tests of individual parameters is there evidence against the hypothesis that the parameter of interest is stable. He also notes that this calls into question the necessity or even validity of omitting data due to concerns about structural instability arising from the 'tech boom' and global financial crisis (GFC) and notes that there is no evidence to suggest the last 5-year sample is superior to the full sample. Henry (2014, p.61) also reports that there is no evidence of parameter instability for the time varying portfolio regressions.

4.4.1 Empirical Generalisations

Meyers (1973) finds that over a 17-year period from 1950 and 1967, and depending on how stationarity is defined, beta was stationary for between 50 and 75 percent of the stocks on the NYSE. The question of whether the value of beta *can be assumed* constant over time depends not only on the length of the sample period, but also on the consequences of wrongly assuming stationarity, which depends on the application. If the value of beta in the latter part of a sample period differs from that in the earlier part of the period, the average beta over the entire sample period may be a poor predictor of beta in the next period. He concludes that stability of beta "should be tested empirically for any analysis in which stationarity is important" (Meyers 1973, pp.318–319).

Baesel (1974) tested various estimation periods from one year to nine years to determine the impact of the length of the estimation period on the stability of estimated betas. He concluded that stability of individual beta coefficients increases as the length of the estimation period increases, and also depends on the extremity of the beta (i.e. more extreme values are less stable). Altman *et al*. (1974) using data for the French stock market for an 8 year period, carried out a similar analysis and found substantial evidence of multi-period stability of beta for single securities, and the longer the period, the more stationarity results. Roenfeldt *et al.* (1978) estimated betas using monthly data over a 4-year period and tested the stability of predictions based on them. They found that "forecasting betas based on a four-year previous period are more reliable for subsequent four-, three-, and two-year periods than for only the next year. However, if a one-year forecast is desired, it is better to base it on a four-year previous period than simply to use the immediately preceding year" (Roenfeldt et al. 1978, p.120).

Theobald (1981) investigates the optimal data set length for estimating beta. As previously mentioned, this involves a trade-off between improving the precision of estimates by having more observations, and increasing the risk that beta changes during the sample period. The method he uses is to calculate correlation coefficients between betas estimated from non-overlapping data sets of different calendar lengths (similar to Blume). The paper demonstrates that beta stationarity "will not increase indefinitely with estimation period length" (Theobald

1981, p.747). It is estimated that an optimal data set length is 15 years (using monthly data), although the results are similar for any period between 10 and 17.5 years. This is qualified by noting that the optimal length of the data set cannot be applied indiscriminately and must have regard to structural changes in betas.

Kim (1993, p.241) claims that most empirical studies *do not* support the assumption of stationary of beta over relatively long periods of time. In regard to optimal data set length, Blume (1971) suggested cautiously that betas are stable over a 7-year period. Gonedes (1973) reported that a 7-year estimation period was more efficient than shorter and longer periods tested. Kim uses a Bayesian method of identifying structural break points and finds that "high beta firms have shorter stationary interval of betas, while the low beta firms have longer interval" and the "overall average length of stationary interval is about five years" (Kim 1993, p.248).

As we have seen, Daves *et al* (2000) recommended a 3-year estimation period using daily data. They observe that the previous research "concludes that the optimal estimation period ranges from four to nine years" (Daves et al. 2000, p.8).

This brief survey suggests that a variety of results have been obtained for studies of beta stability. Some support the common practice of using five years of data, or suggest a shorter period, but most of the studies discussed suggest periods greater than five years, and some propose periods longer than 10 years. These studies are at an aggregate level, without regard to differences between industries. Kim reports the important result that beta is more stable for low beta firms.

4.4.2 Stability Testing

The choice of estimation interval is essentially an empirical question of identifying the longest period over which beta is stable.

A classic test for structural change is the Chow test, which involves splitting the sample into two sub-periods, and estimating the parameter of interest (beta) in each period, and then testing the equality of the two estimates using an F-statistic. Unfortunately, this test requires that the structural break point to be known. It might be employed simply to test beta stationarity between successive 5-year periods. Or it may be used in the context of an event study. For example, some major unexpected event occurs which changes investors' information about likely future earnings, and leads to a substantial change in share values. Such an event might be a candidate for a structural break point, and the Chow test could be used to test whether the beta after that event was the same as before the event; i.e., whether it structurally changed at that point. A variation on the same theme is to include a dummy variable for the period after the suspected structural break, which is multiplied by the excess market return, and the parameter on this term is tested for statistical significance using a t-test.

More generally, the existence and timing of any structural break point(s) is usually unknown. Furthermore, there is an unreliable subjective element in the choice of break-points using the Chow test (Hansen 2001, pp.118–119). To find an unknown break date, a sequential search process is conducted. In some of the studies reviewed this has involved starting with a short sample period and then incrementally adding observations, on each occasion including a dummy variable equal to 1 only on the last added period (which is multiplied by the excess market return). If a t-test shows that this term is significantly different from zero, then that added period is a structural break date. The process can be continued by incrementally adding period and using a new dummy variable.

Sequential tests of candidate break have been greatly improved in recent decades, with new tests for determining the structural break dates based on minimising the overall squared errors of the model (see: Hansen 2001). Confidence intervals relating to the timing of the break (expressed as a time period range with a given confidence) are produced for each possible break point. Some of the main methods have been implemented in Stata for time series and panel data in the user-contributed command, xtbreak (Ditzen et al. 2020).[15]

In testing the stability of beta, there is a question as to whether the test should be carried out separately for each firm in the comparator set or whether it should be a test of the stability of the average beta. Given that it is the average beta, and its confidence interval, that is used for determining the reasonable range for forecasting the energy network beta, there appears to be good reason to base the stability test on the average beta. Hence, either the portfolio or pooling methods of estimation, discussed in section 3.4.1 would be suitable.

4.5 Exclusion of data

In considering whether data should be excluded in the estimation of a relevant beta, there are two aspects to consider: how to treat outliers and how to treat significant events.

4.5.1.1 Outliers

A model may lack robustness if there are a small number of overly influential data points, which may cast doubt on inferences based on the model, or affect its performance in making out-of-sample predictions. The influence of an observation is the combined effect of being an outlier (where the residual term from the regression is large in absolute value) and having high leverage (where a predictor takes an extreme value relative to its mean).

Brailsford et al (1997, pp.21–22) consider that outliers can exert considerable influence over beta estimates and that the decision to exclude outliers depends on the research context. Depending on the purpose of the estimation, the validity of excluding outliers depends on whether the observations are correctly measured or are data errors. The appropriate response to highly influential observations depends on whether they are believed to reflect the data generation process or are inconsistent with it. As Greene (2012, p.141) points out:

> since the distribution of disturbances would anticipate a certain small percentage of extreme observations in any event, simply singling out observations with large residuals is actually a dubious exercise. On the other hand, one might suspect that the outlying observations are actually generated from a different population.

If the extreme observations are actually correct measurements, then removing theme may mean removing the most important observations in the sample. Conversely the outliers may be the

[15] The ado package and documentation is available at: <https://github.com/JanDitzen/xtbreak>.

result of unique events such that their recurrence is highly unlikely and then removing them would mean a more accurate model for prediction or parameter estimation purposes. There are tests to detect outliers and influential observations, and estimation techniques to address them (see section 3.4.2).

A key consideration, in relation to both outliers and the impact of significant events is the use of the beta and whether the outlier is likely to be relevant given the designated use of the beta in the economic regulation context.

4.5.1.2 Significant events

Examples of significant events are matters like the global financial crisis, the Covid pandemic, and other abrupt changes in the macroeconomic or regulatory environment. In some cases significant events could be relatively short lived while in others they could persist at a lower intensity level for some time so that a clear delineation cannot be readily determined.

The treatment of significant events can be handled in the estimation by the use of dummy variables, variables that proxy the significant event or by exclusion of the data period. However, depending on the nature, intensity and duration of the event it may difficult to specify how to treat the event statistically and what data to exclude. There is also the issue of determining whether the significant event is in effect in the form of an outlier that is not likely to recur.

Where there are large economy-wide shocks such as with the COVID episode, one would expect considerable uncertainty to develop and impact on financial markets and key financial relationships until that uncertainty diminished. On one hand, this might suggest avoiding the use of data for such periods assuming there is a return to more normal conditions and recognising the need to establish parameters that are the best estimates of forward looking return expectations. On the other hand: (i) these episodes happen every now and then (e.g. previously with the GFC) and excluding them could bias the estimates of the actual risk that these businesses carry; and (ii) from an econometric perspective, these shock periods are likely to be the data that best helps to establish the value of beta, since there is likely to be a larger movement of the explanatory variable (market return).

We suggest that the guiding criterion should be what is the best approach to determine an equity beta that meets the relevant regulatory objective for the forthcoming regulatory period while recognising the nature of the regulatory arrangements and their impact on risk. Large shocks may affect economy-wide returns in particular but the impact on regulated network energy businesses is likely to be substantially muted on the revenue side given revenue caps are adopted for the NEM the potential impact may still be relevant in arriving at an estimated of systematic risks.

We note that the current AER comparator set entails estimating betas for the longest historical series, the longest period after tech boom (3 July 1998 to 30 October 2001) and excluding the GFC (5 September 2008 to 30 October 2009); and most recent five years of data. We also note the extensive statistical testing by Henry (2009, 2014) finding no evidence of beta instability including for the whole sample period.

4.6 Commercial practice

As discussed in section 3.2. the SFG Consulting (2013) report reviewed a large number of independent expert reports used for valuation purposes. However, only a small number of the independent expert reports included a detailed discussion of their WACC valuation methodology. As noted, the independent experts used their judgement, guided by theory, to adjust the mechanistic estimates of beta to reflect what they believe to the best beta for the future.

For example, KPMG Corporate Finance’s independent expert report for Windlab Limited in April 2020 included the following rationale for their estimate of Windlab’s beta:

> “we consider the two year betas to be more relevant than the five year betas given recent changes in the wind energy sector (i.e. grid connection issues, decline in electricity prices, decline in MLF factors, etc.) and given the low statistical significance of five year betas” (KPMG 2020, p.8)

SFG’s 2013 report did not discuss in depth the independent experts’ estimates of beta or how the experts arrived at their estimates, perhaps because the independent experts’ final estimate of expected return was the principal focus of the report. However, the SFG 2013 Report tabled final results only for those expert reports that used a beta between 0.75 and 1.25 on the basis that only values in this range allow for a proper comparison of a firm’s expected return with the expected return on the market.

How far back from the present one goes when estimating beta using historical return data and the unit of time over which return is calculated are important practical decisions. Ford (2019) in his research paper: “Estimating betas in practice: Alternatives that matter and those that do not” finds that:

> “Betas are nearly identical whether or not the returns are adjusted for dividends and whether raw returns are used instead of excess returns. By far, the choice of using weekly or monthly returns and estimating two- or five-year Betas are more impactful decisions than is the accounting for dividends or the risk-free rate.” (Ford 2019, p.1)

He does not say whether using weekly or monthly return data or estimating beta over two or five years results in a systematically predictable difference. Inspection of his tabulated results does not indicate any systematic difference, some firms have a higher beta when the shorter period is used, others have a lower beta. There is no reason to expect a difference at the group level, because the differences are likely a function of the level of trading. A firm with low trading volume may yield a lower than “true” estimated beta when weekly returns are used whilst a firm with exceptionally trading volume may yield a higher than “true” estimated beta (Damodaran 1999).

A review by Professor Raymond da Silva Rosa for this report of 23 independent expert reports completed over the period January 2014 to June 2021 for companies classified as Utilities by Connect4.com revealed that only a small number provided details on the return interval used and how far back in time they went in regressing firm return against market return in estimating beta.

It seems most independent experts follow the commercial services (e.g., Bloomberg) in using the pairing of two years/weekly returns or five years/monthly returns when estimating beta. A range of ostensibly comparable companies is selected and outliers are removed, although there is no clear rule as to what constitutes an outlier result and why.

For instance, Calibre Partners' (2021) independent expert report for Tilt Renewables used 12 listed electricity companies as the comparable set to estimate beta. The 12 companies' asset betas were estimated to lie in the range 0.45 to 1.24 using 2 years of weekly data (median beta 0.66) and between 0.09 and 1.19 using 5years of monthly data (median beta 0.56). Calibre Partners settled on an estimate of asset beta between 0.50 and 0.60 after removing the outliers from their sample of 12 companies.

Beyond removing outliers and justifying doing so by appeal to theory, none of the independent expert reports discussed excluding data within the period of estimation, or made mention of significant events. Similarly, there was no discussion of the impact of lower interest rates and/or inflation on beta. The implicit assumption seems to be that using more recent time periods to estimate beta addresses the issues that are raised with lower interest rates and beta. More generally, there is an implicit assumption that if lower interest rates and inflation are issues than they are more likely to be a concern in estimates of the market risk premium.

4.7 Conclusion

For a given return interval (choice of frequency), the trade-off for the estimation period is simply that a longer period provides more observations and lower standard errors but that a longer time period means that it is more likely that a firm may have different characteristics over a longer period. If there is a concern about a change in characteristics, that would suggest a shorter period should be used, or at least used to check beta stability.

However, the characteristics of regulated energy network service businesses in Australia, in particular the impact of the regulatory arrangements and the natural monopoly essential service nature of their services, are not expected to change materially over reasonably long time periods, and in any case the form of regulation would greatly mute the impact of non-diversifiable macroeconomic variables. Henry's studies (2009, 2014) find strong evidence of beta stability in the AER comparator set including for the longest period available that includes the tech shock and the global financial crisis. These aspects are considered in more detail in the following chapter.

5 CHOICE OF ESTIMATION PERIOD

5.1 AER Request

The AER request asks us to advise on the period of time-series data that the AER could use to estimate equity beta and the relative advantages and disadvantages of long or shorter data periods. In answering we have been asked to consider:

- Whether you would you expect the equity beta for regulated energy networks or other proxy firms to materially change through time?
- Whether the reduction in ex-ante returns set by the AER are likely to have materially changed the systematic risk for regulated energy networks through time?
- Will reductions in either the risk-free rate, or the inflation rate over recent years, be likely to have materially changed the systematic risk of regulated energy networks relative to the broader Australian equities market? Does the answer to this question depend on whether the changes to the risk free rate or inflation in recent years are (or should be assumed to be) cyclic or structural?
- Whether it is appropriate to use historical estimates of beta for firms no longer listed?
- When, if ever, it is appropriate to exclude data from the time-series of comparable firms — for example, should COVID impacted market periods, or other periods, be excluded?

In order to answer these questions we have reviewed relevant theoretical and empirical studies, finance sector practice and the regulatory arrangements in chapters 3 and 4.

5.2 Longer or shorter periods – the basic trade-off

There are two interrelated aspects to consider when considering the relevant time period for estimation. There is a need to determine the interval for measuring returns – i.e. the frequency of the observations – and there is a need to determine the estimation period – i.e. the length of the period over which the time series data are analysed. For a given return interval (choice of frequency), the trade-off for the estimation period is simply that a longer period provides more observations and lower standard errors but that a longer time period means that it is more likely that a firm may have different characteristics.

5.2.1 Choice of estimation interval

Stock market returns are available on a daily, weekly, monthly or longer basis. Table 5.1 below summarises the advantages and disadvantages of daily, weekly or monthly data. Longer return intervals (e.g. annual) are not considered because they would not provide sufficient observations in a relevant time frame.

Table 5.1: Advantages and disadvantages of using daily, weekly or monthly data

	Advantages	*Disadvantages*
Daily	Scope to greatly reduce standard errors of beta estimates while at the same time choosing a short time period if there is a strong concern to obtain a recent estimate of beta. Serial correlation or heteroscedasticity in the error terms may lead to misleadingly low standard errors but can be readily corrected with econometric techniques. This is not a bias issue.	More likely to suffer from thin trading issues leading to bias in the beta estimates. There are statistical techniques to correct for thin trading but as the problem is likely to be most significant for daily data there is less confidence in daily data compared with weekly or monthly data. There is an 'intervalling' problem where a mis-match between the estimation period and the holding period introduces a mathematical bias and there is evidence that a size related bias problem primarily affects betas using daily data. Recent research has found that the use of longer frequency monthly data substantially reduces an 'opacity' effect clearly present in daily data.
Weekly	Provides the scope for a sufficiently large sample to reduce standard errors substantially while still choosing an estimation period that takes account of recent impacts on beta. If there is a concern about beta instability then weekly data over a shorter time period are preferable to monthly data. If there is not a concern about parameter instability then weekly data can provide good statistical precision for as many years as parameter stability is likely. Serial correlation is likely to be less significant than for daily data. Thin trading issues are likely to be less significant than for daily data. Thin trading effects can be tested for and addressed.	There is still an intervalling problem. There is evidence that the effect is small for intervals between 20 and 30 days. Patterson (1995) considers that monthly data are preferred to reduce the scope for the intervalling problem. It is not clear if there is an intevalling effect in the existing weekly estimates used by the AER. When the standard CAPM tests are done using monthly data they perform in a superior manner to when performed using weekly data.
Monthly	Serial correlation less significant than for daily data. Thin trading issues are less likely than for	There is still some scope for a size related bias associated with the intervalling problem.

	Advantages	***Disadvantages***
	higher frequency data. The intervalling problem of size related bias is considered less significant than for higher frequency data however the scope for bias still exists. There is less evidence of an 'opacity' effect in monthly data compared with higher frequency data. The use of monthly data over around a five year period appears to be the most common practice including in the finance sector and Brailsford *et al.* claim that it is generally accepted that around 50 data points are required to obtain reliable OLS estimates.	There is more scope for beta to change over the five year time period required to provide sufficient statistical observations. According to Henry (2009, 2014), for the AER comparator set there are too few observations using monthly data if individual betas are estimated.

An assessment of each return interval based on the assessment criteria provided by the AER is set out below.

5.2.1.1 Reliability

Reliability is the main criterion for evaluation of the return interval.

- Daily data are likely to be particularly prone to thin trading, intervalling problems, 'opaque effects' and associated bias issues.
- Monthly data, while commonly used, provide substantially less observations than weekly data and may be more prone to time dependent beta changes because of the longer period that would be required to ensure there were sufficient observations. There can still be intervalling problems deriving from the difference between the holding and estimation periods. Opaque effects are less likely than for higher frequency data.
- Weekly data provide sufficient observations to provide low statistical sampling error and can be estimated for shorter time periods where there are concerns about beta instability. There can still be intervalling problems deriving from the difference between the holding and estimation periods and opacity effects. Henry (2009, 2014) did not detect beta instability problems using weekly data.

Three other criteria: relevance to the Australian benchmark; suitability for use in a regulated environment; and simplicity would be met similarly by each time interval in Table 5.1.

5.2.2 Choice of estimation period

5.2.2.1 General considerations

There is reasonable evidence that betas vary over time, although we are not aware of studies covering energy network businesses with similar regulatory arrangements as those that apply in Australia. If there is a concern about a change in factors that are likely to affect beta, and hence a change in beta, that would imply a shorter period should be used. It would in any case be useful to check for beta stability over the estimation period and then investigate potential causes of instability and determine whether they are likely to continue.

Various studies have confirmed that there are other sources of risk, apart from the single measure market-wide movements in the SLCAPM but studies have also shown mixed results, and observed instability of beta does not necessarily mean instability in expected returns. Arbitrage price theory (APT) is an alternative to the SLCAPM that takes account of different sources of risk, but it has the disadvantage of providing no theory as to what risk variables to include. As discussed in section 7.1, a conditional CAPM has been developed that allows for time dependent effects that depend on publicly available conditioning information at a point in time. These models are complex and less transparent than the SLCAPM. They are also prone to overfitting[16] as researchers identify and incorporate other variables that may impact on risk over time. However, one important result from models with multiple betas is that the time variation in betas contributes a relatively small amount to the time variation in expected asset returns while time variation in the risk premiums is relatively more important.

This finding is consistent with definition of the market risk premium as the price of risk with the beta measuring the amount of perceived risk relative to the market as whole where the beta is one and the price of risk is the market risk premium. The implication is that economy-wide developments that impact on non-diversifiable systematic risk would primarily impact on the market risk premium rather than the relative measure of risk as measured by an equity beta. This interpretation is also consistent with the focus in the literature and regulatory submissions on the relationship between the market risk premium and the risk free rate. It is also consistent with commercial practice.

The impact of economy wide developments on betas and in particular betas for regulated network energy businesses in Australia is ultimately an empirical issue. However, an assessment of the characteristics of these network energy businesses and in particular the regulatory arrangements that apply can provide guidance on whether their underlying (unobservable) betas vary over different time periods. The true betas are unobservable because they should be based on expected returns but are estimated using actual returns. The impact of the regulatory arrangements is considered in the following sub-section.

In order to determine the most appropriate time period for estimation there is a need to determine the likely stability of betas over that time frame and if there is instability whether

[16] Overfitting refers to the practice of including variables that in effect contribute to explaining the random error in the model rather than the relationships between the variables and this will make the model less reliable for forecasting.

the beta estimates should be retained or whether the source of the instability should be removed. We suggest that the guiding principle in the regulatory context should be to choose a methodology that is best suited to ensuring that the beta that will apply over the regulatory period best contributes to ensuring the regulatory objective of efficient investment for the long term interest of consumers. In some cases this may mean excluding some data and relying on an assessment of fundamental key factors affecting the true betas of the regulated network energy businesses.

Another issue for consideration is recognition that the different terms in the WACC are based on different periods. A number of other parameters of the weighted average cost of capital (WACC) have been estimated using data with 10-year terms. This includes the risk-free rate (using ten-year Commonwealth Government Securities), and the cost of debt (using a benchmark corporate BBB+ debt instrument of 10 years maturity with a trailing average methodology) and the market risk premium. If greater consistency within the cost of capital estimation framework is of value, there is an issue of deciding whether a 10-year sample period for estimating equity betas may be preferred or a five year period to align with the regulatory period as advocated by Lally (2020).

Although consistency is a consideration, so is the availability of relevant information. The objective is to obtain the best estimates of the cost of capital for the regulatory period and this must be determined on an *ex ante* basis. A reliable estimate of the market risk premium may need to rely on a long historical series to obtain a reasonably reliable statistical estimate. And a ten year cost of debt with a trailing average specification may best measure the efficient debt costs that a firm faces over the regulatory period.

We now turn to three specific questions in the terms of reference relating to the choice of the period for estimation.

5.2.2.2 Whether you would you expect the equity beta for regulated energy networks or other proxy firms to materially change through time?

There are two aspects. First there is an issue of the length of the time period and second the scope for change over, say, the most recent five year period.

If one were to use historical data over a longer time period, say ten years, it is reasonable to hypothesise that there would more likely be a change in beta estimates than for a shorter recent period. There could be major economy-wide events that occurred in the past that are not likely to recur and there could be changes in the characteristics of relevant comparators and their economic and regulatory environment that affect their systematic risk. For these reasons there is *ceteris paribus* an advantage in using a shorter recent period rather than a very long historical period.

However, we consider that the dominant factor to consider for the comparator set is the form of economic regulation that applies. As explained in section 2.2, the regulatory arrangements contain a number of features that greatly limit the systematic risk that would otherwise apply in the absence of the regulatory protection. There is in effect no or very limited revenue risk for the regulatory period and cost risk is greatly reduced with indexing of the RAB with actual inflation each period and in effect a guarantee of specified expected real rate of return to be applied to the indexed RAB for each period, cost pass-through mechanisms and regular re-setting of costs as well as other measures for sharing under and over operating and capital expenditure.

As far as cash flow risk is concerned, the main risk relates to under or over spending on operating and/or capital expenditure relative to approved forecast estimates, although the variability of these expenditures is greatly mitigated by the efficiency benefit scheme for operating expenditure and the capital efficiency sharing scheme for capital expenditure. It is reasonable to conclude that collectively these regulatory arrangements mean that cash flow risk for regulated network energy businesses is very low relative to the average that applies to firms in the broader market. In addition, the regulated network energy businesses are natural monopolies where there is by definition no competition and the service is essential with a low income elasticity of demand.

With cash flow systematic risk being very low the other main factor that could impact on realised share returns would be changes in investors' discount rates, as discussed in section 2.2, but it could be expected that such changes would apply to the market as a whole and not just the regulated network energy businesses. Given these features and recognising that economy-wide shocks are likely to impact on the market risk premium much more than industry betas we consider that the betas of network energy businesses would not change much over time and particularly in the period since the regulatory arrangements described in chapter 2 apply. If the proxy firms had similar characteristics to the regulated firms this conclusion would apply to them as well. However, it would still be useful to estimate beta over various periods to test for stability and likely causes of instability. This then may be relevant in helping to determine the best point estimate for beta within a reasonable range. It is noted that there may well be many factors that will not recur but any significant events may have effects that will arise again but from different sources.

The AER does update its estimates of beta regularly and table 5.2 shows a comparison of beta estimates for the Henry study using 2013 data and updates for 2018, 2019 and 2020 (AER 2020, p.12). The 2020 Rate of Return Annual Update showed *slightly higher betas on average* for the period 2018-2020 compared with the 2014 estimates of Henry for each of the three sample periods tested, but less so for the longest period. Increases in beta were most noticeable for the most recent five year periods for 2018 and 2019 where the betas were 0.72 compared with 0.46 for the Henry study. However, the August 2020 beta for the most recent five years declined to 0.55. This development suggest some caution on giving sole weight to just the most recent 5 years.

Table 5.2: Comparison of re-levered weekly average firm equity beta estimates (OLS)*

Period	*Average of firm-level estimates*			
	Henry 2013	AER Sep 2018	AER Aug 2019	AER Aug 2020
Longest period	0.52	0.57	0.56	0.56
Post tech boom and excluding GFC	0.56	0.61	0.61	0.56
Recent 5 years	0.46	0.72	0.72	0.55

Note: * Data to June 2013, September 2018, August 2019, August 2020.

Source: (AER 2020, p.12).

5.2.2.3 *Whether it is appropriate to use historical estimates of beta for firms no longer listed?*

This depends on the likely stability of beta for if beta is considered stable the historical use of estimates of beta for firms that are no longer listed would contribute to lowering the standard errors for the beta estimates. As just discussed, the regulatory arrangements collectively are considered to be very powerful in greatly limiting risk for regulated network energy businesses and the regulatory arrangements themselves are considered to have been very stable over a long time frame. We also note that Henry (2014, 2009) found no systematic evidence of beta instability for the longest historical series including the tech shock and the global financial crisis. We note the information provided in Table 5.2 suggests some caution should be applied in using data for just the last five years.

Recognising these considerations, at this stage, we think it is reasonable to continue to use historical estimates of betas for firms no longer listed as part of the information set. But that the stability of betas should continue to be tested.

5.2.2.4 *When, if ever, it is appropriate to exclude data from the time-series of comparable firms — for example, should COVID impacted market periods, or other periods, be excluded?*

Where there are large economy-wide shocks such as with the COVID episode, one would expect considerable uncertainty to develop and impact on financial markets and key financial relationships until that uncertainty diminished. On one hand, this might suggest avoiding the use of data for such periods assuming there is a return to more normal conditions and recognising the need to establish parameters that are the best estimates of forward looking return expectations. On the other hand: (i) these episodes happen every now and then (e.g., previously with the GFC) and excluding them could bias the estimates of the actual risk that these businesses carry; and (ii) from an econometric perspective, these shock periods are likely to be the data that best helps to establish the estimate of beta, since there is likely to be a larger movement of the explanatory variable (market return).

However, we reiterate that it would be useful to test for stability in the beta parameter and determine the likely cause. If there is no evidence of instability when the whole sample is used then we consider the whole sample should be used. We note this position is consistent with the recommendation of Henry (2014, p.63).

If there is strong evidence of beta instability we consider that it would be relevant to identify the source and determine (1) whether the impact was greatly mitigated by the impact of the regulatory arrangements in supporting returns; and (2) whether removing it was justified based on its unique nature. The guiding criterion should be what is the best approach to determine an equity beta for the forthcoming regulatory period while recognising the nature of the regulatory arrangements and their impact on risk. Large shocks may affect economy-wide returns in particular but the impact on regulated network energy businesses is likely to be substantially muted in terms of an impact on systematic, non-diversifiable risk. The extent of the arrangements also may mean that many diversifiable risks are also reduced.

5.2.2.5 Whether the reduction in ex-ante returns set by the AER is likely to have materially changed the systematic risk for regulated energy networks through time?

The reduction in ex-ante returns set in the allowed WACC by the AER is largely related to recognising a lower risk-free rate in the CAPM and a lower allowed cost of debt. The market risk premium allowed for AER regulatory purposes has been relatively stable but subject to much dis-agreement over whether and to what extent there is an inverse relationship between the market risk premium and the risk free rate. As the risk free rate has declined the allowed return to equity has declined with a relatively stable approved market risk premium.

In answering this question, first consider that beta measures the non-diversifiable risk of the entity relative to the market as a whole. We consider that regulatory arrangements for regulated network businesses greatly limit their non-diversifiable risk in terms of the variability of their returns relative to the returns for market as a whole. In terms of realised earnings the main potential variability relates to over and under expenditure on approved operating and capital expenditure where there are sharing schemes in place that allocate approximately 30 per cent of the under or over amount in present value terms to the regulated business for operating expenditure and exactly 30 per cent in present value terms for capital expenditure. This means there is very high cash flow stability that should in turn be reflected in the measure of systematic risk. We recognise that the systematic risk as measured by the beta depends on both a cash flow beta component and an investor discount rate component, as discussed in section 2.2 and investors may have different and changing expectations about discount rates but we consider that their views on discount rates are likely to relate to the market as a whole and be mainly reflected in the market risk premium. To be clear, we consider that the market risk component of the discount rate would be the predominant factor that would change over time relative to a measure of systematic risk (measured by the equity beta) which captures the non-diversifiable risk of the entity under consideration relative to the market as a whole. So we do not see a clear theoretical or commercial argument for the lower *ex ante* returns set by the AER to have materially changed the systematic risk for regulated energy networks through time.

To reiterate, the question is: has the variability in returns for the regulated entity increased relative to the returns for the market as a whole? This is an empirical question but our *a priori* contention would be that there would not likely have been a material change in the systematic risk for regulated energy networks through the past decade or so. This contention reflects our assessment of how low the true beta is likely to be given the protection of the regulatory arrangements to returns as discussed in Section 2.2 (strict revenue cap can be chosen, tariff structures can be set to better recover fixed costs, real return applied each period to an indexed asset base, unavoidable cost pass through mechanisms, operating and capital efficiency sharing schemes that diminish both upside and downside potential, trailing average cost of debt in place of the on-the-day approach and regular resetting of prices to reflect forecast costs) and recognising that there have been some considerable swings in market returns in recent years that have not transmitted to the regulated energy networks in terms of financial shocks.

We would expect that if there was an impact of *ex ante* returns on the systematic risk of energy networks through time it would be reflected in the market price for risk rather than the relative risk (beta) of the regulated entity. We consider that the very high protection to returns afforded the regulated entities with the existing regulatory arrangements is a dominant factor limiting the scope for changes in systematic risk for regulated energy networks. However, there is a separate issue of whether the reduction in *ex ante* returns means that there is a material impact on incentives to ensure efficient investment. In this respect we suggest the focus of attention should be on the level of the market risk premium and the issue of whether overall expected returns for the market as a whole are lower now than a decade or more ago.

5.2.2.6 Will reductions in either the risk-free rate, or the inflation rate over recent years, be likely to have materially changed the systematic risk of regulated energy networks relative to the broader Australian equities market? Does the answer to this question depend on whether the changes to the risk free rate or inflation in recent years are (or should be assumed to be) cyclic or structural?

Key considerations just discussed above are relevant to this question. Some additional points are discussed below.

Ang, Brière and Signori (2012) investigate the impact of inflation on the betas of individual equities. They find that over the period 1990 to 2010, US stocks with inflation-hedging properties had higher average returns than stocks with low inflation betas.[17] Pertinently, Ang *et al*. document large time variation in stock inflation betas. These findings indicate that inflation can be a relevant concern for beta estimation, particularly in periods when there is a change in the rate of inflation. However, two significant considerations suggest that it is not a relevant concern in the present period. First, inflation has been low, and with limited variability, for some time, and second, the regulatory structure for energy networks substantially mitigates inflationary effects.

The reduction in the risk free rate in recent years has reflected lower inflation outcomes and

[17] Inflation beta is a standardized measure of the relationship between a security's return and change in the level of inflation. To illustrate, a security with an inflation beta of 1.2 implies that a 1% increase in inflation would lead to a 1.2% increase in the return to the security. In a period of change in inflation, securities with different inflation betas would record different betas.

expectations and strong and persistent action by central banks around the world, including the Reserve Bank of Australia, to lower the risk free rate for macroeconomic management purposes. Bond yields are noticeably lower across the board. The low interest rate environment has supported strong stock market returns and this does raise an issue as to the impact on the market risk premium (where we understand there is, however, evidence of a structural decline over a long period of time until recently).

These economy-wide developments affect all firms and investors and, conceptually, we do not see theoretical support for their having a significant impact on the systematic risk of regulated energy network businesses, particularly in a low inflation environment. We also reiterate the strong protection that the regulatory arrangements provide for interest rate risk and inflation outcomes and consider that this inflation protection is most likely to be much higher than exists on average in the market economy.

The AER (2018c, p.147) in its explanatory statement for the rate of return instrument noted that its regulatory treatment was to deliver “the initial real rate of return plus ex-post inflation outcomes” and that this approach would reduce systematic risk exposure because firms are insulated from inflation risk. The AER noted that, with this approach, the effects of inflation are already incorporated in the observed financial market data and so the equity beta based on that financial data would reflect this treatment of inflation. In addition, the trailing average cost of debt provides a natural hedge against movements in interest rates.

Thus the method for accounting for inflation provides compensation to regulated firms for outturn inflation when the allowed rate of return is applied to the regulatory asset base to calculated the allowed return on capital each period. This protection will continue and be improved with changes in measures of expected inflation that the AER is proposing to use as documented in its recent position paper on the treatment of inflation (AER 2020). See also the discussion of the regulatory arrangements in section 2.2. We agree with the AER interpretation on these matters in terms of the allowance for a return on capital.

We note that the main risk to the cash flows is in relation to under and over expenditure outcomes for operating and capital expenditure but the risk is greatly diminished with efficiency sharing schemes. Our understanding is that the regulatory arrangements first determine the best nominal forecasts of these expenditures over the regulatory period then convert them to a present value using the allowed WACC and then determine prices indexed by the CPI such that the present value of the total revenue will equal the present value of the total allowed costs (the NPV=0) condition. This means there is both specific price risk and volume risk applying to both operating and capital expenditure. For example, the operating expenditure forecasts contain both a cost price element and a volume element and either could turn out significantly different to what was projected. However, these are risks that are not likely to be linked to general inflation as measured by the CPI. In addition, some of these risks may be specific or unique to the regulated firm and therefore diversifiable and not relevant for pricing in the CAPM.

In relation to consideration of whether changes in the risk free rate or inflation should be treated as cyclic or structural, given the high protection from the regulatory arrangements from actual inflation and interest rate risk and the likelihood that economy-wide pricing developments would mainly impact on the market risk premium we don’t consider there would be a materially different effect if changes in the risk free rate were cyclic or structural.

In relation to commercial practice we also note that, there is implicit assumption that if lower interest rates and inflation are issues, then they are more likely to be a concern in estimates of the market risk premium. Thus, we would expect that if there was an impact of a reduction in inflation or the risk free rate on the cost of capital it would be reflected in the market risk premium which is the price of risk rather than the systematic risk relative to the market as a whole as measured by the beta for regulated energy network businesses.

5.2.2.7 Conclusion

In conclusion, the nature of regulation of network energy businesses in Australia is expected to lead to considerable revenue stability and full recovery of allowed costs and this in turn is likely to mean considerable stability in systematic risk for such entities. This should mean that, absent unexpected material economy-wide shocks, the longest historical period is still likely to be highly relevant. However, we suggest that beta needs to be continually tested for stability and where there is convincing statistical evidence of a change using recent data we consider more emphasis should be given to recent data but there should not be sole reliance on such data.

The advantages and disadvantages of using different time periods for estimating beta are summarised for the three historical periods used by the AER in Table 5.3.

Table 5.3: Advantages and disadvantages of different time periods for estimating beta

	Advantages	*Disadvantages*
Longest historical period	With weekly data provides a large number of observations to help ensure low statistical (sampling) error. There is considerable support for beta stability from the existing data set. Beta instability can be tested for.	At some stage beta instability and relevance may become an issue but significant instability seems unlikely given the strong protection to stability provided by the regulatory arrangements.
Excluding significant events	Still provides scope for a sufficiently large sample to reduce standard errors substantially while choosing an estimation period that is likely to provide more stable beta estimates.	Excluding significant events can remove valuable valid information about the impact of significant events on systematic risk. Less data observations will mean higher statistical (sampling error).
Last five years	Gives more weight to recent developments.	Higher standard (sampling) errors than for the other options. Not necessary if there is good a priori evidence to support beta stability.

An assessment of the key features of each period based on the assessment criteria provide by the AER is set out below.

5.2.2.8 Reliability

This is the main criterion for evaluation of the time period.

- Provided there is not strong statistical evidence of beta instability the longest time period would provide the most reliable estimates for beta.
- The exclusion of data is not necessary and would produce less statistically reliable estimates of beta if there is no clear statistical evidence of beta instability.
- The most recent time period will produce the least statistically precise estimates of beta if there is no clear statistical evidence of beta instability. However, with weekly data there should still be relatively low sampling error for a five year period.
- If there is reasonable evidence of beta instability then more weight should be considered for the recent evidence but longer term estimates should still be considered in the information set given the empirical evidence that has been presented to date.

Three other criteria: relevance to the Australian benchmark; suitability for use in a regulated environment; and simplicity would be met similarly by each time period in Table 5.3.

6 IDENTIFYING COMPARATORS FOR ENERGY NETWORKS

6.1 AER Request

The AER request asks us to advise on the proxy firm comparator set that the AER could use in the 2022 RORI for the purpose of estimating equity beta, and also to discuss the relative advantages and disadvantages of including different types of firms in the comparator set.

6.2 General Principles

The AER's method for estimating equity beta has been to use a group of comparator firms and to calculate an average (unlevered) beta. The AER has drawn its comparators from Australian businesses that are either wholly or mostly engaged in the provision of energy network services. The AER aims to estimate the beta of a benchmark efficient entity defined as 'a pure play, regulated energy network business operating within Australia'. A 'pure play' business is one that only provides the relevant regulated energy services, and is not engaged in other activities.

6.2.1 Number of Comparators

A great benefit from using a group of similar firms to estimate beta is that it expands the data set and improves the reliability of the beta estimate. Not only can the precision of the beta be greatly improved, but what is equally important, the resulting beta estimate is more reliable for forecasting. One reason for this is the observation that there are mean-reversion tendencies of betas within industries (see section 3.5.2). Patterson observes that there is "a strong portfolio-size effect on the forecasting accuracy" of beta (1995, pp.127–128). He cites a study which demonstrated that "the mean square error of the predictions using OLS estimation was reduced by more than two thirds when ten securities with similar betas were grouped together rather than being estimated singly" (1995, p.128). The incremental error-reduction effect diminishes for larger groups of comparators.

Damodaran (2011, p.138) suggests beginning with a narrow list of comparators and widening as needed. Since the most closely comparable businesses will be first on the list, there is clearly a trade-off when widening the list between achieving a reasonably precise and stable estimate of beta, and its representativeness to the business risks of the regulated energy networks.

Some businesses can be considered as 'pure play' regulated energy networks. In one sense, such securities can be viewed as adequate comparators for the purpose of determining beta. The key question is with regard to reliability in forecasting. Further widening the group of comparators means including businesses that have differentiating characteristics, and the importance of those differentiating characteristics for business risk is generally unknown. Set against this drawback there is the advantage of improving the precision of the average beta estimate and, arguably, the resulting average beta is likely to represent a more reliable forecast.

As Patterson has observed, the benefits of this widening process are substantial for up to around 10 securities, but diminish beyond that point. The benefits will, of course, depend on whether such a group is feasible without including businesses that are too dissimilar. Broadly speaking however, having approximately 10 securities in the comparator group, if feasible, appears to be a useful rule of thumb.

6.2.2 Characteristics of Good or Acceptable Comparators

The comparators need to be selected so that the underlying drivers of their systematic risk are as similar as possible to the regulated firm of interest. Unexpected changes in economy wide variables such as GNP, inflation, real interest rates and market risk aversion often affect systematic risk, but the nature and degree of impact of such factors may be similar for similar businesses.

The choice of comparator businesses is related to the fundamental analysis discussed in section 3.3.1. The comparators that have similar business risk will generally be businesses:

(a) in the same industry and/or with similar production processes; and

(b) that have similar business risk factors.

For some firms it is also possible to look for comparators in other parts of the supply chain, or that specialise in supplying similar groups of customers, which can sometimes mean they have similar systematic risks. Another basis for comparison may be the use of similar technologies. For example, firms that manage regulated infrastructure networks might be useful candidates as comparators, or telecommunications ‘poles and wires’ businesses. The presence and form of regulatory arrangements will also be relevant in assessing whether they are likely to face similar systematic risk.

Some business risk factors are discussed in section 3.3. Stewart (1991) reports the results of a study by Stern Stewart & Co which identified that the following business risk factors were correlated with asset betas:

1. *Operating risk*: the variability of returns on capital earned over a business cycle is directly related to business risk;
2. *Strategic risk:* greater ability to create value in the future (i.e., achieve a high rate of return growth rate) implies higher risk;
3. *Asset management risk*: firms with lower business risk compared to their competitors have: more effective working capital management; greater capital intensity rather than labour intensity; newer plant and equipment; and longer average useful plant life.
4. *Size and diversity:* larger companies are generally less risky than smaller firms because they have more experience, take less risk per decision made, and are usually more geographically diversified and hence less exposed to economic cycles specific to one country.

Lally (2000) reviews some of the literature in this area and considers that key determinants of systematic risk include: the nature of the firm's output, duration of firms' contracts, degree of monopoly power, form of regulation, operating leverage, capital structure, and the firm's real growth options. These sorts of factors have been considered in various regulatory contexts including by the AER in previous determinations of beta for regulated network energy businesses.

The nature of the firm’s output relates to the sensitivity of demand for the product compared to economy wide demand that impacts on overall market returns. This can be reflected in relative revenue variability with businesses providing 'essential' services likely to experience relatively low revenue variability. The form of regulation refers, for example, to the extent to which price caps or revenue caps apply with an expectation that revenue caps would ceteris paribus reduce revenue variability relative to price caps. Typically regulation that provides for effective cost recovery reduces systematic risk relative to the systematic risk for unregulated firms.

Operating leverage refers to the extent to the share of fixed operating costs in total costs with high operating leverage expected to mean higher systematic risk. Real growth options refer to the extent to which a firm may have growth options but their value is uncertain and there is value in delaying an investment which can be shown to impact on systematic risk. The regulatory arrangements are expected to suppress the impacts of operating leverage and real growth options because of the impact in reducing uncertainty and suppressing revenue variability.

In brief, the key characteristics of good or acceptable comparators that we consider are important are:

- Operating in the same industry and the same or a similar market or with similar production processes
- Low variability in returns over a business cycle
- Size and diversity that contribute to return stability
- Natural monopoly type characteristics
- Essential service or services with a relatively low income elasticity of demand
- High operating leverage reflected in a relatively high share of fixed costs
- Regulation or contractual arrangements or demand characteristics that contribute to high return stability, and
- Data that is limited to approximately the last 10 years.

6.2.3 Use of Overseas Firms as Comparators

Ideally, the beta for each firm will be estimated against a common market index. Beta is a measure of *relative* business risk, that is, relative to a fully diversified optimal portfolio which is proxied by a broad stock market index. The beta of a firm estimated in relation to one market can be quite different to its beta estimated relative to another market, a fact well-established with dual listed businesses.

Damodaran suggests that if there is an insufficient number of comparators in the same local market then one way of expanding the sample is to consider including other firms in the same business that are listed and traded in other markets, *but* when doing so he suggests including only comparators from nearby markets: e.g. for comparators for companies in Greece we might look to other European markets, and for comparators for companies in Brazil we might look to other Latin American markets (Damodaran 2011, p.142). By analogy, New Zealand may be a useful source of comparators for Australia. It will be especially convenient if the New Zealand businesses are dual listed in Australia.

In past consultations, service providers have supported "the inclusion of international energy firms and other Australian infrastructure firms in the comparator set" but the Consumer Challenge Panel (CCP) has been opposed to this because such firms are not seen as close comparators the risk of providing regulated energy network services (AER 2018a, p.48). Consultant reports often report betas for a sample of international energy businesses, mostly drawn from the USA (Frontier Economics 2016, Allen Consulting Group (ACG) 2008, Competition Economists Group (CEG) 2013). Some of these US comparators are examined in section 6.4.

Important shortcomings with the use of foreign businesses as comparators for Australian energy networks include:

(1) US energy utilities are generally vertically integrated businesses that include energy retailing, electricity generation and/or natural gas wholesaling; and are not just providers of electricity network or gas pipeline access. The upstream and downstream activities that they are engaged in are riskier than is the provision of natural monopoly infrastructure services. This will upwardly bias any average beta estimates obtained from the US energy market. It would be difficult to correct for such upward bias and the consulting reports which use this data typically do not attempt to do so.

(2) As stated, these betas are measured against different market indexes. Their geographical remoteness from Australia means that they are exposed to different systematic risks. Some studies that use international comparisons make a range of adjustments to attempt to correct for the very different compositions of overseas market portfolios. For example, Allen Consulting Group (ACG 2008) re-weights the sectors of the NYSE market index to resemble the sector composition of the ASX market index, and adjusts for the difference between the average gearing of firms in the NYSE index and in the ASX index. However, there is no way to be sure that these adjustments do in fact make the overseas betas more closely comparable to the Australian betas, and little support is provided for the validity and reliability of these procedures.

(3) In the AER's 2018 consultation process on rate of return, a forum for concurrent expert evidence was conducted, and one of the points of expert agreement was that there are no simple adjustments that can be made to make international data comparable to domestic data (Australian Energy Regulator (AER) 2018a, p.246).

If a wide range of international comparators is to be used, then an International Capital Asset Pricing Model (ICAPM) should, in principle, be used. This approach estimates betas relative to an international market portfolio.[18] However, studies that use USA energy comparators (e.g., ACG 2008, CEG 2013 and Frontier 2016) do not use the ICAPM. It does not appear to be a method widely used by regulators.

If overseas firms are used as comparators, it is important to understand differences in regulatory

[18] An example is the Morgan Stanley MSCI World Index, which includes only developed countries, or the ACWI index which also includes emerging economies: <https://www.msci.com/acwi>.

arrangements and allow for their impact. Although there are inevitably likely to be difficulties in ensuring comparability of overseas firms, their inclusion may still help to inform a view of a preferred estimate, or to better inform specific questions such the impact of different regulatory arrangements on business risk.

6.3 Australia and New Zealand Candidate Comparators

Our approach is to begin by identifying a wide range of possible comparator firms in Australia and New Zealand. Many of the New Zealand firms we identify are listed on the Australian Stock Exchange (ASX). Attention is restricted to large firms, defined here as having a market capitalisation greater than $1bn. The initial focus is on businesses that own energy networks, and the focus then widens to other listed infrastructure businesses.

6.3.1 Energy Network Businesses

6.3.1.1 ASX-listed energy network businesses

There are ten publicly-listed firms in the Utilities industry classification of the ASX which have a market capitalisation greater than $1bn.[19] Among these, Tilt Renewables Ltd was recently (since 15 March 2021) subject to a takeover by Mercury NZ and a consortium led by AGL.

Several of these firms are primarily involved in electricity generation and/or retailing, without interests in energy networks. They include:

- AGL Energy Limited (AGL), which is primarily engaged in electricity generation and energy retail. It has a broad power generation portfolio including coal-fired and gas-fired generation, as well as renewable sources including hydro, wind, landfill gas, solar and biomass. AGL is also one of the largest energy retailers in Australia.
- Contact Energy (CEN), Genesis Energy Limited (GNE), Mercury NZ Limited (MCY), and Meridian Energy Limited (MEZ) are all New Zealand-based energy producers with energy retailing businesses. CEN, MCY and MEZ each has a portfolio of electricity generation assets. GNE is engaged in petroleum production and sales via Kupe Oil & Gas. CEN has some involvement in natural gas and telecommunications infrastructure. The basic business of all these businesses is integrated energy production and retail.

One of the businesses listed in the ASX Utilities industry sector is a diversified infrastructure fund. Infratil Limited (IFT), is New Zealand-based and although most of its assets are in New Zealand, is also has investments in Australia and the US. Its portfolio includes airports (66% of Wellington International Airport); electricity generation (50.8% of Trustpower and some NZ renewables energy investments), telecommunication networks (100% of Vodafone NZ), data centres, and social infrastructure (50% of RetireAustralia and Infratil Infrastructure Property). Although it has a diverse infrastructure portfolio, much of it is not related to essential

[19] AGL Energy Ltd (AGL); APA Group (APA); Ausnet Services Ltd (AST); Contact Energy Ltd (CEN); Genesis Energy Ltd (GNE); Infratil Ltd (IFT); Mercury NZ Ltd (MCY); Meridian Energy Ltd (MEZ); Spark Infrastructure Group (SKI); and Tilt Renewables Ltd (TLT).

facilities, and does not include energy networks. This suggests that it is unlikely to be a useful comparator.

This leaves only three relevant comparators listed on the ASX:

- AusNet Services (AST) owns and operates the Victorian electricity transmission network; one of the five Victorian electricity distribution networks; and one of three gas distribution networks in Victoria. It also has an unregulated arm, Mondo, which provides contracted infrastructure asset and related services to business, government, communities and households. The business unit owns and operates a portfolio of assets that fall outside the regulated asset base. It accounted for around 8% of AusNet's revenue, and 16% of its capital expenditure in 2020.
- Spark Infrastructure (SKI) is an Australian infrastructure fund which principally owns electricity infrastructure assets. These include 49% of SA Power Networks, 49% of Powercor and Citipower in Victoria, and 15% of Transgrid in NSW. Beyond these electricity network assets, it owns the Bowman Solar Farm, which represents about 3% of its assets.
- APA Group (APA) builds, owns and operates energy infrastructure – primarily gas transmission pipelines, but also gas storage and processing, and gas-fired and renewable energy power generation businesses. It also provides asset management services for third parties, primarily relating to the operation of gas networks. It owns the Victorian gas transmission system, the Roma to Brisbane pipeline, the Amadeus gas pipeline, the Carpentaria Pipeline, the Central West Pipeline and the Moomba to Sydney Pipeline, among many others. It also owns 50% of the SEA Gas pipeline, 20% of Queensland gas distributor Allgas, and has a 19.9% interest in the MurrayLink and Directlink electricity interconnectors. It owns several wind farms and solar farms, and has interests in gas processing facilities. It also operates gas networks for Australian Gas Networks.

These three businesses are listed in Table 7.1 with their listing date, market capitalisation, and an indicative beta reported on the Macquarie online trading website. To be clear, we do not know how these betas are calculated and we are not suggesting they could be used by the AER. They are presented only to provide indicative comparisons of market risk across the potential comparator firms discussed in this section.

Table 6.1: ASX-listed Energy Networks

ASC code	*Company name*	*List date*	*Market Cap ($m)*	*Beta**
APA	APA Group	13/6/00	11,197	0.57
AST	Ausnet Services Ltd	14/12/05	6,576	0.77
SKI	Spark Infrastructure Group	16/12/05	3,791	0.55
	Average		7,188	0.63

* Morningstar research, <https://www.trading.macquarie.com.au>, accessed 2 June 2021.

The assets of Ausnet Services and Spark Infrastructure are predominantly regulated. APA states that only 8.3 per cent of its revenue is subject to regulated outcomes. This refers to its revenue from the Victorian Transmission System, the Roma to Brisbane Pipeline, the Amadeus Gas Pipeline, and the Goldfields Gas Pipeline. These four pipelines are wholly-owned by APA and subject to full regulation. However, this does not account for all of its assets subject to some form of economic regulation:

- some of its income from investments is derived from fully regulated businesses, including electricity interconnectors such as MurrayLink and Directlink (APA 19.9 per cent);
- several of its wholly-owned pipelines are subject to 'light regulation' including: the Marsden to Wilton segment of Moomba Sydney Pipeline; the Central West Pipeline; the Carpentaria Gas Pipeline; and the Kalgoorlie to Kambalda Pipeline;
- some of its investments are in infrastructure subject to 'light' regulation including Allgas (APA 20 per cent);
- its asset management activities carried out for Australian Gas Networks, which account for 4.7 per cent of its revenue, are predominantly for the operation of fully regulated gas networks.

In addition to this regulated revenue, much of its other income is from bilateral contracts for supplying major customers via unregulated lateral pipelines, presumably under long-term arrangements. APA reports that (in addition to the 8.3 per cent of regulated revenue) 79.8 per cent of its revenue is from capacity charges, 2.9 per cent is from contracted fixed revenue. This suggests that notwithstanding that a minority of its assets are subject to full regulation, its overall revenues may have characteristics similar to those of a more comprehensively regulated energy networks business.

6.3.1.2 Unlisted Australian energy network businesses

There are a number of government-owned and private electricity networks in Australia (i.e., owned by businesses not listed in Australia). In electricity transmission networks:

- *Government-owned* transmission providers include Powerlink in Queensland and TasNetworks in Tasmania. Government-owned distribution businesses providers include Energex and Ergon Energy in Queensland, TasNetworks in Tasmania, and Power and Water in NT. In addition, in the NSW government owns Essential Energy and 49.6% of Endeavour Energy and Ausgrid;
- *Wholly-private* transmission networks include ElectraNet in SA. Wholly-private distribution businesses include Evoenergy in NSW, and Jemena and United Energy in Victoria;
- *Majority-private* businesses include transmission business TransGrid in NSW, distributors Powercor and Citipower in Victoria, SA Power Networks in SA. In each of these cases, the listed infrastructure fund Spark Infrastructure has a minority interest. Other majority private businesses include Ausgrid and Endeavour Energy in NSW, which are owned by consortia of investment funds and the NSW government;
- *Wholly public*: AusNet, which owns the Victorian electricity transmission network and a Victorian electricity distribution network, is a listed company.

6.3.1.3 Delisted Australian energy network businesses

Several delisted energy network businesses were included by the AER in its comparator set chosen in its 2018 Rate of Return Instrument. These are listed in Table 6.2. The key point to emphasise about this group is that some of the businesses were delisted a considerable time ago. AGL Energy, Alinta and GasNet were all delisted approximately 14 years ago. Hastings Diversified Utilities was delisted over 8 years ago. Envestra and DUET were delisted six and four years ago respectively.

Table 6.2: Sample periods for comparator firms used by the AER

#	*Firm*	*Period*	*Sectors*
1	AGL Energy	Jan 1990 – Oct 2006	Electricity, Gas
2	Alinta	Oct 2000 – Aug 2007	Gas
3	DUET Group	Aug 2004 – May 2017	Electricity, Gas
4	Envestra	Aug 1997 – Oct 2014	Gas
5	GasNet	Dec 2001– Nov 2006	Gas
6	Hastings Diversified Utilities	Dec 2004 – Nov 2012	Gas

There would appear to be a strong case for removing AGL Energy, Alinta and GasNet from the list of comparators, since the extended period of time since their data was current increases the likelihood that the data may not be representative of the recent past. Previous discussion has highlighted that over extended periods betas may change, due in part to structural changes that cause changes in the business risks of an industry relative to the market as a whole. Similar concerns would also suggest that Hastings could be excluded. There would appear to be merit in retaining DUET, which was delisted comparatively recently, and probably also retaining Envestra.

In any pooled beta estimation process it is likely to be desirable to have a balanced panel in the sense of having the same number of periods per business. Thus, if a 10-year sample were used, than the latest 10 years of data for a delisted business could be used alongside the latest 10 years of data for a listed firm.

6.3.1.4 New Zealand Energy Networks

In New Zealand there is generally integration of electricity generation and energy retail. In some cases, oil and gas production is integrated with energy retail. However, these businesses generally do not have a significant presence in energy transmission or distribution. There are several examples listed on the ASX, including: Contact Energy (CEN); Genesis Energy Limited (GNE); Mercury NZ Limited (MCY); and Meridian Energy Limited (MEZ).

In regard to electricity networks, the most important business is Transpower, which owns and operates the electricity transmission network in New Zealand, and is owned by the New Zealand government. The four largest electricity distributors are:

- *Orion*: 89.3% owned by Christchurch City Council and 10.7% by the Selwyn District Council;
- *Powerco*: owned by Queensland Investment Corporation and AMP Ltd;
- *Vector*: owned 75.1% by Entrust (a consumer trust) and the balance by private investors; and
- *Wellington Electricity*: owned jointly by Cheung Kong Infrastructure Holdings Limited (CKI) and Power Assets Holdings Limited – both part of the Cheung Kong group of companies and listed on the Hong Kong Stock Exchange (HKEx).

New Zealand has four important gas pipeline businesses, including Powerco and Vector listed above, as well as:

- *First Gas Ltd*: owned by First State, itself wholly-owned by Mitsubishi UFJ Financial Group; and
- *GasNet*: 100% owned by Whanganui District Council.

None of the electricity or gas network businesses listed above is publicly traded.

6.3.2 Other ASX-listed Infrastructure Businesses

This section describes businesses listed on the ASX in transportation and telecommunication services industries which have a market capitalisation greater than $1bn. This includes firms that own and operate: toll roads; freight transport infrastructure; airports; and telecommunications infrastructure.

6.3.2.1 Transportation infrastructure

Table 6.3 lists transport infrastructure businesses. This excludes logistics companies such as Qube Holdings Ltd and air-carriers such as Air New Zealand Ltd and Qantas Airways Ltd. Freight transport infrastructure operator Dalrymple Bay Infrastructure has only been listed since December 2020, and for this reason it is not given further consideration.

The remaining listed businesses include:

- *Toll road operators*: Atlas Arteria and Transurban Group;
- *Freight transport infrastructure operator*: Aurizon Holdings; and
- *Airports*: Auckland International Airport and Sydney Airport (SYD).

These five businesses are listed in Table 6.3 with their listing date, market capitalisation, and an indicative beta reported on the Macquarie online trading website. The betas are on average at a similar level to the energy network businesses listed in Table 6.3.

Table 6.3: ASX-listed Transport Infrastructure Businesses

ASC code	*Company name*	*List date*	*Market Cap ($m)*	*Beta**
AIA	Auckland Internat. Airport Ltd	22/2/99	9,969	0.52
ALX	Atlas Arteria	25/1/10	5,831	0.57
AZJ	Aurizon Holdings Ltd	22/11/10	6,534	0.70
SYD	Sydney Airport	2/4/02	15,545	0.67
TCL	Transurban Group	14/3/96	37,923	0.56
	Average		15,160	0.60

* Morningstar research, <https://www.trading.macquarie.com.au>, accessed 2 June 2021.

6.3.2.2 Toll road operators

The operations of the two toll roads businesses are as follows.

- *Transurban* has a large portfolio of tolls road interests, including two major toll roads in Melbourne, six tollways in Brisbane, and 10 toll roads in Sydney. It also has toll road interests in the USA and Canada. The concession periods vary from 16 years to 68 years.
- *Atlas Arteria* (formerly Macquarie Atlas Roads) is an infrastructure fund comprising a portfolio of toll road interests France, Germany and the United States. Most of these toll roads have long-term concessions expiring between 2035 and 2060.

Toll road concessions typically (but not always) specify a maximum annual increase in tolls over the life of the concession. For this reason, the income streams have some resemblance to regulated businesses.

6.3.2.3 Freight rail infrastructure

Aurizon Holdings Ltd provides access to, and operates and manages, the Central Queensland Coal Network (CQCN), and it is also a major bulk rail freight operator across Australia. Its principal business segments are:

- *Above rail operations*: Aurizon operates coal haulage operations on the CQCN and in the Hunter Valley NSW, and operates bulk freight trains in South-East Queensland, NSW and elsewhere in Australia. Coal is railed from mines in central Queensland and from mines in the Hunter Valley NSW to domestic customers and to coal export terminals in Queensland and NSW. Aurizon’s Bulk business includes haulage of a range of bulk commodities such as iron ore, base metals, minerals, grain and livestock across Queensland and NSW and Western Australia. Above rail operations account for 72 per cent of Aurizon’s revenue and 52 per cent of its EBIT.
- *Track access*: Aurizon operates the 2,670km CQCN, which is an open access rail network connecting multiple major coal mining systems with more than 40 mines in central Queensland with five coal export terminals at three Queensland ports. Track access accounts for 28 per cent of Aurizon’s revenue and 48 per cent of its EBIT.

The track access segment of Aurizon's business is a regulated network infrastructure business with some similarities to regulated energy networks including a total revenue cap. A key difference may be that the amount of coal transported on the network will depend on mine productivity and international demand, and may differ in its degree of risk compared to usage on electricity and gas networks over a longer time frame then the regulatory period. In its above rail operations Aurizon competes with other above-rail operators such as Qube and Genesee & Wyoming. This business does not appear to have similar business risk to an energy network business.

6.3.2.4 Airports

Auckland International Airport Ltd operates this major airport in New Zealand, providing airport facilities and supporting infrastructure. It caters for the movement of aircraft, passengers and cargo, and provides utility services which support the airport. It leases space for terminals, cargo buildings, investment properties and hangars. It also provides services to the retailers within the terminals and car parking facilities to airport visitors. Aeronautical income comprises: (a) Airfield income from aircraft landing and parking charges (which represents 19 per cent of total operating revenue); and (b) Passenger services charges (accounting for 25 per cent of revenue). Together, aeronautical income accounts for 44 per cent of operating revenue. The other main sources of income are: (a) Retail income (26 per cent of revenue); (b) Car parking income (9 per cent); and (c) Rental income (20 per cent).

Sydney Airport Holdings owns and operates this major airport in Australia. It provides aeronautical, retail, property, car rental and parking and ground transport services. Aeronautical services contribute 33 per cent of its revenue. Retail services contribute a further 33 per cent of revenue. Property and car rental provides 27 per cent and Parking and ground transport contributes 7 per cent of revenue.

Passenger movements, and especially international passengers, are a significant driver of airport revenue, with the majority of aeronautical revenue coming from passenger charges, and some other sources of income driven by passenger movements. Part of the passenger market is business-related and part is tourism-related. The latter may be viewed as discretionary expenditure and as such it may be sensitive to broader economic conditions, although not necessarily specific to any one country.

6.3.2.5 Telecommunications services

Eight telecommunications businesses with market capitalisation over $1 bn are listed in Table 6.4. This table shows the listing date, market capitalisation, and an indicative beta reported on the Macquarie online trading website.

Excluded from the table are the following businesses:

- TPG Telecom is a major provider of telecommunications services to retail and wholesale customers in Australia via its nationwide fixed fibre and mobile network infrastructure, said to be the second largest voice and data network in the country. It has multiple brands including Vodafone, TPG, iiNet, Lebara, Internode and AAPT. TPG Telecom was created from a merger of TPG and Vodafone Hutchison Australia

(VHA) in 2020, and the current entity has only been listed since that time. This means there is insufficient data relating to continuous business.

- Hutchison Telecomm's principal activity is ownership of a 25 per cent equity interest in TPG, and as consequently it cannot be used as a comparator, and due to the large change in TPG due to its merger with VHA.
- Uniti Group Limited is a provider of wireless and fibre broadband services; and specialty services. It has only been listed since 2019.

A description of the telecommunications businesses listed in Table 6.4 follows.

Table 6.4: ASX-listed Telecommunications Businesses

ASC code	*Company name*	*List date*	*Market Cap ($m)*	*Beta**
CNU	Chorus Ltd	21/11/11	2,705	0.99
MAQ	Macquarie Telecom Group Ltd	27/9/99	1,070	0.57
SPK	Spark New Zealand Ltd	22/8/91	7,879	0.70
TLS	Telstra Corporation Ltd	17/11/97	40,794	0.76
VOC	Vocus Group Ltd	10/6/99	3,392	0.60
	Average		11,168	0.72

Chorus owns the majority of telephone lines and exchange equipment in New Zealand and provides nationwide fixed line access to telecommunications retailers. Chorus was demerged from Telecom New Zealand in 2011, and its only business activity is to provide fixed line communications infrastructure. It has won contracts with the New Zealand government to build approximately 70 per cent of the new fibre optic Ultra-Fast Broadband (UFB) network. The Commerce Commission's regulation of broadband services is focussed on Chorus' copper lines network, for which it sets the wholesale prices which Chorus can charge to other telecommunications providers. Under a new regulatory regime effective from January 2022, the Commerce Commission will regulate Chorus in a similar manner to the regulation of electricity lines and gas pipeline businesses by setting a revenue cap and service standards for Chorus's UFB network.

Macquarie Telecom Group is an Australian company engaged in providing telecommunication and hosting services to corporate and government customers within Australia. Its two business segments are: (a) Hosting (includes data centres, cyber security services (to governments) and secure cloud offerings); and (b) Telecom which acquires wholesale services from NBN Co. and supplies services to corporations and government.

Spark New Zealand (formerly Telecom New Zealand) is the largest telecommunications and digital services business in New Zealand. It provides mobile, broadband, cloud services, security, digital services and live sports streaming. It has over 2.5 million mobile customers and over 700,000 broadband connections. It is New Zealand's largest Internet Service Provider and second largest mobile operator, with its own 3G mobile network. In both cases its largest competitor is Vodafone NZ. Broadband services are provided via the Chorus copper wires network or by fibre-to-the-premises (FTTP). Mobile services represent 36 per cent of its revenue; voice services account for 11 per cent; and Broadband services 19 per cent of revenue. It also provides other services to consumers, businesses and governments including: Cloud, security and service management (12 per cent); Procurement and partners (11 per cent); Managed data, networks and services (7 per cent); and Other (4 per cent).

Telstra is Australia's largest telecommunications business. It supplies 18.8 million retail mobile services, 3.8 million retail fixed bundles and standalone data services and 960,000 retail fixed standalone voice services. It operates telecommunications networks and markets voice, mobile, internet access, pay television and other products and services. Its network infrastructure services are in a business segment called Telstra InfraCo. The revenue of this segment, including internal access charges, accounted for 18 per cent of total revenue in 2019.

Vocus has three main business segments: Vocus Network Services, Retail and New Zealand, and it also undertakes large infrastructure projects. Vocus Network Services provides specialist fibre and network solutions across Australia, New Zealand and Asia. Its network connects all mainland capitals with Asia and has backhaul fibre connecting most regional centres in Australia. Vocus Network Services accounts for 35 per cent of total revenue. Vocus' Retail division is a retail consumer business in Australia, with brands Dodo and iPrimus in the residential market, and Commander and Engin in the small and medium business market. This business accounts for 42 per cent of total revenue. The New Zealand division includes both fibre network and a retail business 226,000 broadband customers. The retail brands are Slingshot and Orcon. The New Zealand segment accounts for 23 per cent of revenue. The management of large telecommunications infrastructure projects on behalf of governments accounts for the remaining 1 per cent of total revenue.

The foregoing descriptions suggest that for some of these telecommunications businesses, the provision of infrastructure services, while important, does not account for the majority of their revenue. This includes Macquarie Telecom, Spark New Zealand, Telstra and Vocus. Only Chorus is primarily a provider of telecommunications infrastructure, and it is also subject to access regulation with price control. This finding suggests that Chorus may be a reasonable comparator for energy network businesses, but the other ASX-listed telecommunications businesses do not appear to be as useful as comparators.

6.3.3 Statistical comparisons

This section examines data relating to fundamentals of business risk for several of the businesses previously discussed including:

- three currently-listed energy network businesses, APA, AusNet services, and Spark Infrastructure;
- toll road infrastructure operator, Transurban;
- regulated New Zealand telecommunications infrastructure business, Chorus.
- regulated rail track owner and above-rail haulage operator Aurizon; and
- two airport operators, Auckland International Airport and Sydney Airport.

The statistical measures are those suggested by Damodaran as outlined in section 3.3.1, namely:

- *Sensitivity of revenues to market conditions*, as indicated by the correlation coefficient between rates of change in revenue and rates of change in the ASX-200 accumulation index;
- *Degree of operating leverage*, which is indicated by the correlation coefficient between rates of change in EBIT and rates of change in revenue; and
- *Degree of financial leverage*, which is indicated by the average ratio of debt to business value (i.e. the sum of debt plus equity).

These indicators have been calculated using 10 years of data for each of the comparator businesses, with the exceptions of: Spark Infrastructure (9 years); Chorus (9 years); and Sydney Airport (7 years). The indicators are shown in Table 6.5.

Table 6.5: Fundamental analysis of comparators

	Sensitivity of revenues to market conditions	*Degree of operating leverage*	*Degree of financial leverage*
APA Group	-0.20	0.67	0.68
AusNet Services	-0.27	0.59	0.66
Spark Infrastructure	0.07	0.95	0.77
Transurban	0.24	-0.05	0.63
Chorus	0.47	0.95	0.69
Aurizon	-0.11	0.34	0.32
Sydney Airport	0.30	0.80	0.76
Auckland Airport	0.38	0.68	0.31

Data source: Annual reports; S&P/ASX 200 Accumulation (XJOA).

It is noted that the energy network businesses have the lowest sensitivity of revenues to market conditions consistent with relatively low risk for their revenues and this is also the case for Aurizon. Transurban and the Airports have higher sensitivity to market conditions but the sensitivity is still relatively low. It can be expected that firms with higher operating leverage (higher fixed costs to total costs) have greater sensitivity to market conditions although it could also be expected that regulation would dampen the impact of operating leverage on systematic risk because it would reduce both revenue and earnings volatility. All of the non-energy businesses in Table 7.5, except Chorus, have relatively low or similar operating leverage compared with the average for energy network businesses and the operating leverage for Chorus is similar to Spark Infrastructure. With the exception of Aurizon and Auckland Airport the financial leverage of the other businesses are similar and consistent with relatively low financial risk.

6.3.4 Concluding comments

There are currently three energy three listed energy network businesses in Australia, as listed in Table 6.1. Although a significant proportion of the assets of APA Group are not subject to formal regulation, incomes are mostly under long-term contract, and many assets are subject to light regulation which carries with it the threat of more prescriptive regulation. Thus it is reasonable to expect that the business risk of APA is not greatly dissimilar to that of the regulated energy network assets of Spark Infrastructure and AusNet.

Among the six delisted businesses currently included in AER's comparator group, four have been identified as having diminished in their relevance, due to the distance of time since their delisting. These four businesses could be usefully removed from the comparator group, retaining only DUET and Envestra, which were delisted comparatively recently.

Among other Australian and New Zealand infrastructure businesses some additional candidates for the comparator group have been identified, all of which are listed on the ASX. The most relevant of those identified are:

- two toll road infrastructure funds, Transurban and Atlas Arteria. Whilst not regulated, these businesses are constrained by long-term concession agreements; and
- a regulated New Zealand telecommunications infrastructure business, Chorus.

This completes a list of eight comparator businesses, which is broadly similar in number to the current comparator group.

If a wider comparator group is needed, then other Australian and New Zealand businesses that are possible candidate comparators (although by no means as close as the aforementioned) are: the regulated rail track owner and above-rail haulage operator Aurizon; and two airport operators, Auckland International Airport and Sydney Airport. These other comparators may have or are likely to have dissimilar business risks to energy networks. We are less confident that they could usefully be used as comparators. The slightly narrower group of eight reasonable comparators would seem to be adequate.

6.4 USA Energy Utilities

This section considers overseas comparators, listed on overseas exchanges. Some stakeholders and consultants have argued that US energy utilities should be used as comparators for determining the cost of equity of Australian energy networks. There are a large number of listed energy utilities in the USA, many more than are listed in Australia. However, there are limitations to using these businesses as comparators. If overseas firms are used as comparators, it is important to understand differences in regulatory arrangements and allow for their impact. Although there are inevitably likely to be difficulties in ensuring comparability of overseas firms, their inclusion may still help to inform a view of a preferred estimate, or to better inform specific questions such the impact of different regulatory arrangements on business risk.

This section firstly considers what can be learned from US energy utility betas about differences in betas between gas and electricity utilities and the effects of regulation on betas. It then discusses the relative advantages and disadvantages of including overseas firms in the comparator set.

6.4.1 What do US energy utility betas tell us?

This section provides some descriptive information on US energy utility betas. Initially, the data is drawn from a sample of 56 US utilities compiled by Competition Economics Group (CEG, 2013), and used by Frontier (2016, pp.27–29). The data used here is listed in Appendix C, Table C.1.

6.4.1.1 Description of the sample

The number of utilities by form of regulation, and by electric and gas, is shown in Table 6.6. There are many more electricity utilities compared to gas utilities. Vertical integration of electricity businesses into generating and retailing is commonplace. Gas utilities are generally also involved in retailing, but less commonly integrated into gas production. Several utilities are horizontally diversified into telecommunications or other services (Competition Economists Group (CEG) 2013, pp.47–68).

Table 6.6: No. Utilities by Electricity, Gas and Form of Regulation

Form of regulation	*Electric utility*	*Gas utility*	*Total*
Incentive	19	4	23
Non-incentive	10	1	11
Both	15	4	19
NA	3	.	3
Total	47	9	56

Data source: CEG (2013); Frontier (2016).

Table 6.7 shows the proportion of revenue regulated for the same classification of utilities by regulation type and by energy type. There does not appear to be any notable differences in the average proportions of regulated revenue by regulation type. Similarly, there is no significant difference between the average proportions of the revenues of electricity and gas utilities that are regulated. The average utility for the sample as a whole has 83 per cent of its revenue regulated.

Table 6.7: Average proportion of revenue regulated

Form of regulation	*Electric utility*	*Gas utility*	*Total*
Incentive	86%	79%	84%
Non-incentive	86%	97%	87%
Both	80%	88%	81%
NA	71%	.	71%
Total	83%	85%	83%

Data source: CEG (2013); Frontier (2016).

Table 6.8 shows the average debt-to-enterprise value of firms in each of the same categories. It shows that the average debt-to-enterprise value percentage for the sample as a whole is 45 per cent. The average is slightly lower for gas utilities than for electric utilities. The overall average of 45 per cent is much lower than the corresponding statistic for Australian energy networks. The vertical integration of the US industry, compared to the vertical separation of Australian energy networks, may be one explanation for this difference. Differences in tax structures or in the debt and equity market conditions between the US and Australia may contribute to this difference in average gearing.

In its 2016 study, Frontier re-levers US betas to the 60 per cent level used for Australian energy networks by the AER (Frontier Economics 2016, p.27). This is an invalid procedure because the 60 per cent standard gearing used by Frontier is not representative of the US utilities. The purpose of re-levering is to put comparator firms on a common basis, however the betas of firms in another market are expressed relative to the market risks of that other market, and similarly, de-levering needs to have regard to optimal gearing *in that other market*. If the average gearing of energy utilities listed on the New York Stock Exchange is 45 per cent, then it is not plausible to maintain that the optimal gearing in that market is far from that percentage. Frontier's procedure incorrectly substantially increases the level of the average beta. For example, the average beta estimate for all 56 utilities based on weekly data is 0.64, but by re-levering using 60 per cent, this was raised to 0.88 (Frontier Economics 2016, p.29).

In our view, Frontier's method is not correct. The average debt-to-enterprise value percentage for the US utilities of 45 per cent arguably provides a better basis for re-levering those betas. The re-levered equity beta estimates presented below are based on a standardised 45 per cent debt-to-enterprise value ratio.

Table 6.8: Average debt-to-enterprise value (percent)

Form of regulation	*Electric utility*	*Gas utility*	*Total*
Incentive	44	37	43
Non-incentive	49	35	48
Both	48	43	47
NA	36	.	36
Total	46	39	45

Data source: CEG (2013); Frontier (2016).

6.4.1.2 Average equity betas

The average of the equity beta estimates, based on *monthly* data, are shown in the first panel of Table 6.9. In the monthly data:

- there are no significant differences to be observed in equity betas between the different forms of regulation;
- the average equity beta of gas utilities is significantly lower than for electric utilities.

The average equity beta estimates based on *weekly* data are shown in the second panel of Table 6.9. In the weekly data:

- there are again no significant differences to be observed in equity betas between the different forms of regulation;

- however, there is no significant difference between the average equity beta of gas utilities and that for electric utilities.

We also note that the average beta for monthly data is lower than for the weekly data for both gas and electric utilities.

Table 6.9: Beta by Electricity, Gas and Form of Regulation*

Form of regulation	*Electric utility*	*Gas utility*	*Total*
A. Monthly data			
Incentive	0.60	0.38	0.56
	(0.04)	(0.05)	(0.04)
Non-incentive	0.58	0.54	0.58
	(0.05)	.	(0.04)
Both	0.56	0.53	0.55
	(0.05)	(0.08)	(0.04)
NA	0.56	.	0.56
	(0.08)	.	(0.08)
Total sample	0.58	0.46	0.56
	(0.03)	(0.05)	(0.02)
B. Weekly data			
Incentive	0.66	0.57	0.64
	(0.03)	(0.02)	(0.02)
Non-incentive	0.64	0.7	0.65
	(0.04)	.	(0.04)
Both	0.63	0.63	0.63
	(0.04)	(0.04)	(0.03)
NA	0.61	.	0.61
	(0.02)	.	(0.02)
Total sample	0.64	0.61	0.64
	(0.02)	(0.02)	(0.02)

* Standard error of mean in parentheses.

Data source: CEG (2013); Frontier (2016).

6.4.1.3 Average re-levered equity betas

The averages of the re-levered equity beta estimates, based on monthly data, are shown in the first panel of Table 6.10. The overall average re-levered (monthly) beta is 0.56. The average equity beta estimates based on weekly data are shown in the second panel of Table 6.10. The sample average re-levered (weekly) beta is 0.64. In both the monthly and weekly data:

- there are no significant differences to be observed in equity betas between the different forms of regulation;
- there is no significant difference between the average equity beta of gas utilities and that for electric utilities.

We also note that the average beta for monthly data is lower than for the weekly data for both gas and electric utilities.

Table 6.10: Re-levered Beta by Electricity, Gas and Form of Regulation*

Form of regulation	*Electric utility*	*Gas utility*	*Total*
A. Monthly data			
Incentive	0.61	0.44	0.58
	(0.05)	(0.07)	(0.04)
Non-incentive	0.53	0.64	0.54
	(0.05)	.	(0.04)
Both	0.53	0.54	0.53
	(0.05)	(0.07)	(0.04)
NA	0.64	.	0.64
	(0.06)	.	(0.06)
Total sample	0.57	0.51	0.56
	(0.03)	(0.05)	(0.03)
B. Weekly data			
Incentive	0.67	0.66	0.67
	(0.03)	(0.04)	(0.03)
Non-incentive	0.59	0.83	0.61
	(0.04)	.	(0.04)
Both	0.60	0.65	0.61
	(0.03)	(0.04)	(0.03)
NA	0.71	.	0.71
	(0.04)	.	(0.04)
Total sample	0.63	0.67	0.64
	(0.02)	(0.03)	(0.02)

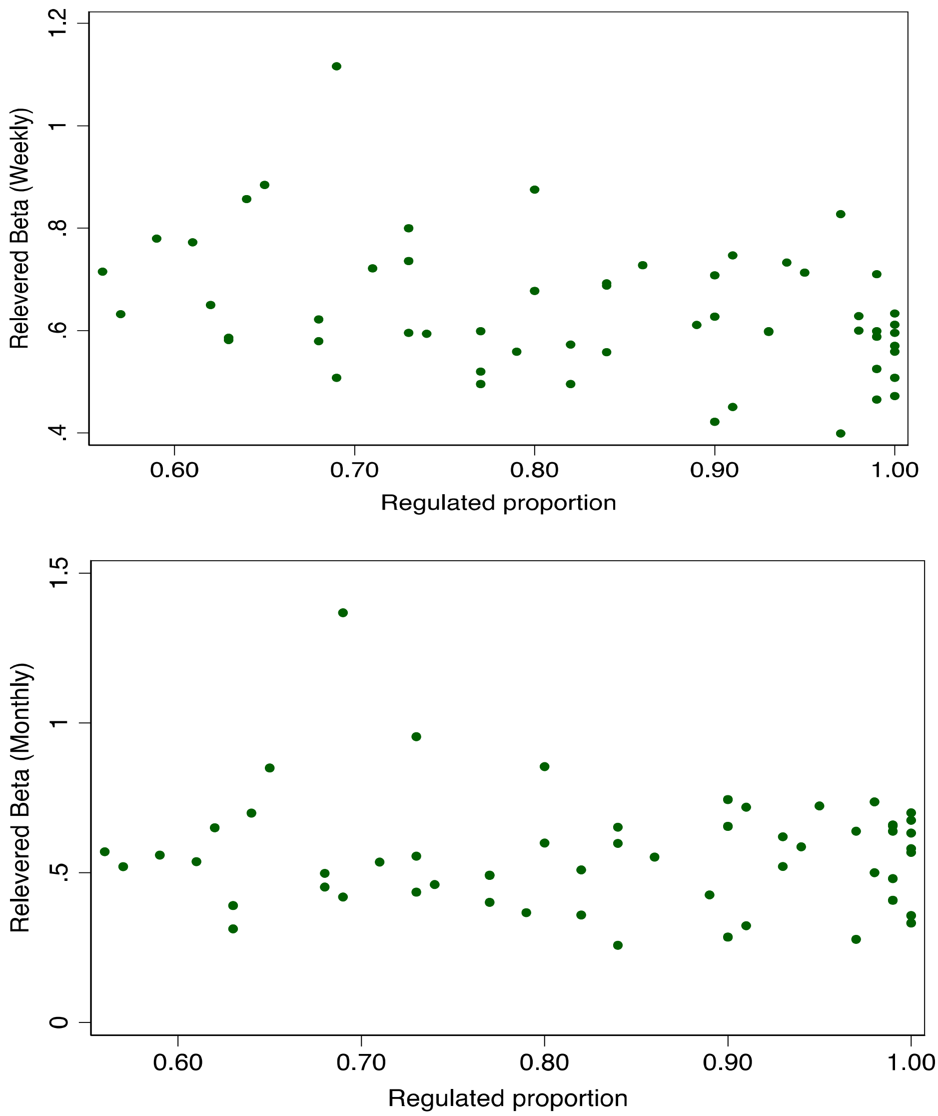
* Standard error of mean in parentheses.

Data source: CEG (2013); Frontier (2016).

In regard to the relationship between a firm's beta and the proportion of revenue which is regulated, the monthly and weekly re-levered beta estimates show different pictures. The first panel of Figure 6.1 shows estimates based on monthly data. It shows there is no relationship at all between the re-levered beta and the proportion of revenue which is regulated. The second panel of Figure 6.1 based on weekly data, shows a significant relationship between the re-levered beta and the proportion of revenue which is regulated. In this case, for a business with 95 per cent of its revenue regulated, the average re-levered beta is 0.6; whereas for a business that is 60 per cent regulated, the average beta is 0.7. The only way of reconciling these different messages from the monthly and weekly betas would be to conclude that:

- Higher proportions of revenue regulated may reduce the equity beta;
- The sensitivity of the equity beta to the degree of regulation is not substantial.

Figure 6.1: Re-levered Beta by Proportion of Revenue Regulated



6.5 Use of Accounting Information

The RFQ also requests consideration of estimating beta for unlisted firms with financial accounts information. This may be possible, but likely to be a difficult exercise and quite experimental in nature. Further, these estimates would not be directly comparable to the estimates obtained from market data for listed firms, raising conceptual issues of how such different estimates might be combined. Some additional discussion of accounting betas is in section 3.3.3.

6.6 Weighting Comparators and Adjusting Betas

This section considers alternative ways of combining or adjusting betas to produce comparators that can be used for forecasting the equity beta of a benchmark efficient entity.

6.6.1 Alternative Weighting Schemes

This section discusses the relative advantages and disadvantages of different methods of assigning weights to comparable firms used to estimate the equity beta. The alternative weighting schemes include equal weights, market capitalisation weights, according to the precision of beta estimates, and weighting according to relevance of comparators.

6.6.1.1 Market Value Weights and Simple Averages

It is a convenient property of OLS that, if a market model is estimated for a portfolio of securities, with the dependent variable: $R_p = \sum_k w_k R_k$, where R_p is the return on the portfolio, R_k is the return on security k, and w_k is the weight for security k; then the estimated beta for the portfolio is equal to the weighted average of the estimated betas from the individual market models is: $\hat{\beta}_p = \sum_k w_k \hat{\beta}_k$. The weights must, or course, sum to unity. If a simple average is used, the weights are 1/N (where N is the number of securities).

For an investor, it will be most meaningful to calculate portfolio returns that use market value weights for averaging the returns on the constituent securities, since the result will actually be equal to the return to the investor on the portfolio. However, the purposes of the regulator in averaging betas is quite different. The weights should represent the relevant importance of each of the comparators as a comparator. If there is no information to bring to bear on an assessment of the relative importance of comparators, then a simple average, which gives them equal weight, would be the most useful approach.

The problem with using market capitalisation weights in this context, is that it is unrelated to the importance of the business as a comparator. For example, as indicated in Table 7.1, the market capitalisation of APA Group is greater than that if AusNet and Spark Infrastructure combined. However, APA is no more important as a comparator than the other two businesses. Thus, market capitalisation weights are not useful for the purpose of estimating a representative beta for a regulated business derived from the betas of the comparators. A simple average is a useful measure and may well be the best method of averaging, especially if the available information on the relevance of comparators is not sufficiently reliable and defensible.

6.6.1.2 Weights Based on Sample Size

With unbalanced estimation periods for firms in a comparator group, the procedure of calculating the arithmetic average of the betas will nevertheless treat all firms as having equal weight. Portfolio-based estimation methods will require a balanced panel. We have also discussed a pooling method of estimation. Using that method with an unbalanced panel would result in greater weight being given to firms form which there are more observations. One way of counteracting that effect would be to apply a frequency weight to each firm, with the weight applying to firm j being proportionate to: $\bar{N}/N_j$, where $\bar{N}$ is the average number of observations per firm in the sample, and N_j is the number of observations for firm j. This would result in the firms having equal weight on the average beta.

6.6.1.3 Weights Based on Precision of Estimates

Some of the most common methods of combining the results of econometric models, such as an estimated parameter (or a prediction) from different models, use measures of the precision of each of the estimated parameters (or predictions) being combined. Examples can be drawn from meta-analysis and Bayesian model averaging.

Meta-analysis refers to the quantitative analysis of the results of empirical studies. It is often used as a means of review and synthesis of previous studies. There are various methods for combining summary statistics from multiple studies, but each method is based on the same principle that the estimate from each study is weighted by the precision of that estimate. In two widely used alternative approaches, the measures of precision are respectively: weighting by sample size; and weighting by the estimated inverse variance of each effect size.

Since the weights must sum to unity, if sample size is used for weighting, then the weight assigned to model j is the number of observations used to estimate beta for security j divided by the summation of the number of observations used in the beta regressions for all securities in the comparator group. If the inverse variance for beta $(1/\hat{\sigma}_{\beta j}^2)$ is used, then the jth weight is created by dividing this by: $\sum_{k=1}^{N}\left(1/\hat{\sigma}_{\beta k}^2\right)$.

A similar principle is used in the literature on Bayesian model averaging, in which modelling results are averaged using weights that are estimates of the degree of confidence in each model as representing the 'true' model; i.e., the best representation of the data generation process. In this literature a common weighting scheme is based on the Bayesian Information Criterion (BIC) of the model. A common measure of precision is: $\exp\left(-0.5.\,\mathrm{BIC}_j\right)$, and again this needs to be divided by the sum of such measures for all beta models in the comparator group to obtain the weight.

6.6.1.4 Functional Weights Based on Comparable Business Activities

Weights may be functionally based. Examples include:

- Weights may be based on an assessment of the proximity of the comparator's business functions to the functions of the benchmark efficient entity.
- If the benchmark entity has several distinct functions, and different comparators are used for each of the functions, then the weights may be chosen to represent the costs accounted-for by these separate functions in the benchmark entity.

An example of the latter is the benchmarking method used by the Netherlands Authority for Consumers and Markets (ACM) (see: Economic Insights 2020). To estimate productivity trends relevant to electricity and gas transmission system operator (TSO) businesses, ACM used eight comparator industries to represent the main activities of energy transmission businesses. The industries were selected by ACM's consultant by first identifying the main TSO activities, and then selecting comparator industries for each of those functions. This was not a one-to-one matching. For some activities more than one industry was relevant, and some industries were relevant to several TSO functions. Weights were used for calculating an average across the comparator sectors. ACM commissioned a study of the functional activities and cost structures of energy TSOs, which was used to estimate appropriate weights to be applied to each of the comparator industries for the purpose of averaging.

In the context of AER's calculation of the average beta for comparator businesses, the task would involve examining the activities and analysing the business risks of the comparator businesses using the bottom-up method discussed in section 3.3.2. This could be used to produce a proximity measure for each business.

6.6.2 Adjusting Betas for Relevant Attributes

This section considers whether it would be feasible to adjust betas for attributes of comparator businesses such as: the proportion of the firm that is regulated; differences in the regulatory framework; or differences in the systematic risk of an overseas equity market relative to that of the Australian equity market.

If the sample is widened to include energy network businesses not listed in Australia, such as US utilities, then it would be necessary to make adjustments in an attempt to make the comparators from distant markets more comparable. This section addresses options to make such adjustments, having regard primarily to two issues: The first is adjusting for differences in risk and in the composition of the market portfolios which make betas difficult to compare across countries. The second issue, is options for adjusting for differences in business risk due to jurisdictional differences in the structures of energy utilities (whether vertically integrated or vertically separated) and the form of regulation that applies.

The level of business risk for otherwise similar firms can be vastly different depending on the location of their operations. The opportunity cost of capital depends on the location of the business operations rather than the location of the capital sources. Countries have different specific risk associated with differences in macroeconomic conditions and volatilities, political environments, regulations, commercial law rights of parties, financial accounting and reporting requirements, and in the case of energy utilities, economic regulation. Adjusting for country-specific risk factors is difficult.

Many of the methodologies used to make adjustments to international comparators involve various subjective judgements with little empirical basis. A more well-established quantitative method is to use the International CAPM. This method involves regressing security rates of return against rates of return on a world portfolio of securities. The accumulation index for the world portfolio needs to be adjusted by the relevant exchange rate before calculating rates of return. An international risk-free rate will also need to be chosen, since the method assumes an integrated world financial market. This method can be used to derived estimates of betas against a common market index.

There are several practical difficulties with estimating the International CAPM, including having sufficient data to estimate statistically significant betas. If this method can be practically carried out for the Australian-New Zealand comparators on the one hand, and a similar number of US energy utilities on the other hand, so that average local and average global betas are obtained, then it may be possible to calculate a factor of proportionality to apply to US energy utility betas more broadly. We are not aware of this having been done, and therefore its feasibility is not known.

Another line of inquiry relates to the average differences between betas of vertically-separated energy network businesses and those of vertically integrated utilities. Some possible approaches are as follows.

- Examining specific cases where listed businesses have become separated into network businesses and 'gentailers', and comparing the betas of the separated businesses after the demerger with the beta of the combined business before the merger. Such demergers have occurred with some listed energy utilities firms in Australia and New Zealand.
- Comparing the betas of businesses that are non-network energy businesses (such as AGL) against those that are 'pure play' energy networks. With suitable weights these could be combined using a 'bottom-up' beta estimation process to derive a beta for an integrated energy utility. There are examples of such businesses in Australia. There may possibly be examples in the USA.

Making adjustments for the form of regulation will always be difficult. For one reason, there can be various differences between regulatory frameworks, and it is difficult to know which features are the most salient for business risk. Empirical examination of this issue would require either a great deal of data, or several convenient natural experiments of changes in a regulatory framework that could be used as the basis for an event study. There are inevitably difficulties in established reliable results that would not be overturned in the next analysis.

6.7 Conclusions

As explained in section 6.2, the AER aims to estimate the beta of a benchmark efficient entity defined as 'a pure play, regulated energy network business operating within Australia'. A 'pure play' business is one that only provides the relevant regulated energy services, and is not engaged in other activities.

As specified in the terms of reference potential comparator options for the AER going forward include, but are not limited to:

- No substantive change to the comparator set (or potentially relatively minor changes to constituents that will still primarily be based on Australian regulated energy networks).
- Including other listed Australian infrastructure firms we consider likely to face a similar level of systematic risk as an Australian regulated energy network business (with appropriate adjustments to equity beta estimates if required).
- Including overseas regulated energy networks (with appropriate adjustments to equity beta estimates if required).
- Including unlisted Australian regulated energy networks with betas to be estimated from financial information/accounts (if possible).

Table 6.11 contains a summary of the advantages and disadvantages of using different comparator sets as specified in the terms of reference, with the inclusion of an additional option that removes four firms from the comparator set, and an adjustment for the second option (described above) to allow for inclusion of an entity operating in New Zealand but listed on both the Australian and New Zealand stock exchanges. The criteria of reliability, relevance to the Australian benchmark, suitability for use in a regulated environment and simplicity are considered in the assessment.

In determining an appropriate comparator set it is important to recognise that in the economic regulation context there is a need to obtain a beta estimate that is the best predictor of the beta over the regulatory period. The concept of the mean square error (MSE) of a predictor is relevant for assessing the predictive potential of an estimate. The MSE takes account of both the variance and potential bias of a predictor.

The MSE can be written as the sum of the variance of the estimator and the squared bias of the estimator. The MSE is relevant because a larger sample size may reduce the variance of an estimator but entail more bias depending on the relevance of the sample. Given the information we have reviewed we are only able to assess the impacts in relation to MSE based largely on qualitative information.

Table 6.11: Advantages and disadvantages of using different comparator sets

Comparator set	***Advantages***	***Disadvantages***
(1) No substantive changes to existing set	Ensures high comparability of the comparators will mean low statistical sampling error (but will not necessarily ensure the least biased estimate). Meets the 'pure play' definition of a regulated network energy business operating in Australia. Relevant, suitable for use in a regulated environment and simple to implement.	Six of the nine firms in the existing comparator set have been delisted. Of these, four have been identified as having diminished in their relevance, due to the distance of time since their delisting. Removal of these four businesses, and retaining only DUET and Envestra, which were delisted comparatively recently would likely mean a better benchmark forecasting beta reflecting both sampling error and bias i.e. a lower mean squared error (MSE) than for the comparator set.
(2) Remove four firms in the comparator set due to the distance of time since their delisting and potential for bias.	Ensures high comparability of the comparators and should be sufficient to ensure relatively low sampling error while also minimising the scope for bias in the beta estimate i.e. to achieve a relatively low MSE. Meets the 'pure play' definition of a regulated network energy business operating in Australia. Relevant, suitable for use in a regulated environment and simple to implement.	May mean a higher variance in the estimate of beta (but as noted potentially a lower MSE reflecting lower bias).
(3) Option (2) plus include two toll companies, listed in Australia and	If four firms are removed from the comparator set because of the time since delisting this would leave only five firms from the existing comparator set. A	The addition of the two toll companies listed in Australia and Chorus, the telecommunications

Comparator set	***Advantages***	***Disadvantages***
Chorus the telecommunications infrastructure provider, operating in New Zealand but listed in both Australia and New Zealand.	larger comparator set of approximately 10 would be better, assuming sufficient comparability. There is scope to add two listed toll companies and one listed telecommunications infrastructure provider to the comparator set which may contribute to a better benchmark forecasting beta (lower MSE) than for option (1). No adjustments would need to be made to the betas given similar risk characteristics. Relevant, suitable for use in a regulated environment and simple to implement.	infrastructure provider in New Zealand would not be consistent with a strict interpretation of the 'pure play' benchmark.
(4) Including overseas regulated energy networks with adjustments if required	Offers considerable scope to increase the sample size which could contribute to the lowest statistical sampling error (but the estimates could be biased).	The main scope for increasing the sample size would involve using US observations but these are measured against different market indexes, face different business circumstances, different regulatory arrangements, and tend to relate to vertically integrated energy businesses, only parts of which are regulated. There is considered to be too much risk of bias in the estimates. There are also no simple adjustments that can be made to ensure comparability.
(5) Including unlisted firms with betas estimated using accounting data	Could provide relevant additional information.	Difficult to implement, limited observations and the estimates would not be directly comparable to the estimates obtained from market data for listed firms.

7 DISCUSSION OF BROADER COST OF CAPITAL ISSUES

This chapter provides a discussion of broader cost of capital issues including how the literature has addressed the scope for beta to depend on various factors that may change over time. Some of the findings have been drawn on in chapter 4, and the material is included for completeness in supporting various contentions in the paper.

7.1 Conditional CAPM and Beta Stability

The SLCAPM is a single period model where the time frame is not defined. When the SLCAPM is estimated it is assumed that it holds period by period and this requires returns to be independently and identically distributed over time. However, this assumption is unlikely to hold which implies that beta is likely to be time dependent. A vast literature has developed addressing the estimation of beta.

Various studies have investigated whether the parameters of the SLCAPM, including the equity beta, are time dependent and related to factors that vary across time periods. The studies that we are aware of tend to cover a wider sample of firms than regulated network energy businesses. However, the findings of such studies may provide some relevant insights particularly in relation to major economy-wide developments.

As an extension of the SLCAPM, a conditional CAPM has been developed that allows for time dependent effects that depend on publicly available conditioning information at a point in time. Galagedra (2004) and Ferson (2005) provide useful summaries of theoretical and empirical studies of the conditional CAPM and beta stability. Patterson (1995) also provides a brief review of the time series properties of beta. Wright, Mason and Miles (2003, p.63) consider that the general finding is that conditional models that allow for time-varying coefficients can perform substantially better than unconditional models. However, they note that they are prone to overfitting (as time dependent conditioning variables are included) and they considered there was no consensus or test about how to assess the choice of conditioning factors including a compelling economic story.

As explained by Ferson (2005, p.380) the earliest empirical tests were ‘latent variable models’. Latent variable models assume that expected returns vary over time as functions of a small number of risk premiums that are common across assets. These models allow for time varying expected returns but maintain the assumption that the conditional betas for each risk source are fixed parameters over time. For example, the study by Ferson and Harvey (1996) of international equity returns used a model in which conditional betas of the national equity markets depend on local information variables while global risk premia depend on global variables. The risk variables could be variables that signify different risks other than for the market portfolio, for example returns from corporate bonds could be an additional variable or the market portfolio could be disaggregated into several portfolios.

Ferson (2005, p.380) claims that the empirical evidence suggests that the conditional asset pricing models should be consistent with either (1) a time varying beta or (2) more than one beta for each asset. Ferson reports mixed results from two studies of time varying betas and three studies of conditional multiple beta models. However, for the multiple beta models Ferson (p. 381) reports) that the studies of Ferson and Harvey (1991 for US data), Evans (1994) and

Ferson and Korajczyk (1995) find that while such models are rejected using the usual statistical tests, they still capture a large fraction of the predictability of stock and bond returns over time. And that allowing for time varying betas, these studies find that the time variation in betas contributes a relatively small amount to the time variation in expected asset returns, while time variation in the risk premium are relatively more important.

Turning to some of the earlier literature, Galagedera provides a review of various CAPM models and tests for those models. He reports mixed findings for the predictability of the SLCAPM and notes a number of studies investigating beta instability over time (Galagedera 2004, p.7, Bos & Newbold 1984, Faff et al. 1992, Brooks et al. 1994, Faff & Brooks 1998). The earliest study of separate betas for bull and bear markets by Fabozzi and Francis (1977) found no evidence supporting beta instability over bull and bear markets.

However, Patterson (1995, p.137) noted that there was some subsequent evidence that values of beta are conditional on the level of realised market returns and that these tendencies are particularly evident in periods of historically high stock price volatility. For example, he reports that Wiggins (1992) concluded that small, loser and high historical beta stocks tend to have systematic risk in up markets that in down markets while large and low historical beta stocks exhibit the opposite behaviour. He also cites Bhadwaj and Brooks (1993) who reported similar findings.

Galagedera (2004, p.11) reports that Pettengill, Sundaram and Mathur (1995) highlighted that the weak and intertemporally inconsistent results of studies testing for a systematic relation between return and beta is due to the conditional nature of the relation between the beta and the realised return. They postulated a positive (negative) relation between the beta and returns during an up (down) market. According to Galagedera (2004, p.11) their study of US stocks for 1926-1990 found a systematic conditional relationship between the beta for the total sample period as well as across sub-sample periods. Patterson (1995, p.137) also reports that Kryzanowski and To (1984) argued that much of the instability of betas is not real instability at all because observed betas are based on historical returns whereas the true beta is a function of expected returns.

Another approach to addressing the potential instability of betas is APT developed by Ross (1976) where returns are related to various unspecified independent factors and it is assumed there are no riskless arbitrage opportunities. Patterson (1995, pp.147–153), referring to APT, argued that the APT approach is difficult to assess empirically because it is mute with respect to the identity of the number of factors and that it is much more complex than the CAPM to implement and it is not obvious that it results in improved estimates of the required return on equity. However, he recognises that the model is useful for highlighting that returns to individual assets are likely to be related to more than just the market return. In this respect, as noted by Patterson (1995, p.149), Chen, Roll and Ross (1986) examined the following systematic risk variables: monthly growth in industrial production; changes in expected inflation; unanticipated inflation; unanticipated changes in risk premiums as measured by the difference between realised returns on corporate Baa bonds and on long term government bonds; and unexpected changes in the term premium as measured by the difference in the realised returns on long and short government bonds.

Wright, Mason and Miles (2003, pp.59–62) discuss consumption based models of the CAPM that highlight intertemporal factors that influence asset pricing. The consumption based CAPM focusses on an individual's choice of intertemporal consumption and investment in risky assets yielding a 'stochastic discount factor' model for empirical testing. However, this has led to complex statistical approaches and concerns about overfitting. For example they discuss non-linear APT models and raise a concern that they are subject to overfitting where an overfitted model fits both underlying deterministic components and random errors reducing its reliability for forecasting. They contend that a carefully specified conditional CAPM will perform better than a non-linear model (Wright et al. 2003, p.76), although as noted it too will be prone to overfitting.

7.2 CAPM and Higher-order Moments

Another consideration in assessing beta stability is whether higher order moments of the distribution of returns might be relevant and also have an impact over time. The CAPM assumes that the distribution of returns is normal or that investors are only concerned with the mean expected return (first moment) and variance of returns (second moment). The third standardized moment is skewness and the fourth standardise moment is kurtosis). Skewness refers to skewness in the distribution of data to one side or the other. Kurtosis refers to the extent to which tails are thinner or thicker than a normal distribution.

Patterson (1995, pp.39–40) discusses the relevance of skewness noting that there is evidence particularly over long periods of time that the distribution of return possibilities is positively skewed (consistent with truncation on the downside of -100% and unlimited on the upside). He reports a model by Kraus and Litzenberger (1976) which assumes that investors have preference for positive skewness. Their model was motivated by the prior empirical findings that were interpreted as inconsistent with the SLCAPM reflected in a lower slope and higher intercept in the CAPM equation than predicted by the traditional theory. The measure of skewness is systematic skewness reflecting both skewness and co-movement with the market portfolio. They estimate their model for US data spanning the period 1936 to 1967. They confirm the statistical significance of their measure of skewness and improved predictability when their measure of skewness is included and that the beta coefficient almost doubles when skewness is recognised. Patterson notes that returns for utilities may be negatively skewed because of regulatory caps on upside potential and considers that systematic skewness and beta tend to be positively correlated which may result in a lower beta than for the standard model.

Galagedera (2004, pp.8–9) reports mixed results of a number of other empirical studies on the validity of the CAPM in the presence of skewness. However, Harvey and Siddique (2000) examined an extended CAPM with conditional skewness and found it was significant with a conditional skewness risk premium of 3.6 per cent per year (Wright et al. 2003, p.62). Galagedera also notes that a few studies have shown that non-diversified skewness and kurtosis play an important role in determining security valuations. Galagedera *et al.* (2003), using Australian data found strong empirical evidence to suggest that in the presence of skewness in the market returns distribution, the expected excess rate of return is related not only to beta but also to systematic co-skewness. The issue then is whether and to what extent skewness is time dependent and the relevance to regulated network energy businesses in the NEM.

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APPENDIX A: DECOMPOSITION OF ASSET BETA

This appendix was prepared by Professor Tim Coelli, an Associate of Economic Insights Pty Ltd and Adjunct Professor, School of Economics, University of Queensland.

This appendix shows how an asset beta can be decomposed into its underlying revenue and cost beta components and how a revenue beta can be decomposed into revenue betas for different categories of revenue.

The beta for a stock is defined as the ratio of the covariance between that stocks' return and the market return divided by the variance of market returns.

For two random variables *x* and *y*, the definition of covariance is:

$$Cov(x,y)=E[(x-E(x))(y-E(y))]=E(xy)-E(x)E(y) \quad (1)$$

The covariance between a linear combination of two random variables and a third random variable is therefore:

$$\begin{aligned} Cov((ax+by),z) &= E((ax+by)z)-E(ax+by)E(z) \\ &= aE(xz)+bE(yz)-aE(xz)-bE(yz) \\ &= aCov(xz)+bCov(yz)\ , \end{aligned} \quad (2)$$

where *a* and *b* are constants, and *z* is a third random variable.

This results shows that the covariance between a linear combination of two random variables and a third random variable, is equal to the linear combination of the constituent covariances.

Beta decomposition #1- the relationship between an asset beta and revenue and cost betas

Consider now the accounting relationship:

$$PV(\text{revenue})=PV(\text{fixed costs})+PV(\text{variable costs})+PV(\text{asset}).$$

To construct a beta decomposition for this relationship we define five random variables. Namely:

$x_1=$ one dollar of $PV(\text{revenue})$

$x_2=$ one dollar of $PV(\text{fixed costs})$

$x_3=$ one dollar of $PV(\text{variable costs})$

$x_4=$ one dollar of $PV(\text{asset})$

$x_5=$ one dollar of $PV(\text{market return})$.

Thus we need to use a multivariate version of the above linear combination result.

From page 870 of Greene (2003) we have:

$$Cov(\mathbf{a}'\mathbf{x}, \mathbf{b}'\mathbf{x}) = \mathbf{a}'\boldsymbol{\Sigma}\mathbf{b}, \tag{3}$$

where **x** is a $n\times 1$ vector of random variables, *a* and *b* are $n\times 1$ vectors of constants, and $\boldsymbol{\Sigma}$ is the $n\times n$ covariance matrix of the random vector **x**.

Consider now the linear combination:

$$-PV(\text{revenue})x_1 + PV(\text{fixed costs})x_2 + PV(\text{variable costs})x_3 + PV(\text{asset})x_4,$$

where the PV measures are constants.

For this case we define

$$\mathbf{a} = (-PV(\text{revenue}), PV(\text{fixed costs}), PV(\text{variable costs}), PV(\text{asset}), 0)'$$

and

$$\mathbf{b} = (0,0,0,0,1)'.$$

Thus we obtain

$$Cov(\mathbf{a}'\mathbf{x}, \mathbf{b}'\mathbf{x}) = \mathbf{a}'\boldsymbol{\Sigma}\mathbf{b}$$

$$= -PV(\text{revenue})\sigma_{15} + PV(\text{fixed costs})\sigma_{25} + PV(\text{variable costs})\sigma_{35} + PV(\text{asset})\sigma_{45}$$

where σ_{ij} is the covariance between x_i and x_j. That is, the *ij*-th element of $\boldsymbol{\Sigma}$.

Also note that the diagonal elements of $\boldsymbol{\Sigma}$ are variance measures. That is, σ_{ii} is the variance of x_i.

If we divide this equation through by $PV(\text{revenue})\sigma_{55}$ and rearrange terms we obtain:

$$\beta_1 = \beta_2 \frac{PV(\text{fixed costs})}{PV(\text{revenue})} + \beta_3 \frac{PV(\text{variable costs})}{PV(\text{revenue})} + \beta_4 \frac{PV(\text{asset})}{PV(\text{revenue})},$$

where $\beta_i = \sigma_{i5} / \sigma_{55}$.

Beta decomposition #2- the relationship between a total revenue beta and revenue betas for individual components of total revenue

Consider now the revenue decomposition:

$$PV(\text{revenue}) = PV(\text{regulated revenue}) + PV(\text{other revenue}).$$

To construct a beta decomposition for this relationship we define four random variables. Namely:

$$x_1 = \text{one dollar of } PV(\text{revenue})$$
$$x_2 = \text{one dollar of } PV(\text{regulated revenue})$$
$$x_3 = \text{one dollar of } PV(\text{other revenue})$$
$$x_4 = \text{one dollar of } PV(\text{market return}).$$

We then define the linear combination:

$$-PV(\text{revenue})x_1 + PV(\text{regulated revenue})x_2 + PV(\text{other revenue})x_3,$$

where the PV measures are constants.

Then, using again equation (3), we define

$$\mathbf{a} = (-PV(\text{revenue}), PV(\text{regulated revenue}), PV(\text{other revenue}), 0)'$$

and

$$\mathbf{b} = (0, 0, 0, 1)'.$$

Thus we obtain

$$Cov(\mathbf{a}'\mathbf{x}, \mathbf{b}'\mathbf{x}) = \mathbf{a}'\mathbf{\Sigma}\mathbf{b}$$

$$= -PV(\text{revenue})\sigma_{14} + PV(\text{regulated revenue})\sigma_{24} + PV(\text{other revenue})\sigma_{34}.$$

Dividing this equation through by $PV(\text{revenue})\sigma_{44}$ and rearranging terms we obtain:

$$\beta_1 = \beta_2 \frac{PV(\text{regulated revenue})}{PV(\text{revenue})} + \beta_3 \frac{PV(\text{other revenue})}{PV(\text{revenue})},$$

where $\beta_i = \sigma_{i4} / \sigma_{44}$.

From page 870 of Greene (2003) (Greene, W. H. (2003), *Econometric Analysis*, fifth edition, Prentice Hall, New Jersey) we have:

$Cov(\mathbf{a}'\mathbf{x}, \mathbf{b}'\mathbf{x}) = \mathbf{a}'\mathbf{\Sigma}\mathbf{b}$, (3)

where **x** is a n×1 vector of random variables, a and b are n×1 vectors of constants, and $\mathbf{\Sigma}$ is the n×n covariance matrix of the random vector **x**.

Consider now the linear combination:

$$-PV(\text{revenue})x_1 + PV(\text{fixed costs})x_2 + PV(\text{variable costs})x_3 + PV(\text{asset})x_4,$$

where the PV measures are constants.

For this case we define

$$\mathbf{a} = (-PV(\text{revenue}), PV(\text{fixed costs}), PV(\text{variable costs}), PV(\text{asset}), 0)'$$

and

$$\mathbf{b} = (0, 0, 0, 0, 1)'.$$

Thus we obtain

$$Cov(\mathbf{a}'\mathbf{x}, \mathbf{b}'\mathbf{x}) = \mathbf{a}'\mathbf{\Sigma}\mathbf{b}$$

where σ_{ij} is the covariance between x_i and x_j. That is, the *ij*-th element of $\mathbf{\Sigma}$.

Also note that the diagonal elements of $\mathbf{\Sigma}$ are variance measures. That is, σ_{ii} is the variance of x_i.

If we divide this equation through by $PV(\text{revenue})\sigma_{55}$ and rearrange terms we obtain:

$$\beta_1 = \beta_2 \frac{PV(\text{fixed costs})}{PV(\text{revenue})} + \beta_3 \frac{PV(\text{variable costs})}{PV(\text{revenue})} + \beta_4 \frac{PV(\text{asset})}{PV(\text{revenue})},$$

where $\beta_i = \sigma_{i5} / \sigma_{55}$.

<u>Beta decomposition #2- the relationship between a total revenue beta and revenue betas for individual components of total revenue</u>

Consider now the revenue decomposition:

$$PV(\text{revenue}) = PV(\text{regulated revenue}) + PV(\text{other revenue}).$$

To construct a beta decomposition for this relationship we define four random variables. Namely:

$x_1 = \text{one dollar of } PV(\text{revenue})$
$x_2 = \text{one dollar of } PV(\text{regulated revenue})$
$x_3 = \text{one dollar of } PV(\text{other revenue})$
$x_4 = \text{one dollar of } PV(\text{market return})$.

We then define the linear combination:

$$-PV(\text{revenue})x_1 + PV(\text{regulated revenue})x_2 + PV(\text{other revenue})x_3,$$

where the PV measures are constants.

Then, using again equation (3), we define

$$\mathbf{a} = (-PV(\text{revenue}), PV(\text{regulated revenue}), PV(\text{other revenue}), 0)'$$

and

$$\mathbf{b} = (0,0,0,1)'.$$

Thus we obtain

$$Cov(\mathbf{a}'\mathbf{x}, \mathbf{b}'\mathbf{x}) = \mathbf{a}'\mathbf{\Sigma}\mathbf{b}$$

$$= -PV(\text{revenue})\sigma_{14} + PV(\text{regulated revenue})\sigma_{24} + PV(\text{other revenue})\sigma_{34}.$$

Dividing this equation through by $PV(\text{revenue})\sigma_{44}$ and rearranging terms we obtain:

$$\beta_1 = \beta_2 \frac{PV(\text{regulated revenue})}{PV(\text{revenue})} + \beta_3 \frac{PV(\text{other revenue})}{PV(\text{revenue})},$$

where $\beta_i = \sigma_{i4} / \sigma_{44}$.

APPENDIX B: CURRICULUM VITAE

Dr John Fallon

Position	Director
Business address:	1/45 Parkside Circuit Hamilton, Qld 4007
Mobile:	0419 171 634
Email address	john@economicinsights.com.au

Qualifications

Doctor of Philosophy (Economics), University of Western Ontario, Canada.

Master of Arts (Economics), University of Western Ontario, Canada.

Bachelor of Economics (First Class Honours in Economic Statistics, University Medallist), University of Queensland.

Key Skills and Experience

John is a Senior Economic Advisor and the founder of Economic Insights Pty Ltd. John has training and experience in a wide range of economic fields. His areas of expertise encompass economic regulation, competition policy, industrial economics, international economics, public enterprise reform, public finance, economic development, macro-economics, quantitative analysis and economic modelling.

John has been an adviser on economic regulation issues in several major price determinations and regulatory hearings in relation to electricity, gas, airports, rail, seaports and water infrastructure, for both private and public clients. He has also been an adviser on competition issues in relation to several high profile mergers in the energy, airline, wholesale and retail sectors. He has provided expert opinion on market definition and competition issues in several other markets and been the team leader for a wide range of public benefit tests of legislative restrictions on competition.

John has also been the team leader for macroeconomic, economic regulation, industry, tax, trade and strategy development surveys for a large number of consulting projects in developing countries.

Prior to becoming an economic consultant John acquired experience as an economist and manager at the Reserve Bank of Australia, Industry Commission, the Organisation for Economic Cooperation and Development (OECD) and the Queensland Treasury.

Key Projects

Access Issues

- Report for Economic Regulaiton Authority of Western Australia on Framework and Approach for Western Power's fifth access arrangement review (2021).
- Report for Glencore on declaration of the Dalrymple Bay Coal Terminal (2019).
- Advice to Svitzer Australia on access pricing at the Port of Darwin (2019).

- Assisted Synergies Economic Consulting in providing reports on access pricing issues for a price arbitration and revocation of declaration of the Port of Newcastle for Glencore (2018).
- Expert witness for foundation customers in a dispute with Aurizon about the pricing of risk for the Wiggins Island Rail Project (2017-18).
- Advisor to the potential users of West Pilbara rail and port infrastructure on access pricing and the cost of capital (2014-15).
- Report for Anglo-American Coal on asset stranding, the cost of capital and the socialisation of costs in relation to user charges for rail infrastructure in Queensland (2010).
- Report for the Minerva Joint Venture in relation to the asset value for the West Blackwater Access Undertaking Proposed by Queensland Rail Network Ltd (2009).
- Report on third party access and price regulation of the Dalrymple Bay coal loading facility in Queensland for Queensland Treasury (2000).
- Expert report on third party access price issues with respect to the Hunter Rail Network for the New South Wales Minerals Council (1998–99).
- Reports on access prices in relation to the Cairns and Mackay Port Authorities and the Brisbane Markets Authority for the Queensland Treasury (1999).
- Report on asset valuation, depreciation and rate of return issues in relation to Queensland Rail for the Queensland Treasury (1999).

Other Economic Regulation

- Independent Price Expert to determine MIRRAT's proposed cargo tariffs for 2021-2022 (2021).
- Supervised research projects and reports at the Queensland Competition Authority on: regulatory objectives and pricing principles, pricing for capacity expansion, pricing disparities for medical equipment, risk and the form of regulation, the split cost of capital, trailing average cost of debt, market parameters for the cost of capital, financial capital maintenance, depreciation, annuities and incentive regulation (2012-2014).
- Report for the New Zealand Competition Commission on regulatory precedents for setting the cost of capital within a range (2014).
- Report on the future of infrastructure in Australia, focussing on regulatory and other policy issues affecting investment including principles and frameworks for effective regulation, competition and vertical integration issues, the effective use of public private partnership arrangements, taxation arrangements and case studies (2005).
- Expert report on cost of capital and dividend imputation issues in relation to compensation for the acquisition of land for coal mining (2003-04).
- Various reports on cost of capital issues for electricity, gas and water utilities (2003).
- Adviser to the Commonwealth Treasury of Australia on industry self regulation (2000).
- Asset valuation, rate of return and pricing guidelines for local councils for the Queensland Department of Local Government and Queensland Treasury (1999–2000).
- Report on the criteria for deciding whether government businesses should be declared as monopolies for the purpose of price monitoring and competitive neutrality issues for the Queensland Competition Authority (1997).

Electricity

- Reports for Tenaga Nasional (Malaysian vertically integrated energy utility) with London Economics International on asset valuation, efficiency incentive schemes and regulatory guidelines (2016-17).
- Assisted London Economics International in the preparation of expert reports on productivity measurement for the regulation of power generation in Ontario (2016-17).
- Reports for the New Zealand Commerce Commission on asset valuation and total factor productivity measurement in the presence of sunk costs and incorporating the principle of financial capital maintenance (2009).
- Expert witness report to the Supreme Court of Queensland on behalf of Origin Energy in relation to a dispute about the benchmark retail cost index in Queensland (2009).
- Advice on principles for roll forward and indexation of the asset base for electricity distribution businesses, in association with Dr Denis Lawrence, for the New Zealand Commerce Commission (2007).
- Report on cost allocation principles and practices for common and fixed costs in the electricity and gas sectors, in association with Dr Denis Lawrence, for the New Zealand Commerce Commission (2006-07).
- Development of a methodology for determining compensation in relation to the provision of ancillary generation services to the network operator in Tasmania (2004).
- Report on the recovery of costs associated with full retail contestability in New South Wales for Energy Australia (2000).
- Report on the form of regulation for electricity, particularly the issue of regulating prices, revenue or the rate of return for the Queensland Competition Authority (2000).
- Adviser to the Northern Territory Power and Water Authority on their submission to the Northern Territory Utilities Commission on the price of access to their network (1999–2000).
- Report on the form of price control for regulation of prices in the electricity distribution and retail sector in New South Wales for Energy Australia for an IPART price review (1999).
- Report on the regulation framework for the electricity industry in Queensland for the Queensland Competition Authority (1999).

Gas

- Chairman of an Independent Panel to review the rate of return guidelines for gas pipelines for the Economic Regulation Authority of Western Australia (2018).
- Reports for the Netherlands Authority for Consumers and Markets on various topics in efficiency benchmarking of gas networks (2017).
- Advice to the New Zealand Commerce Commission on pricing principles and price methodologies for gas distribution businesses (2009).
- Benchmarking the performance of Australian gas distribution utilities relative to US gas distribution businesses for determining regulated prices (2007).
- Advice on various aspects of economic regulation of gas distribution businesses for the New Zealand Commerce Commission (2007).
- Peer review of a report on the rationale for policy intervention in the supply of gas to the WA domestic market for the WA government (2007).

- Advice on regulatory treatment of taxation for gas distribution businesses for the New Zealand Commerce Commission (2007).
- Advice on approaches and issues in relation to asset valuation for gas distribution businesses, in association with Dr Denis Lawrence, for the New Zealand Commerce Commission (2007).
- Reports on rate of return, asset valuation and cost allocation issues for Gascor in relation to major price arbitration (2001).
- Report on asset valuation issues in relation to gas pipelines for the Queensland Competition Authority (2001).
- Adviser and expert witness on pricing principles and various cost of capital issues in the gas, coal mining and electricity industries in relation to the price of gas supplied by the South West Queensland producers for the Pipeline Authority of South Australia and the Electricity Transmission and Supply Authority of South Australia (1996).

Water

- Reports for the Independent Competition and Consumer Commission (Australian Capital Territory) on various issues relation to the regulation of water and sewerage and retail electricity prices including (for water) the tariff structure, cost of capital, incentive schemes and developer charges (2016-17).
- Advisor to the Independent Competition and Regulatory Commission (ACT) on the cost of capital (2014).
- Report on the competition implications and public benefits of the Queensland Water Grid Manager and associated asset aggregations (2007).
- Assessment of the competitive effects of horizontal and vertical integration and pricing options for water infrastructure in South East Queensland (2006).
- The options for water reform in North West Queensland (2005).
- Asset valuation, capital contributions, the cost of capital and pricing issues in relation to water infrastructure for the Burdekin Haughton irrigation scheme for the Queensland Competition Authority (2001–02).
- Report on the appropriate organisational structure for Sydney Water and the Sydney Water Catchment Authority for the New South Wales Cabinet Office (1999).

Telecommunications and Post

- Report for the Australian Competition and Consumer Commission on regulated prices for Telstra's Domestic Transmission Capacity System (2015-16).
- Reports for Spark New Zealand and Vodafone New Zealand for their submissions on review of the Telecommunications Act in New Zealand (2015-16).
- Report for Australia Post on Methodology for costing Community Service Obligations (2016).
- International benchmarking study of the total factor productivity performance of Australia Post and six international postal services
- Development of price index methodology for regulation of telecommunication services for the Peruvian regulator (2006).

- Optimal capacity provisioning in the context of growth and uncertainty for Telstra's submission to the regulation of the PSTN (2004).
- Estimation of average tenure for broadband subscribers as an input into imputation tests for Telstra (2004).
- Assessing the competition implications of Telstra's broadband prices and the bundling of telecommunications products including the use of imputation tests (2004).
- Quantifying differences between broadband penetration rates for Australia and other countries, report prepared for Telstra (2003).
- Privatisation and the regulatory framework for telecommunications services in Papua New Guinea for the World Bank (2000-02).

Transport

- Economic rationale and form of block exemption orders for liner shipping conference agreements for the Singapore Competition Commission (2006).
- Advice to the Board of Airline Representatives of Australia on landing charges at Sydney, Brisbane and Perth airports. Prepared reports on single till and dual till issues, asset valuation and the cost of capital (2000).
- Report on third party access and price regulation of the Dalrymple Bay coal loading facility in Queensland for Queensland Treasury (2000).
- Adviser to the developers of the rail line from Darwin to Alice Springs on the price of access to the infrastructure (1999-2000).
- Report on asset valuation, depreciation and rate of return issues in relation to Queensland Rail for the Queensland Treasury (1999).
- Adviser to Queensland Rail on infrastructure investments (1996).

Mergers and Alliances

- Advisor to Allens in a dispute between the Independent Consumer and Competition Commission of PNG and PNG Mainport Liner Services, Steamships Limited and Consort Express Lines Limited in relation to competition issues for a shipping and stevedoring merger in PNG (2019).
- Assisted Synergies Economic Consulting in preparing a report on competition issues relating to the proposed sale of Aurizon's intermodal business to Pacific National (2018).
- Assisted Professor Flavio Menezes in the preparation of a report on the application of auction theory to the proposed merger of Tabcorp and Tatts (2017).
- Public benefit test of Water Grid Manager and water asset aggregations and associated regulatory arrangements in South East Queensland (2007).
- Assessment of the competitive effects of telecoms mergers and vertical integration issues in Portugal (2006).
- Assessment of the competitive effects of mergers in the wagering and gaming industries for TabCorp (2006).
- The competition implications of vertical and horizontal integration in the electricity industry in Australia for electricity utilities (2004-05).

- Co-ordinator of the team that advised the AGL on trade practice issues in its proposed acquisition of Loy Yang A in the electricity sector (2003).
- Airline alliances, market structure and efficiency, prepared for Qantas in relation to the proposed alliance with Air New Zealand (2003)
- Advice to a private client on the competition implications of an acquisition in the food processing sector (1997).
- The trade practices implications of an acquisition in the bathroom products market for a private client (1996).
- Report on the public benefit effects of the takeover of Queensland Independent Wholesalers by Davids for a private client (1996).
- Adviser to Composite Buyers Pty Ltd in relation to the public benefits of a merger (1995).
- Adviser to Caltex and Ampol in relation to a proposed merger (1995).
- Adviser and expert witness for the Trade Practices Commission in the proposed takeover by QUF Industries Limited of Port Curtis Dairy Association Ltd (1994).
- Adviser and expert witness for the Trade Practices Commission in the proposed takeover by Coles Myer Limited of Foodland Australia Limited (1994).
- Economic adviser and expert witness for Sagasco (a major gas exploration and distribution company) in a takeover bid by Santos (1993).
- Economic adviser and expert witness for Queensland Independent Wholesalers in the proposed takeover by Davids Holdings Pty Ltd (1992).

Other Trade Practice and Competition Issues

- Expert witness for the Commission of Inquiry into the fuel price subsidy in Queensland (2007).
- Report on the effectiveness of an on-line auction system for the allocation of timber in Victoria (2008).
- Advice on market definition and competition issues in relation to the use of a bulk cargo unloading crane system at Geelong Port (2007).
- Advice on market definition and competition issues in relation to the separation of Queensland Rail's electrification assets from the access regime for below rail services (2007).
- Economic report on regulation of stevedoring and the competitive effects of cabotage arrangements in Papua New Guinea for Steamships Pty Ltd (2006).
- Report on the competitive effects and public benefits of licensing restrictions in wagering and gaming for TabCorp (2005).
- A public benefit assessment of restrictions on competition in the provision of compulsory third party insurance (2005).
- Market definition and competition issues in relation to the allocation of timber milling licenses for the Queensland Department of Primary Industries (2003).
- Market definition issues in relation to the gaming market for Queensland Treasury (2003).
- The pricing of financial services for a private client in relation to a matter before the Administrative Appeals Tribunal (2002).

- Expert witness for Queensland Crown Law on collusive price fixing arrangements and associated damages in the concrete industry in South East Queensland (1996–2001).
- Market definition issues in relation to tourism services in North Queensland (2001).
- Market definition and competition issues in relation to the thoroughbred racing and wagering industries for Queensland Crown Law (2001).
- Market definition and competition issues in relation to an agreement between Microsoft and the Queensland Government for Queensland Crown Law (2000).
- Advice to a private client on the waste paper market in Australia (1997–98).
- Advice to the Queensland Treasury on microeconomic reform and national competition policy.
- Report on the price implications of price fixing in concrete markets for a private client (1996).
- Adviser to the Australian Competition and Consumer Commission on predatory pricing (1996).
- Prepared reports to the Queensland Treasury on public benefit criteria to assess whether anti-competitive restrictions are justified, and market definition and trade practices issues in relation to sponsorship arrangements in the insurance industry, the workers compensation scheme, the assignment of timber milling licences and the assignment of rights to on sell water allocations (1996).
- Prepared a report on market definition for an industry submission to the Australian government on the activities of the Prices Surveillance Authority (1994).

Public Enterprise Reform

- Adviser to the World Bank and Asian Development Bank on public enterprise reform issues in a number of developing countries (1992-2009).
- Adviser to Queensland Treasury on public enterprise reform issues, accountability arrangements and performance indicators for public enterprises (1992–98).
- Adviser to the Brisbane City Council on the financial and economic impact of corporatisation of its transport operations (1997).
- Adviser to private clients on competition policy and valuation issues in relation to privatising certain public enterprises in Queensland (1996).
- Adviser to the Queensland Civil Contractors Federation on the competition policy implications of commercialising Queensland Transport's business activities (1996).
- Adviser to the Queensland Commission of Audit on public enterprise pricing strategies (1996).
- While employed by the Queensland Treasury responsible for developing and implementing the Government's policy for corporatisation of government-owned enterprises. Prepared a White Paper on “Corporatisation in Queensland” that provided comprehensive guidelines for corporatisation (1991–92).
- Member of a number of steering committees on corporatisation and industry restructuring — for Electricity, Railways, Ports, Water and Queensland Investment Corporation. Queensland representative on the Commonwealth-State Steering Committee on National Performance Monitoring of Government Enterprises (1991–92).

Cost Benefit Analysis

- Team leader for several public benefit tests of existing legislation. These tests have varied from minor reviews based on key economic principles to comprehensive cost benefit analyses involving economy-wide and regional models. Key studies are outlined below.
- Public benefit test of Water Grid Manager and water asset aggregations and associated regulatory arrangements in South East Queensland (2007).
- Assessment of the economy wide effects of closure of the Tiwai Point aluminium smelter in New Zealand (2006).
- Public benefit test of regulations in relation to heavy vehicle driver fatigue (2006).
- Public benefit test of compulsory third party insurance legislation in Queensland (2005).
- Public benefit test of restrictions on interstate advertising in the racing industry in New South Wales (2004).
- Public benefit test of the home warranty insurance and builder's licensing functions of the Queensland Building Services Authority (2002).
- Public benefit test of the licensing of building certifiers and plumbers in Queensland (2002).
- Public benefit test of proposed regulation of the fitness industry in Queensland (2000).
- The costs and benefits of introducing full retail contestability in electricity in Queensland for Ergon Energy (2000).
- Public benefit test of the Transport Operations Act (covers taxis, buses and air travel in Queensland) (1999).
- Public benefit test of veterinary legislation restrictions on competition in Queensland (1999).
- Adviser to the Queensland Treasury on the public benefit test and dissenting report on the review of the Queensland Chicken Meat Industry (1998).
- Adviser to the Insurance Council of Australia on public benefit reviews of Compulsory Third Party Insurance undertaken in Western Australian and Tasmania (1998).
- Public benefit test of restrictions on competition in the dairy industry in Queensland (1998).
- Adviser to the Insurance Council of Australia on public benefit, privatisation and competition issues in relation to worker's compensation arrangements for Victoria and Queensland and development of a competitive framework (1997–98).
- Adviser to AAMI on public benefit, privatisation and competition issues in relation to compulsory third party insurance arrangements (1997).
- Adviser to a private client on public benefit, competition and economic development issues in the sugar industry (1997).
- Evaluated the costs and benefits of Australian Commonwealth government contributions to economic modelling (1995).
- Contributed to a comprehensive framework for assessing the economic impact of road investments in Queensland for the Queensland Transport Department (1994).
- Supervised a cost benefit analysis of container deposit legislation for the Industries Assistance Commission (1987).

Employment Record

Senior Economic Advisor, Economic Insights Pty Ltd (June 2014 – present)

Casual lecturer, Globalisation and Economic Development, University of Queensland (2015-2016)

Casual Lecturer, Infrastructure Regulation and Economic Policy, Crawford School of Economics and Policy, Australian National University (2012-2014)

Director of Research, Queensland Competition Authority (January 2012-May 2014)

Director, Economic Insights Pty Ltd (August 2006- January 2012).

Vice President, CRA International Pty Ltd (December 2004-July 2006).

Principal, Network Economics Consulting Group Pty Ltd (March 2003-November 2004).

Managing Director, Economic Insights Pty Ltd (September 1992-February 2003).

Director, Government Owned Enterprises Unit, Queensland Treasury (April 1991- September 1992).

Assistant Commissioner, Economic Studies, Industry Commission, Canberra (1990-April 1991).

Lecturer, (Macroeconomics of Developing Countries) Australian National University (1990).

Economist, Economics and Statistics Department, OECD, Paris (1987–89).

Director, Industries Assistance Commission (IAC) Canberra (1986–87).

Teaching Assistant, University of Western Ontario, London, Canada (part-time, 1982–85).

Principal Research Officer, Assistant Director and Acting Director, IAC (1980–82).

Tutor, (Quantitative methods) University of Queensland (part-time, 1979–80).

Bank Officer, Reserve Bank of Australia, Brisbane (1971–80).

Michael Cunningham

Position	Associate, Economic Insights Pty Ltd and Director Quantonomics Pty Ltd
Business address:	28 Albert St, Brunswick East, VIC 3057, AUSTRALIA
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Qualifications

Master of Commercial Law, Melbourne University

Master of Commerce (Hons), Melbourne University

Bachelor of Economics, Monash University

Key Skills and Experience

Michael Cunningham became an Associate of Economic Insights in late 2013 following more than a decade as a senior regulatory manager with the Essential Services Commission of Victoria (ESC). Michael has extensive experience in the regulation of energy, water and transport networks and in detailed productivity analysis.

Michael developed Victoria's minimum feed-in tariffs for 2014, and conducted research into Victoria's energy retail market, including methods for estimating retailer margins, and research into emerging regulatory issues such as household electricity control products. Other projects undertaken for the ESC relating to retail electricity included leading two empirical studies into retailer margins and into residential customer responsiveness of time-varying feed-in tariffs. Michael also produced the ESC's analysis of the productivity of the Victorian water industry in 2012, and on secondment to the Victorian Competition and Efficiency Commission in 2011, for the Inquiry into a State-Based Reform Agenda, he was lead author of its Productivity Information Paper (Dec 2011).

In August 2011, he produced a substantial ESC internal research report on "Returns to Businesses in Regulatory Decision Making: What is best practice?" which examined in detail the broad range of issues relating to regulated rates of return.

Michael has led many key ESC reviews, including:

- Review of the Rail Access Regime 2009-10
- Reviews of Victorian Ports Regulation 2009 & 2004
- Reviews of Grain Handling Access Regime 2009, 2006 & 2002
- Taxi Fare Review 2007-08
- Review of Port Planning 2007

- Implementing the Victorian rail access regime 2005 & rail access arrangement approvals 2006 & 2009
- Review of the Supply of Bottled LPG in Victoria 2002.

Prior to joining the ESC, Michael was a commercial advisor at Gascor Pty Ltd for the re-determination of the natural gas price under Victoria's (then) principal gas supply contract for Gippsland gas. From 1997 to 1999, he was an Associate Analyst at Credit Suisse First Boston Australian Equities, carrying out financial analysis of Australia listed infrastructure businesses and utilities. For more than 10 years Michael was employed by Gas & Fuel Corporation Victoria (GFCV) and was responsible for developing forecasting models, operations research, project evaluation, developing management performance reporting systems and tariff design.

As Manager, Resource Strategy, he participated in contract negotiations, and carried out key analysis, relating to the supply of LNG (for the Dandenong storage facility), and participated in the development of gas transmission prices. From 1994 to 1997, he was seconded to the Gas Industry Reform Unit (GIRU) in Victoria's Treasury department and assisted with the negotiation and settlement of the Resource Rent Tax dispute between GFCV and Esso-BHP (approximately $1 billion in claims). He was a member of the negotiating team that settled a new 13-year gas supply agreement to supply 95% of Victoria's natural gas. In addition to being a member of the negotiating team, he was responsible for carrying out all of the forecasting and risk analysis of key contractual terms such as take-or-pay, maximum day quantity and quantity renomination options.

Recent Publications

- Journal article: 'Productivity Benchmarking the Australian Water Utilities' *Economic Papers* (June 2013)
- Conference paper: Cunningham M B & Harb, D 'Multifactor productivity at the sub-national level in Australia', 41st Australian Conference of Economists 2012
- Submissions:
  - 'Submission to MCE consultation on the separation of electricity transmission and distribution' (Nov 2011)
  - 'Submission to AEMC consultation on AER rule change request' (Dec 2011)
  - 'Submission to PC Consultation on Electricity Network Regulation' (Apr 2012)
  - 'Processes for stakeholder negotiation for electricity regulation', submission to PC (Nov 2012)
  - 'Submission to Productivity Commission Review of the National Access Regime' (Feb 2013)
  - 'Options to Strengthen the Law Prohibiting Misuse of Market Power', submission to Treasury (Feb 2016).

Completed Projects with Economic Insights

Electricity

- For the Essential Services Commission Victoria (ESC), developed options for feed-in tariffs for small renewable electricity generators in Victoria to apply in 2015 (2014), and again provided advice to the ESC in 2015 in relation to feed-in tariff applicable in 2016.

Gas

- On behalf of Jemena Gas Networks, carried out productivity analysis, benchmarking and forecasting partial productivity to support its access arrangement proposal (2014) submitted to the Australian Energy Regulator (AER).
- On behalf of Australian Gas Networks (AGN), carried out productivity and benchmarking analysis (2015) to support its proposed access arrangement submitted to the AER.
- For three Victorian gas distribution businesses (AGN, Multinet Gas and AusNet Services) carried out carried out productivity and benchmarking analysis to support their forthcoming proposed access arrangements to be submitted to the AER (2016).
- On behalf of Multinet Gas, carried out econometric analysis of the gas distribution opex cost function to support its access arrangement proposal (2016).
- On behalf of ATCO Gas Australia (AGA), carried out productivity and benchmarking analysis (2018) to support its proposed access arrangement currently being prepared for submission to the ERA.
- On behalf of JGN carried out productivity benchmarking and econometric analysis for the purpose of forecasting partial productivity to support its access arrangement proposal (2019).
- Carried out productivity benchmarking and econometric analysis for Evoenergy to support its access arrangement proposal in 2020. Also carried out productivity benchmarking analysis for AGN SA to support it access arrangement proposal in 2020.

Water

- For the Commonwealth Department of Environment, with Denis Lawrence, carried out an economic benchmarking study of the Murray Darling Basin Authority's River Murray Operations joint venture against similar Australian rural water businesses using data envelopment analysis (2014).
- For the ESC, carried out an econometric benchmarking study of Victorian urban water businesses against urban water businesses throughout Australia in 2014, and updated the study again for the ESC in 2017..

Telecommunications

- For the ACCC, with John Fallon and Joe Hirschberg, undertook an econometric study to develop an hedonic pricing model for the major telecommunications retail services, to measure movements in prices while controlling for changes in service characteristics. The telecommunications services included were fixed line voice services, internet services, and mobile phone services (2018).
- For the Australian Competition and Consumer Commission (ACCC), with John Fallon and Tim Coelli, undertook an econometric study of competitive pricing of domestic transmission capacity services (DTCS), to assist the ACCC in its review of DTCS prices on regulated routes (2015).

Economic Regulation — Allowed rate of return

- With John Fallon, prepared advice to the New Zealand Commerce Commission on international practices regarding setting regulated rates of return within a range of best estimates (2014).

Economic Regulation — Benchmarking

- With Denis Lawrence, John Fallon and Valentin Zelenyuk, in 2017 prepared advice to the Netherlands Authority for Consumers and Markets (ACM) on topics relating to benchmarking the efficiency of electricity and gas transmission system operators (TSOs) in Europe, including in relation to selecting cost drivers, estimating the cost of capital, choosing the modelling method and explaining the results. This advice will inform the ACM in its forthcoming benchmarking of European electricity and gas TSOs.

- With Denis Lawrence and John Fallon, provided advice in 2020 to the Netherlands ACM on the projected rate of frontier shift over the five-year regulatory period commencing 2022 for the regulated energy transmission businesses, Gasunie Transport Services and TenneT. The study included: (i) reviewing international studies and regulatory decisions on energy transmission productivity; (ii) calculating total factor productivity (TFP) and partial factor productivity (PFP) indexes and trends for selected Dutch industries considered comparable to the Dutch energy transmission sector; (iii) using data envelopment analysis and econometric analysis applied to selected industries in a number of European countries to separate productivity gains associated with catch-up from those associated with shifts in the frontier, and to identify differences in productivity trends relevant to opex and capital inputs; and (iv) advising the ACM on appropriate allowances for frontier shift to be included in the regulatory plans.

Professor Raymond da Silva Rosa

Position	Associate
Business telephone number:	+61 8 6488 2974
Mobile:	0416 196 350
Email address	ray.dasilvarosa@uwa.edu.au

Qualifications

BCom (Honours), PhD (UWA, 1996)

Academic Positions

UWA

- Professor of Finance, UWA Business School
- Member, UWA Senate (Elected, Term: 2015 to 2023)
- Elected Chair, UWA Academic Board & Council (1st term beginning Jan 2019, 2nd term ending Dec 2023)
- Fellow, St Catherine's College, The University of Western Australia

External

- Non-Executive Director, Absolute Equity Performance Fund Ltd (ASX:AEG)
- Member, Editorial Board, Accounting & Finance - academic journal
- Member, Editorial Board, Meditari Accountancy Research Journal – academic journal
- Honorary, Faculty of Business & Economics, University of Melbourne.

Prior

- President and Board Member, Accounting & Finance Association of Australian & New Zealand (July 2015- June 2017)
- Head, Accounting & Finance, UWA Business School (Jul 2008 - Dec 2011; Dec 2016 - Dec 2018)
- Associate Dean – International, UWA Business School (August 2010 to November 2012)
- Senior Visiting Fellow, MBA Program Melbourne Business School, University of Melbourne (courses taught: M&A, Investments)
- Visiting Associate Professor, Stern School of Business, New York University (Jan 2008 to June 2008)
- Associate Professor, UWA Business School (2001 to 2007)
- Senior Lecturer, Faculty of Economics and Business, University of Sydney (1998 to 2001)
- Member, Editorial Board, Australian Accounting Review
- Member, Editorial Board, Australian Journal of Management

Research and teaching

Research

Ray is the co-author of the corporate finance textbook: “Investments” by Bodie, Ariff, Da Silva Rosa, Kane and Marcus (1st Australian edition) McGraw-Hill 2007.

Ray has also has published numerous journal articles on takeovers, corporate governance and corporate finance, won various related research grants and provided expert evidence in over 15 legal court cases, commissioned either by ASIC or private parties.

Some of the concluded or settled class action cases in which Ray has provided expert opinion are those involving Centro Properties (2010), NAB Ltd (2012), Allco Finance Group (2016), QBE Insurance Group (2017), Arasor International Ltd (2016), UGL Ltd (2019).

Teaching

- Investment Analysis Third year undergraduate unit with 500+ students 2011 to 2021
- Investments Melbourne Business School, MBA program, 2011 & 2012, UWA Business School MBA program 2009.
- Advanced Corporate Finance – Fourth year honours program, 2008 – 2019
- Mergers & Acquisitions UWA Executive MBA program, 2008 to 2017
- Economics & Finance for Mining and Energy (Co-Lecturer) 2008 and 2009.
- Corporate Financial Policy – Second year undergraduate unit 2008
- Foundations of Finance, Stern School of Business, New York University 2008
- Behavioral Finance, Stern School of Business, New York University 2008
- Financial Acumen for Executives – Designed and delivered six customized modules on investments and corporate finance to 15 upper-echelon executives of a top 20 ASX-listed company in 2009 and in 2010.

APPENDIX C: DECLARATION

I, John Joseph Fallon, Director of Economic Insights Pty Ltd, declare that I have read the Federal Court Guidelines for Expert Witnesses and that I have made all inquiries I believe are desirable and appropriate and that no matters of significance which I regard as relevant have, to the best of my knowledge, been withheld from the Court.

30 June 2021

John Joseph Fallon signature and date

I, Michael Bradbury Cunningham, Associate of Economic Insights Pty Ltd, declare that I have read the Federal Court Guidelines for Expert Witnesses and that I have made all inquiries I believe are desirable and appropriate and that no matters of significance which I regard as relevant have, to the best of my knowledge, been withheld from the Court.

30 June 2021

Michael Bradbury Cunningham

I Raymond Da Silva Rosa, Associate of Economic Insights Pty Ltd, declare that I have read the Federal Court Guidelines for Expert Witnesses and that I have made all inquiries I believe are desirable and appropriate and that no matters of significance which I regard as relevant have, to the best of my knowledge, been withheld from the Court.

30 June 2021

Raymond Da Silva Rosa signature and date