Statistical Advice to the ERA on DBP Submission 56

June 2016

Project: 0002_ERA_2016

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Revised following comments by Partington and Satchell (2016)[1]

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Economic Regulation Authority

Project:

0002_ERA_2016

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[1] Partington, G. and S. Satchell, *Report to the ERA: Comments on Statistical Reports by Pink Lake*, 31st May 2016.

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Executive Summary

Pink Lake Analytics was engaged by the Economic Regulation Authority (ERA, or Authority) to review the recent Submission[2] and Appendices provided by Dampier Bunbury Pipeline (DBP) in support of its proposed access arrangement and to provide statistical advice on statements made therein in relation to the Return on Equity (RoE) calculation.

Upon review it is clear that the positions of the Authority and DBP are divergent. The Authority derives an RoE calculation from the Henry[3] statistical version of the Sharpe-Lintner Capital Asset Pricing Model (SL CAPM). The statistical model itself is valid – in predicting the data it minimises the squared error difference between observations and model predictions. Furthermore, the model includes a free-intercept term in excess of the risk-free rate (α), so for its class of models (i.e., linear models with a single predictor) it provides an unbiased estimate of β, the measure of an asset's exposure to systematic risk in the market. The Authority then omits the α estimate of abnormal returns from the Henry model in its implementation of the Sharpe-Lintner CAPM for the RoE calculation, deeming these abnormal returns as not reflective of the systematic risk in market prices that is faced by benchmark efficient firms. The Authority then makes a discretionary decision in revising the estimate of β upwards to derive the RoE calculation, in keeping with past practice and to address in part the known weaknesses of the SL CAPM related to bias from non-negligible borrowing and transaction costs.

In contrast, DBP implements the Black CAPM model by first estimating a zero-beta premium (ZBP). Effectively, this ZBP estimate is a measure of the abnormal returns in excess of the risk-free rate. As such, although the Black CAPM is marginally biased in terms of its predictions (as it does not include a free-intercept term) this bias is statistically insignificant. Where DBP and the Authority differ in their positions is that DBP include the full weight of the ZBP, as a de facto measure of abnormal returns in their RoE calculation, whereas the Authority includes only a proportion of these abnormal returns (through its β adjustment).

Importantly, the different positions reflect whether model validation should be applied to the statistical model and not the RoE calculation. The statistical model is an assessment of the past data, whereas the RoE calculation is a forwards projection of the market risk that cannot be diversified away. For the Authority, the statistical model employed is already an optimally fitting model under reasonable model assumptions. Hence, there is no reason to undertake further the model validation proposed by DBP when adopting the Authority's position. In contrast, DBP propose to apply the model validation to the RoE calculation itself. As the DBP RoE calculation is essentially the same as their statistical model, then it is self-evident that their RoE calculation does not exhibit significant model bias. Similarly, it is self-evident that the Authority's RoE calculation does exhibit model bias, as it deliberately excludes the abnormal return component estimated in the Henry model in excess of the risk-free rate. Both the Henry model and the Black CAPM are valid, depending on the position being adopted. The question of which position to accept - either the Authority's or DBP's - is therefore not a statistical question, but a question of economics, and one that falls outside the scope and expertise of this consultancy.

[2] DBNGP Transmission Pty Ltd, *Proposed Revisions DBNGP Access Arrangement, 2016 – 2020 Access Arrangement Period Supporting Submission: 56*, 24 February 2016.
[3] Henry, O.T., *Estimating β: An update*, April 2014, [Source: https://www.aer.gov.au/system/files/D14%2052760%20%20Estimating%20Beta_%20An%20update%20Olan%20T%20Henry%20April%202014.pdf].

The consequence, however, of accepting DBP's position over that of the Authority is significant in terms of the RoE. Each position can be summarised by the compensation each position pays in excess of the theoretical SL CAPM (with β estimated through the Henry method, but excluding abnormal returns associated with α). Accepting DBP's position will imply a compensation of up to 4.52% (depending on the current estimate of β which varies through time). This compensation is more than three times the compensation of up to 1.37% that would be paid if the Authority's position involving the β bias adjustment is accepted (see Case Study 1 below). Significantly, if abnormal returns are allowed to be explicitly included in the Black CAPM through the inclusion of a free-intercept term, as they are in the Henry model, and this is then not included in the forward looking estimates for the return on equity, then the compensation paid under the Black CAPM is significantly reduced. This is evidenced by the up to 1.6% compensation paid when applying SFG (2014)[4] estimates of the ZBP. Inclusion, or otherwise, of the abnormal returns in the statistical model is again an economic question, not a statistical question, although from a statistical perspective one would always expect to include abnormal returns (i.e., a free-intercept term) to improve the fitting of the model.

Questions of model validity, such as whether the ZBP estimate is over-valued and consequently should a free-intercept term be included in the statistical estimation of the Black CAPM, are thus largely economic rather than statistical questions. However, a key statistical issue is the reliability of the ZBP measure, i.e., is the ZBP measure consistent with respect to changes in the market over time and in how it is implemented. Upon review of the Submission and associated documents there is strong evidence that the ZBP measure is not reliable, namely:

- The variance of the ZBP estimator is large.
- The ZBP estimates are highly variable through time (i.e., are non-stationary).
- Estimation of the ZBP is implemented by different practitioners in different ways, leading to radically different estimates.

Throughout the DBP Submission the ZBP estimate provided is treated as a fixed value within the Black CAPM model. However, the ZBP estimate is perhaps the term in the Black CAPM that is most subject to uncertainty. Yet DBP ignore that uncertainty. There is evidence that the ZBP estimate can differ significantly both between time periods when estimated by the same practitioner, the same practitioner can put forward multiple methods of estimating the ZBP, and different practitioners apply different methods, and consequently the ZBP estimate can vary widely. Moreover, an incorrectly specified ZBP estimate can have significant financial consequences given the high sensitivity of the RoE calculation to the inclusion of abnormal returns, and indeed the calculated compensation to be paid for borrowing and transaction costs. As such, quantifying the uncertainty in the ZBP estimate through Monte Carlo simulation, and studying the impact of this uncertainty on the RoE and associated compensation level has been proposed as a further scope of works (Scope 1).

Other issues raised by DBP appear secondary, and are briefly summarised here:

- The $\hat{\beta}^*$ calculation proposed by DBP is mathematically ill-posed for ZBP/MRP ratios above 1. The inverse of $\hat{\beta}^*$ is ill-posed for all values of the ZBP/MRP ratio, and may not be used to justify some of the claims that DBP have made with regard to under-valuing $\hat{\beta}$. For these reasons the $\hat{\beta}^*$ calculation should not be considered for the upwards revision of the $\hat{\beta}$ estimate, given the

[4] SFG Consulting, *Cost of equity in the Black Capital Asset Pricing Model*, *Report for Jemena Gas Networks, ActewAGL, Networks NSW, Transend, Ergon and SA Power Networks*, 22 May 2014.

uncertainty in both the ZBP and $\hat{\beta}$ estimates and the need for a smoothly varying $\hat{\beta}^*$ calculation.

- Points raised by DAA[5] and ESQUANT[6] do not, on the whole, address the economic issue of the difference in position between DBP and the Authority. The results presented are largely self-evident if the position of the Authority is rejected *a priori*. Their results do not apply if the Authority's position is accepted.
- It is argued within this report that a cross-validation approach should be preferred to the model adequacy test where either is applicable, given cross-validation can be applied in principle to a broader range of model validation problems. However, neither are really applicable to the evaluation of CAPM models for the reasons given above, and the debate between the implementation of a cross-validation criterion or model adequacy test is then seen to be largely irrelevant.
- If cross-validation is to be applied then, following the work of ESQUANT[7], it is recommended that one-step ahead time series cross-validation should be adopted by the Authority for purposes of model validation. If forecasts over longer time horizons are required then time series cross-validation with overlapping data should be adopted.
- The issues raised by HoustonKemp (2016)[8] with regard to data processing are considered as readily resolved, although they will likely introduce some small bias into the Authority's estimates. Resolution of these data processing issues falls within the proposed Scope 1. The Authority's estimates of $\hat{\beta}$ and the RoE should be revised following any correction to the Authority's code base.
- Institution of a private code repository on behalf of the Authority will enable the Authority to implement version control over its code base and demonstrate to the public and the proponent that appropriate code revisions have been made in a timely fashion. Implementation of a private code repository has been recommended as part of Scope 2.

[5] Data Analysis Australia, *Review of Statistical Aspects of Capital Asset Pricing Model*, February 2016, Appendix K.

[6] ESQUANT Statistical Consulting, *Review of ERA Cross-Validation Approach, A report prepared for DBP*, 24 February 2016, Appendix I.

[7] ESQUANT Statistical Consulting, *Review of ERA Cross-Validation Approach, A report prepared for DBP*, 24 February 2016, Appendix I.

[8] HoustonKemp Economists, *The Black CAPM: Response to the ERA's Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2010, A Report for DBP,* February 2016, Appendix H, p. vii.

Terms of Reference

1. Pink Lake Analytics was invited by ERA to review the position of DBP and its consultants in relation to the Authority's Draft Decision, as contained within the DBP 'Submission': *Proposed Revisions DBNGP Access Arrangement, 2016-2020 Access Arrangement Period Supporting Submission: 56*. This review focuses only on the Return on Equity component of the Submission.
2. As such the following Appendices in support of the Submission have been reviewed:
    - *Estimating beta to be used in the Sharpe-Lintner CAPM*, CEG, February 2016, Appendix F.
    - *Evaluating Forecasts: Response to the ERA's Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020, A Report for DBP*, HoustonKemp Economists, February 2016, Appendix F.
    - *The Black CAPM: Response to the ERA's Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020*, HoustonKemp Economists, February 2016, Appendix G.
    - *Review of ERA Cross-Validation Approach, A Report Prepared for DBP*, HoustonKemp Economists, February 2016, Appendix H.
    - *Review of ERA Cross-Validation Approach*, ESQUANT Statistical Consulting, February 24, 2016, Appendix I.
    - *Review of Statistical Aspects of Capital Asset Pricing Model*, Data Analysis Australia, February 2016, Appendix K.
3. In reviewing the Submission reference will be made to the Authority's 'Draft Decision': *Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020*, and to DBP's original 'Submission 12': *Proposed Revisions DBNGP Access Arrangement, 2016-2020 Regulatory Period, Rate of Return, Supporting Submission: 12.*
4. A copy of Pink Lake's letter to the ERA defining the scope of this consultancy is attached as Appendix A to this report.
5. The outcome of this advice is to provide a series of scopes that address on behalf of ERA the statistical matters raised by DBP in their Submission and within their supporting evidence.

Declaration

6. This report has been prepared by Rohan Sadler of Pink Lake Analytics Pty Ltd.
7. As the author of this report I have read, understood and complied with the Expert Witness Guidelines entitled *Expert Witnesses in Proceedings in the Federal Court of Australia* (as defined in the Federal Court of Australia's Practice Note CM 7; attached as Appendix B). As the author I have made all the inquiries that I believe are desirable and appropriate and that no matters of significance that I regard as relevant have, to my knowledge, been withheld from this report.
8. A curriculum vitae for the consultant has been provided as Appendix C.

Introduction

1. There is now a large volume of material to respond to when reviewing the Submissions, the Draft Decision, and their associated Appendices, even when the scope is constrained to the Return on Equity (RoE)[9] component within the calculation of the rate of return[10].
2. This overview therefore seeks to summarise the key differences in position between the Authority and DBP. In so doing the attempt will be made to align the analytical evidence on which the differing positions are based.
3. We define analytics loosely here as methods involving data analysis and the evaluation of different tools or scenarios that are designed to gain insight into a decision problem, so as to improve decision outcomes. Our intent is to support the two parties in developing a data-driven, evidence-based approach to resolving points of difference where practicable.
4. The key reason, in simple terms, of why the Authority has rejected DBP's proposal to adopt the Black Capital Asset Pricing Model (CAPM) is the concerns it raises with regards to the estimates of the zero-beta premium (ZBP)[11]. The ZBP is pivotal in DBP's assessment of the RoE calculation as it is a key input into the Black CAPM. Hence rejection of the ZBP estimate equates to rejection of the overall rate of return derived from the Black CAPM estimate.
5. Before issues with the estimation of the ZBP are addressed then the context needs to be set. At the heart of the discussion is that the Authority estimates an empirical Sharpe-Lintner (SL) CAPM by including a free-intercept term in the statistical model. This intercept term implicitly measures the abnormal returns attributable to a sector of the market (in this case providers of gas infrastructure) over and above the risk-free rate[12]. However, for reasons to be described in following sections, this abnormal return is ignored when calculating the RoE.
6. Both parties currently agree that a portion of this abnormal return should be included in the RoE calculation. This 'compensation' reflects that firms in the market do not have access to a perfectly riskless asset in which to invest in.
7. DBP argue that this portion of compensation is proportional to the zero-beta premium (ZBP) that they estimate (with a nominal ZBP of 9.4%; see Case Study 1: Compensating for Bias).
8. The Authority, on its part, compensate for a portion of this abnormal return by increasing the estimated value of β[13] (from 0.52 in the Rate of Return Guidelines to 0.7 in the recent Draft Decision).
9. Hence the key question highlighting the difference of opinion between the Authority and DBP is what is an appropriate compensation for firms for operating in a market that is not entirely risk-free? Or in other words, what is an appropriate risk-adjusted RoE?
10. The answer to this question is largely economic, and hence falls outside the current scope. However, a set of back-of-the-envelope figures and reasoning are provided here to illustrate where differences in the respective positions of the Authority and DBP reside.

[9] Return on equity is the net income returned on an investment as proportion, and relation to the rate of return
[10] The rate of return is the gain or loss on an investment over a specified period, expressed as a percentage increase over the initial investment cost.
[11] The zero-beta rate defines a portfolio of market assets that has zero systematic risk, but which has the same expected return as the risk-free rate.
[12] Theoretically, the risk-free rate is the RoE of an investment with zero risk. In practice, it is evaluated using Commonwealth Government Securities, or other minimal risk bonds.
[13] β is applied as a measure of an asset's risk relative to a market index. A low β value indicates a less volatile asset, or a volatile asset whose price movements are not highly correlated with the market. Thus β is a measure of an asset's systematic risk (i.e., the risk that cannot be reduced by diversification to other assets). In principle, the risk represented by β is the only kind of risk for which investors should receive an expected return higher than the risk-free rate of interest.

11. Other issues, including discussion regarding the application of either the model adequacy test or cross-validation, are either of minor importance or are potentially easily resolved once the above issues are resolved.
12. This report consists of three core sections. The first addresses in more detail the issue of abnormal returns and how these have been considered by the Authority and DBP to date. This first section also describes to what extent DBP proposes to compensate for a portion of the abnormal return through the ZBP estimate, and compares the DBP approach to how the Authority currently undertakes the compensation.
13. The second section then examines the statistical issues in estimating the ZBP, and addresses each of the concerns the Authority has concerning the ZBP estimate, namely:
    - The ZBP as it is calculated by DBP, appears over-valued.
    - The variance of the ZBP estimator is high.
    - The ZBP estimates are highly variable through time (i.e., are non-stationary).
    - Estimation of the ZBP is implemented by different practitioners in different ways, leading to radically different estimates.
    - The ZBP is estimated using an indexed market portfolio (the ASX 300) and not a risk-efficient portfolio, and thus does not satisfy a key assumption of the theoretical model. This criticism can also be applied the SL CAPM model as well, and is one of a number of reasons why abnormal returns should be explicitly modelled in the Black CAPM model, as is done with the Henry version of the SL CAPM (see Sections 18-20 below).
    - The $\hat{\beta}^*$ calculation proposed by DBP is mathematically ill-posed for ZBP/MRP ratios above 1. The inverse of $\hat{\beta}^*$ is ill-posed for all values of the ZBP/MRP ratio, and may not be used to justify some of the claims that DBP have made with regard to under-valuing $\hat{\beta}$.
14. The third section addresses the differences between the model adequacy test and cross-validation, ones that should not influence the final decision of the Authority. Further comments on this topic are given in Appendix D.
15. A fourth section relates to criticisms of the Authority's method of data preparation, and acknowledges that those issues should be resolved prior to any future analysis.
16. The report then considers where further evidence-based investigation may be useful to clarify the issues outlined above. Each of these investigative tasks are then described in detail in Appendix E as candidate scopes that the Authority may wish to pursue in future, in keeping with this report's terms of reference.
17. The summary results of this review will then be presented as the conclusions, along with key recommendations.
18. This report includes revisions to address the critique of Partington and Satchel (2016).[14] The revisions are footnoted, and are concentrated on Sections 65-68 where it is suggested that there are good reasons for why abnormal returns should be included explicitly in the estimation of both the SL and Black CAPM.

[14] Partington, G. and S. Satchell, *Report to the ERA: Comments on Statistical Reports by Pink Lake*, 31st May 2016, p. 5.

Abnormal Returns and Compensation

The Authority's Position

19. Abnormal returns are modelled as part of the empirical SL CAPM by including a free-intercept term, following the practice of Henry (2014).[15]
20. This empirical model includes a static mean value of the risk-free rate (termed 'static empirical SL CAPM' model in Table 22 of Appendix 4 of the Draft Decision; [16] and equivalently termed as the 'DAA Intercept Model' in Appendix K of the Submission[17]).
21. Hence, the model[18] fitted by the Authority to the weekly asset return data extracted from the Bloomberg service for the current constituents of the ASX market index is equivalent to:

$$\boldsymbol{r_{it} = r_f + \alpha_i + \beta_i(r_{mt} - r_f) + \varepsilon_{it}} \qquad (1)$$

where r_{it} is the return on the asset (or portfolio) i at time t;

r_{mt} is the return on the indexed market portfolio at time t;

r_f is the risk-free rate averaged over the assessment period;

α_i is the asset specific abnormal return in excess of the risk-free rate;

β_i is the asset β, i.e., a measure of systematic risk in comparison to the market as a whole; and,

$\boldsymbol{\varepsilon_{it}}$ is a Gaussian noise term defined as $\boldsymbol{\varepsilon_{it}} \sim N(0; \sigma_i^2)$.

Both α_i and β_i are estimated, whereas the returns and risk-free rate comprise the information inputted into the model.

22. This model, by definition, minimises the squared error difference between model predictions and observations. There is therefore no need to ensure that the model is 'validated' (although there is a need to check standard linear model assumptions), as it can be assumed that the model minimises prediction error for the given data. As this model includes a free-intercept term, it has a lower squared error difference between predictions and observations than any model excluding a free-intercept term, for those models containing r_{mt} as the single linear predictor of the model. In this sense, the model provides unbiased predictions relative to models without a free-intercept term. Moreover, the model delivers BLUE[19] (best linear

[15] Henry, OT, *Estimating β: An update, Report for the Australian Energy Regulator,* April 2014, p. 6.
[16] ERA, *Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020, Appendix 4 Rate of Return,* 22 December 2015, p. 179.
[17] Data Analysis Australia, *Review of Statistical Aspects of Capital Asset Pricing Model*, February 2016, Appendix K, Section 59(b), p. 22.
[18] ERA, *Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020, Appendix 4 Rate of Return,* 22 December 2015, Equation 39, Section 822, p. 176.
[19] The Gauss–Markov theorem states that for a linear regression model with equivariant and uncorrelated errors with expectation zero the best linear unbiased estimator (BLUE) of the model coefficients is given by the ordinary least squares (OLS) estimator.

unbiased estimator) for β, given the ordinary least squares (OLS) procedure is used for estimating the model parameters.[20,21]

23. The risk-free rate is treated simply as an 'offset' as it is a fixed input into the model. The model can therefore be alternatively expressed as:

$$r_{it} - r_f = \alpha_i + \beta_i(r_{mt} - r_f)$$

$$r_{it} = \alpha_i + (1 - \beta_i)r_f + \beta_i r_{mt}$$

$$r_{it} = \alpha_i^H + \beta_i r_{mt}$$

where α_i^H is the intercept term including both the risk-free rate and abnormal returns, and equates to the intercept term applied by Henry (2014).[22]

24. The risk-free rate in the Henry model is in no way estimated from the asset and market raw returns, as examined by DAA. [23] Consequently, their assertion that '*the justification given by Henry for using the intercept in the estimation for beta in the Sharpe-Lintner CAPM does not apply to this data*'[24] is clearly incorrect (and hence so too is the underlying premise of their test).
25. The model that is used for estimation of β_i from the data is not the same as the model applied to the RoE calculation. The Authority's RoE calculation, following re-levering of $\hat{\beta}_i$, may be defined as:

$$\boldsymbol{r_i = r_f + \hat{\beta}_i(r_m - r_f)} \qquad (2)$$

26. Clearly, the abnormal return in excess of the risk-free rate (α_i) has been omitted from the RoE evaluation. Also the dependence on time for the returns has been dropped. The RoE is thus a valuation based on past data but which takes into account a forecast of the risk-free rate and the market return to provide a market risk premium (MRP = $r_m - r_f$).
27. Furthermore, the estimate $\hat{\beta}_i$ from the empirical model (i.e., before re-levering) has been upwardly revised to a single value $\hat{\beta}^A$ (following re-levering). This upwards revision is to 'compensate' for a portion of the abnormal return above the risk-free rate, given firms do not have access to perfectly riskless investment options. This upwards revision therefore accepts the critique of the SL CAPM that proponents of the Black CAPM provide, but without applying a correction based on the ZBP.
28. The Authority's revised RoE (r^A) calculation is therefore:

$$\boldsymbol{r^A = r_f + \hat{\beta}^A \times MRP} \qquad (3)$$

29. In the Draft Decision the magnitude of the upwards revision is set at the Authority's discretion, but is thus far consistent with past decisions. In the Rate of Return Guidelines the estimate

[20] ERA, *Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020, Appendix 4 Rate of Return,* 22 December 2015*,* Section 1020, p. 228.
[21] Data Analysis Australia, *Review of Statistical Aspects of Capital Asset Pricing Model*, February 2016, Appendix K, Section 69(c), p. 30.
[22] Henry, OT, *Estimating β: An update, Report for the Australian Energy Regulator,* April 2014, p. 6.
[23] Data Analysis Australia, *Review of Statistical Aspects of Capital Asset Pricing Model*, February 2016, Appendix K, Section 69(e), p. 30.
[24] Data Analysis Australia, *Review of Statistical Aspects of Capital Asset Pricing Model*, February 2016, Appendix K, Section.69(g), p. 30.

$\hat{\beta}_i = 0.52$ (following a re-levering adjustment) is revised upwards to $\hat{\beta}_i^A = 0.70$ in the Draft Decision.

30. In no way does the Authority assert that the forward looking expected RoE calculation, with abnormal returns excluded (Eqn. 2), aligns with observed market returns ex post. Clearly abnormal returns are not included in the RoE calculation, and consequently the RoE calculation is not a purely statistical predictive model, although it's $\hat{\beta}_i^A$ parameters are informed by the predictive model (Eqn. 1).
31. It is confirmed by DBP that 'if the intercept is added to the model forecasts, then the problem of bias essentially vanishes'. [25] Here, the model forecasts equate to the unadjusted RoE calculation, with the abnormal return added, which then also equates to the Henry version of the SL CAPM. The Henry SL CAPM produces unbiased predictions of market returns, given the data, whereas the theoretical forward looking RoE calculation does not.
32. If one accepts the position of the Authority then it is insensible to apply a model validation method on the RoE calculation, as DBP have done throughout the Submission and Submission 12. It is only sensible to apply model validation, such as a model adequacy test or a cross-validation measure of prediction error, to the model fitted to the data.

DBP's Position

33. DBP estimate a value of β_i from a model defined by the ZBP (i.e., r_z):

$$\boldsymbol{r_{it} = r_z + \beta_i^B (r_{mt} - r_z) + \varepsilon_{it}} \qquad (4)$$

where β_i^B is the Black CAPM instance of β_i;

r_z is the zero-beta rate of return, with $r_z = ZBP + r_f$.

34. DBP rely on the two-pass methodology, where a first-pass value of β_i^B is estimated using the SL CAPM model over a range of time intervals, and which includes a free-intercept term. [26] These first-pass β_i^B estimates are then used during a second-pass to calculate a time-varying zero-beta premium (ZBP = $r_z - r_f$) in a model that excludes a free-intercept term. These ZBP values are then weighted against volatile stocks using the reciprocal of estimates of the idiosyncratic risks of each stock. [27]
35. To reduce measurement error DBP place the stocks into portfolios that retain much of the cross-section variation in β_i^B. [28] Alternatively, a bias correction could have been applied to the ZBP estimates instead. [29]

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[25] DBNGP Transmission Pty Ltd, *Proposed Revisions DBNGP Access Arrangement, 2016 – 2020 Access Arrangement Period Supporting Submission: 56*, 24 February 2016, Section 6.123, p. 53.

[26] NERA Economic Consulting, *Estimates of the Zero-Beta Premium, A report for the Energy Networks Association,* June 2013, p7. After Fama and MacBeth (1973) and Litzenberger and Ramaswamy (1979)

Fama, Eugene F. and James D. Macbeth, "Risk, return and equilibrium: Empirical tests", *Journal of Political Economy*, 1973, pp. 607-636.

Litzenberger, Robert H. and Krishna Ramaswamy, "The effect of personal taxes and dividends on capital asset prices: Theory and empirical evidence, *Journal of Financial Economics*, 1979, pp. 163-195.

[27] NERA Economic Consulting, *Estimates of the Zero-Beta Premium, A report for the Energy Networks Association,* June 2013, p. 8.

[28] NERA Economic Consulting, *Estimates of the Zero-Beta Premium, A report for the Energy Networks Association,* June 2013, p. 8., after Fama and MacBeth (1973)

[29] After Shanken (1992), NERA Economic Consulting, *Estimates of the Zero-Beta Premium, A report for the Energy Networks Association,* June 2013, p. 8.

36. The bias-corrected ZBP values are then compounded to provide a mean annual ZBP estimate. The ZBP can then be deduced by subtracting the mean annual risk-free rate from the ZBP. Once estimated, the ZBP can be treated as a fixed term in estimating β_i^B by applying Equation 3. Equivalently, ZBP values can be applied when computing the RoE.
37. DBP apply the same model for estimating β_i^B as they do to their RoE calculation.
38. From a statistical perspective predictions from the Black CAPM RoE equation are consistent with asset returns only when the ZBP estimate approximates the abnormal return α_i from the Henry model. Otherwise, predictions from the Black CAPM RoE equation are biased.
39. Under these conditions the DBP RoE satisfies a model validation based on the predictions (either the model adequacy test or a minimum cross-validation prediction error criterion). In contrast, the Authority's RoE calculation can never satisfy the model validation as proposed by DBP, unless both ZBP and α_i are approximately zero.

Critique

40. The DBP model (Equation 3), unlike the empirical SL CAPM (Eqn. 1), is biased in its predictions of asset returns, [30] simply because it does not include a free-intercept term. Excluding the free-intercept term from the statistical model assumes that there exists a strong theoretical reason as to why abnormal returns for the gas utility sector of the market should not be considered in the estimation of β.
41. This is evidenced by the fact that, when DBP defines its RoE interval, it selects an asymmetric 20th – 99th percentile range. This range is generated by those values of β^* that satisfy the model adequacy test. Bias in predictions is also evidenced by the empirical SL CAPM providing lower Wald test statistics than the Black CAPM. [31]
42. Given the evidence presented by DBP it is clear this bias in the Black model is not statistically significant, although it still exists. The conclusion to be drawn from this is that the DBP estimate of the ZBP is close to the abnormal return above the risk-free rate.
43. In effect, DBP are seeking compensation for a large portion of the abnormal returns that are observed in the data. These abnormal returns have been estimated by the Authority at close to 10.5% since June 2000 for the gas market equities. The ZBP provided by DBP therefore equates to 9.41%. [32]
44. The abnormal return measures the performance of an asset above the expected performance given market returns. There are many potential reasons why abnormal returns may exist. These reasons may include survivorship bias and the attractiveness to investors of an asset due to its regulated or monopolistic status in the market, which may be seen to reduce the risk of the asset relative to the market, particularly in times of economic downturn.
45. The extent to which the abnormal returns should be compensated for by the Authority is a question of economics, and is thus outside the terms of reference of this scope.

Shanken, Jay, "On the estimation of beta pricing models", *Review of Financial Studies*, 1992, pp. 1-33.

[30] Given the set of simple unbiased linear regressions that include free-intercept terms.

[31] The DAA Intercept model, or its variant in the DAA Common Intersection model, returns Wald Test values of between 5.1 and 6.2; whereas the Black CAPM returns values of between 8.7 and 9.9. Data Analysis Australia, *Review of Statistical Aspects of Capital Asset Pricing Model*, February 2016, Table 7, p25, Appendix K.

[32] DBP apply a ZBP/MRP ratio of 1.238 in their provided code (cells L7 to N7 of the worksheet 'BETASTAR' in Excel workbook 'SECDAT.xls'), and which is used to compute their $\hat{\beta}^*$ estimate. With an MRP of 7.6% then the ZBP is therefore 9.41%, yielding a ZBR of 11.71% given a risk-free rate of 1.96%.

46. Case Study 1 presents a back-of-envelope analysis to quantify the degree to which DBP's proposal compensates for a portion of the abnormal return, relative to the Authority's position.
47. The ZBP given by DBP is in Case Study 1 paying the asset 4.52% over and above the risk-free rate of 1.96% in the RoE calculation. To support their proposed level of compensation then DBP should argue that this level of compensation does not outweigh reasonable transaction or borrowing costs.
48. Moreover, the DBP proposal results in more than three times the compensation than what the Authority has put forward in its Draft Decision.
49. SFG (2014) have also developed an estimate of the ZBP,[33] although their estimate is significantly different in specification and estimation as compared to the DBP version of the Black CAPM.
50. The SFG estimate of the ZBP equates to a compensation close to that of the Authority. The main point of difference between SFG (2014) and NERA (2013), [34] upon which DBP's estimate of the ZBP is based, is that SFG (2014) included a free-intercept term in the second pass of their two-pass estimation procedure. Consequently, the ZBP is much lower when abnormal returns are accounted for in the Black CAPM model.
51. Without DBP including the free-intercept term representing abnormal returns in their second-pass estimation then the estimate of the ZBP is forced to compensate for the abnormal return in the model fitting process. This produces an estimate of the ZBP close to the abnormal return. DBP's estimate of the ZBP is therefore likely inflated.
52. At the very least, the unremarked difference in estimation methods between SFG (2014) and DBP which - produce dramatically different results - is alone sufficient grounds to reject DBP's model, due to an unexplained inconsistency in what should be a standard method for computing the ZBP. This point was raised in Sections 853-860 in the Draft Decision, but is nowhere addressed by DBP in their Submission.
53. DBP's estimate of the ZBP is above the MRP; their ratio of ZBP/MRP = 1.238 is greater than one. This is in contrast to Brennan (1971), who states that the ZBP should lie between the borrowing and lending rates.[35]

[33] SFG Consulting, *Cost of equity in the Black Capital Asset Pricing Model*, *Report for Jemena Gas Networks, ActewAGL, Networks NSW, Transend, Ergon and SA Power Networks*, 22 May 2014, Section 102, p. 27.

[34] NERA Economic Consulting, *Estimates of the Zero-Beta Premium, A report for the Energy Networks Association,* June 2013, Table 5.2, p16.

[35] Brennan M., "Capital market equilibrium with divergent borrowing and lending rates", *Journal of Financial and Quantitative Analysis*, 6, pp. 1197-1205, 1971.

Note that a distinction should be drawn between the Brennan (1971) model and that of Black (1972). Brennan considers differential borrowing and lending rates in an economy where a risk-free security exists. Black (1972) considers both when there is no risk-free security and when the investor is precluded from holding short positions in the risk-free security. Hence a restriction on trading in the riskless security is assumed here to realise a premium above the risk-free rate when borrowing (after McKenzie and Partington, 2014).

Black, F. "Capital market equilibrium with restricted borrowing", *Journal of Business*, pp. 444-455, 1972

McKenzie M. and G. Partington, *Report to the AER, Part A: Return on Equity*, on behalf of The Securities Industry Research Centre of Asia-Pacific (SIRCA) Limited, October 2014, p.21.

CASE STUDY 1: COMPENSATION OF ABNORMAL RETURNS

This case study examines the portion of the abnormal return that is compensated within the RoE calculations given by both DBP's and the Authority's position. The method applies estimates accessible from the Submission, Submission 12, the Draft Decision and the Rate of Return Guidelines.

The 'compensation' is defined here as the difference in RoE between the theoretical SL CAPM and an alternative CAPM model. This difference in the RoE applies the estimates of β derived from the empirical SL CAPM, as in this instance the DBP Black CAPM is close to the empirical SL CAPM in its β estimates. This compensation may be expressed as a proportion of the abnormal return.

Several alternative compensations are compared. In addition to Submission 12 and the Draft Decision estimates we have included the NERA (2013) ZBP estimate, on which methods the DBP estimate is based. We also include the ZBP estimate of SFG (2014). Input figures for these back-of-envelope calculations are provided in Table 1 and Table 2, alongside the results.

For the Authority's RoE calculation the compensation above the risk-free rate is equal to the MRP multiplied by the difference between the estimated $\hat{\beta}$ and the upwardly revised value of $\hat{\beta}^A$. Compensation above the risk-free rate for the Black CAPM is given here as $\left(1-\hat{\beta}\right)\times ZBP$. As the mean $\hat{\beta}$ before revision reported by the Authority has varied between the RoE Guidelines and the Draft Decision then both values of $\hat{\beta}$ have been reported (see Section 84).

Table 1. Comparing Levels of Compensation for $\widehat{\boldsymbol{\beta}} = \mathbf{0.52}$

Source	ZBP (%)	Compensation (%)	Proportion of Total Abnormal Return	Input Parameter Values
ERA Draft Decision	-	1.37	0.13	$MRP = 7.6\%$ $\hat{\alpha}^H = 10.5\%$[36] $r_f = 1.96\%$ $r_m = MRP + r_f = 9.9\%$ $\hat{\beta} = 0.52$ $\hat{\beta}^A = 0.70$
DBP Submission 12	9.41	4.52	0.43	
NERA (2013)	8.19	3.93	0.37	
SFG (2014)	3.34	1.60	0.15	

Table 2. Comparing Levels of Compensation for $\widehat{\boldsymbol{\beta}} = \mathbf{0.61}$

Source	ZBP (%)	Compensation (%)	Proportion of Total Abnormal Return	Input Parameter Values
ERA Draft Decision	-	0.68	0.06	$MRP = 7.6\%$ $\hat{\alpha}^H = 10.5\%$ $r_f = 1.96\%$ $r_m = MRP + r_f = 9.9\%$ $\hat{\beta} = 0.61$ $\hat{\beta}^A = 0.70$
DBP Submission 12	9.41	3.67	0.35	
NERA (2013)	8.19	3.19	0.30	
SFG (2014)	3.34	1.30	0.12	

[36] This approximate value for $\hat{\alpha}^H$ was estimated during the work for the Draft Decision, and so would not be the estimate corresponding to the Rate of Return Guidelines value for $\hat{\beta}$ of 0.52. Hence the measure 'Proportional to Abnormal Return' is illustrative only.

CASE STUDY 2: HOW THE COMPENSATIONS APPLY

DBP and the Authority differ in how they apply compensations for part of the abnormal return. Their respective RoE calculations differ, including how estimates of β are adjusted to compensate the firm for not having access to a perfectly riskless asset.

The Henry CAPM and Black CAPM parameters may be estimated from the data (in this case represented by the sample of circles in Figure 1 below). When evaluated at the MRP of 7.6% these models define points A and B, respectively, in Figure 1. The difference between A and B is the bias in the statistical model in predicting asset returns at the specified MRP, with the Henry CAPM (point A) being the unbiased estimate as it includes a free-intercept term. Note that DBP's Black CAPM is a close approximation of the Henry CAPM.

The Authority then provides both an unrevised RoE calculation that excludes the abnormal return in excess of the risk-free rate (i.e., the classic SL CAPM with $\hat{\beta}$), and a RoE calculation that revises upwards the estimate of $\hat{\beta}$ to compensate by amount DE for any transaction costs (i.e., the $\hat{\beta}^A$ RoE). This compensation may be expressed proportional to the total abnormal return given by AE (as in Table 1, Box 1).

The DBP proposal estimates the $\hat{\beta}^B$ parameter of the Black CAPM, and provides the $\hat{\beta}^*$ adjustment to the Authority's $\hat{\beta}$ estimate. These estimates result in the same level of compensation given by CE. The Black CAPM achieves this compensation by replacing the risk-free rate with the ZBR in the CAPM model, while keeping $\hat{\beta}^B$ constant, whereas $\hat{\beta}^*$ adjusts $\hat{\beta}$ to provide the same level of compensation as the Black CAPM while keeping the risk-free rate as the fixed intercept term.

Note the SFG (2014) ZBP estimate provides a compensation much closer to D than C.

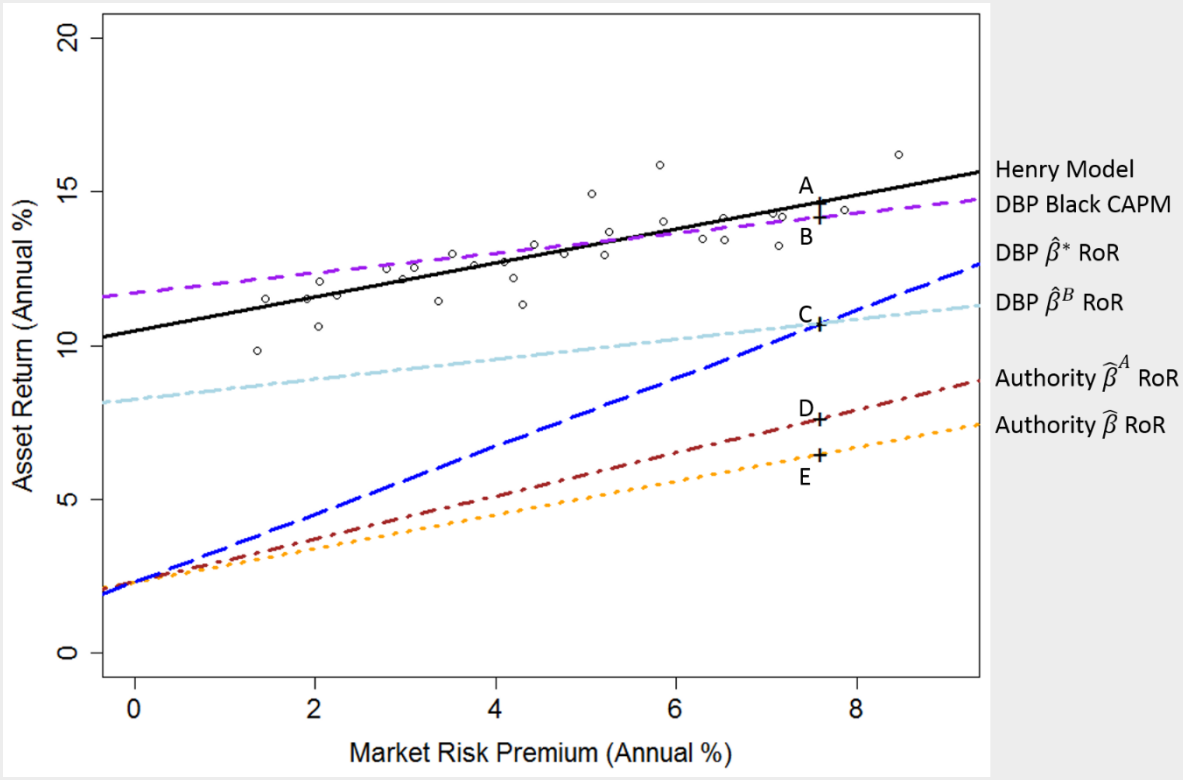

Figure 1. Compensation and Abnormal Returns for Various CAPM Models

54. DBP correctly argue that the (risk-efficient) market portfolio of all risky assets is not observable.[37] On this basis it argues that the MRP based on all risky assets is undefined because the market return (and hence MRP) estimated on a portfolio of stocks is not a risk-efficient market return as defined by Brennan (1971). DBP apply this logic to effectively free its analysis from the constraint that the ZBP must be less than the MRP, allowing itself to accept ZBP/MRP ratios that are greater than one.
55. This same logic can be applied to DBP's estimates of the ZBP. That is, DBP's estimates of the ZBP are based on the market index, not the portfolio of all risky assets, or at least a risk-efficient portfolio of the stock market assets. This implies that the ZBP based on all risky assets remains undefined, and the actual ZBP estimate provided does not have any real linkage to the theoretical ZBP. It appears that in the case of the ZBP then DBP accept estimates based on the stock market portfolio as representative of estimates based on all risky assets, but not in the case of the MRP. DBP do not provide any rationale to justify this inconsistency in their application of the observed market portfolio.[38]
56. Regardless, the violation of the theory provided by Brennan (1971) *prima facie*, as indicated by ZBP being greater than the forward looking MRP estimate, suggests that DBP's estimate of ZBP is over-inflated.
57. DBP make the claim that:
    "If the regulatory regime were such that only one model were to be used to estimate the return on equity (which DBP does not agree is the case), then in order for the ERA to set a value for $\hat{\beta}^*$ having regard to the theoretical findings of the Black CAPM, it must estimate value for β and ZBP/MRP and it must use DBP's betastar formula to determine the appropriate increment to $\hat{\beta}^*$.[39]
    It is a non sequitur reasoning that says that if regard is to be paid to the Black CAPM then the DBP method of compensation MUST be applied, especially if there are valid grounds for dismissing DBP's implementation of the Black CAPM.
58. Regard has been paid by the Authority to the theoretical underpinnings of the Black CAPM, as may be evidenced in Sections 818-863 of the Draft Decision.
59. In so doing, the Authority has revised its estimate of β upwards to $\hat{\beta}^A$.
60. However, if the estimate of β from the Black CAPM is either inconsistent among practitioners (which it is) or there are sufficient grounds to suspect its estimate is unreliable (as is discussed in the following section), then it is neither irrational nor unreasonable for the Authority to give zero weight to DBP's RoE calculation.
61. In lieu of a reliable, objective method to compensate firms for borrowing and transaction costs in the market then the it remains at the discretion of the Authority to determine the magnitude of the upward revision $\hat{\beta}^A$.[40]

[37] DBNGP Transmission Pty Ltd, Proposed Revisions DBNGP Access Arrangement, 2016 – 2020 Access Arrangement Period Supporting Submission: 56, 24 February 2016, Section 6.63, p. 41.

[38] This point illustrates only that if the logic behind DBP's critique of the Authority's position was applied to DBP's own position then that position becomes untenable. Note that Partington and Satchell (2016) state clearly that observability of the risk-efficient portfolio is not an issue, so long as the market proxy is risk-efficient.
Partington S. and G. Satchell. *Report to the ERA: Comments on Statistical Reports by Pink Lake*, 31st May 2016, p. 5, referring to Partington S. and G. Satchell. *Report to the ERA: the cost of equity and asset pricing models*, 15th May 2016, Theorem 3, p. 39.

[39] DBNGP Transmission Pty Ltd, *Proposed Revisions DBNGP Access Arrangement, 2016 – 2020 Access Arrangement Period Supporting Submission: 56*, 24 February 2016, Section 4.35, p. 21.

[40] *"The AER's use of its foundation financial model did not involve an error of discretion. Nor was the Tribunal persuaded that that the AER's selection of an equity beta of 0.7 was wrong"* as stated in the summary of the Australian Competition Tribunal's decision on the Australian Economic Regulator's (AER) use of regulatory

62. It is therefore clearly false for DBP to claim that *"the way that the ERA has proposed to have regard to the Black CAPM is neither rational nor reasonable"*[41] when its own approach has clear flaws.
63. Similarly, it is false for DBP to maintain that "*the ERA misses a key point: all of its own estimates of the zero-beta premium are above zero, and in fact much higher than would be the case if its own adjustment for bias using the "theoretical implications" (DDA4, para 256, p58) of the Black CAPM were true. This inconsistency should, at the very least, have caused the ERA to question the quantum of its own bias adjustment, and thence to employ a robust empirical test of outputs to determine which of these two inconsistent results is likely to be correct."*[42] The Authority has in all fairness examined the bias adjustment as compensation arising from their method of upwards revision and that of DBP. The similarity between DBP's estimate of the ZBP and the abnormal return estimated through the Henry model should, in turn, have caused DBP to question the quantum of its own zero-beta 'bias' adjustment. Moreover, this similarity of the DBP Black ZBP and the Henry α estimates supplies the prime reason as to why DBP finds its Black CAPM model unbiased in its model adequacy test.
64. There are a number of reasons why abnormal returns may exist, including potentially survivorship bias and the attractiveness to investors during an economic downturn of a regulated market presenting as a low-risk investment option. A further potential source of abnormal returns is the use of an index of market returns that is not considered to be risk-efficient, as both SL and Black CAPM theory require.[43] The following Sections (65-68) have been revised following comment by Partington and Satchell (2016).[44]
65. To illustrate this point we may represent the expected returns of an efficient market portfolio in terms of the inefficient market index as:

$$r_{mt}^{eff} = \alpha^{ineff} + r_{mt}^{ineff}$$

66. Substituting this expression back into the theoretical SL model provides:

$$r_{it} = r_f + \beta_i\left(r_{mt}^{eff} - r_f\right)$$
$$r_{it} = r_f + \beta_i\left(\alpha^{ineff} + r_{mt}^{ineff} - r_f\right)$$
$$r_{it} = r_f + \alpha^{ineff}\beta_i + \beta_i\left(r_{mt}^{ineff} - r_f\right)$$
$$r_{it} = r_f + \alpha + \beta_i\left(r_{mt}^{ineff} - r_f\right)$$

discretion [Source: http://www.competitiontribunal.gov.au/__data/assets/pdf_file/0003/30666/Summary-AER-Review-Decisions-26-Feb-2016.pdf].

[41] DBNGP Transmission Pty Ltd, *Proposed Revisions DBNGP Access Arrangement, 2016 – 2020 Access Arrangement Period Supporting Submission: 56*, 24 February 2016, Section 4.42, p. 22.

[42] DBNGP Transmission Pty Ltd, *Proposed Revisions DBNGP Access Arrangement, 2016 – 2020 Access Arrangement Period Supporting Submission: 56*, 24 February 2016, Section 5.14, p. 26.

[43] Discussed by many authors, including Roll, R. (1977) "A critique of the asset pricing theory's tests: Part I", *Journal of Financial Economics*, 4, pp. 129-176.

[44] Partington and Satchell (2016) are correct in stating that: *"However, in the case that the proxy for the market portfolio is inefficient, it is not the case that we can treat the problem as in PL paragraph 64-65, we need to consider the fact that the inefficient portfolio will have a different beta as well. In effect PL are considering a special case of a more general problem where it becomes harder to make simple adjustments".* Sections 64-65 seek simply to illustrate that for the Black CAPM an abnormal return should be allowed in the second-pass of the estimation procedure, and possibly in the estimation of β itself given the ZBP estimate.
Partington S. and G. Satchell. *Report to the ERA: Comments on Statistical Reports by Pink Lake*, 31st May 2016, p. 5.

The Black CAPM solves similarly to define an abnormal intercept term α, assuming that the ZBP is perfectly known *a priori*.

67. That is, applying a risk-inefficient index to a CAPM model naturally leads to abnormal returns above (or below) the risk-free rate. This abnormal return is likely positive, as by definition for the level of risk presented by a risk-inefficient market index there is a risk-efficient portfolio that provides higher returns. This point illustrates that there likely exists multiple sources of abnormal returns which do not reflect systematic risk (as may exist in a regulated market). A key point is therefore that abnormal returns should be included as a free-intercept term within any regression modelling of asset returns, be it the SL or Black CAPM. Inclusion of an abnormal return is what the Authority undertakes in implementing the Henry statistical model, and which SFG (2014)[45] include in the second-pass of their ZBP estimation, and which DBP do not account for in any apparent manner.
68. For the Black CAPM the result suggested by Sections 65-66 is confounded by both the possibility of the ZBP estimate changing significantly, depending on whether a risk-efficient or risk-inefficient portfolio is applied as the market index, and that the ZBP estimate is uncertain (i.e., ZBP is not perfectly known).[46]
69. DBP are correct to argue that the manner in which the Authority applies its discretionary power to the upwards revision of its RoE calculation cannot in principle be emulated by the proponent *a priori*.[47] An empirically objective (i.e., data driven) method of deriving the upwards revision would be ideal, and is essentially what DBP are arguing for when proposing their version of the Black CAPM. However, such an objective approach is difficult to implement robustly. Furthermore, such an approach might not be able to account for the economic aspects informing any revision. It follows that if the DBP position is rejected then questions of what this objective method of upward revision of $\hat{\beta}$ should look like, and what level of compensation as a portion of the total abnormal return should be considered as fair, should be resolved through economic and not statistical reasoning.
70. Rules such as the 95th or 99th percentile are, as DBP have stated,[48] inappropriate in providing an empirical basis to the upwards revisions. While these tail percentiles are used only as a guide by the Authority when exercising its discretionary power, consideration needs to be made of the volatility of the market returns during the assessment periods. It is foreseeable that mean market return may remain the same between periods but volatility increase, in which instance a tail percentile may increase dramatically in value. In this scenario, volatility of the market will then be a strong component of the upwards revision of $\hat{\beta}$, instead of a consideration focused solely on the need for a bias correction.
71. A criticism regarding the Henry (2014) model specification relates to the assumption that the risk-free rate does not vary substantially with time. From a statistical perpective, The evidence suggests that the risk-free rate is not time constant, and allowing the risk-free rate to vary with time during estimation would be desirable from a statistical perspective. For example, Commonwealth bond yields have been set much lower post-GFC than what they were prior

[45] SFG Consulting, *Cost of equity in the Black Capital Asset Pricing Model*, *Report for Jemena Gas Networks, ActewAGL, Networks NSW, Transend, Ergon and SA Power Networks*, 22 May 2014.
[46] Partington S. and G. Satchell. *Report to the ERA: Comments on Statistical Reports by Pink Lake*, 31st May 2016, p. 5.
[47] DBNGP Transmission Pty Ltd, *Proposed Revisions DBNGP Access Arrangement, 2016 – 2020 Access Arrangement Period Supporting Submission: 56*, 24 February 2016, Section 4.35, p. 21.
[48] DBNGP Transmission Pty Ltd, *Proposed Revisions DBNGP Access Arrangement, 2016 – 2020 Access Arrangement Period Supporting Submission: 56*, 24 February 2016, Section 6.53, p. 39.

to the GFC.[49] However, the Authority's specification of the SL CAPM is consistent with past practice, and there may be other economic-based reasons why the risk-free rate is treated as statically valued in the estimation process.

Estimating the Zero-Beta Premium

72. The key reason, in simple terms, of why the Authority has rejected DBP's proposal to adopt the Black CAPM is the concerns the Authority raises with regards to the estimates of the zero-beta premium (ZBP).
73. The concerns that the Authority raises in regard to the ZBP are:
    a. The ZBP as it is proposed, appears to be exceptionally high.
    b. The variance of the estimator is high.
    c. The estimates are highly variable through time.
    d. Estimation is implemented by different practitioners in different ways, leading to radically different estimates.
74. The first concern was raised in a previous section of this report. The first concern appears to stem from a free-intercept term not being included in DBP's estimation of the Black CAPM to represent abnormal returns in excess of the risk-free rate, particularly in the second stage of its estimation of the ZBP. Likely, this leads to inflated values of the ZBP as the parameter estimates are forced to compensate for the absence of a free-intercept term.
75. Addressing the comments in Appendix F, CEG (2016) make the point that the Authority estimate values for the ZBP/MRP ratio from 0.61 to 5.57, and that they should use the minimum of this value as the basis of their compensation above the risk-free rate.[50]
76. Such an argument is not well founded, as the Authority's implementation of the Black CAPM, much like that of NERA (2013)[51] and SFG (2014),[52] is largely arbitrary in its choice of decision parameters. The example provided by the Authority in the Draft Decision is illustrative only, and not informative for the purposes of the RoE calculation. Conceivably the Authority could choose a set of decision parameters at its discretion that pushes down the minimum estimate of the ZBP/MRP ratio even further, below the lower bound of 0.61
77. The fact remains that the methods for deriving a ZBP estimate are highly arbitrary, and highly sensitive to the choice of decision parameters. Such a position goes back to the AER Guidelines which conclude that the estimation of the ZBP is "*neither simple nor transparent*", in which case *"the estimation of parameters for the Black CAPM is not sufficiently robust such that the model could be implemented in accordance with good practice"*.[53]
78. CEG (2014) argue that:[54]

[49] The 2008 Global Financial Crisis where CGS 5 year rates were frequently topping 7%, but are currently touching 2%, a difference of 300%. [Source: http://www.rba.gov.au/speeches/2015/sp-ag-2015-03-16.html]
[50] Competition Economists Group, *Estimating beta to be used in the Sharpe-Lintner CAPM,* February 2016, Appendix F, Section 10, pp. 2-3.
[51] NERA Economic Consulting, *Estimates of the Zero-Beta Premium, A report for the Energy Networks Association,* June 2013.
[52] SFG Consulting, *Cost of equity in the Black Capital Asset Pricing Model*, *Report for Jemena Gas Networks, ActewAGL, Networks NSW, Transend, Ergon and SA Power Networks*, 22 May 2014.
[53] Australian Energy Regulator, *Better Regulation, Explanatory Statement, Rate of Return Guideline (Appendices)*, December 2013, p. 17.
[54] Competition Economists Group, *Estimating beta to be used in the Sharpe-Lintner CAPM,* February 2016, Appendix F, Section 11, p. 3.

"The fact that the evidence may not lead to a narrow range for the best estimate of low beta bias is not a rational reason to make that adjustment on some other basis than the available evidence".

Such an argument ignores the downside and upside risks. From a statistical perspective the true value of the ZBP may be located far away from the best estimate given a high variability in ZBP estimates and inaccuracy in its method of estimation. If the estimate of the ZBP is simply taken at face value then the resulting compensation may be many times greater than what it may need to be (see Case Study 1). Moreover, one may arrive at an overly inflated estimate during one assessment period only to arrive at an unduly deflated estimate for the next assessment period.

79. The following argument by CEG (2014) is non sequitur: [55]

"This stands in stark contrast to the ERA's position in relation to estimating ZBP/MRP (the determinant of low beta bias) – whereby the ERA effectively concludes that because different estimation techniques give rise to different values then no evidence should be used"

It is logical that where the evidence is fallible or of high uncertainty then the evidence is given low or zero weight.

80. Regardless, nowhere in DBP's Submission and associated appendices does DBP deny or provide evidence to the contrary that the ZBP estimate is exceptionally high. Consequently, DBP do not deny or provide evidence to the contrary that the value of their RoE calculation may be exceptionally high.
81. The variance of the ZBP estimator may be assumed to be high, and nowhere has DBP in its Submission and associated Appendices denied that the variance of the estimator is high. In statistical terms this leads to the ZBP estimate being highly non-informative, with the best guess of the ZBP estimate little better than any other guess of the ZBP estimate.
82. To demonstrate this point then Scope 1: 'Variance of the ZBP Estimator' is proposed. This scope would quantify the variance of the ZBP estimator as it is estimated by DBP (2015) and SFG (2014), and examine how a possibly high variance propagates through to the respective RoE calculations as variance in the ZBP estimate is excluded from the DAA (2016) analysis. The variance of the ZBP estimate and its influence on the RoE calculation will be compared with the variance estimates of the different parameters in the Henry CAPM, and how they propagate through to a measure of uncertainty in the Authority's RoE calculation. In so doing the reliability of the SL CAPM in delivering a more consistent range of RoE valuations than the Black CAPM would be demonstrated.

[55] Competition Economists Group, *Estimating beta to be used in the Sharpe-Lintner CAPM,* February 2016, Appendix F, Section 13, p. 3.

CASE STUDY 3: A DANGEROUS INVERSE

DBP propose the $\hat{\beta}^*$ calculation to upwardly revise the Authority's estimate of $\hat{\beta}$ so that the level of compensation is equivalent to that provided by their Black CAPM model.[56]

$$\widehat{\boldsymbol{\beta}}^*_{\boldsymbol{jt}} = \left(\mathbf{1} - \frac{\boldsymbol{ZBP_t}}{\boldsymbol{MRP_t}}\right)\widehat{\boldsymbol{\beta}}_{\boldsymbol{jt}} + \frac{\boldsymbol{ZBP_t}}{\boldsymbol{MRP_t}} \qquad (5)$$

CEG (2016) rightfully claim that the Authority's upward revision $\hat{\beta}^A$ is equivalent to a $\hat{\beta}^*$ revision.[57] This upward revision is determined at the Authority's discretion, informed by the confidence interval of $\hat{\beta}$. It is not derived from a statistical mechanism, such as DBP's Black CAPM approach. CEG then reason that the lowest bound of a sensitivity analysis of the ZBP estimated conducted by the Authority (i.e., ZBP/MRP $= 0.61$) may be applied as an input into the inverse of the above equation, namely:

$$\hat{\beta}^{INV} = \frac{\hat{\beta}^* - ZBP/MRP}{1 - ZBP/MRP}$$

With $\hat{\beta}^A = 0.7$ as input then CEG derive $\hat{\beta}^{INV} = 0.23$.[58] CEG then conclude that this 'natural' $\hat{\beta}^{INV}$ is too low.

This line of reasoning seems at face value plausible until one considers other possible values of the ZBP/MRP ratio. The $\hat{\beta}^{INV}$ calculation as a function of ZBP/MRP is discontinuous at 1, leading to implausible values of the 'natural' $\hat{\beta}$ of $\pm\infty$ (Figure 2). Indeed, if CEG follow their own logic and were to apply DBP's ratio ZBP/MRP $= 1.238$ to $\hat{\beta}^A = 0.7$ then they would expect a 'natural' $\hat{\beta}^{INV} = 2.26$. They would then have to reason that the Authority's upward revision of $\hat{\beta}^A$ is far too high.

The ill-posed nature of the $\hat{\beta}^*$ calculation is further illustrated by the ratio ZBP/MRP = 1.238 that DBP apply to their $\hat{\beta}^*$ calculation. It should be safely assumed that a $\hat{\beta}$ value should have a higher $\hat{\beta}^*$ value than a lower $\hat{\beta}$ value, i.e., $\hat{\beta}^*$ is monotonically increasing with respect to $\hat{\beta}$. However, given $\hat{\beta} = 0.61$ then $\hat{\beta}^* = 1.093$ (Eqn. 5). In contrast a lower value of $\hat{\beta}$, say 0.52, returns $\hat{\beta}^* = 1.11$. This second $\hat{\beta}^*$ value is greater than the first $\hat{\beta}^*$ value despite the associated $\hat{\beta}$ estimate being lower, i.e., the $\hat{\beta}^*$ is not monotonically increasing whenever the ZBP/MRP > 1. In fact, all $\hat{\beta} < 1$ returns a $\hat{\beta}^* > 1$ whenever the ZBP/MRP > 1.

In effect, the $\hat{\beta}^*$ calculation is a shrinkage estimator that shrinks all values of $\hat{\beta}$ to 1. The further away $\hat{\beta}$ is from one, the greater distance it is shrunk to the value 1. The inverse of this shrinkage estimator is discontinuous at ZBP/MRP $= 1$, and indeed as ZBP/MRP moves away from 1 the closer $\hat{\beta}^{INV}$ approaches 1 (Figure 2). The significant sensitivity of $\hat{\beta}^*$ to ZBP/MRP when $\hat{\beta}$ takes on low values, and when the estimate ZBP/MRP is highly uncertain and itself highly sensitive to input decision parameters, means that the $\hat{\beta}^*$ calculation is unsuitable for RoE evaluations.

[56] DBNGP Transmission Pty Ltd, *Proposed Revisions DBNGP Access Arrangement 2016 – 2020, Rate of Return - Supporting Submission: 12*, 31 December 2014, Equation 6, Section 5.145, p. 68.

[57] Competition Economists Group, *Estimating beta to be used in the Sharpe-Lintner CAPM,* February 2016, Appendix F, Section 102, p 32.

[58] Competition Economists Group, *Estimating beta to be used in the Sharpe-Lintner CAPM,* February 2016, Appendix F, Section 103, p. 33.

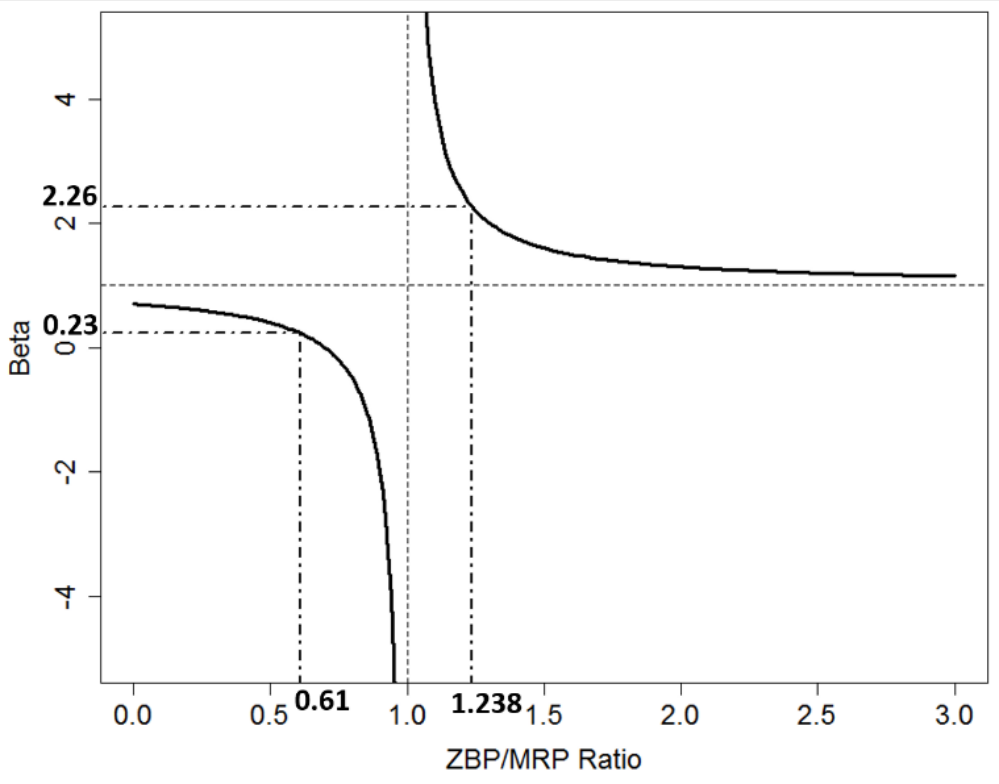

Figure 2. The Inverse Function of the $\widehat{\beta}^*$ Calculation.

Comment on Betastar

84. CEG (2016) proceed to argue that the Authority's upwardly revised estimate of $\hat{\beta}^A = 0.7$ equates to a 'natural' $\beta = 0.23$.[59] As discussed in Case Study 3: 'A Dangerous Inverse' the behaviour of the transformation that is being applied needs to be well understood. In particular, applying DBP's estimate for the ZBP/MRP ratio of 1.238, rather than a lower bound value of 0.61, leads to a 'natural' $\beta = 2.26$ given the Authority's estimate of $\hat{\beta}^A = 0.7$. If CEG were then to follow their own logic they would have to argue that the Authority's upward revision is too high. Hence CEG's main conclusion that the implied value of $\hat{\beta}$ is well below any credible estimate[60] is a completely void point, arising as it does from an ill-posed inverse of a seemingly logical, but ultimately ill-posed, mathematical expression. [61] This ill-posed expression for the $\hat{\beta}^*$ calculation means that the $\hat{\beta}^*$ calculation is unsuitable for computing compensations for borrowing and transaction costs. Moreover, it should call into question the

[59] Competition Economists Group, *Estimating beta to be used in the Sharpe-Lintner CAPM,* February 2016, Appendix F, Sections 102-103, pp. 32-33.

[60] Competition Economists Group, *Estimating beta to be used in the Sharpe-Lintner CAPM,* February 2016, Appendix F, Section 110, p. 34.

[61] An ill-posed mathematical expression is *sensu stricto* one where at least one the following conditions do not hold: (1) a solution exists; (2) the solution is unique; (3) the solution's behaviour changes continuously with the initial conditions. Clearly, the inverse of the $\hat{\beta}^*$ is ill-posed as it violates the third condition. Likewise, the $\hat{\beta}^*$ calculation may be argued to be ill-posed as when the ZBP/MRP ratio varies continuously from below one to above one then behaviour of the function shifts from monotonically increasing to monotonically decreasing with respect to $\hat{\beta}$. As both $\hat{\beta}$ and the ZBP/MRP ratio are uncertain then having a monotonically increasing $\hat{\beta}^*$ calculation would be a hard requirement for the performance of any calculation of compensation.

likely inflated estimate of the ZBP/MRP ratio, namely when the ZBP is greater than the MRP. If the math is ill-posed for these ZBP values then likely the theory underpinning the estimation of ZBP does not apply to these extreme ZBP values. ZBP estimates should be closely scrutinized for their implications in the RoE calculation and not be taken at face value.

Propagation of Uncertainty in ZBP Estimates into the RoE

85. HoustonKemp (2016) confirm that the ZBP, and consequently the ZBP, possesses high variance, with the ZBP ranging from -15% to 15% from 1974 to 2013.[62]
86. Even when HoustonKemp (2016) calculate the long term mean of the ZBP, which is approximately close to 8%, the 95% confidence band covers the approximate range from 4 to 12%.[63] High variability in ZBP estimates results in high uncertainty in the mean ZBP estimate. Moreover, estimating a single ZBP value over as much of the market history as possible assumes that there exists an 'equilibrium' ZBP value. However, CEG (2016) provide evidence of at least one structural break in market returns.[64] If there is no market equilibrium then the ZBP estimates can not be assumed to be stationary, and local estimates of ZBP should be applied, particularly when forecasts are being made of future RoE projections (i.e., estimates of at least the systematic risk component of asset returns). Such an approach ensures estimates that are more consistent with the prevailing RoE in the market, which is a requirement of NGR 87.
87. CEG (2016)[65] correctly point out that it is difficult to determine which figures the Authority is drawing on from within Tables 28-31 of the Draft Decision for its estimate of β. The lower bound of 0.41 is the lower 2.5% confidence bound of the bootstrapped $\hat{\beta}$ within the 'Mean All' column across all estimators. Similarly, the upper bound of 0.81 is given as the upper 97.5% confidence bound of the bootstrapped $\hat{\beta}$ within the 'Mean All' column across all estimators. The mean values and the median bootstrapped $\hat{\beta}$ largely coincide. The central tendency of $\hat{\beta}$ ranges from 0.591 to 0.641 across the estimators, and for convenience this is rounded to a range from 0.60 to 0.65. The bulk of the estimates are weighted towards 0.61, the middle of the range 0.41 to 0.81, and this value has been applied here in Case Studies 1 and 2.
88. The Rate of Return Guidelines derived a central estimate of $\hat{\beta} = 0.52$. DBP in their Submission apply $\hat{\beta} = 0.55$. It should be inferred from the Draft Decision that a best estimate of $\hat{\beta} = 0.61$, although this measure of central tendency was never reported in the Draft Decision. Instead, only the upwards revision of $\hat{\beta}^A = 0.7$ was reported.
89. It is recommended that the Authority always report its central tendency measure and associated confidence bounds.
90. It is also recommended that the Authority re-evaluate its weighting across all of the individual and portfolio assets, as it may be a potential source of future contention, and state clearly in

[62] HoustonKemp Economists, *The Black CAPM: Response to the ERA's Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2010, A Report for DBP,* February 2016, Appendix H, Figure 4, p. 21.

[63] HoustonKemp Economists, *The Black CAPM: Response to the ERA's Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2010, A Report for DBP,* February 2016, Appendix H, Figure 5, p. 22.

[64] Indeed CEG state that there is a structural clear break in β values, and hence non-stationarity of the time series over recent years. Competition Economists Group, *Estimating beta to be used in the Sharpe-Lintner CAPM,* February 2016, Appendix F, Figures 7-8, p. 41.

[65] Competition Economists Group, *Estimating beta to be used in the Sharpe-Lintner CAPM,* February 2016, Appendix F, Sections 106-109, pp. 33-34.

its reporting as to how it arrived at that weighting in determining its central tendency and confidence bound estimates prior to revision.

91. The evidence presented by CEG (2016) regarding a recent structural break in $\hat{\beta}$ values, originating from 2012, appears valid.[66] It is worth noting that over this period the gearing of key firms in the gas infrastructure segment of the market has markedly decreased.[67]
92. Possible non-stationarity of ZBP values is also evidenced by HoustonKemp (2016) in the first 20 years of their time series, as ZBP estimates slowly but surely climb from approximately -5% to 8%.[68] If estimates were strictly non-stationary there would be no climb, although significant variation about the mean value may still be evidenced.
93. If 'local' estimates of ZBP are applied for forecasting purposes then these will associated with high uncertainty (i.e., local estimates derived from recent data, rather than all data). Just as the MRP forecast applied in the RoE calculation can be revised, and will change over subsequent assessment periods, so should the ZBP forecast. Hence any appeal to the long-term stability of the mean ZBP estimate appears irrelevant, although such an appeal constitutes a key justification for the continued use of ZBP estimates by DBP. Indeed, the Rate of Return Guidelines recommend MRP projections refer to returns over both the past five and 20 years.
94. Uncertainty in the overall RoE estimate for the Black CAPM will therefore be compounded by both the stochasticity implicit in the ZBP estimate, uncertainty in β estimates, and stochasticity in the historical MRP. What this means is that estimation of a time-varying ZBP can lead to extreme ZBP estimates that have undue influence on the regression, and hence on the estimation of β and the subsequent RoE calculation.
95. HoustonKemp (2016) claim that: [69]

    Thus, under these conditions, it will make no difference whether one sums up daily Fama-MacBeth estimates to produce weekly or monthly estimates of the zero-beta premium or one sums up daily returns to produce weekly and monthly returns and then used these returns to produce weekly and monthly estimates.

    This statement is highly unlikely to hold when applied to the data for two reasons:

    a. Monthly and weekly estimates of β are known to differ in the first-pass of the ZBP estimation procedure, with monthly estimates of β typically lower than weekly estimates. Hence ZBP estimates will most likely differ.
    b. Monthly aggregation leads to lower levels of 'noise' in the data given by the market and asset returns, relative to weekly aggregation of the data. This will most likely lead to different estimates of the ZBP depending on the level of aggregation chosen, given the likely high influence outliers in the time-varying ZBP estimate have on the mean ZBP estimate, due to the law of large numbers.[70]

[66] Competition Economists Group, *Estimating beta to be used in the Sharpe-Lintner CAPM,* February 2016, Appendix F, Section 136, p. 46.

[67] From 0.584 to 0.474, ERA, *Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020, Appendix 4 Rate of Return,* 22 December 2015, Section 888, p. 192.

[68] HoustonKemp Economists, *The Black CAPM: Response to the ERA's Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2010, A Report for DBP,* February 2016, Appendix H, Figure 5, p. 22.

[69] HoustonKemp Economists, *The Black CAPM: Response to the ERA's Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2010, A Report for DBP,* February 2016, Appendix A2 of Appendix H, p. 27.

[70] The weak law of large numbers states that the mean converges in probability towards the expected value as sample size increases. Extending this law to the regression setting then monthly aggregation of the mean returns will effectively be more smoothed towards the global mean return than for weekly aggregation. This would result in more smoothed estimates of time-varying β in the first-pass estimation of the ZBP (i.e., lower variance), and consequently a lower variance of the time-varying ZBP. Testing this logic against the data is part of the rationale behind proposing Scope 1: "Variance of the ZBP estimator", detailed in Appendix D.

96. HoustonKemp (2016) also claim that:[71]

> *Estimates that are too high to be consistent with a theory, on the other hand, are estimates that suggest either that the theory is wrong or that the data used to test the theory is not the data that the theory requires one use. There is no sign in their work that Kan, Robotti and Shanken (2013) view the estimates that they produce as being implausibly high in the sense of being unreliable.*[72]

This statement is not wholly correct as Kan, Robotti and Shanken (2013) report OLS estimates of the ZBR across the different models as ranging from 0.68% to 2.2% per month. Among these models was the Henry version of the CAPM, with a 'ZBR' return of 1.61% per month, which incorporates both the abnormal return and the risk-free rate. Kan, Robotti and Shanken (2013) report in Table II a ZBR of 1.14% for the ICAPM model. The t-ratio associated with this ZBP estimate suggests that the ZBR estimate, was not significantly different from the risk-free rate. This implies that any derived ZBP estimate would not be significantly different from zero. This suggests that ZBP was much less than the abnormal returns observed in this particular market for the ICAPM. Other models produced ZBR estimates in excess of the abnormal returns of the Henry CAPM, but Kan, Robotti and Shanken (2013) showed that the ICAPM model performed better and more consistently in a model-fitting capacity. Note that none of this discussion resolves the regulator's problem of choosing an appropriate ZBR value, as the ZBR value will differ between the different models.

97. Nowhere has DBP or its consultants denied that estimates of ZBP (or ZBR) differ wildly between practitioners. Moreover, neither DBP nor its consultants have provided any evidential proof that their method of estimation is the 'correct' method over and above their peers.
98. Even the same practitioner will provide more than one estimate of the ZBP, based on how assets are partitioned into portfolios. For instance, NERA (2013) report that the ZBR estimate can be either 11.05% or 13.95% depending on whether the market assets were divided into portfolios or not.[73] It would then seem like cherry picking to choose one estimate over another.
99. CEG (2016) argue that the reason why the SFG (2014)[74] estimate of ZBP is much lower is because SFG (2014) have included more factors, including book-to-market value, when dividing the market assets into a greater number of portfolios.[75] However, it is more likely that the SFG (2014) estimate differs from those of other practitioners because they include a free-intercept term in their second-pass estimation of the ZBP, thereby accounting for much of the abnormal returns present in the market data. In the same vein, HoustonKemp (2016) point to results where 30 portfolios, which considers also book-to-market value, rather than 10 portfolios were applied to the data to support an argument in favour of DBP's Black CAPM model. Interestingly, when the referenced paper in Kan, Robotti and Shanken (2013) change

[71] HoustonKemp Economists, *The Black CAPM: Response to the ERA's Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2010, A Report for DBP,* February 2016, Appendix H, p. 24.

[72] Kan, R., C. Robotti and J. Shanken, "Pricing model performance and the two-pass cross-sectional regression methodology", *Journal of Finance*, 2013, pp. 2617-2649.

[73] NERA Economic Consulting, *Estimates of the Zero-Beta Premium, A report for the Energy Networks Association,* June 2013, Table 5.2, p.26.

[74] SFG Consulting, *Cost of equity in the Black Capital Asset Pricing Model*, *Report for Jemena Gas Networks, ActewAGL, Networks NSW, Transend, Ergon and SA Power Networks*, 22 May 2014, Section 102, p. 27.

[75] Competition Economists Group, *Estimating beta to be used in the Sharpe-Lintner CAPM,* February 2016, Appendix F, Section 96, p. 31.

the support of their data, leading to different portfolios being defined, then the performance of the different CAPM models also change relative to one another.[76]

100. Similar arguments can be put forward about how other decision parameters are arrived at in the estimation of the ZBP. The Authority in its Draft Decision identify at least ten decision parameters.[77] Which values of these decision parameters should be applied is highly arbitrary, subject to contention, and to date DBP has in no sense demonstrated that their selection of decision parameters are optimal with regards to model accuracy or theory.
101. A similar critique can be levelled at the SL CAPM, particularly with respect to the risk-free rate applied (i.e., whether to use either five-year or ten-year bonds, and the identity of those bonds, or whether to use daily, weekly or monthly returns). However, the SL CAPM involves far fewer decision parameters and these decision parameters are a subset of those applicable to the Black CAPM anyway. Hence the SL CAPM is more parsimonious and subject to less 'design' error than the Black CAPM, despite the accepted flaws of the SL CAPM.

Model Adequacy Test or Cross-Validation

Recommended Practice

102. Much of the discussion thus far on the model-adequacy test proposed by DBP and cross-validation as proposed by the Authority, as reported in DBP's Submissions and the Authority's Draft Decision, is largely irrelevant for the purposes of determining the RoE.
103. If the Authority's position is to be believed and the Henry model, as the statistical model, is taken as the model to be validated then there is no need to undertake the model adequacy test (or cross-validation for that matter). This is because all simple linear models with a free-intercept term, such as the Henry model, are unbiased in their predictions. Relative to models omitting the free-intercept term, such models minimise the squared error loss (i.e. difference between observations and model predictions under OLS), assuming that the common modelling assumptions of the linear statistical model are satisfied.
104. In this instance the Black CAPM as presented by DBP is a biased model, as it includes no free-intercept term (although the evidence says that this bias in predictions is small and statistically non-significant given the uncertainty associated with the β_i^B estimate).
105. It is confirmed by DBP that "*if the intercept is added to the model forecasts, then the problem of bias essentially vanishes*".[78] That is, there is no model bias if the estimated abnormal returns are added to the Authority's RoE calculation.
106. However, if the strong reasoning for the Authority's position is not accepted, and it then became a hard requirement that the revised RoE equation should predict market returns, rather than provide an informed view of the systemic risk component of the market returns, then clearly for reasons put forward in Section 37 above the Authority's RoE equation is biased. The RoE equation will likely always be rejected by the proposed model adequacy test and have a high cross-validation error when predicting asset returns, compared to models that are both the statistical model and the RoE calculation (as is the case with the proposed Black CAPM).

[76] Kan, R., C. Robotti and J. Shanken, "Pricing model performance and the two-pass cross-sectional regression methodology", *Journal of Finance*, 2013, pp. 2617-2649.
[77] ERA, *Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020, Appendix 4 Rate of Return,* 22 December 2015, Section 855, p. 184.
[78] DBNGP Transmission Pty Ltd, *Proposed Revisions DBNGP Access Arrangement, 2016 – 2020 Access Arrangement Period Supporting Submission: 56*, 24 February 2016, Section 6.123, p. 53.

107. In this instance there is again no need to perform a model adequacy test or cross-validation assessment of prediction error.
108. If the position of the Authority is accepted then discussion of whether $\hat{\beta}_i$ is biased or not becomes paramount, as a measure of systematic risk. If the position of the Authority is rejected then discussion of bias in RoE predictions becomes paramount (i.e., model bias).
109. The Authority's position would seek simply to apply model validation to the statistical model estimated from the historical data, as the measure of undiversifiable risk the asset is exposed to relative to the market that informs the Authority's RoE calculation may not be directly estimated from the data. The DBP position would want to test more how well the RoE predicts future data. In that vein DBP propose Methods A, B and C as different means of dealing with future data, which from the Authority's position is irrelevant.[79]
110. Much of the discussion provided by DAA (2016)[80] with regard to model bias is largely irrelevant as it only states the obvious, and only examines the question of model appropriateness from the perspective where the Authority's position is *a priori* rejected. Again, if the Authority's position was *a priori* accepted then "*the problem of bias essentially vanishes*".[81]
111. ESQUANT's findings on cross-validation are again largely self-evident.[82] Again, the consultant only examines the question of model appropriateness from the perspective where the Authority's position is *a priori* rejected, so the results do not add anything new to determining the RoE.
112. In essence, both the model adequacy test and cross-validation apply reasonably similar methods for generating forecasts, especially if cross-validation is restricted to the time series method (as opposed to leave-one-out or k-fold cross-validation).[83]
113. One-step ahead time series cross-validation, consistent with ESQUANT's findings and recommendations, should be adopted by the Authority. If forecasts over longer time horizons are required then time series cross-validation with overlapping data should be adopted.
114. A cross-validation approach is recommended over and above the model adequacy test. As DAA (2016) highlight: *"a mathematically more complex situation where the absence of practical analytic methods means that cross validation is appropriate"*.[84] Mathematically more complex situations arise when one considers the high sensitivity of the ZBP estimate to decision parameters, and when the ZBP has high variance. Hence, to enable a capacity to deal with these complex situations then the cross-validation approach should be preferred. In contrast, the model adequacy test will likely not be informative in these more complex situations, regardless of any other arguments for or against the model adequacy test.
115. Further comments on cross-validation and the model adequacy test are provided in Appendix E.

[79] Data Analysis Australia, *Review of Statistical Aspects of Capital Asset Pricing Model*, February 2016, Appendix K, Section 74, p. 32.
[80] Data Analysis Australia, *Review of Statistical Aspects of Capital Asset Pricing Model*, February 2016, Appendix K.
[81] DBNGP Transmission Pty Ltd, *Proposed Revisions DBNGP Access Arrangement, 2016 – 2020 Access Arrangement Period Supporting Submission: 56*, 24 February 2016, Section 6.123, p. 53.
[82] ESQUANT Statistical Consulting, *Review of ERA Cross-Validation Approach, A report prepared for DBP*, 24 February 2016, Appendix I.
[83] *"DBP's model adequacy test is a form of cross-validation with bias as the loss-function"* in ESQUANT Statistical Consulting, *Review of ERA Cross-Validation Approach, A report prepared for DBP*, 24 February 2016, Appendix I, p. 35.
[84] Data Analysis Australia, *Review of Statistical Aspects of Capital Asset Pricing Model*, February 2016, Appendix K, Section 75(e), p. 32.

Literature Search Refinement

116. Tellingly, neither DBP nor its consultants provide a reference of where their proposed model adequacy test has been applied in the extant literature, despite an abundant literature on forecasting time series.
117. Although of minor importance, the literature search by HoustonKemp (2016)[85] may be improved by the inclusion of more specific search terms. Although Wald and t-tests are ubiquitous in the statistical literature, more so than cross-validation, they are generally applied to identifying whether a hypothesized parameter value falls within a confidence region given by the sampling distribution of a statistic. In contrast, cross-validation is applied more to assessment of out-of-sample prediction accuracy, as stated by the Authority,[86] generally in the context of automatic selection of model 'tuning' parameters to maximise prediction accuracy. Clearly there will be more 'hits' for 'Wald test' on a search engine than for 'cross-validation'.
118. Significantly, cross-validation has almost three times more hits in the two forecasting journals than the Wald test given HoustonKemp's (2016) own data.[87] This would logically suggest that cross-validation is more applicable to forecasts than the Wald test.
119. Similarly, the search that HoustonKemp apply can be refined to exclude instances of Wald test where forecast or time-series prediction is not explicitly stated. Searching the abstracts (were allowed by the search engine) of the same journals as utilised by HoustonKemp (2016)[88] with the key words "forecast" or "time-series and prediction", and either "cross-validation" or "Wald" should locate those papers that are dedicated to the use of those validation methods when forecasts are made. These searches were undertaken for this report. These searches were restricted to 1997 onwards (i.e., the last 20 years), to represent current statistical practice. This selection should, in principle, represent the 'tip of the iceberg' when it comes to the broader application of cross-validation and Wald tests with respect to forecasting.
120. The results of the searches are reported in Tables 3 and 4. Clearly, cross-validation is more ubiquitous with regard to forecasting than the Wald test. Different journals will have different quality search engines and indexing methods, and will be responsive to different types of language (e.g., forecasting in the financial literature, time-series prediction elsewhere). The one exception to this finding was the Journal of Financial Economics, which is not explicitly a forecasting journal. Moreover, journals dedicated to time series analysis also displayed more hits for cross-validation than for the Wald test.
121. This is further evidenced in the broader literature across other knowledge domains such as climatology and the natural sciences, where cross-validation and forecast returns 39,400 hits compared to 29,700 on a Google Scholar search. Similarly, a search of the publisher Taylor and Francis, one of the five main publishers of academic literature globally and perhaps the publisher with the most versatile search engine, returned 6,739 hits for cross-validation as

[85] HoustonKemp Economists, *Evaluating Forecasts: Response to the ERA's Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020, A Report for DBP,* February 2016, Appendix G, Section 3.2, p. 13.
[86] ERA, *Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020, Appendix 4 Rate of Return,* 22 December 2015, Section 1036, p. 230.
[87] HoustonKemp Economists, *Evaluating Forecasts: Response to the ERA's Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020, A Report for DBP,* February 2016, Appendix G, Section 3.2, p. 13.
[88] HoustonKemp Economists, *Evaluating Forecasts: Response to the ERA's Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020, A Report for DBP,* February 2016, Appendix G, Tables 2-4, pp. 14-15.

opposed to 1,689 hits for Wald when combined with the term 'forecast', across abstracts of all journals (both finance and non-finance).

122. One would treat the instances of Wald as applied to forecasts as inflated in these results, as Wald tests may be applied to statistical models and not the forecasts within each paper. However, cross-validation is inevitably only applied to forecasts when discussing time-series.
123. Focusing solely on k-fold cross-validation as HoustonKemp (2016)[89] have done, as opposed to cross-validation more broadly, is irrelevant, as there are a number of alternatives to k-fold cross-validation.
124. These above points should hopefully address the communication gap that has led to confusion as to whether the t-test and Wald test are *"not explicitly referenced in the statistical literature"* [90], with respect to predictions and forecasts. The above searches could have been, but were not, extended to include 'Hotelling's T-test' as a moniker for the Wald test.

Table 3. Search results from "time-series" and "prediction".

	Hits for "cross-validation"	Hits for "Wald"
Journal of Finance	32	0
Journal of Financial Economics	29	71
Journal of Financial and Quantitative Analysis[91]	0	0
Review of Financial Studies	1489	1508

Table 4. Search results from "forecast".

	Hits for "cross-validation"	Hits for "Wald"
International Journal of Forecasting	10	1
Journal of Forecasting	4	1
Journal of Econometrics	3	2
Journal of Time Series Analysis	34	0
Journal of Time Series Econometrics	4	2
International Review of Financial Analysis	1	0

[89] HoustonKemp Economists, *Evaluating Forecasts: Response to the ERA's Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020, A Report for DBP,* February 2016, Appendix G, Table 3, p. 15.

[90] Data Analysis Australia, *Review of Statistical Aspects of Capital Asset Pricing Model*, February 2016, Appendix K, Section 73 (a), p. 31.

[91] The search engine on the Cambridge University Press website appeared to perform poorly and not return any results.

Validating Data Preparation

125. HoustonKemp (2016) offer a number of criticisms of the way in which daily price data was processed by the Authority in its Draft Decision:[92]

We have examined the ERA's code and found a number of problems with the way in which the regulator assembles its data that are sufficiently serious as to cast doubt on the reliability of the ERA's results.

First, the ERA incorrectly computes the returns to stocks on the days immediately following ex-dividend days. The ERA incorrectly presumes that a purchaser of a share of stock on the ex-dividend day will pay the sum of the price at the close of business and the dividend distributed.

Second, there is no sign in the ERA's code that it takes steps to ensure that dividends and prices are denominated in the same currency. We show that when dividends and prices are denominated in different currencies that returns can be very badly mismeasured.

Third, the ERA selects stocks based on whether they are currently members of the All Ordinaries and so, because membership of the All Ordinaries is determined by market capitalisation, on their current market capitalisations. So the ERA has selected a set of stocks that are known to have performed well on average.

Stocks that over the last five years or 20 years have performed well will be more likely, all else constant, than stocks that have performed badly over the last five years or 20 years to be current members of the All Ordinaries. It is likely, therefore, that the ERA's results suffer from survivorship bias.

Fourth, rather than setting the return to a stock on a day when it does not trade – or over a week or a month when it does not trade – to missing, the ERA sets the return to zero if a price has previously been recorded.

Treating missing returns as zero returns can lead to estimates of the beta of a stock that are biased towards zero.

126. For comparisons between the Authority and DBP to be valid then the method of processing the data will have to be aligned, and the criticisms provided by HoustonKemp addressed.
127. Any required corrections of the Authority's procedures will be included in Scope 1.

To track the different versions of the Authority's code, and that of DBP and its consultants, then it is recommended that a code repository be instituted. This forms the rationale behind the proposal of Scope 2: 'Development of a Code Repository'.

[92] HoustonKemp Economists, *The Black CAPM: Response to the ERA's Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2010, A Report for DBP,* February 2016, Appendix H, p. vii.

Conclusions

128. The difference in the positions of the Authority and DBP hinge upon what is a fair level of compensation for a portion of the abnormal returns. Both parties agree that some level of compensation is required, in keeping with the criticisms of the SL CAPM.
129. DBP have estimated a Black CAPM where the zero-beta premium (ZBP) is very close in value to the abnormal return. This results in a high level of compensation being proposed relative to the position of the Authority.
130. The Authority applies the Henry model and uses its discretionary power to revise upwards its estimate of β (following re-levering of the β estimate). It also omits the abnormal return from its RoE calculation.
131. The Authority does not adopt the ZBP estimate given the following concerns:
    a. The ZBR as it is proposed, appears to be exceptionally high.
    b. The variance of the estimator is high.
    c. The estimates are highly variable through time.
    d. Estimation is implemented by different practitioners in different ways, leading to radically different estimates.
132. Nowhere in DBP's reporting (the Submission and associated Appendices), is it denied that the ZBP estimate is exceptionally high, or that the variance of the estimator is high, or that the estimates of the ZBP is highly variable through time, or that the ZBP estimate is highly sensitive to decision parameters in how the ZBP estimate is calculated. From a statistical perspective the ZBP estimate would be seen as highly unstable, and to a large degree non-informative, for these reasons.
133. The Authority has full discretion under NGR 40(3) to revise upwards its estimate of β if estimates of the upwards revision generated from DBP's Black CAPM cannot be trusted (and hence are not consistent with the allowed rate of return objective). Ideally, the Authority might develop a transparent and objective method to revise upwards their RoE valuation, as argued for by DBP. However, the feasibility of a mechanical adjustment rule will depend on whether relevant economic theory can usefully guide such an approach in practice.
134. Specifically, the Authority's RoE calculation is distinctly different from the Henry model used to estimate β. In essence, as abnormal returns are removed from Henry model to define the RoE calculation then it seems illogical to expect that the RoE calculation will predict the asset returns. If model validation based on a comparison between forecasts of the model and the data is to be performed then the Henry model, as the statistical model, should be the one validated. The level of compensation to be applied as a portion of the abnormal return then becomes an economic argument.
135. If the Authority's approach is accepted then much of the criticism provided by DBP disappears.
    a. DAA assess predictions from variants of the Authority's RoE calculation only, rather than the underlying Henry statistical model. Their conclusion that the RoE calculation leads to poor predictions of market returns[93] is true, but is irrelevant when model validation should be applied to the underlying statistical model.
    b. If model validation is applied to the underlying statistical model then all the discussion of model adequacy tests and cross-validation disappears as the Henry model already minimises the squared error loss relative to models excluding a free-intercept term. Hence, the Henry model already possesses the minimum squared error loss for all

[93] Data Analysis Australia, *Review of Statistical Aspects of Capital Asset Pricing Model*, February 2016, Appendix K, Section 76, p. 32.

simple linear regressions with free-intercept terms when estimating parameters through ordinary least squares.

136. If the Authority's approach is not accepted then there is also no need to apply the model adequacy test as it is clear that the Authority's RoE will fail any test against the data. Note that the Authority's RoE remains unbiased for 'expected return' (i.e., for the systematic risk component in market returns), with the argument being that the Authority should not be rewarding abnormal returns above the risk-free rate and a reasonable set of transaction and borrowing costs.
137. A cross-validation framework is still recommended in preference to the model adequacy test. The main reason is that the cross-validation framework has broader applicability, particularly in addressing the sensitivity of models to decision parameters and in incorporating the high variance of the Black CAPM estimate of β.
138. In total, two candidate scopes have been submitted in Appendix D, which are designed to answer key uncertainties in the debate between DBP and the Authority, or to support the Authority in its reasoning of its position. These are:

    Scope 1: Variance of the ZBP Estimator

    Scope 2: Development of a Code Repository

139. In summary, the recommendations from this report are that the Authority:
    a. explores whether an objective and reliable method for the upwards revision as compensation for borrowing and transaction costs may be put in place;
    b. always reports its central tendency measure and associated confidence bounds;
    c. re-evaluates its weighting across all of the individual and portfolio assets when providing its final estimate of β and its confidence bounds for the SL CAPM, prior to any upwards revision of the β estimate, given that a lack of clarity with regard to reporting may be a potential source of future contention. Moreover, the Authority should state clearly in its reporting as to how it arrived at the weighting used to determine its estimates of β and the associated confidence bounds; and
    d. employ a one-step ahead time series cross-validation, consistent with ESQUANT's findings and recommendations. If forecasts over longer time horizons are required then time series cross-validation with overlapping data should be adopted.

Glossary

ACRONYM	DEFINITION
ARIMAX	Auto-Regressive Integrated Moving-Average with Covariates Model
BLUE	Best Linear Unbiased Estimator
CAPM	Capital Asset Pricing Model
CEG	Competition Economists Group
DAA	Data Analysis Australia
DBP	Dampier-Bunbury Pipeline
GARCH	Generalised Auto-Regressive Conditional Heteroskedasticity models
LAD	Least Absolute Deviations Estimator
MM	MM estimator
MRP	Market Risk Premium
OLS	Ordinary Least Squares
RoE	Return on Equity
SL	Sharpe-Lintner
T-S	Theil-Sen estimator
ZBP	Zero-beta premium, i.e., the quantity by which the ZBR exceeds the risk-free rate.
ZBR	Zero-beta rate

Mathematical Terms

TERM	DESCRIPTION
α_i	The abnormal return over and above the risk-free rate.
$\hat{\alpha}^H$	Estimate of the abnormal return given Henry's method. This abnormal return includes the risk-free rate.
β	A measure of an asset's risk relative to a market index. A low β value indicates a less volatile asset, or a volatile asset whose price movements are not highly correlated with the market. Thus β is a measure of an asset's systematic risk (i.e., the risk that cannot be reduced by diversification to other assets). In principle, the risk represented by β is the only kind of risk for which investors should receive an expected return higher than the risk-free rate of interest.
$\hat{\beta}$	An estimate of β
$\hat{\beta}^*$	The estimate of β following an upwards revision to provide a RoE equivalent to that of the Black CAPM.
$\hat{\beta}^A$	The Authority's estimate of β given the Henry CAPM.
$\hat{\beta}^B$	An estimate of β returned by the Black CAPM.
$\hat{\beta}_{it}^{FP}$	A 'first-pass' estimate of β within the Black CAPM two-pass estimation procedure for asset i at time t.
δ_{it}^{FP}	Abnormal return in excess of the risk-free rate in the first pass of the two-pass estimation procedure of the Black CAPM.
δ_{it}^{SP}	Abnormal return in excess of the risk-free rate in the second pass of the two-pass estimation procedure of the Black CAPM.
ε_{it}^{FP}	Residual term for the first-pass equation of the two-pass estimation procedure of the Black CAPM.
ε_{it}^{SP}	Residual term for the second-pass equation of the two-pass estimation procedure of the Black CAPM.
i	An index of each asset
λ	Coefficient of the β adjusted market return in SFG (2014).[94]
$N(\mu, \sigma^2)$	A (multivariate) normal distrubtion given by mean μ and variance σ^2.
$\boldsymbol{r^A}$	The Authority's RoE following re-levering and upwards revision of $\hat{\beta}^A$.
r_f	The risk-free rate.
r_{it}	The return of the asset at time t.
r_{mt}	The return given by the market index at time t.
r_z	The zero-beta rate (ZBR).
s	Index of set of observations prior to a given time t, in the first pass of the two-pass estimation procedure for the Black CAPM.
t	An index of time.
$Var(\cdot)$	Variance measure of a parameter.

[94] SFG Consulting, *Cost of equity in the Black Capital Asset Pricing Model*, *Report for Jemena Gas Networks, ActewAGL, Networks NSW, Transend, Ergon and SA Power Networks*, 22 May 2014, Section 100, p. 27.

Appendix A: Terms of reference

9th March 2016

Pink Lake Analytics

90 Meriwa St
Nedlands, WA 6009
rohan.sadler@pinklake.com.au
0433 192 600

Our reference: 0001_ERA_1601

Mr Richard Begley

Principal Regulatory Advisor
Economic Regulatory Authority
Level 4, 469 Wellington Street
Perth, WA 6000

Dear Richard,

Re: Quotation for consultancy on the merits of the DBP betastar approach.

Thank you for the opportunity to submit a quotation for the consultancy associated with DBP's response to the Authority's Draft Decision. Reiterating the terms of reference you have kindly provided the key tasks for a first stage of the consultancy are:

- Review DBP's and its consultants' views on the Authority's Draft Decision relating to the Black CAPM (and by association, betastar).
- Identify the key points of challenge to the draft decision.
- Scope a work program to address those key points.

Any criticisms of the Authority's analysis on conclusions regarding the stability of the Black CAPM and the zero-beta premium in the Australian context by the consultant (CEG, DAA, HoustonKemp) should be closely evaluated. Furthermore, Esquant's review of the proposed cross-validation approach should be assessed and commented on.

Any detailed econometric analysis arising from this evaluation may be scoped for completion in a second stage of the consultancy. As such, any econometric analysis is outside the current scope.

Timing and Resources

<omitted>

Cost

<omitted>

Project Personnel

Rohan Sadler will be the key personnel assigned to the project and for whom a Curriculum Vitae has been provided. In summary, Rohan is a statistician with a strong focus on environmental monitoring and resource economics, and who specialises in spatial analysis and data governance. Key qualifications and experience relevant to this scope consists of:

- PhD (computational statistics, landscape ecology; UWA).
- Astat Accreddited Professional Statistician (Statistical Society of Australia).
- Adjunct Senior Lecturer, School of Agricultural and Resource Economics, The University of Western Australia.
- Peer-reviewed publications across a variety of applications and including:
  - portfolio optimisation
  - benefit-cost analysis
  - risk analysis
  - principal-agent contracts
- Three years consultancy experience in the resource industry.
- Five years of research and involvement in national scale research initiatives (Market Based Instruments programme; CRC Plant Biosecurity; CRC Bushfires).
- Previous casual employment with the Authority for work on the Authority's draft decision.

If you have any questions regarding this quotation, please don't hesitate to contact the undersigned at rohan.sadler@pinklake.com.au or on 0433 192 600.

Yours Sincerely,

Rohan Sadler
Director, Pink Lake Analytics

Appendix B: Expert Witnesses in Federal Court Proceedings

FEDERAL COURT OF AUSTRALIA
Practice Note CM 7
EXPERT WITNESSES IN PROCEEDINGS IN THE FEDERAL COURT OF AUSTRALIA

Practice Note CM 7 issued on 1 August 2011 is revoked with effect from midnight on 3 June 2013 and the following Practice Note is substituted.

Commencement

1. This Practice Note commences on 4 June 2013.

Introduction

2. Rule 23.12 of the Federal Court Rules 2011 requires a party to give a copy of the following guidelines to any witness they propose to retain for the purpose of preparing a report or giving evidence in a proceeding as to an opinion held by the witness that is wholly or substantially based on the specialised knowledge of the witness (see **Part 3.3 - Opinion** of the *Evidence Act 1995* (Cth)).

3. The guidelines are not intended to address all aspects of an expert witness's duties, but are intended to facilitate the admission of opinion evidence[95], and to assist experts to understand in general terms what the Court expects of them. Additionally, it is hoped that the guidelines will assist individual expert witnesses to avoid the criticism that is sometimes made (whether rightly or wrongly) that expert witnesses lack objectivity, or have coloured their evidence in favour of the party calling them.

Guidelines

1. General Duty to the Court[96]

1.1 An expert witness has an overriding duty to assist the Court on matters relevant to the expert's area of expertise.

1.2 An expert witness is not an advocate for a party even when giving testimony that is necessarily evaluative rather than inferential.

1.3 An expert witness's paramount duty is to the Court and not to the person retaining the expert.

[95] As to the distinction between expert opinion evidence and expert assistance see *Evans Deakin Pty Ltd v Sebel Furniture Ltd* [2003] FCA 171 per Allsop J at [676].
[96] The "*Ikarian Reefer*" (1993) 20 FSR 563 at 565-566.

2. The Form of the Expert's Report[97]

2.1 An expert's written report must comply with Rule 23.13 and therefore must

(a) be signed by the expert who prepared the report; and

(b) contain an acknowledgement at the beginning of the report that the expert has read, understood and complied with the Practice Note; and

(c) contain particulars of the training, study or experience by which the expert has acquired specialised knowledge; and

(d) identify the questions that the expert was asked to address; and

(e) set out separately each of the factual findings or assumptions on which the expert's opinion is based; and

(f) set out separately from the factual findings or assumptions each of the expert's opinions; and

(g) set out the reasons for each of the expert's opinions; and

(ga) contain an acknowledgment that the expert's opinions are based wholly or substantially on the specialised knowledge mentioned in paragraph (c) above[98]; and

(h) comply with the Practice Note.

2.2 At the end of the report the expert should declare that "[the expert] has *made all the inquiries that* [the expert] *believes are desirable and appropriate and that no matters of significance that* [the expert] *regards as relevant have, to* [the expert's] *knowledge, been withheld from the Court*."

2.3 There should be included in or attached to the report the documents and other materials that the expert has been instructed to consider.

2.4 If, after exchange of reports or at any other stage, an expert witness changes the expert's opinion, having read another expert's report or for any other reason, the change should be communicated as soon as practicable (through the party's lawyers) to each party to whom the expert witness's report has been provided and, when appropriate, to the Court[99].

2.5 If an expert's opinion is not fully researched because the expert considers that insufficient data are available, or for any other reason, this must be stated with an indication that the opinion is no more than a provisional one. Where an expert witness who has prepared a report believes that it may be incomplete or inaccurate without some qualification, that qualification must be stated in the report.

2.6 The expert should make it clear if a particular question or issue falls outside the relevant field of expertise.

2.7 Where an expert's report refers to photographs, plans, calculations, analyses, measurements, survey reports or other extrinsic matter, these must be provided to the opposite party at the same time as the exchange of reports[100].

[97] Rule 23.13.
[98] See also *Dasreef Pty Limited v Nawaf Hawchar* [2011] HCA 21.
[99] The *"Ikarian Reefer"* [1993] 20 FSR 563 at 565
[100] The *"Ikarian Reefer"* [1993] 20 FSR 563 at 565-566. See also Ormrod *"Scientific Evidence in Court"* [1968] Crim LR 240

3. Experts' Conference

3.1 If experts retained by the parties meet at the direction of the Court, it would be improper for an expert to be given, or to accept, instructions not to reach agreement. If, at a meeting directed by the Court, the experts cannot reach agreement about matters of expert opinion, they should specify their reasons for being unable to do so.

J L B ALLSOP
Chief Justice
4 June 2013

Appendix C: Curriculum Vitae of Dr Rohan Sadler

Rohan Sadler

Curriculum Vitae

Profile

Rohan is a professional statistician who is involved in data science, remote sensing, and resource economics with a broad range of clients. With a strong background in the agricultural and environmental domains he has been developing the ecoinformatics capacity of organisations to deliver workflow improvement, data governance, analytics and evidence-based evaluation of management effectiveness.

Education

2006 **PhD**, *The University of Western Australia*, Perth.
Image-based Modelling of Pattern Dynamics in a Semiarid Grassland of the Pilbara, Australia

1993 **B.Sc.Agric.**, *The University of Western Australia*, Perth.

2014- **Diploma of Information Technology**, *TAFE NSW*, Online.

Experience

Vocational

2016- **Director, Data Scientist**, *Pink Lake Analytics*, Perth.

- Water potential profiles of native seed germination success (Botanic Gardens and Parks Authority, Western Australia).

2015–2016 **Free Lance Data Scientist**, *Bush Futures*, Perth.

- Empirical testing of theoretical capital asset pricing models and portfolio optimisation (Economic Regulatory Authority of Western Australia, Western Australia).
- Cleaning, shaping, databasing and analysis of 30+ years of mammal trapping data for the Otways Region (subcontracted through Barbara Wilson on behalf of Department of Environment, Land, Water and Planning, Victoria).
- Heat mapping of availablility of mental health services in Perth (Ray Dunne Public Relations, Western Australia).

2012-2015 **Senior Scientist**, *Astron*, Perth.

- Data Team Leader (Emergency Oil Spill Response for various Oil and Gas clients).
- Initiated data governance and workflow development within Astron.
- Innovated lidar assessments of landform change, and multispectral assessments of vegetation impacts of altered surface water flows and groundwater abstraction for WA's resource industry.
- Built Astron's remote sensing capacity and team, spanning various platforms and sensors, including product development and delivering client projects both in and outside of Australia.
- Statistical project support and population modelling for various clients.

2010-2012 **Research Assistant Professor**, *The University of Western Australia*, Perth.
Cooperative Research Centre for Plant Biosecurity

- Research and development evaluation
- Pest Management Area strategy optimisation

2007-2009 **Post-Doc**, *The University of Western Australia*, Perth.
Design of conservation contracts (DAFF, Market Based Instruments)
Fire behaviour in rehabilitated open forest (ARC Linkage with Worsley Alumina).

2005-2010 **Casual Lecturing and Tutoring**, *The University of Western Australia*, Perth.
Statistics, Decision Tools, GIS

Postgraduate Supervision

2014- **Thayse Nery de Figueiredo**, *PhD Thesis*, UWA, in progress.
Optimal land-use change to increase water quality, quantity and biodiversity outcomes

2014- **Maria Solis Aulestia**, *PhD Thesis*, UWA, in progress.
Land use dynamics in the Chure region of Nepal.

2012 **Hoda Abougamous**, *PhD Thesis*, UWA, complete.
An economic analysis of surveillance and quality assurance as strategies to maintain grain market access.

2011 **Bernard Phillimon**, *Masters Thesis*, UWA, complete.
Assessment of bushfire risk through remote sensing.

Professional Affiliations

Accredited Statistician (AStat), Statistical Society of Australia.

Adjunct Senior Lecturer, School of Agricultural and Resource Economics, The Univeristy of Western Australia.

Member, The Institute of Analytics Professionals of Australia (IAPA).

Professional Contributions

2014 **Member**, Statistical Society of Australia
Training Committee, National Branch.

2010 **Chairman**, Statistical Society of Australia
Branch Committee, Western Australia.

2008-2009 **Member**, Statistical Society of Australia Incorporated, WA Branch Committee.

Awards

2013 **Innovation Award**, Astron Environmental Services.
2012 **Best Paper**, Australian Journal of Agricultural and Resource Economics

Key Projects

Environmental Policy.

- Agent-based modelling of saline water table management, Katanning catchment (DAFF)
- Agricultural Land Retirement as an Environmental Policy (LWA)
- Auctions for Landscape Recovery Under Uncertainty (DAFF)

Pest Management.

- Optimal Investment in Research and Development for Plant Biosecurity (CRC Biosecurity)
- Long Term Weed Management on Barrow Island (Gorgon)
- Leggadina and Mus Population Dynamics on Thevenard Island (Chevron)
- Aerial Survey of Feral Animals, Fortescue Marsh (DPAW)

Data Management.

- Otways Long Term Fauna Trapping Data (Parks Victoria)
- Scientific Monitoring for Oil Spill Response (Apache, ROC, VOGA)
- Data Governance: Strategy, Policy and Standards (Astron)
- Optimal Seed Farm Design (BGPA, Saudi Arabia)

Fauna Monitoring.

- Thevenard Island Mouse (Chevron)
- Northern Quoll (Polaris)
- Macropod Population Viability Analysis (Gorgon)

Remote Sensing.

- Remote Sensing of Pre- and Post- Fuel Loads (Worsley)
- Landform Change Detection (Gorgon)
- Vegetation Impacts of Seismic Surveys (Gorgon)
- Vegetation Mapping (RTTI, India)
- Groundwater Drawdown Impacts on Vegetation (BHPBIO)
- Surface Water Flow Impacts on Vegetation (FMG)

Key Products

ePower Toolbox, *BMT Oceanica, Australian Institute of Marine Science, QUT*. Provides power analysis and cost-response curves for the optimal design of beyond BACI (before-after-control-impact) studies.

Landform Change Analysis, *Astron*.
Provides an error budget for identification of statistically significant areas of landform change from LiDAR and photogrammetric DEM (digital elevation model) change assessment.

Vegetation Impacts of Groundwater and Surface Flow Alteration, *Astron*.
Identifies vegetation areas at greatest impact of groundwater drawdown or surface flow modification, as observed from time series of remote sensed imagery.

Peer Reviewed Publications

Matthias M Boer, Paul Johnston, and Rohan J Sadler, *Neighbourhood rules make or break spatial scale invariance in a classic model of contagious disturbance*, Ecological Complexity **8** (2011), no. 4, 347–356.

Matthias M Boer, Craig Macfarlane, Jaymie Norris, Rohan J Sadler, Jeremy Wallace, and Pauline F Grierson, *Mapping burned areas and burn severity patterns in SW Australian eucalypt forest using remotely-sensed changes in leaf area index*, Remote Sensing of Environment **112** (2008), no. 12, 4358–4369.

Matthias M Boer, Rohan J Sadler, Ross A Bradstock, A Malcolm Gill, and Pauline F Grierson, *Spatial scale invariance of southern Australian forest fires mirrors the scaling behaviour of fire-driving weather events*, Landscape Ecology **23** (2008), no. 8, 899–913.

Matthias M Boer, Rohan J Sadler, Roy S Wittkuhn, Lachlan McCaw, and Pauline F Grierson, *Long-term impacts of prescribed burning on regional extent and incidence of wildfires—evidence from 50 years of active fire management in SW Australian forests*, Forest Ecology and Management **259** (2009), no. 1, 132–142.

Kerryn A Chia, John M Koch, Rohan J Sadler, and Shane R Turner, *Developmental phenology of Persoonia longifolia (Proteaceae) and the impact of fire on these events*, Australian Journal of Botany **63** (2015), no. 5, 415–425.

_____ , *Establishing Persoonia longifolia (Proteaceae) in restored jarrah forest following bauxite mining in southern Western Australia*, Restoration Ecology (2016) *In press*.

Kerryn A Chia, Rohan J Sadler, Shane R Turner, and Carol C Baskin, *Seasonal con- ditions required for dormancy break of Persoonia longifolia (Protecaeae), a species with a woody indehiscent endocarp*, Annals of Botany (2016). *In press.*

Veronique Florec, Rohan J Sadler, Ben White, and Bernie C Dominiak, *Choosing the battles: The economics of area wide pest management for Queensland fruit fly*, Food Policy **38** (2013), 203–213.

James J Fogarty and Rohan Sadler, *To save or savour: A review of approaches for measuring wine as an investment*, Journal of Wine Economics **9** (2014), no. 03, 225–48.

Aaron D Gove, Rohan Sadler, Mamoru Matsuki, Robert Archibald, Stuart Pearse, and Mark Garkaklis, *Control charts for improved decisions in environmental management: a case study of catchment water supply in south-west Western Australia*, Ecological Management & Restoration **14** (2013), no. 2, 127–134.

Gavan S McGrath, Rohan Sadler, Kevin Fleming, Paul Tregoning, Christoph Hinz, and Erik J Veneklaas, *Tropical cyclones and the ecohydrology of Australia's recent continental-scale drought*, Geophysical Research Letters **39** (2012), no. 3, n/a–n/a.

Ram Pandit, Maksym Polyakov, and Rohan Sadler, *Valuing public and private urban tree canopy cover*, Australian Journal of Agricultural and Resource Economics **58** (2014), no. 3, 453–470.

Hazel R Parry, Rohan J Sadler, and Darren J Kriticos, *Practical guidelines for modelling post-entry spread in invasion ecology: Advancing risk assessment models to address climate change, economics and uncertainty.* NeoBiota **18** (2013), 41–66.

Deanna P Rokich, Jack Harma, Shane R Turner, Rohan J Sadler, and Beng H Tan, *Fluazifop-p-butyl herbicide: Implications for germination, emergence and growth of Australian plant species*, Biological Conservation **142** (2009), no. 4, 850–869.

Rohan J Sadler, Veronique Florec, Ben White, and Bernie C Dominiak, *Calibrating a jump-diffusion model of an endemic invasive: Metamodels, statistics and qfly*, 19th International Congress on Modelling and Simulation, Perth, Australia, 2011, pp. 12–16.

Rohan J Sadler, Martin Hazelton, Matthias M Boer, and Pauline F Grierson, *Deriving state-and-transition models from an image series of grassland pattern dynamics*, Ecological Modelling **221** (2010), no. 3, 433–444.

Rohan J Sadler, Douglas B Purser, and Susan Baker, *Hay quality and intake by dairy cows 2. Predicting feed intake with consumer demand models*, Animal Production Science (2016). *In press.*

Grezegorz Skrzypek, Rohan J Sadler, and Andrzej Wiśniewski, *Reassessment of recommendations for processing mammal phostphate $\delta^{18}O$ data for paleotemperature reconstruction*, Palaeogeography, Palaeoclimatology, Palaeoecology **446** (2016), 162–67.

Grzegorz Skrzypek and Rohan Sadler, *A strategy for selection of reference materials in stable oxygen isotope analyses of solid materials*, Rapid Communications in Mass Spectrometry **25** (2011), no. 11, 1625.

Grzegorz Skrzypek, Rohan Sadler, and Debajyoti Paul, *Error propagation in normalization of stable isotope data: a Monte Carlo analysis*, Rapid Communications in Mass Spectrometry **24** (2010), no. 18, 2697–2705.

Ben White and Rohan Sadler, *Optimal conservation investment for a biodiversity-rich agricultural landscape*, Australian Journal of Agricultural and Resource Economics **56** (2012), no. 1, 1–21.

Appendix D. Candidate Scopes

Scope 1: Variance of the ZBP Estimator

A key reason to reject DBP's position is the broad evidence that the ZBP estimate that is relied upon possesses high uncertainty. However, the impact of uncertainty in the ZBP estimate on the Black CAPM RoE calculation has not as yet been measured (both with and without abnormal returns). It is important to understand the effect uncertainty in ZBP estimates has on each of the RoE, β and compensation levels under the Black CAPM, given the significant influence of ZBP estimates on compensation levels (see Case Study 1 for an example). Once these effects of uncertainty in ZBP estimates are quantified then the reliability of the ZBP estimate from one assessment period to another may be assessed.

The key method underlying this approach involves Monte Carlo simulation of data within the Black CAPM two-stage estimation process. Note that

$$r_{it} = r_z + \beta_i^B (r_{mt} - r_z)$$

with the ZBR (r_z) given by ZBP + r_z. In the two-pass estimation process then firstly uncertainty in the ZBP estimate is a function of the uncertainty in β estimates during the first pass of the estimation process. Hence, a model can be constructed of the two-pass methodology using:

$$r_{i,t-s} = r_{ft} + \delta_{it}^{FP} + \beta_{it}^{FP}\left(r_{m,t-s} - r_{f,t-s}\right) + \varepsilon_{it}^{FP} \qquad s = 1,2,\dots,S \text{ [101]}$$

$$\hat{\beta}_{it}^{FP} \sim N\left(\beta_{it}^{FP}, Var\left(\beta_{it}^{FP}\right)\right) ;\ \hat{\delta}_{it}^{FB} \sim N\left(\delta_{it}^{FP}, Var\left(\delta_{it}^{FP}\right)\right) \text{ [102]}$$

$$r_{i,t-s} = r_{ft} + \delta_{it}^{SP} + ZBP_t^{SP}\left(1 - \beta_{it}^{FP}\right) + \lambda\left(\beta_{it}^{FP} r_{m,t}\right) + \varepsilon_{it}^{SP} \text{ [103]}$$

$$\widehat{ZBP}_t^{SP} \sim N\left(ZBP_t^{SP}, h\left(Var\left(\beta_{it}^{FP}\right), Var\left(\delta_{it}^{SP}\right), Var(\lambda)\right)\right)$$

where FP and SP refer to first-pass and second-pass estimation steps; $\delta_{it}^{:}$ is the abnormal return over and above the risk-free rate (together they can be modelled as a single intercept term, as occurs in the Henry model); and h is some function of the multivariate co-variance of the parameter estimators in the second pass of the equation. Note that the variance of the estimators of the parameters in each pass of the equation are dependent on the variance of the residuals. Implicitly, realisations of $Var\left(\beta_{it}^{FP}\right)$ is dependent on the covariance between β_{it}^{FP} and δ_{it}^{FP}. If the residual variance is high, which it most likely will be, then variance of the estimators will also be high. Here the risk-free rate is taken to be known *ex post*.

In practice $\widehat{ZBP}_t^{SP}$ is returned to provide a single mean or annualised estimate of the ZBP. The standard error of ZBP is therefore readily calculable from the $\widehat{ZBP}_t^{SP}$. We would use here the single portfolio

[101] S is taken to be five years, composed of monthly intervals. NERA Economic Consulting, *Estimates of the Zero-Beta Premium, A report for the Energy Networks Association,* June 2013, Equation A.2, p. 41.

[102] Alternatively, these parameters from the first-pass estimation may be specified together as a multivariate normal distribution.

[103] SFG Consulting, *Cost of equity in the Black Capital Asset Pricing Model*, *Report for Jemena Gas Networks, ActewAGL, Networks NSW, Transend, Ergon and SA Power Networks*, 22 May 2014, Section 100, p. 27.

method which allows a bias correction of the $\widehat{ZBP}_t^{SP}$ estimates[104]. The variance of the bias-corrected ZBP is itself dependent on the variance of the parameters of both the first-pass and second-pass estimations. It is these variance components that are propagated and accumulated through each pass of the estimation procedure into the estimation of β_i^B. In contrast, the SL CAPM depends only on variability embodied in the data, given the standard assumptions of the linear regression model.

What is not considered within this scope is the sensitivity of the ZBP estimate to model form and data processing methods (i.e., a wide range of decision parameters in the formation of the ZBP estimate). Instead, differences in ZBP estimates will be studied in relation to:

- Inclusion of δ_{it}^{FP} and/or δ_{it}^{SP}.
- weekly or monthly data, with S = 261 weeks or 60 months, respectively (i.e., 5 years).
- calculated over 5 years or 20 years, as specified in the Rate of Return Guidelines.
- λ constrained to a value of one or unconstrained.

These scenarios will be compared with equivalent SL CAPM models to compare uncertainty in RoE estimates with those resulting from applying the ZBP estimate under the Black CAPM.

With autocorrelation in the data known to be low then a Monte Carlo solution may proceed by simulating from the multivariate normal distributions specified above. Moreover, stationarity of the ZBP estimate may also be considered for the five year data by applying rolling windows.

Also included in this scope is the need to deal with the criticism raised by HoustonKemp (2016) of the way in which daily price data was processed by the Authority in its Draft Decision[105]:

> *We have examined the ERA's code and found a number of problems with the way in which the regulator assembles its data that are sufficiently serious as to cast doubt on the reliability of the ERA's results.*
> *First, the ERA incorrectly computes the returns to stocks on the days immediately following ex-dividend days. The ERA incorrectly presumes that a purchaser of a share of stock on the ex-dividend day will pay the sum of the price at the close of business and the dividend distributed.*
> *Second, there is no sign in the ERA's code that it takes steps to ensure that dividends and prices are denominated in the same currency. We show that when dividends and prices are denominated in different currencies that returns can be very badly mismeasured.*
> *Third, the ERA selects stocks based on whether they are currently members of the All Ordinaries and so, because membership of the All Ordinaries is determined by market capitalisation, on their current market capitalisations. So the ERA has selected a set of stocks that are known to have performed well on average.*
> *Stocks that over the last five years or 20 years have performed well will be more likely, all else constant, than stocks that have performed badly over the last five years or 20 years to be current members of the All Ordinaries. It is likely, therefore, that the ERA's results suffer from survivorship bias.*
> *Fourth, rather than setting the return to a stock on a day when it does not trade – or over a week or a month when it does not trade – to missing, the ERA sets the return to zero if a price has previously been recorded.*

[104] NERA Economic Consulting, *Estimates of the Zero-Beta Premium, A report for the Energy Networks Association,* June 2013, Equation A.5, p. 42.
[104] HoustonKemp Economists, *The Black CAPM: Response to the ERA's Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2010, A Report for DBP,* February 2016, Appendix H, p. vii.

Treating missing returns as zero returns can lead to estimates of the beta of a stock that are biased towards zero.

These data processing issues will need to be resolved before proceeding with the scope. An initial opinion is that the above changes are readily implemented, and the impact these data processing issues have had on values of $\hat{\beta}$ may be readily quantified. The third criticism with regard to the currency of constituents is perhaps the more important in terms of introducing bias into estimates of β. However, upon review it appears that DBP's processing of their data is subject to a similar bias, and no action on this issue should be taken at this point in time.

Deliverables

This scope will therefore be designed to:

1. Resolve the four HoustonKemp (2016) criticisms of the Authority's data processing method, and assess impact of changes to the Final Decision.
2. Develop a Monte Carlo procedure to provide a variance estimate of the ZBP, ZBR and ZBP/MRP estimates, both with and without abnormal returns.
3. Estimate the variance in RoE and β as impacted by the variance of the ZBP estimator under the Black CAPM, and compare this to the SL CAPM.
4. Consequently, evaluate the robustness of the Black CAPM and SL CAPM in terms of meeting the requirements of the allowed rate of return objective.
5. At most, deliver a 20 page report demonstrating both rationale and results, excluding administrative documentation such as Curriculum Vitae and Terms of Reference.

Time and Cost

Scope Activities	**Hours**	**Cost ($120/hr)**
1. Monte Carlo simulation of ZBP Variance Estimates	32	$3,840
2. Sensitivity analysis of RoE and β for Black and SL CAPM	24	$2,880
3. Improving data processing	16	$1,920
4. Deliver Report	96	$11,520
Total	**168**	**$20,160**

The scope and costs are negotiable. Costs exclude GST.

Personnel

Rohan Sadler is an AStat accredited statistician with 8+ years of research and consulting experience for industry and government at state and national levels, primarily in the domains of environmental monitoring, resource economics, data management and remote sensing. A Curriculum Vitae for Rohan is included in Appendix C.

Scope 2: Development of a Code Repository

Each of the different submissions following the Rate of Return Guidelines has been accompanied by programmable code. In effect, this code describes how the Authority and each Proponent and Consultant have arrived at their results. Moreover, this code base is evolving. For example, the Authority has significantly expanded its code base to several thousand lines of R code since the Rate of Return Guidelines were released. The code base will expand further both in response to criticisms, such as those put forward recently by HoustonKemp (2016)[106], and to resolving key uncertainties, as in quantifying the impact that variance in ZBP estimates have on estimates of β, and consequently the level of compensation above the risk-free rate that is paid in the RoE calculation (as in Scope 1).

A code repository provides both easy access to relevant code and a version control system, thereby supporting the work of multiple developers of the code base. It will allow all of the Authority's code to be stored in a central location, and will document the historical record of changes made to the database while attributing those changes to specific users (within the Authority and between Proponents and Consultants). The code repository can be accompanied by a wiki that documents how the repository may be accessed and updated by users with the Authority, and how the repository is to be maintained by the Authority's IT staff.

Recommended is a Mercurial repository supported by a TRAC (or other) content management system. Code within the repository can be delivered through a web browser, and will require a virtual machine set up on the Authority's infrastructure. Mercurial is also supported by the TortoiseHg client supporting a ready-to-use GUI in Microsoft Windows. The software is free and allows for distributed revision (i.e., allowing to developers to work on code offline before re-integration into the code base). Mercurial allows different levels of access to different users.

In future, a 'published' version of the code base associated with each of the Authority's decisions may be released into the public domain, in much the same way as each of the Authority's reports may be published. As is experienced elsewhere in the develop community this sharing of code will likely lead to better communication among the different actors in the market, and convergence of the code base over time as issues are resolved in common to deliver an authoritative means of evaluating the RoE.

Deliverables

1. Institute a private code repository for the Authority using Mercurial.
2. Ingest all currently available code as is.
3. Provide online documentation for the Authority's staff to access and update code within the code repository and supporting content management system.
4. Provide online documentation for the Authority's IT staff to administrate and provide ongoing maintenance of the code repository. This includes enabling the IT staff to publish a portion of the repository publically through an on-line service when required.
5. Provide training materials and a 2-4 hour workshop for relevant staff in the use of the code repository.

[106] HoustonKemp Economists, *The Black CAPM: Response to the ERA's Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2010, A Report for DBP,* February 2016, Appendix H, p. vii.

Time and Cost

Scope Item	Hours	Cost ($120/hr)
1. Institute a code repository	16	$1,920
2. Training in use of a code repository	16	$1,920
Total	**32**	**$3,840**

Institution of the code repository will require support of the Authority's IT staff to get the private code repository server routed and running. This scope does not include the purchase of an on-line service for the public release of portions of the code base, only support for the Authority's IT staff when required to mirror the private repository on a public repository.

The scope and costs are negotiable. Costs exclude GST.

Personnel

Rohan Sadler is an AStat accredited statistician with 8+ years of research and consulting experience for industry and government at state and national levels, primarily in the domains of environmental monitoring, resource economics, data management and remote sensing. A Curriculum Vitae for Rohan is included in Appendix C.

Appendix E. Comments on Cross-Validation and the Model Adequacy Test

140. Given that market returns exhibit low autocorrelation,[107] it follows that leave-one-out or k-fold cross-validation may viably be applied. Importantly, each of the cross-validation methods, apart from a small level of sampling 'noise' appear to differentiate the different models similarly (i.e., the SL-CAPM that ESQUANT implement has an approximately 0.1, or 0.2%, greater prediction error). From a 'power to discriminate' point of view the different cross-validation methods appear to perform similarly, despite differences in the estimated prediction error.[108]
141. ESQUANT (2016) make the case that longer term forecasts are more relevant than shorter term forecasts. However, for purposes of model validation it is not necessary to aggregate the daily, weekly or monthly data. In this scenario issues of autocorrelation in aggregate measures are unlikely to arise, and hence leave-one-out and k-fold cross-validation remain viable methods.
142. ESQUANT (2016) also note that variance of the prediction is much greater than the bias. Hence, variance in the predictions should be given weight in assessing the accuracy of each model.
143. However, a leave-one-out strategy may be approximated by the rapid computation of the generalised cross-validation (GCV) statistic. Hence a leave-one-out strategy may be considered a viable alternative to the overlapping time series cross-validation when the overlapping time series cross-validation starts to become computationally infeasible (e.g., when using daily time series rather than monthly time series of data). In this instance, the autocorrelation of the time series should be tested, and if negligible then GCV estimate of the prediction error should provide reasonable discrimination between different proposed models, akin to that of the time series cross-validation.
144. The overlapping time series cross-validation would be seen as preferable to a blocked time series cross-validation for longer forecasts as it generates more predictions. The benefit of a greater number of predictions is a reduction in sampling bias to provide a more accurate estimate of the cross-validation prediction error. An improved estimate of the cross-validation prediction error obviates the need for a long-term time series, which is the main advantage of the SPPR database over the Bloomberg database, for purposes of model validation.
145. The question then remains of why one would apply cross-validation measures of prediction error over and above the proposed model adequacy test. As DBP claim, the model adequacy test they propose is not "*nonsense*",[109] for many of the reasons described by DAA (2016), especially as the forecast generating mechanism is essentially the same as that for time series cross-validation (note that nowhere in its reporting has the Authority referred to the model adequacy test as "*nonsense*").

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[107] ERA, *Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020, Appendix 4 Rate of Return,* 22 December 2015, Section 886, p. 192.
Data Analysis Australia, *Review of Statistical Aspects of Capital Asset Pricing Model*, February 2016, Appendix K, Section 56 (d), p. 19.

[108] ESQUANT Statistical Consulting, *Review of ERA Cross-Validation Approach, A report prepared for DBP*, 24 February 2016, Appendix I, Tables 1-3, pp. 26-27.

[109] DBNGP Transmission Pty Ltd, *Proposed Revisions DBNGP Access Arrangement, 2016 – 2020 Access Arrangement Period Supporting Submission: 56*, 24 February 2016, Section 5.14(g), p. 26.

146. Resoundingly though DBP have not provided any direct reference for their test in the extant literature, whereas a number of references both advocating and critiquing different cross-validation methods for time series may readily be sourced. This still doesn't mean that the model adequacy test is "*nonsense*", just that their test does not appear to be common practice in the time-series literature where Diebold-Mariano tests[110] are popularised.
147. The position of DAA (2016)[111] in rejecting the Mincer-Zarnowitz test should be considered as correct, especially as cross-validation can be used to estimate both bias and variance in predictions of the model (although it requires greater computational effort which for practical reasons may be unwarranted).
148. HoustonKemp (2016) make the following claim:[112]

> *This problem is sometimes referred to as the problem of making multiple comparisons. When the 10 tests are not independent of one another, the probability that one will reject the null hypothesis at least once can be even higher.*
> *A Wald test of the joint hypothesis that each of 10 null hypotheses is simultaneously true, on the other hand, will not suffer from this problem. This is because the test examines simultaneously whether each of the 10 hypotheses are true rather than considering the hypotheses one at a time. In addition, the test takes into account that the 10 tests, were they to be conducted separately, might not be independent of one another.*

While technically true, the relevant perspective is one where there are 10 portfolios, to which a single model has been applied. Moreover, when Wald tests are applied in this case then the multiple comparison problem comes down to comparing multiple models. In this instance 12 models are presented, and 24 Wald test statistics are reported.[113] Within a Wald test there is technically no multiple comparison issue. Between multiple Wald tests there is highly likely a multiple comparison issue.

149. DAA (2016)[114] have clarified that the t-statistics are essentially used for scoring which portfolios are producing closer fitting predictions, rather than being used to represent individual t-tests *per se*. Consequently, it is quite correct to say that the multiple comparison issue does not reside with the t-test statistics.
150. The last couple of points illustrate that the main concern of DBP is to validate only a small handful of models, and for which their model adequacy test may be reasonably acceptable although unusual. Term this the 'Proponent's model validation problem'.
151. The Authority's concern is somewhat different. It is confronted by the fact that there are multiple ways in which a Black CAPM and an SL CAPM may be specified. For example, to include as SFG (2014) have done an abnormal return in their second pass estimation of the ZBP. Other issues relate to how data are processed (e.g., daily, weekly or monthly data), and how autocorrelation and other breaches of standard modelling assumptions are dealt with (e.g., to employ robust models or models that explicitly model autocorrelation and/or

[110] Diebold, F. and R. Mariano, "Comparative predictive accuracy", *Journal of Business and Economic Statistics*, 1995, pp. 253-263.
[111] Data Analysis Australia, *Review of Statistical Aspects of Capital Asset Pricing Model*, February 2016, Appendix K, Section 73(c), p. 31.
[112] HoustonKemp Economists, *Evaluating Forecasts: Response to the ERA's Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020, A Report for DBP,* February 2016, Appendix G, Section 2.3, p. 6.
[113] Data Analysis Australia, *Review of Statistical Aspects of Capital Asset Pricing Model*, February 2016, Appendix K, Table 7, p. 25.
[114] Data Analysis Australia, *Review of Statistical Aspects of Capital Asset Pricing Model*, February 2016, Appendix K, Section 70(a), p. 31.

volatility). The Authority's decision space is much larger than that of a Proponent, and may be termed the 'Regulator's model validation problem'.

152. It does not take too much imagination to see that while a model adequacy test may serve the interests of a Proponent in their model validation problem, it is not optimal for navigation of the Regulator's model validation problem.
153. First of all, as a thought experiment, one can consider the space of all models that have been considered in the Submissions and the Draft Decision to date. Counting loosely there are:
    a. Twelve possible CAPM models to consider[115] (excluding Fama French, ICAPM and other CAPM variants).
    b. Six possible methods of dealing with breaches of standard linear regression assumptions[116] (OLS, LAD, MM, T-S, ARIMAX, and GARCH; and excluding multiple possible GARCH formulations).
    c. Ten or more possible decision parameters regarding how data are shaped and how a CAPM model is to be applied to the data.[117]
    d. Each of the decision parameters may take on multiple values, so for simplicity's sake say there are three possible values for each decision parameters.
154. At a bare minimum there are then 2,160 combined data/model variants to be considered, and at least 180 times more combined data/model variants to consider when resolving Regulator's problem than in the Proponent's problem.
155. From this, the Regulator will likely have regard to different data/model variants, and will then determine an approach which best satisfies the requirements of ARORO. Such an exercise therefore involve multiple decision parameters for consideration.
156. In order to resolve the Regulator's problem of determining an approach which best meets the ARORO, a cross-validation approach is more desirable as compared to the model adequacy test. As DAA (2016) highlight: *"a mathematically more complex situation where the absence of practical analytic methods means that cross validation is appropriate"*.[118] A number of such complex situations, particularly in relation to the decision parameters and in the high variance of the ZBP estimator, are present in the difference in position between the Authority and DBP. While DBP may claim that the Regulator's problem is not their concern, they have not considered in depth the issues concerning estimation of the ZBP, and the implications of the consequent uncertainty on the level of compensation to be paid as a proportion of the abnormal returns above systemic risk extant in the data.
157. The difference in the respective positions, and whether the Authority's position is accepted or not, ultimately is an economic question of accepting or rejecting abnormal returns in the RoE valuation, and hence is outside the scope and expertise of this consultancy. From a statistical perspective explicit inclusion of abnormal returns (i.e., a free-intercept term), is preferred as good practice during the estimation of both CAPM models, as inclusion of abnormal returns improves model fit and reduces bias in the resulting parameter estimates.

[115] Data Analysis Australia, *Review of Statistical Aspects of Capital Asset Pricing Model*, February 2016, Appendix K, Table 7, p. 25.

[116] ERA, *Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020, Appendix 4 Rate of Return,* 22 December 2015*,* Table 27, p. 192.

[117] ERA, *Draft Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020, Appendix 4 Rate of Return,* 22 December 2015*,* Section 855, p. 184.

[118] Data Analysis Australia, *Review of Statistical Aspects of Capital Asset Pricing Model*, February 2016, Appendix K, Section 75(e), p. 32. This is also the reason why AIC is useful mainly when comparing well-defined models (i.e., ones were the likelihood is readily computed), as stated in section 75(d), but is generally less applicable to 'tuning' issues involved with data shaping to which cross-validation is more suited.