Estimation of the Market Risk Premium

A review of weighting of arithmetic and geometric means

Report to the ERA on Gas Rate of Return Guidelines

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Client:

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Executive Summary

The Economic Regulation Authority (ERA) is currently reviewing the gas rate of return guidelines (the guidelines). The ERA first published the guidelines on 16 December 2013. They detail the methods the ERA intended to use to estimate the allowed rate of return for gas transmission and distribution services providers. The National Gas Rules require the ERA to review the guidelines periodically, this being the reason for the current review.

The ERA currently applies both the Ibbotson and Wright approaches to estimate upper and lower bounds on the market risk premium (MRP). The Ibbotson approach considered in this report uses the concept of a long-run average market risk premium as today's best estimate of the future market risk premium.

As part of the Western Power AA4 process, Western Power has provided the ERA with a report from its consultant, HoustonKemp Economics (HoustonKemp), titled *'A Constructive Review of the ERA's Approach to the MRP'* - that is, the market risk premium. HoustonKemp's report questions the ERA's historical approach, and proposes that, if historical average returns are used, they should be the arithmetic rather than geometric average. Moreover, HoustonKemp propose an MRP estimate of 6.77%, based on a minimum standard error criterion for the MRP arithmetic estimate. This criterion selects only the 1883-2016 data scenario, while dismissing the 1937-2016, 1958-2016, 1980-2016 and 1988-2016 data scenarios that each provide markedly lower MRP estimates. This proposed MRP forward estimate is 1.37% higher than the 5.40% determined for DBP in June 2016.

The difference in position between what HoustonKemp have proposed and that of the Authority hinges on whether the arithmetic sample mean return should be compounded or not. This issue is readily resolved - if the Authority considers that market participants operate over a longer-period investment horizon (as articulated by Partington and Satchell, titled "*Advice to the AER on Cost of Equity Issues in 2016 Electricity and Gas Determinations"*) then a weighted mixture of the arithmetic and geometric means should be applied. However, if the Authority considers the investment horizon of rational market participants to be a single period then the HoustonKemp proposal of the arithmetic mean alone should be applied.

Importantly, a review of the different positions suggests that a 50/50 weighting of the arithmetic and geometric means to form the forward looking MRP estimate can be justified if the investment horizon is long-term. An efficient shrinkage estimator that minimizes the predictive accuracy of cumulative returns will weigh the geometric estimator more heavily than an unbiased estimator, based on a log-normal distribution of returns. From a purely statistical perspective the efficient estimator is to be preferred over the unbiased estimator, so as to minimise overall forecast error, given cumulative returns are in effect being forecasted. Moreover, the data scenario relevant to current market conditions is likely to be shorter than the 1883-2016 scenario proposed by HoustonKemp, due to the risk of structural breaks in the data series, arising from either impaired data quality despite the adjustment of pre-1958 data, or some structural change in the market. Any structural break in the data series also increases the weighting for the geometric mean within an efficient estimator of the MRP. Under these conditions, the optimal weighting for the geometric mean to minimise forecast cumulative returns under a log-normal assumption has been demonstrated to be as high as 80% for a 10-year investment horizon, and 40% for a 5-year investment horizon.

Tentatively, it is advised that an investment horizon be explicitly defined by the Authority when constructing the MRP forecast. This investment horizon will then inform the Authority of an appropriate weighting for the geometric mean. Under the log-normal assumption this weighting may be directly calculated from the horizon of the forecast. This distributional assumption is likely incorrect in practice as the asset return data are likely heavy-tailed, making direct calculation of the appropriate weighting infeasible. Hence, the Authority's fallback 'equanimous' position of a 50/50 weighting of the arithmetic and geometric means may be retained until better information is acquired as to the distributional nature of the returns.

The Authority will be wedded to a compromise strategy that weights the lowest arithmetic mean and the highest geometric mean if it is committed to utilizing five data scenarios rather than a single, authoritative data scenario. This strategy does not return an unbiased or efficient estimate of the forward looking MRP, as HoustonKemp correctly argue. However, due to a positive correlation between geometric and arithmetic means across the different data scenarios then the alternative proposed by HoustonKemp of selecting only the 1883-2016 data scenario risks introducing significant upward bias to forecast cumulative returns. Indeed, there are arguable grounds for dismissing the 1883-2016 data scenario altogether through application of a 'consistency of data method' criterion. Until one data scenario may be clearly proven to be superior to another then it is advisable that the Authority retains its compromise strategy when averaging across the five data scenarios. Moreover, if the data prior to 1958 are retained then an 'equanimous' position of weighting the BHM and NERA estimates equally should also be retained, given the data prior to 1958 are uncertain in nature.

Terms of Reference

1. Pink Lake Analytics was invited by the Authority to provide an evaluation and opinion of the different methods that may be applied in estimating the future market risk premium (MRP) under the Ibbotson approach. The conclusions of this report will inform the Authority in its review of the gas rate of return guidelines. The scope for this study is set out in Appendix A of this report.

2. As such, the following Appendices in support of the Submission have been reviewed:

   - HoustonKemp Economics – *A Constructive Review of the ERA's Approach to the Market Risk Premium* – October 2017 – (pp.4-13) (Attachment 1)
   - Australian Energy Regulator – *Final Decision: Jemena distribution determination 2016 to 2020* – May 2016 – (pp.3-216-3-220) (Attachment 2)
   - G. Partington and S. Satchell – *Advice to the AER on cost of equity issues in 2016 electricity and gas determinations* – April 2016 – (pp.51-52) (Attachment 3)
   - HoustonKemp Economics – *The Cost of Equity: Response to the AER's Draft Decisions for the Victorian Electricity Distributors, ActewAGL Distribution and Australian Gas Networks* – January 2016 – (pp.xi-xiii) (Attachment 4)
   - NERA – *Attachment M15_NERA: Further Assessment of the Historical MRP: Response to the AER's Final Decisions for the NSW and ACT Electricity Distributors* – June 2015 – (pp.iv-vi and pp.14-28) (Attachment 5)
   - Dr. Martin Lally – *The cost of equity and the market risk premium* – July 2012 – (pp.31-32) (Attachment 6)

3. The outcomes of this work are two-fold:

   - The first outcome is an evaluation of the arguments put forward in the above documents, and so address the type of mean (arithmetic or geometric) that should be used to calculate the market risk premium.
   - The second outcome is the provision of an opinion as to the type of mean the ERA should use when calculating the market risk premium using the Ibbotson method. This finding should be informed by the evaluation performed for the first task, and should address:
     - whether there is a clear case for using either the arithmetic mean or the geometric mean, or whether it is more appropriate to continue to use a simple average of the arithmetic mean and the geometric mean; and
     - if it is more appropriate to use a simple average of the arithmetic mean and the geometric mean, whether it should be calculated using the *lowest arithmetic mean* and the *highest geometric mean*, or whether there is an alternative calculation method that may be more appropriate.

Declaration

4. This report has been prepared by Rohan Sadler of Pink Lake Analytics Pty Ltd.

5. 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.

6. A curriculum vitae for the consultant has been provided as Appendix C.

Introduction

7. The Economic Regulation Authority (ERA) is currently reviewing the gas rate of return guidelines (the guidelines). The ERA first published the guidelines on 16 December 2013. They detail the methods the ERA intended to use to estimate the allowed rate of return for gas transmission and distribution services providers. The National Gas Rules require the ERA to review the guidelines periodically, this being the reason for the current review.

8. The ERA currently applies both the Ibbotson and Wright approaches to estimate upper and lower bounds on the market risk premium (MRP). The Ibbotson approach considered in this report uses the concept of a long-run average market risk premium as today's best estimate of the future market risk premium. The Authority's method for the Ibbotson approach applies an on-the-day risk-free rate to arrive at an on-the-day estimate of the market return on equity, rather than the historical risk-free rate.

9. The ERA is also working on the fourth Western Power access arrangement (AA4). The weighted average cost of capital (WACC) is a significant component of Western Power AA4, and some of the issues arising from Western Power AA4 are also relevant to the ERA's review of the guidelines.

10. However, there are mixed views as to the best averaging technique to apply to the set of yield estimates. In past decisions, the ERA has concluded that an arithmetic average will tend to overstate returns, whereas a geometric average will tend to understate them, and so has selected a point estimator that is the simple average of the lowest arithmetic mean and the highest geometric mean across five different data scenarios.

Review of the documents under consideration

HoustonKemp Economics – A Constructive Review of the ERA's Approach to the Market Risk Premium, October 2017, pp. 4-13.

11. HoustonKemp raise several key issues in their report. Firstly, estimates of the historical MRP differ depending on the correction applied to Lamberton's yield data. Table 3[1] contrasts the MRP estimates from data with yield adjustments based on either BHM or NERA.[2] The NERA estimates are argued to be better than the BHM estimates. Consequently, when the Authority's methodology of averaging the lowest arithmetic mean and the highest geometric mean over the five scenarios is applied then the MRP estimate increases with the NERA adjustment. The MRP estimate in this case increases from 5.50% to 5.59%, based on the 2016 revised estimates.[3] This

[1] HoustonKemp Economics, "A Constructive Review of the ERA's Approach to the Market Risk Premium", October 2017, p 5.

[2] Brailsford, T., J. Handley and K. Maheswaran, *The historical equity risk premium in Australia: Post-GFC and 128 years of data*, Accounting and Finance, 2012, pp. 237-247.
NERA, "Further Assessment of the Historical MRP: Response to the AER's final decisions for the NSW and ACT electricity distributors", A report for ActewAGL Distribution, AGN, APA, AusNet Services, CitiPower, Energex, Ergon Energy, Jemena Electricity Networks, Powercor, SA Power Networks and United Energy, June 2015.

[3] HoustonKemp Economics, "A Constructive Review of the ERA's Approach to the Market Risk Premium", October 2017, p8.

effect is due to the NERA geometric mean estimate of the MRP being 0.35% higher than that of the BHM estimate for the 1883-2016 scenario.[4]

12. MRP scenarios that include more data will have a lower standard error for the estimate of the arithmetic and geometric means of the historical excess returns than MRP scenarios that consider fewer data (e.g., 1988-2016). Specifically, HoustonKemp state that:

    "Placing a larger weight on more recent observations than on less recent observations might sound like an attractive strategy if the long-run average MRP has shifted substantially over time. There is a large cost, however, associated with placing a larger weight on more recent observations than on less recent observations. Placing a larger weight on more recent observations can substantially lower the precision of the estimates that one produces. So unless one suspects that the long-run average MRP has shifted substantially over time, the costs of placing a larger weight on more recent observations than on less recent observations are likely to exceed the benefits of doing so."[5]

13. An estimate of the MRP that applies the lowest arithmetic mean will be a downwardly biased, whereas the highest geometric mean will be either upwardly or downwardly biased estimate of the long-run average annual MRP.[6] HoustonKemp support this point with a bootstrap simulation centred on the arithmetic mean estimate of the MRP for the 1883-2016 period.

14. An MRP estimator based on the highest geometric mean will also be imprecise as it is likely this geometric mean will be based on a sample that excludes some of the data.[7]

15. The arithmetic mean estimate of the MRP provides an unbiased estimate of the single-period cumulative return, whereas the single-period cumulative return based on the geometric mean is biased.[8] This argument is supported by Appendix 1, which represents mathematically the bias of the different estimators.[9] The argument for a single-period cumulative return is supported by Lally.[10] As such, HoustonKemp argue for the geometric mean to be dismissed.

16. If the geometric mean is dismissed, and data providing the lowest standard error are to be applied, then the arithmetic mean of 6.77% should be applied as the Authority's estimate. This is because this estimate is derived from the longest time series (1883-2016), and NERA's yield adjustment preferred.[11]

17. It is our opinion that these issues may be reduced to three key decisions, namely:
    - The weighting applied to the time-period on which the MRP is based. The Authority applies equal consideration to the five MRP scenarios considered, whereas HoustonKemp propose applying full weight to the 1883-2016 data, and zero weight to the other periods.

[4] First row of Table 3, HoustonKemp Economics, "A Constructive Review of the ERA's Approach to the Market Risk Premium", October 2017, p5.

[5] HoustonKemp Economics, "A Constructive Review of the ERA's Approach to the Market Risk Premium", October 2017, pp. 8-9.

[6] HoustonKemp Economics, "A Constructive Review of the ERA's Approach to the Market Risk Premium", October 2017, p9.

[7] HoustonKemp Economics, "A Constructive Review of the ERA's Approach to the Market Risk Premium", October 2017, p9.

[8] HoustonKemp, "A Constructive Review of the ERA's Approach to the Market Risk Premium", October 2017, p12.

[9] HoustonKemp Economics, "A Constructive Review of the ERA's Approach to the Market Risk Premium", October 2017, Appendix A, p36. Note that the unconditional expectation of the arithmetic mean estimate, forecasted over n periods through compounding will be $E(R(t)^n) = e^{n\left(\mu+\frac{1}{2}n\sigma^2\right)}$, as compared with equation A.5. It is both upwardly biased compared to the 'true' cumulative return, and greater than the cumulative return based on the estimated geometric return, for all n. This last observation is due to the arithmetic mean – geometric mean inequality.

[10] Lally M., "The Cost of Equity and the Market Risk Premium", July 2012, pp.31-32.

[11] HoustonKemp Economics, "A Constructive Review of the ERA's Approach to the Market Risk Premium", October 2017, p13.

- The weighting applied to the BHM and NERA yield adjusted estimates of the MRP. The Authority applies equal weight to each method. HoustonKemp propose to apply full weight to the NERA method, and zero weight to the BHM method. Note that there is a significant difference between the NERA and BHM estimates for the 1883-2016 period only (0.35%), and only slight difference for the 1936-2016 period (-0.06%). There is negligible difference between NERA and BHM estimates for the 1958-2016, 1980-2016 and 1988-2016 periods.
- Whether the decision-making entity considers only the one-period cumulative return, or a cumulative return that compounds the MRP estimate over multiple periods. The Authority may well be considering a longer-term horizon when calculating the cumulative return, as argued for by Partington and Satchell,[12] whereas HoustonKemp argue that this 'forecasting' horizon should only be one year. The consequence of this decision is that if the Authority considers a long-term horizon for the cumulative investment return in its determination then more weight should be applied to the geometric mean estimate of the MRP. However, if only a single-period horizon is considered, as proposed by HoustonKemp, then zero weight should be applied to the geometric mean estimate.

Australian Energy Regulator – Final Decision: Jemena distribution determination 2016 to 2020, May 2016, pp. 3-216-3-220.

18. The AER have relied on an equal weighting of the arithmetic and geometric means in their recent determination on the Jemena network distribution. In so doing they have relied primarily on the advice provided by Partington and Satchell.[13] Much of this section within the determination explains the reasoning of AER in its preference for the position of Partington and Satchell over that of HoustonKemp (and formerly NERA).

19. Importantly, the AER state that:

    "We have previously considered arithmetic and geometric averages relevant when estimating a 10 year forward looking market risk premium using historical annual excess returns. The Tribunal found no error with this approach."[14]

    This clearly states that the forecasting horizon considered by the AER in its determination of the future compounded return, and hence the market risk premium, is 10 years. Note that the definition of a fixed forecasting horizon may be equated with what a regulator considers as appropriate information that a rational market participant would consider when making investment decisions. This reflects a key decision criterion of the Authority when it moved away from a single estimate of MRP towards defining a range of possible future outcomes for the MRP:

[12] G. Partington and S. Satchell, "Advice to the AER on cost of equity issues in 2016 electricity and gas determinations", April 2016, p51-52.
G. Partington and S. Satchell, "Report to the AER: Analysis of criticism of 2015 determinations", October 2015, pp.44-46.
G. Partington and S. Satchell, "Report to the AER: Return of equity and comment on submissions in relation to JGN", May 2015, pp.16-17.

[13] G. Partington and S. Satchell, "Report to the AER: Analysis of criticism of 2015 determinations", October 2015, pp.44-46.
G. Partington and S. Satchell, "Report to the AER: Return of equity and comment on submissions in relation to JGN", pp.16-17.

[14] Australian Energy Regulator, "Final Decision: Jemena distribution determination 2016 to 2020", May 2016, pp.3-216-3-220.

"… its previous long run historical estimate of 6 per cent could be a poor predictor of the MRP prevailing in future regulatory periods. The Authority therefore dropped the fixed estimate of 6 per cent, instead establishing a range of possible future outcomes for the MRP, informed by information that a rational market participant would use in making investment decisions."[15]

G. Partington and S. Satchell – Advice to the AER on cost of equity issues in 2016 electricity and gas determinations, April 2016, pp. 51-52

20. Partington and Satchell state that the *"HoustonKemp analysis is simply irrelevant"*.[16] We believe this assertion is based on Partington and Satchell considering a longer-term forecasting horizon when they refer to the *"geometric rate of return per annum"*,[17] than the single-period forecasting horizon considered by HoustonKemp. If, for example, the forecasting horizon is 10 years for the cumulative return then the analysis of HoustonKemp for the single-period returns is redundant. The principal reason for dismissing the HoustonKemp argument when long-term horizons are considered is that the sampling error implicit in any historical arithmetic mean estimate of returns will provide an upward biased estimate of the cumulative return.

21. That Partington and Satchell consider the investment horizon as long term, over which the cumulative return on an investment is forecast, rather than a single period, is made clear in their statement:

    "NERA (2015, History) makes the point that the AER does not compound its estimate of the rate of return and thus should only consider a single period return. However, the point of setting the regulatory return is to select a rate at which new investment is a zero NPV activity. Underlying the rate setting, therefore, is the concept that the return is compounded."[18]

22. The question is then whether "*a rational market participant"*[19] would apply a long-term or single-period horizon in calculating its cumulative return when making its investment decisions, in keeping with the Authority's articulation of its decision criteria. In our opinion, the answer to this question will resolve whether, as HoustonKemp propose, that only the single-period return should apply given *"Australian regulators never compound an estimate of the weight average cost of capital that uses the arithmetic mean of a sample of returns and so should avoid completely using geometric means"*.[20]

[15] ERA, "Final Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020", Appendix 4 Rate of Return, 30 June 2016, p. 103.

[16] G. Partington and S. Satchell, "Advice to the AER on Cost of Equity Issues in 2016 Electricity and Gas Determinations", April 2016, p52.

[17] G. Partington and S. Satchell, "Report to the AER: Analysis of criticism of 2015 determinations", October 2015, p44.

[18] G. Partington and S. Satchell, "Report to the AER: Analysis of criticism of 2015 determinations", October 2015, p44.

[19] ERA, "Final Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020", Appendix 4 Rate of Return, 30 June 2016, p. 103.

[20] HoustonKemp Economics, "A Constructive Review of the ERA's Approach to the Market Risk Premium", October 2017, p12.

[20] Lally M., "The Cost of Equity and the Market Risk Premium", July 2012, pp. 31-32.
NERA, "The Market Risk Premium", A report for CitiPower, Jemena, Powercor, SP AusNet and United Energy, February 2012, pp. 3-12.

HoustonKemp Economics – The Cost of Equity: Response to the AER's Draft Decisions for the Victorian Electricity Distributors, ActewAGL Distribution and Australian Gas Networks, January 2016, pp. xi-xiii

23. For the most part this report reiterates the arguments made in HoustonKemp (October 2017)[21]. Importantly, this report elaborates its position on Lally (2012). Namely, that:

    "… Lally concludes that an estimate of the WACC is never compounded".[22]

    Moreover, HoustonKemp iterate beforehand that:

    "… while in ensuring the zero-NPV condition is satisfied the unknown discount rate or true WACC will be compounded, the allowed rate applied to the RAB, that is, an estimate of the WACC, will not be compounded"[23]

24. It is our opinion that the above statement contrasts directly with HoustonKemp's subsequent statement based on a previous NERA report:

    "while the utility's true WACC is compounded, the WACC is a parameter and not an estimate. In other words, the true WACC is not a random variable."[24]

    While Australian regulators may "*never compound an estimate of the weight average cost of capital that uses the arithmetic mean"*[25] it is likely that other market actors do when making investment decisions in practice. The question in this case is which entity's perspective is the Authority referring to in its (explicitly stated) decision criteria, as this perspective will underpin the reasoning behind the Authority's determinations. For example, if the decision criterion adjudicates with reference to "*information that a rational market participant would use in making investment decisions*",[26] then it may be argued that a long-term horizon is to be preferred to a single-period horizon. In this example, the decision criterion would then be consistent with the utility's perspective and a compounding of the WACC to forecast a cumulative return.

25. Note that the second part of the above statement is misleading from a statistical perspective in our opinion, i.e., "*the WACC is a parameter and not an estimate. In other words, the true WACC is not a random variable"*.[27] A basic assumption of the MRP forecast is that market returns are said to come from an unknown distribution of returns. Any estimator based on a sample of these returns, such as the historical MRP estimate based on either an arithmetic or geometric mean, is itself a random variable with its own sampling distribution. As the estimated WACC is a function of the MRP estimate then it too is a random variable. Only for simplicity would one assume away this randomness, especially if a long-term horizon is adopted, as any sampling error associated

[21] HoustonKemp Economics, "A Constructive Review of the ERA's Approach to the Market Risk Premium", October 2017, pp.4-13.

[22] HoustonKemp Economics, "The Cost of Equity: Response to the AER's Draft Decisions for the Victorian Electricity Distributors, ActewAGL Distribution and Australian Gas Networks", January 2016, pxiii.

[23] HoustonKemp Economics, "The Cost of Equity: Response to the AER's Draft Decisions for the Victorian Electricity Distributors, ActewAGL Distribution and Australian Gas Networks", January 2016, pxii.

[24] HoustonKemp Economics, "The Cost of Equity: Response to the AER's Draft Decisions for the Victorian Electricity Distributors, ActewAGL Distribution and Australian Gas Networks", January 2016, pxiii.

[25] HoustonKemp Economics, "The Cost of Equity: Response to the AER's Draft Decisions for the Victorian Electricity Distributors, ActewAGL Distribution and Australian Gas Networks", January 2016, p12.

[26] ERA, "Final Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline 2016-2020", Appendix 4 Rate of Return, 30 June 2016, p. 103.

[27] HoustonKemp Economics, "The Cost of Equity: Response to the AER's Draft Decisions for the Victorian Electricity Distributors, ActewAGL Distribution and Australian Gas Networks", January 2016, pxiii.

with the WACC estimate will likely be compounded and will be non-negligible. That the true WACC is a parameter and not an estimate is irrelevant – it is akin to the true distribution of returns being known. If the true distribution of returns was known then there would be no need to acquire a historical sample of excess returns to calculate the MRP estimate, and there would be no argument as to whether an arithmetic or geometric mean should be applied. It occurs as profoundly contradictory to go through a process of estimating the historical MRP to only then deny that the uncertainty associated with that historical estimate has any influence on a forecast of the future MRP or the cumulative returns the MRP estimate implies. Instead, an idealised rational market participant would be making decisions with the uncertainty of the forecast in mind.

NERA – Attachment M15_NERA: Further Assessment of the Historical MRP: Response to the AER's Final Decisions for the NSW and ACT Electricity Distributors – June 2015, pp.iv-vi and pp.14-28.

26. The arguments set out in this report mirror that of the two HoustonKemp reports reviewed above. Primarily, NERA argue for a single-period forecast against the position of Partington and Satchell that argues for a consideration of multi-period returns. The difference in the two positions is again highlighted with NERA's statement:

    "We are therefore forced to conclude that the ACT, which had not had the benefit of reading our March 2012 and June 2013 submissions or the advice of Lally provided in July 2012, is in error when it states that:

    > *'Envestra's submission that ... only the arithmetic mean may be used cannot be accepted once it is understood that the arithmetic mean of annual historic returns is not an unbiased estimate of ten year returns.'"*[28]

27. Again, it is our opinion that the forecasted multiple-period return will be overestimated (i.e., have an upward bias) when the arithmetic mean of past returns is applied as an estimator of the true return. This result is well established by Blume (1974) and Jacquier et al (2003).[29] That said, the arithmetic mean still has value and should not be dismissed altogether. Indeed, the weighting assigned to the arithmetic mean relative to the geometric mean increases with a shorter forecast horizon for future cumulative returns and a longer series of historical data to form the estimate.

28. NERA contends a weighting towards the geometric mean with:

    "As we point out in our March 2012 report, however, if the AER ever were to compound an estimate of the WACC over 10 years, it would then need to convert the 10-year return back to an annual return, thus reversing any compounding, so that it could use the annual return to determine the annual revenue requirement for each year of a regulatory control period."[30]

[28] NERA, "Attachment M15_NERA: Further Assessment of the Historical MRP: Response to the AER's Final Decisions for the NSW and ACT Electricity Distributors", June 2015, p17.

[29] Blume ME, "Unbiased Estimators of Long-Run Expected Rates of Return", *Journal of the American Statistical Association*, vol. 69, 1974, pp. 634–638.
Jacquier E, Kane A, Marcus AJ, "Geometric or Arithmetic Mean: A Reconsideration", *Financial Analysts Journal*, 59, pp.46-53.

[30] NERA, "Attachment M15_NERA: Further Assessment of the Historical MRP: Response to the AER's Final Decisions for the NSW and ACT Electricity Distributors", June 2015, p17.

This statement may be criticized as follows: if, say, the arithmetic mean is applied then the 10-year return will be an overestimate compared to the 10-year return generated by the 'true' MRP. Regardless of whether the compounding is reversed or not the forecast 10-year return will be higher than the likely 'true' 10-year return. Better still, an estimator that is relatively efficient[31] compared to an alternate estimator will provide an estimate of the cumulative annual growth rate (i.e., the annual return) that is more accurate for predicting future returns over a given forecasting horizon. This estimator, under most practical situations, will include a weighting of both the geometric mean and the arithmetic mean.[32]

Dr. Martin Lally – *The cost of equity and the market risk premium* – July 2012, pp. 31-32.

29. Dr. Lally's states that:

"The third point of difference between my views and the AER's methodology concerns the merits of geometric averaging. The AER's belief that geometric averages are useful apparently arises from a belief that there is a compounding effect in their regulatory process (AER, 2012, Appendix A.2.1), and therefore the analysis of Blume (1974) and Jacquier et al (2003) applies. However, I do not think that there is any such compounding effect in regulatory situations and the absence of a compounding effect leads to a preference for the arithmetic mean over the geometric mean."[33]

Dr. Lally then demonstrates the net present value (NPV) of a two-period book value. The solution to this heuristic problem is the arithmetic mean. However, it is our opinion that Dr. Lally does not consider the rate of return as an estimate subject to sampling error, but instead as a fixed certain value. Consequently, no sampling error in the estimate is compounded within Lally's calculation of the future book value. If such sampling error were to be included in Dr. Lally's analysis then a bias in the forecast long-term cumulative return would be present when using either the arithmetic or geometric mean, and hence a *"compounding effect"* would be 'found'. HoustonKemp's application of Lally's argument to support their position should therefore be dismissed if a long-term horizon is considered for the forecast cumulative returns.

Recommendations and Reasoning

Weighting applied to the historical data scenario in estimating the MRP

30. Currently, the Authority gives equal weight to two of the five historical scenarios when it averages the minimum arithmetic mean and the maximum geometric mean (i.e., the data scenarios defined over: 1883-2016, 1937-2016; 1958-2016; 1980-2016; and, 1988-2016).

[31] Specifically, an estimator is said to be relative efficient to an alternative if it possesses a lower mean square error for all parameter values when compared to that alternative.

[32] Jacquier E., Kane A., Marcus AJ, "Optimal Estimation of the Risk Premium for the Long Run and Asset Allocation: A Case of Compounded Estimation Risk", *Journal of Financial Econometrics*, vol. 3, 2005, pp.37-55.

[33] Lally M., "The Cost of Equity and the Market Risk Premium", July 2012, p 31.
Blume ME, "Unbiased Estimators of Long-Run Expected Rates of Return", *Journal of the American Statistical Association*, vol. 69, 1974, pp. 634–638.
Jacquier E, Kane A, Marcus AJ, "Geometric or Arithmetic Mean: A Reconsideration", *Financial Analysts Journal*, 59, pp.46-53.

31. HoustonKemp propose assigning full weight to the 1883-2016 scenario alone, arguing that this scenario provides the lowest standard error associated with the MRP estimate among all scenarios.

32. However, it must be noted that there is contention between the BHM and NERA estimates for the 1883-2016 period. If these estimates were compounded over a 10-year period then these differences would be proportionately greater than for the single-period estimate due to the compounding effect.

33. Whether the NERA estimates are more correct or not, the fact that the NERA and BHM estimates differ for the 1883-2016 period, whereas there is minimal difference between estimates from the 1958 and later periods, admits that there is some uncertainty around the early period estimates.

34. A more conservative policy towards the need to minimise data uncertainty could arguably exclude data prior to 1937, if not 1958. This is because there is at most a 0.07% difference in annual returns between the BHM and NERA methods for the 1937-2016 period, and less than a 0.01% difference for the 1958-2016 period. Note that any differences between methods will be compounded if the forecast horizon is long-term and cumulative returns are considered.

35. Indeed, Partington and Satchell (2015) state that:

    "Estimates of returns from the 1800's based on handful of stocks with prices averaged between high and low prices on a monthly basis are rather different to current return measurements for indices such as the ASX 200."[34]

    Hence the BHM and NERA estimates converge after 1958. There is then no need for yield correction after 1958.[35]

36. The value of omitting data prior to 1937 to minimize data uncertainty may be coupled with the increased risk of a longer time-series admitting data that are subject to structural breaks in the market.[36]

37. A simple heuristic that omits earlier data would therefore apply a 'consistency of data method' criterion (i.e., BHM and NERA estimates must be close to equal). This heuristic would reduce the HoustonKemp MRP estimate of 6.77% to 5.22% (i.e., the average of the BHM and NERA estimates for both the arithmetic and geometric means in Table 3).[37]

38. Note that such simple heuristics can be abused. For example, a heuristic to minimize standard error of the estimate will maximise the MRP estimate with the current data, as this coincides with the 1883-2016 period, and is indeed HoustonKemp's choice. The choice of heuristics therefore risk 'cherry picking', as may be seen when comparing the very different MRP estimates provided by the minimum standard error criterion and consistency of data method criterion above.

39. An alternative to both the current method and such simple heuristics is to test the time series of returns for structural breaks to identify a suitable data period for the MRP estimation. However, a method of structural break testing would need to be agreed upon as there are several different

[34] G. Partington and S. Satchell, "Report to the AER: Analysis of criticism of 2015 determinations", October 2015, p46.
[35] HoustonKemp Economics, "A Constructive Review of the ERA's Approach to the Market Risk Premium", October 2017, p4.
[36] G. Partington and S. Satchell, "Report to the AER: Analysis of criticism of 2015 determinations", October 2015, p46.
[37] Table 3, HoustonKemp Economics, "A Constructive Review of the ERA's Approach to the Market Risk Premium", October 2017, p5.

methods available.[38] Note that these structural breaks may simply be a result of different data recording methods,[39] or be process driven. The source of a structural break is largely irrelevant, rather that a structural break occurs in the data series is important.

40. Moreover, there is a trade-off between having a longer time series to reduce standard errors, and having a time series that omits all structural breaks but which defines a potentially short time series with a larger standard error, as HoustonKemp correctly identify. The benefits and costs of this trade-off may, in principle, be valued through bootstrap methods. There are then several different potential sources of error, and each source of error should to some extent be valued in comparison with other sources. However, such an analysis may be argued to be fraught from a methodological stand point.

41. Regardless of any attempt to improve the current methodology, we recommend that the HoustonKemp proposal of 6.77% be dismissed. It is our opinion that minimising standard error is not a sufficient criterion when significant risks of structural breaks and data quality are extant in the longer-term data. These tangible risks can lead to significant bias in estimates of the forward looking MRP.

42. Alternatively, a conservative strategy is to omit the data prior to 1937 so as to remove in part these potential biases. Removing data prior to 1958 is also an option. This is the strategy that we would tentatively recommend in the first instance, as it retains the longest time-period of data possible while omitting potential biases in the data. However, as discussed, this omission of early data comes at the cost of a loss of precision in the estimate.

43. In summary, a more rigorous approach to defining an appropriate data scenario may be achieved through testing for structural breaks in the time series of returns. Likely, this will lead to the definition of a single, authoritative data scenario.

44. For simplicity, we term the Authority's 'averaging' across the five data scenarios to the average of minimum arithmetic mean and maximum geometric mean (i.e., an average of a function of the data scenario estimates). The selection of the minimum arithmetic and maximum geometric mean estimate aims to minimise the bias associated with each estimate, and hence the bias of the MRP forecast overall across a longer-term horizon. This approach does not guarantee that the geometric mean will remain below the 'true' mean, or that the arithmetic mean will remain above the 'true' mean. For example, a final MRP estimate of 5.22% (achieved if only the 1937-2016 data scenario is considered) would be equal to the maximum geometric mean estimate for the 1883-2016 data scenario.[40] Similarly, the minimum given by the 1988-2016 arithmetic mean would be below an MRP estimate based on the 1883-2016 data scenario only. As HoustonKemp have argued, there is no precise means of ensuring that the minimum arithmetic mean and maximum geometric mean across the five data scenarios balance, or indeed reflect better the 'true' historical MRP. That said, the bias associated with selecting a single and incorrect data scenario appear to be of much larger consequence, given the arithmetic mean and geometric mean are positively correlated across the data scenarios. Despite this risk, defining a single,

[38] Apart from likelihood ratio type tests that assume some model of returns, a method of expert elicitation of 'prior' weights could feasibly be considered in a Bayesian weighting and meta-analysis of the forecast MRP. However, this would again introduce contention into the MRP estimation methods. Moreover, both the structural break testing, and any subsequent valuation of method, will likely be sensitive to distributional assumptions applied to the data.

[39] Handley JC, "An Estimate of the Historical Equity Risk Premium for the Period 1883 to 2011", Report prepared for the Australian Energy Regulator, April 2012, p 4.

[40] Table 3, HoustonKemp Economics, "A Constructive Review of the ERA's Approach to the Market Risk Premium", October 2017, p 5.

authoritative data scenario is desirable as it will obviate the Authority's need to 'average' across overlapping data scenarios, by first identifying the minimum arithmetic mean and the maximum geometric mean.

45. When a change in method is proposed the Authority should consider valuing the relative costs of a loss of precision (for example, due to the presence of a structural break reducing the length of the time series) compared to that of a reduced bias (for example, due to the accounting of the structural break) in terms of the WACC that such a proposal will inevitably entail. Until the value of an alternate method is clearly and objectively demonstrated in terms of improving the overall accuracy of the MRP forecast, or indeed a forecast of the cumulative return over an agreed horizon, then the current method of averaging the scenarios should be retained.

Weighting applied to the BHM and NERA yield adjusted estimates of the MRP

46. If, in the first instance, data prior to 1937 (or later) be omitted from the MRP estimate then no decision will be required to weight the BHM and NERA estimates, as they will be more or less the same.

47. The decision to favor the NERA estimate over the BHM estimate, as HoustonKemp propose, does risk admission of a non-negligible bias in terms of forecasted cumulative returns. The current method of weighting (50% BHM and 50% NERA) also carries this risk, which if anything points towards omitting the 1883-2016 scenario altogether.

48. However, if a more statistically rigorous method is sought then we recommend testing for structural breaks, and the subsequent valuation of the impact of a shortening of the time series if structural breaks are detected, before changing the current weighting assigned to the two yield adjustment methods.

49. In practice, the current weighting scheme of the Authority does not value one method of yield adjustment or data scenario more highly than another. This forms an 'equanimous' decision criterion that assigns equal weight whenever there are legitimate options to choose from,[41] and is an acceptable and conservative strategy to adopt when faced with uncertainty that may be attributable to different sources of data error.

Weighting of the arithmetic and geometric means

50. A weighting of the arithmetic mean and geometric mean in forecasting cumulative returns has been explored principally by Blume (1974), Jacquier et al. (2003), and Jacquier et al. (2005).[42] Blume (1974) describe a normal distribution of returns, whereas Jacquier et al. (2003) and Jacquier et al. (2005) describe a log-normal distribution of returns. In particular, both efficient

[41] This 'equanimous' criterion is analogous to a non-informative prior being placed on the belief that a particular data scenario is correct.

[42] Blume ME, "Unbiased Estimators of Long-Run Expected Rates of Return", *Journal of the American Statistical Association*, vol. 69, 1974, pp. 634–638.

Jacquier E, Kane A, Marcus AJ, "Geometric or Arithmetic Mean: A Reconsideration", *Financial Analysts Journal*, vol. 59, 2003, pp.46-53.

Jacquier E., Kane A., Marcus AJ, "Optimal Estimation of the Risk Premium for the Long Run and Asset Allocation: A Case of Compounded Estimation Risk", *Journal of Financial Econometrics*, vol. 3, 2005, pp.37-55.

(Jacquier et al. 2005) and unbiased (Jacquier et al. 2003) estimators can be derived for cumulative returns under the log-normal assumption. Unbiasedness is desirable as the expectation of the estimator equals the 'true' parameter, in this case the cumulative annual growth rate. However, efficient estimators are preferred across the statistics literature – while they may be slightly biased they minimize the error of applying the estimator as a prediction or forecast of future data.

51. To date, the Authority has placed emphasis on developing an unbiased estimator, and so averages a minimum arithmetic mean and maximum geometric mean of the five overlapping data scenarios. However, the unbiased estimator will have higher associated variance than the efficient estimator, and will be a more inaccurate predictor of future cumulative returns in any decision to invest.

52. Both the unbiased and efficient estimators of Jacquier et al. (2003) and Jacquier et al. (2005) are shrinkage estimators for log-normal returns: the arithmetic mean which is upwardly biased for long-term cumulative returns is improved by combining it with the common scenario of where the geometric estimator is downwardly biased. The mixing parameter ρ determining the weights is simply defined in both cases, depending on the forecast horizon H and on the length of the time series on which the one-period MRP estimator is based T:

   - Unbiased Estimator: $\rho = 1 - H/T$ is the weight assigned to the arithmetic mean and $1 - \rho = H/T$ is assigned to the geometric mean.
   - Efficient Estimator: $\rho = 1 - 3H/T$ is the weight assigned to the arithmetic mean and $1 - \rho = 3H/T$ is assigned to the geometric mean.

53. Note that both the unbiased and efficient estimators support the position of HoustonKemp of applying the arithmetic MRP whenever no forecasting of annual returns is considered (e.g., for $H = 0$, and thus $\rho = 1$, the arithmetic mean is both an unbiased and efficient estimator of the cumulative return).

54. Note also that a long-term horizon with increasing H, and the presence of any structural breaks that would reduce T, increase the weighting of the geometric mean within the shrinkage estimator of cumulative returns. Moreover, the efficient estimator places more weight on the geometric mean than the unbiased estimator. If, for example, $H = 10$ years (as may be with the AER) and $T = 80$ years for the 1937-2016 scenario then the weighting for the geometric mean would be 37.5% for the efficient estimator. If significant structural breaks in the market occur at 1980 ($T = 37$) and prior data are therefore excluded from the analysis, then the weighting of the geometric mean would be 81.8% for the efficient estimator.

55. If it is assumed that the relevant investment horizon is equivalent to the Authority's MRP forecast horizon of five years, then $H = 5$. In this case the weighting for the geometric mean may be 18.8% for the 1937-2016 scenario ($T = 80$), and 40.9% for the 1980-2016 scenario ($T = 37$). Furthermore, an investment horizon in perpetuity may also be considered, in which case the weighting for the geometric mean is 100%.

56. If the Authority applies the 'equanimous' criterion[43] to the five different data scenarios[44] then an average of $T = 66.8$ years may be applied. This leads to an average weighting of 44.9% for the geometric mean if a 10-year horizon is considered, and 22.4% for a 5-year horizon. Moreover,

[43] Paragraph 49 above.

[44] Periods for the years 1883-2016; 1937-2016; 1958-2016; 1980-2016; 1988-2016.

application of the 'consistency of data method' criterion would likely exclude the 1883-2016 data scenario from the set of candidate data scenarios. In this case the weighting of the geometric mean would increase to 72.8% under a 10 year-horizon, and 36.4% under a 5-year horizon.

57. If the log-normal distribution is assumed to be correct then the Authority can directly derive a weighting of the arithmetic and geometric means simply by defining the forecast horizon H. **We recommend that the Authority defines the intended forecast horizon $\boldsymbol{H}$ explicitly**. Critically, the Authority will have to decide whether it accepts the HoustonKemp position that the MRP forecast only applies to a single period for the reasons they have given, or if it considers that market participants operate over a longer-period investment horizon (as articulated by Partington and Satchell).

58. Moreover, significant uncertainties remain as to an appropriate value for ρ even if a longer-term forecast horizon H is defined. This is because the log-normal distribution may not be the best model of the asset price data if the data are heavy-tailed. In this case, a log-t or log-Cauchy distribution could be applied, and/or a GARCH type model that accounts for heteroskedasticity in the asset data over time. However, variance estimates of the shrinkage operator would need to be derived to determine an optimal ρ minimizing the mean square error. Such an analysis has no closed-form solution as exists for the log-normal distribution, and would need to be solved computationally. Even then, the estimate of an optimal ρ may be numerically unstable with the computation due to the heavy-tail assumption. This numerical instability implies that an MRP forecast may not be fully reproducible, given the high likelihood that log returns are heavy-tailed in practice.[45] Hence, the log-normal model has heuristic value only for determining the weighting of arithmetic and geometric means in the calculation of the MRP. The log-normal model does however demonstrate that a non-zero weighting of the geometric mean is likely desirable if the forecast horizon is greater than one year.

59. Moreover, from a statistical perspective it would be best practice for the Authority to provide an MRP forecast that minimises forecast (or predictive) error than minimizing bias alone. While our discussion of an efficient estimator has been conducted in isolation of the practicalities of regulation, the discussion above does highlight that a greater weighting of the geometric mean will be favoured when a key statistical criterion for selecting an optimal weighting is considered.

60. As such, we allow for the Partington and Satchell comment cited by NERA where:

"it seems to be a matter for the AER to determine whether it views the regulated return it is setting as an annual return, or a return to be earned over five years, or some other period."[46]

So long as the forecast horizon is multi-period, albeit undefined, and distributional assumptions of the returns and the appropriate data scenario are uncertain, then the 'equanimous' criterion may legitimately be applied to give equal weighting to the arithmetic mean and geometric mean in lieu of better information.

[45] This numerical instability may to an extent be quantified computationally.

[46] NERA, "Attachment M15_NERA: Further Assessment of the Historical MRP: Response to the AER's Final Decisions for the NSW and ACT Electricity Distributors", June 2015, p17.
G. Partington and S. Satchell, "Report to the AER: Return of equity and comment on submissions in relation to JGN", May 2015, p17.

Summary

61. If the Authority considers that market participants operate over a longer-period investment horizon (as articulated by Partington and Satchell) then a weighted mixture of the arithmetic and geometric means should be applied. However, if the Authority considers the investment horizon of rational market participants to be a single period then the HoustonKemp proposal of the arithmetic mean alone should be applied.

62. If a weighted mixture of the arithmetic and geometric means is applied, then this weighting should in the first instance be 50/50. This assertion is supported by the discussion of a log-normal distribution of returns above, and a preference for an efficient estimator of long-term cumulative returns, namely:
    - An efficient shrinkage estimator that minimizes the predictive accuracy of cumulative returns weights the geometric estimator more heavily than an unbiased estimator.
    - The data scenario relevant to current market conditions is likely to be shorter than the 1883-2016 scenario proposed by HoustonKemp due to structural breaks in the data series, either due to impaired data quality despite adjustment of pre-1958 data, or some structural change in the market. Any omission of uncertain data also increases the weighting for the geometric mean within an efficient estimator of the MRP by shortening the length of the time series.

63. Under these conditions, the weighting for the geometric mean has been demonstrated to be as high as 80% for a 10-year investment horizon for a log-normal distribution of returns, or 40% for a 5-year horizon. Tentatively, it is advised that an investment horizon be explicitly defined by the Authority when constructing the MRP forecast. This investment horizon will then inform the Authority of an appropriate weighting for the geometric mean under the log-normal assumption. This distributional assumption may be questioned as the distribution of returns is likely heavy-tailed. However, the argument for a positive weighting of the geometric mean will still likely apply. Hence, the fallback 'equanimous' position of a 50/50 weighting of the arithmetic and geometric means may be retained until better information is received as to the distributional nature of the returns.

64. Valuing the impact of different sources of data error and methodological may be developed and adopted. This framework would be useful in terms of evaluating future proposed changes to decision criteria and weightings of data scenarios. However, such a framework could be contentious in terms of its methodology, thereby reducing its usefulness.

65. While the Authority is committed to utilizing five data scenarios, rather than a single, authoritative data scenario, it will be wedded to the compromise strategy that weights equally the lowest arithmetic mean and the highest geometric mean. This strategy does not return an unbiased or efficient estimate of the forward looking MRP. However, the alternative proposed by HoustonKemp of selecting only the 1883-2016 data scenario, risks introducing significant upward bias to the result due to positive correlation between geometric and arithmetic means across the different data scenarios. Indeed, there are arguable grounds for dismissing the 1883-2016 data scenario altogether through application of a 'consistency of data method' criterion. Until one data scenario may be clearly proven to be superior to another then it is advisable that the Authority retains its compromise strategy of averaging the lowest arithmetic mean and highest geometric mean across the five data scenarios.

66. If the 1883-2016 data scenario is retained the sizeable difference between BHM and NERA estimates will continue to influence the Authority's estimate. Overall, the data prior to 1958 are

uncertain, and differ from recent data in their construction and measurement. While yield adjustments to data prior to 1958 will undoubtedly improve the quality of the data there is no certainty that either the BHM or NERA yield adjustments lead precisely to the ‘true’ data. This contrasts with the daily data available post-1958, which may to a large extent be treated as certain. Given this uncertainty then the ‘equanimous’ criterion may legitimately be retained to weight equally the BHM and NERA estimates.

67. If a single, authoritative data scenario is sought then structural break testing should be introduced. However, structural break testing may initially also be contentious due to the availability of several different methods that would need to be trialed. A robust valuation framework would be most useful in this instance.

Glossary

ACRONYM	DEFINITION
AER	Australian Energy Regulator
ASX 200	Australian Stock Exchange Index containing 200 largest stocks by market capitalisation
BHM	Brailsford, Handley and Maheswaran
H	Investment horizon, implying also consideration of a cumulative return
MRP	Market Risk Premium
NERA	National Economic Research Associates
T	Length of historical data series (years) from which MRP is estimated

Appendix A: Terms of reference

Re: Quotation for consultancy on the estimation of the market risk premium

for the gas rate of return guidelines.

Thank you for the opportunity to submit a quotation for the consultancy to provide an evaluation and opinion of the different methods that may be applied in estimating the future market risk premium (MRP) under the Ibbotson approach. Reiterating the terms of reference (ToR) that you have kindly provided, the analytical tasks to be performed are:

- Evaluate the different methods thus far proposed to calculate the MRP:
    - The ERA has previously argued that the arithmetic mean will tend to overstate returns, whereas a geometric mean will tend to understate them. The ERA therefore applies the mean of the lowest arithmetic mean and the highest geometric mean as its estimator of the MRP.
    - HoustonKemp argues that only an arithmetic mean should be applied, as both the lowest arithmetic mean and highest geometric mean are biased (Attachment 1 in the ToR). These biases do not 'cancel', leading to an overall downward bias, in addition to a loss of precision in the estimator.
    - The issue of compounding is also raised, with Lally (Attachment 6 in the ToR) arguing that if there is no compounding effect in regulator situations then an arithmetic mean is to be preferred.
    - Partington and Satchell support use of the geometric mean (Attachment 3 in the ToR).
- Provide a statistics-based opinion as to the best method to apply when calculating the MRP under the Ibbotson approach:
    - May include proposal of an alternative method of calculation if it can be demonstrated to be superior to the methods proposed thus far.

Timing and Resources

The below milestones (Table 1) provide a commencement date of 4th December 2017 and a completion date of 18th December 2017. No other resources are required for completion of the work.

Table 1. Milestones for the Consultancy

Milestone
1. Conduct review of the provided literature.
2. Assess and evaluate competing methods.
3. Submit draft report providing an opinion.
4. Submit final report.

Project Personnel

Rohan Sadler will be the key personnel assigned to the project and for whom a Curriculum Vitae has been provided. Key qualifications and experience relevant to the scope are:

- PhD (computational statistics, landscape ecology; UWA).
- AStat Accredited Professional Statistician (Statistical Society of Australia).
- Adjunct Senior Lecturer, School of Agricultural and Resource Economics (UWA).
- Peer-reviewed publications across a variety of applications, focusing on:
  - Portfolio optimisation
  - Benefit-cost analysis
  - Risk analysis
  - Principal-agent contracts
- Five years consultancy experience in the resources industry.
- Five years research experience in national scale research initiatives.
- Previous employment with the Authority regarding gas return on equity calculations, both as a casual employee and as a consultant.

If you have any questions regarding this quotation, please don't hesitate to contact me 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[47], 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[48]

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.

[47] 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].

[48] The "*Ikarian Reefer*" (1993) 20 FSR 563 at 565-566.

2. The Form of the Expert's Report[49]

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[50]; 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[51].

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[52].

[49] Rule 23.13.
[50] See also *Dasreef Pty Limited v Nawaf Hawchar* [2011] HCA 21.
[51] The *"Ikarian Reefer"* [1993] 20 FSR 563 at 565
[52] 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

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

- Remotely sensed land use and land cover classification and change within an urban municipality (Emerge Associates, Western Australia)
- Population density estimation of an island gecko species (Range to Reef, Western Australia).
- Phenotypic factors in germination responses of species suitable for mine-site restoration (Botanic Gardens and Parks Authority, Western Australia).
- Water potential profiles of native seed germination success (Botanic Gardens and Parks Authority, Western Australia).
- Statistical Advice to the ERA on DBP Submission 56 (Economic Regulatory Authority Western Australia, Western Australia).
- Cost-response and power analysis in BACI-type experimental designs (BMT Oceanica, Western Australia).

2015–2017 **Free Lance Data Scientist**, *Bush Futures*, Perth.

- Estimation of theta in the return on equity (Economic Regulatory Authority Western Australia, Western Australia).
- Empirical testing of theoretical capital asset pricing models and portfolio optimisation (Economic Regulatory Authority 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 availability of mental health services in Perth (Ray Dunne Public Relations, Western Australia).

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

- 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.
- 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.
- Initiated data governance and workflow development within Astron.
- Data Team Leader (Emergency Oil Spill Response for various Oil and Gas clients).
- 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 University 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
Branch Committee, Western Australia.

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 (DAFF)
- Agricultural Land Retirement as an Environmental Policy (LWA)
- Auctions for Landscape Recovery Under Uncertainty (DAFF)

Pest Management.

- Sample size determination for biosecurity monitoring in the Torres Strait (DAWR)
- 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)

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)

- o Groundwater Drawdown Impacts on Vegetation (BHPBIO)
- o 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.

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