NERA
ECONOMIC CONSULTING

The Fama-French Three-Factor Model

A report for the Energy Networks Association

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Project Team

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Executive Summary

This report has been prepared for the Energy Networks Association (ENA) by NERA Economic Consulting (NERA). The ENA has asked NERA to provide and review evidence on the relevance of the Fama-French three-factor model (FFM) for the purpose of estimating the cost of equity for a benchmark regulated energy utility.

In particular, the ENA has asked NERA to:

- identify whether there is a theoretical basis for the Fama-French three factor model (FFM), and if so, briefly explain what that basis is and compare it to those of the Sharpe-Lintner (SL) Capital Asset Pricing Model (CAPM) and Black CAPM;
- investigate whether the three models are considered relevant by academics or practitioners for estimating the cost of equity;
- compare the ability of the SL CAPM, Black CAPM and FFM to predict the cost of equity in Australia;
- advise whether the model is undermined for use in Australia if one or both factors are not statistically significant;
- assess the statistical significance of premiums associated with the three Fama-French factors in Australia and assess the stability over time of the factors;
- assess the validity of the FFM relative to the obligations of the National Electricity Rules (NER) and National Gas Rules (NGR) and in comparison with the SL CAPM and the Black CAPM in terms of the criteria for assessment set out by the Australian Energy Regulator (AER); and
- conclude whether the FFM is a relevant financial model for the purpose of estimating the cost of equity for a benchmark regulated energy utility.

The full terms of reference are set out in Appendix A.

Framework

We address the terms of reference using as a fundamental guide the new NER and NGR. Under the previous NER, the AER was required to estimate the cost of equity for electricity network businesses using the SL CAPM. Although the previous NGR did not mandate the use of the SL CAPM, in practice, the AER also applied this approach in gas network decisions. The recently revised NER and NGR now require the AER to have regard to financial models generally, Clause 6.5.2 of the rules states:

> *(e) In determining the allowed rate of return, regard must be had to:*
>
> *(1) relevant estimation methods, financial models, market data and other evidence;*
>
> *(2) the desirability of using an approach that leads to the consistent application of any estimates of financial parameters that are relevant to the estimates of, and that are common to, the return on equity and the return on debt; and*

> *(3) any interrelationships between estimates of financial parameters that are relevant to the estimates of the return on equity and the return on debt.*

Return on equity

> *(f) The return on equity for a regulatory control period must be estimated such that it contributes to the achievement of the allowed rate of return objective.*
>
> *(g) In estimating the return on equity under paragraph (f), regard must be had to the prevailing conditions in the market for equity funds.*

These clauses require the AER to consider all relevant financial models and therefore provide greater scope to look at cost of equity models beyond the traditionally adopted SL CAPM.

The NER and NGR say nothing about what sort of theoretical foundations a suitable financial model should have. The AER in its *Explanatory Statement* states that (amongst other things) it will consider whether a model is: [1]

> 'consistent with well accepted economic and finance principles and informed by sound empirical analysis and robust data'.

Later the AER states that: [2]

> 'The intention here is to ensure a method which is well grounded in economic theory would have wide-spread recognition and acceptability.'

In the body of the report, the AER proposes not to use the FFM in large part because the AER states that the FFM lacks an 'economic basis'. [3] In that context, we have been asked to explain the theoretical underpinnings of the FFM, and also of the SL CAPM and Black CAPM.

Attached to each financial model are strengths and weaknesses. These strengths and weaknesses depend on the *bias* that may result from the use of a model and the *precision* with which the use of a model will allow one to estimate the cost of equity. An estimator of a parameter is said to be unbiased if the expected value of the estimator matches the parameter and is said to be biased if the expected value differs from the parameter.[4] The precision of a random variable is the reciprocal of its variance.[5]

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1 AER, *Explanatory statement: Draft rate of return guideline*, August 2013, page 27.

2 AER, *Explanatory statement: Draft rate of return guideline*, August 2013, page 29.

3 AER, *Explanatory statement: Draft rate of return guideline*, August 2013, page 191.

4 See, for example:

Hamilton, J.D., *Time series analysis*, Princeton University Press, Princeton, NJ, 1994, page 741.

5 This definition, standard in the statistics literature, differs from the Oxford Dictionary definition of precision which is:

'accuracy or exactness.'

In statistics a precise estimator can be exact but inaccurate. As Davidson and MacKinnon note, however,

'it is sometimes more intuitive to think in terms of precision than in terms of variance.'

All else constant an unbiased estimator will be preferred to a biased estimator and all else constant a more precise estimator will be preferred to a less precise estimator. In principle, one may be willing to trade off bias for precision. For example, one may be willing to use an estimator that is less precise than an alternative if the bias associated with the estimator is smaller than the bias associated with the alternative.

Since the bias attached to an estimator that uses a pricing model and the precision of the estimator are important parameters, we provide estimates of these parameters for each of the models that the ENA proposes the AER should use for a range of equities.

For a financial model to be of any practical use the parameters of the model must also be reasonably stable. So, in addition, we assess whether the parameters of each model are sufficiently stable that the model can be of practical use.

Finally, if a financial model is of practical use, there should be evidence that it is used in practice. We provide evidence that the models that the ENA proposes the AER should employ are used in practice.

Theoretical foundations

We show that the SL CAPM, Black CAPM and FFM all have theoretical foundations.

The SL CAPM and Black CAPM make assumptions about the behaviour of individuals, the distribution of returns, investor beliefs, the taxes that investors face and the ability of individuals to borrow and lend or to short sell. Both the SL CAPM and the Black CAPM predict that the market portfolio of all risky assets will be mean-variance efficient and that, consequently, there will be a simple linear relation between the cost of equity for a firm and the firm's equity beta computed relative to the portfolio. A portfolio that is mean-variance efficient is a portfolio that has the highest mean return for a given level of risk, measured by variance of return.

As Roll (1977) makes clear, the SL CAPM predicts that the market portfolio of all risky assets must be mean-variance efficient – it does not predict that the market portfolio of stocks must be mean-variance efficient.[6] The empirical version of the model that the AER and others use measures the risk of an asset relative to a portfolio of stocks alone. Stocks have readily available and transparent prices relative to other risky assets such as debt, property and human capital. Stocks, though, make up a relatively small fraction of all risky assets, so the return to a portfolio of stocks need not track closely the return to the market portfolio of

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We agree and so use the terms precise and precision to render our discussion easier to follow.

Davidson, R. and J. G. MacKinnon, *Estimation and inference in econometrics*, Oxford University Press, Oxford, 1993, page 144.

Fowler, F.G. and H.W. Fowler, *Pocket Oxford Dictionary*, Oxford University Press, Oxford, 1966, page 623.

6 Roll, R., *A critique of the asset pricing theory's tests: Part I*, Journal of Financial Economics 4, 1977, pages 129-176.

all risky assets.[7] Thus the empirical version of the SL CAPM that the AER actually employs differs from the theoretical model proposed by Sharpe and Lintner.

The FFM is an example of the Arbitrage Pricing Theory (APT) of Ross (1976).[8] The APT assumes that there are a limited number of pervasive factors and that there are no arbitrage opportunities. Thus the APT does not make strict assumptions about the behaviour of individuals or the distribution of returns. The APT, though, does not specify what factors are pervasive or how many exist. The model states that, consistent with intuition, an investor will be compensated only for risk that he or she cannot diversify away.

Ball (1978) emphasises that theory indicates that financial ratios will provide information about the cross-section of mean returns to stocks.[9] Similarly, Berk (1995) emphasises that theory indicates that the market value of a firm's equity will provide information about the cross-section.[10] Empirically, Fama and French (1992) show that the market value of a firm's equity and the ratio of the book value of the equity to its market value are better predictors of the equity's return than is an estimate of the equity's beta.[11] So Fama and French (1993) assume that there are three pervasive sources of risk or factors:[12]

(a) the excess return to the market portfolio;

(b) the difference between the return to a portfolio of high book-to-market stocks and the return to a portfolio of low book-to-market stocks (*HML*); and

(c) the difference between the return to a portfolio of small-cap stocks and the return to a portfolio of large-cap stocks (*SMB*).

If the assumption is correct, then the APT will imply that there will be a simple linear relation between the cost of equity for a firm and the firm's equity betas computed relative to the three Fama-French factors.

Cochrane (2001) emphasises, in his popular graduate-level text, that if the three-factor model did not hold, there would be near-arbitrage opportunities.[13] We provide a numerical example, which is based on the results that Fama and French (1993) report, of a near-

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7 The mean value of an Australian household's direct investment in stocks in 2010 was $37,505 and the mean value of the household's superannuation account – part of which would have been invested in stocks – was $142,429. The mean net wealth of a household in 2010 was $683,805. Thus the average Australian household in 2010 invested no more than 100 × (37,505 + 142,429)/683,805 = 26 per cent of its net wealth in stocks. See:

Melbourne Institute, *A statistical report on waves 1 to 10 of the Household, Income and Labour Dynamics in Australia Survey*, 2013, page 83.

8 Ross, Stephen, *The arbitrage theory of capital asset pricing*, Journal of Economic Theory 13, 1976, pages 341-360.

9 Ball, R., *Anomalies in relationships between securities' yields and yield surrogates*, Journal of Financial Economics, 1978, pages 103-126.

10 Berk, J., *A critique of size-related anomalies*, Review of Financial Studies, 1995, pages 275-286.

11 Fama, Eugene and Kenneth French, *The cross-section of expected returns*, Journal of Finance 47, 1992, pages 427-465.

12 Fama, Eugene and Kenneth French, *Common risk factors in the returns to stocks and bonds*, Journal of Financial Economics 33, 1993, pages 3-56.

13 Cochrane, John H., *Asset pricing*, Princeton University Press, 2001, page 442.

arbitrage opportunity that would hold were an empirical version of the SL CAPM of the kind that the AER employs to hold instead of the FFM. [14]

Subsequent to the introduction of the FFM in 1993, researchers have developed theories to explain why the Fama-French factors might be pervasive. These theories should not be discounted, of course, merely because they were developed to explain what we observe or because there may be debate over whether the factors capture one risk or multiple risks. As Friedman (1953) emphasises, the first task of a theory is to explain what we observe. [15] Researchers have suggested that the Fama-French factors could be proxies for, among other risks, the risks of financial distress, the risks of an asymmetric exposure to market conditions or risks associated with arbitrage. [16]

Bias and precision

We use Australian data to show that an empirical version of the SL CAPM of the kind that the AER uses can substantially underestimate (overestimate) the returns required on stocks with low (high) betas and substantially underestimate (overestimate) the returns required on value (growth) stocks. These important problems associated with an empirical version of the SL CAPM have been widely documented elsewhere. [17]

An empirical version of the Black CAPM will, by construction, neither underestimate the returns required on stocks with low betas nor overestimate the returns required on stocks with high betas. An empirical version of the Black CAPM, though, may underestimate (overestimate) the returns required on value (growth) stocks. Similarly, the FFM, by construction, will not underestimate the returns required on value stocks or overestimate the returns required on growth stocks. The FFM, though, like an empirical version of the SL CAPM, can underestimate (overestimate) the returns required on stocks with low (high) betas.

It follows that there can be costs associated with using an empirical version of the SL CAPM relative to using an empirical version of the Black CAPM or relative to using the FFM. There will, however, be costs to using an empirical version of the Black CAPM or to using the FFM because the estimates of the cost of equity that they will deliver will be less precise

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[14] Fama, Eugene and Kenneth French, *Common risk factors in the returns to stocks and bonds*, Journal of Financial Economics 33, 1993, pages 3-56.

[15] The second task is to predict what we do not currently observe.

Friedman, Milton, *The methodology of positive economics*, in Positive Economics, University of Chicago Press, 1953, pages 12-14.

[16] Ali, A., L. Hwang, and M.A. Trombley, *Arbitrage risk and the book-to-market anomaly*, Journal of Financial Economics, 69, 2003, pages 355–373.

Petkova, R., and L. Zhang, *Is value riskier than growth?* Journal of Financial Economics, 78, 2005, pages 187–202.

Vassalou, M., and Y. Xing, *Default risk in equity returns*, Journal of Finance, 59, 2004, pages 831–868.

[17] Brailsford, T., C. Gaunt and M. O'Brien, *Size and book-to-market factors in Australia*, Australian Journal of Management, 2012, pages 261-281.

Fama, Eugene and Kenneth French, *Common risk factors in the returns to stocks and bonds*, Journal of Financial Economics 33, 1993, pages 3-56.

than the estimates that an empirical version of the SL CAPM will deliver. So determining which models are to be preferred and under what conditions requires one assess not only the bias attached to estimates of the cost of equity that each model delivers but also the precision of the estimates.

We show, using estimates from a variety of recent submissions, that the precision with which one can estimate the cost of a firm's equity largely depends on the firm's equity beta or betas and the precision with which one can estimate the market risk premium and the two Fama-French factor risk premiums. The precision with one can estimate the cost of a firm's equity also depends on the market risk premium and the two Fama-French factor risk premiums and the precision with which one can estimate the firm's equity beta or betas, but to a lesser extent.

We show that an empirical version of the SL CAPM will deliver a relatively precise estimate of the return required on a stock with a low Sharpe-Lintner beta, the Black CAPM will deliver a relatively imprecise estimate of the return required on a stock with a low Sharpe-Lintner beta and the FFM will deliver a relatively imprecise estimate of the return required on a value stock.

We also show, however, as others have documented, that an empirical version of the SL CAPM will underestimate the return required on a stock with a low Sharpe-Lintner beta and underestimate the return required on a value stock. [18] In other words, for those stocks for which there may be benefits from using an empirical version of the SL CAPM, there also costs.

Our results suggest that it is likely that for low-beta stocks the benefits of using the Black CAPM relative to the SL CAPM will outweigh the costs. Similarly, our results suggest that for value stocks the benefits of using the FFM relative to the SL CAPM will likely outweigh the costs. This is despite the fact that an estimate of the *SMB* premium does not differ significantly from zero in Australian data.

Predictability and stability

A very basic test of the predictive ability of a model is whether portfolios sorted on the basis of past estimates of Sharpe-Lintner or Fama-French betas produce cross-sectional variation in realised returns out of sample. We find that portfolios formed from stocks that have low past estimates of Sharpe-Lintner betas or Fama-French market betas generate high, rather than low, returns out of sample. On the other hand, we find that portfolios formed from stocks that have low past estimates of Fama-French *HML* betas generate low returns out of sample, as the FFM would predict should be the case. Portfolios formed from stocks that have low past estimates of Fama-French *SMB* betas generate returns out of sample that are higher, but not significantly so, than the FFM would predict should be the case.

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[18] Brailsford, T., C. Gaunt and M. O'Brien, *Size and book-to-market factors in Australia*, Australian Journal of Management, 2012, pages 261-281.

Fama, Eugene and Kenneth French, *Common risk factors in the returns to stocks and bonds*, Journal of Financial Economics 33, 1993, pages 3-56.

We also test whether there is evidence that the *HML* and *SMB* premiums change through time. We find no evidence of a change in either Australian data or US data. We note, however, that uncovering evidence of a change through time will be difficult because realised premiums are noisy relative to their means.

Implications

Determining whether the FFM is a relevant financial model for the purpose of estimating the cost of equity for the benchmark firm requires one assess the alternatives.

An empirical version of the SL CAPM of the kind that the AER uses can provide estimates of the cost of equity for a firm that are relatively precise. The bias associated with the estimates if the firm's equity beta differs from one or if the firm's equity behaves like a value stock, though, can be substantial.

An empirical version of the Black CAPM is designed to eliminate the bias associated with estimates of the cost of equity generated by an empirical version of the SL CAPM for firms with equity betas that differ from one. An empirical version of the Black CAPM, on the other hand, delivers estimates that are less precise than estimates generated by an empirical version of the SL CAPM. Estimates of the bias associated with the estimates of the cost of equity that an empirical version of the SL CAPM produces, though, are sufficiently large that for low-beta and high-beta stocks the benefits of using an empirical version of the Black CAPM relative to an empirical version of the SL CAPM are likely to outweigh the costs.

The FFM, alone among the three models that we consider, is designed not to underestimate the cost of equity for a firm whose equity behaves like a value stock. The FFM, on the other hand, delivers estimates that are less precise than estimates generated by an empirical version of the SL CAPM. Estimates of the bias associated with the estimates of the cost of equity that an empirical version of the SL CAPM produces, though, are sufficiently large that for a firm whose equity behaves like a value stock the benefits of using the FFM relative to an empirical version of the SL CAPM are likely to outweigh the costs. SFG (2013) provide some evidence that a regulated energy utility behaves like a value stock. Consequently, we believe that the FFM is a relevant financial model for the purpose of estimating the cost of equity for a benchmark regulated energy utility.

Practical use

Finally, we note that there is evidence that the models that the ENA proposes the AER should employ for the purpose of estimating the cost of equity are used in practice.

SFG (2013) document that independent experts use the SL CAPM to estimate the return required on equity. It notes, however, that the evidence shows that independent expert valuation professionals do not use the model in the way that the AER does.[19] Practitioners are aware of the imprecision associated with regression-based estimates of beta derived from small samples. They are also aware that the Fama-French factors are likely to proxy for risk,

[19] SFG, *Evidence on the required return on equity from independent expert reports: Report for the Energy Networks Association*, June 2013.

and that there could be one or more risks associated with these factors. So practitioners do not mechanically incorporate regression-based estimates of beta into the SL CAPM.[20] Some practitioners adopt beta estimates which are adjusted towards one on the basis of estimation error.[21] Other practitioners make adjustments to their estimates of the cost of equity on the basis of considerations other than regression-based estimates of beta, which include risks.

The Brattle Group (2013) emphasise that it is well known that empirical versions of the SL CAPM tend to underestimate the returns required on low-beta stocks and overestimate the returns required on high-beta stocks.[22] They note that regulators in both Canada and the US, as a result, have made explicit use of an empirical version of the Black CAPM – what the Brattle Group describe as the 'Empirical' CAPM.[23] It is also likely that many market practitioners make implicit use of an empirical version of the Black CAPM by adjusting beta estimates further towards one than can be justified by estimation error or a tendency for beta to revert to a mean of one over time.

Morningstar provides betas relative to the three Fama-French factors for a wide range of companies.[24] These betas can be used to compute equity costs of capital. Morningstar is a source for information on stocks, mutual funds, variable annuities, closed-end funds, exchange-traded funds, separate accounts, hedge funds, and college savings plans and offers an extensive line of Internet, software, and print-based products for individual investors, financial advisors, and institutional clients. It has operations in 27 countries and provides data on more than 433,000 investment offerings worldwide.

The Chartered Financial Analysts (CFA) Institute requires practitioners seeking the CFA designation to understand how to use the FFM to compute the cost of equity. The CFA is the most widely accepted professional qualification for finance practitioners worldwide. To pass the CFA exams, practitioners must have a thorough understanding of the tools most widely used in finance. One such tool is the FFM. Study session 10, for examines:[25]

> 'the well-established methodologies of security analysis'

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[20] In particular, SFG (2013) note that in half of independent experts reports reviewed there was an additional uplift to the cost of equity above the estimate implied by the SL CAPM.

SFG, *Evidence on the required return on equity from independent expert reports: Report for the Energy Networks Association*, June 2013, page 12.

[21] For the theoretical and empirical genesis of this adjustment, see:

Blume, M.E., *On the assessment of risk*, Journal of Finance, 26, 1971, pages 1–10.

Blume, M.E., *Betas and their regression tendencies*, Journal of Finance, 30, 1975, pages 785–795.

Vasicek, O., *A note on using cross-sectional information in Bayesian estimation of security betas*, Journal of Finance, 28, 1973, pages 1233–1239;

[22] The Brattle Group, Estimating the cost of equity for regulated companies, February 2013, page 18.

[23] The Brattle Group, Estimating the cost of equity for regulated companies, February 2013, page 20.

[24] http://corporate.morningstar.com/IB/asp/subject.aspx?xmlfile=5532.xml

[25] CFA, Program Curriculum – Volume 4: Equity, Level II 2010, page 3.

and provides a review of the theory behind the FFM and an illustration of how to use the FFM. CFA course participants:[26]

> 'demonstrate the use of the capital asset pricing model (CAPM), the Fama-French model (FFM)'

We conclude from this evidence that the FFM is used as a practical tool for estimating the cost of equity.

[26] http://www.cfainstitute.org/cfaprog/resources/pdf/LII_SS10.pdf

1. Introduction

This report has been prepared for the Energy Networks Association (ENA) by NERA Economic Consulting (NERA). The ENA has asked NERA to provide and review evidence on the relevance of the Fama-French three-factor model (FFM) for the purpose of estimating the cost of equity for a benchmark regulated energy utility.

In particular, the ENA has asked NERA to:

- identify whether there is a theoretical basis for the Fama-French three factor model (FFM), and if so, briefly explain what that basis is and compare it to those of the Sharpe-Lintner (SL) Capital Asset Pricing Model (CAPM) and Black CAPM;
- compare the ability of the SL CAPM, Black CAPM and FFM to predict the cost of equity in Australia;
- advise whether the model is undermined for use in Australia if one or both factors are not statistically significant;
- assess the statistical significance of premiums associated with the three Fama-French factors in Australia and assess the stability over time of the factors;
- assess the validity of the FFM relative to the obligations of the National Electricity Rules (NER) and National Gas Rules (NGR) and in comparison with the SL CAPM and the Black CAPM in terms of the AER's criteria for assessment; and
- conclude whether the FFM is a relevant financial model for the purpose of estimating the cost of equity for the benchmark firm.

The remainder of this report is structured as follows:

- section 2 examines the theoretical bases for the SL CAPM, the Black CAPM and the FFM and assesses whether the assumptions that each model makes are likely to hold;
- section 3 describes the data that we use;
- section 4 examines whether estimates that each model produces are unbiased and assesses the precision associated with the estimates;
- section 5 assesses the predictive ability of each model and examines whether the factor risk premiums are statistically significant and stable; and
- section 6 offers conclusions.

In addition, Appendix A provides the terms of reference for this report, Appendix B provides a copy of the Federal Court of Australia's *Guidelines for Expert Witnesses in Proceeding in the Federal Court of Australia* and Appendix C provides the curricula vitae of the two authors of the report.

1.1. Statement of Credentials

This report has been jointly prepared by **Simon Wheatley** and **Brendan Quach**.

Simon Wheatley is a Special Consultant with NERA, and was until 2008 a Professor of Finance at the University of Melbourne. Since 2008, Simon has applied his finance expertise in investment management and consulting outside the university sector. Simon's interests and expertise are in individual portfolio choice theory, testing asset-pricing models and determining the extent to which returns are predictable. Prior to joining the University of Melbourne, Simon taught finance at the Universities of British Columbia, Chicago, New South Wales, Rochester and Washington.

Brendan Quach is a Senior Consultant at NERA with eleven years experience as an economist, specialising in network economics and competition policy in Australia, New Zealand and the Asia Pacific. Since joining NERA in 2001, Brendan has advised a wide range of clients on regulatory finance matters, including approaches to estimating the cost of capital for regulated infrastructure businesses.

In preparing this report, the joint authors (herein after referred to as 'we' or 'our' or 'us') confirm that we have made all the inquiries that we believe are desirable and appropriate and that no matters of significance that we regard as relevant have, to our knowledge, been withheld from this report. We acknowledge that we have read, understood and complied with the Federal Court of Australia's *Practice Note CM 7, Expert Witnesses in Proceedings in the Federal Court of Australia*. We have been provided with a copy of the Federal Court of Australia's *Practice Note CM 7, Expert Witnesses in Proceedings in the Federal Court of Australia*, dated 4 June 2013, and our report has been prepared in accordance with those guidelines.

We have undertaken consultancy assignments for the Energy Networks Association in the past. However, we remain at arm's length, and as independent consultants.

2. Theory

The new NER and NGR require the AER to consider all relevant financial models and therefore provide greater scope to look at cost of equity models beyond the traditionally adopted SL CAPM.

The NER and NGR say nothing about what sort of theoretical foundations a suitable financial model should have. The AER in its *Explanatory Statement* states that (amongst other things) it will consider whether a model is: [27]

> 'consistent with well accepted economic and finance principles and informed by sound empirical analysis and robust data'.

Later the AER states that: [28]

> 'The intention here is to ensure a method which is well grounded in economic theory would have wide-spread recognition and acceptability.'

In the body of the report, the AER proposes not to use the FFM in large part because the AER states that the FFM lacks an 'economic basis'. [29] In that context, we have been asked to explain the theoretical underpinnings of the FFM, and also of the SL CAPM and Black CAPM.

In this section we outline the assumptions necessary for each model to be true, assess whether the assumptions are likely to hold and explain what impact relaxing the assumptions will have on the predictions that each model makes.

We begin by describing how the SL CAPM works.

2.1. SL CAPM

Sharpe (1964) and Lintner (1965) assume that: [30, 31]

(i) risk-averse investors choose between portfolios on the basis of the mean and variance of each portfolio's return measured over a single period;

(ii) share the same investment horizon and beliefs about the distribution of returns;

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[27] AER, *Explanatory statement: Draft rate of return guideline*, August 2013, page 27.

[28] AER, *Explanatory statement: Draft rate of return guideline*, August 2013, page 29.

[29] AER, *Explanatory statement: Draft rate of return guideline*, August 2013, page 191.

[30] As we emphasise below, the Black CAPM relaxes assumption (iv). The Black CAPM, on the other hand, requires that no restrictions be placed on short sales.

[31] Lintner, John, *The valuation of risk assets and the selection of risky investments in stock portfolios and capital budgets*, Review of Economics and Statistics 47, 1965, pages 13-37.

Sharpe, William F., *Capital asset prices: A theory of market equilibrium under conditions of risk*, Journal of Finance 19, 1964, pages 425-442.

(iii) face no taxes (or the same rate of tax on all forms of income) and there are no transaction costs; and

(iv) can borrow or lend freely at a single risk-free rate.

With these assumptions, Sharpe and Lintner show that the market portfolio of all risky assets must be mean-variance efficient. A portfolio that is mean-variance efficient is a portfolio that has the highest mean return for a given level of risk, measured by variance of return.

If the market portfolio is mean-variance efficient, the following condition will hold:

$$\mathrm{E}(r_j) = r_f + \beta_j[\mathrm{E}(r_m) - r_f], \quad (1)$$

where:

$\mathrm{E}(r_j)$ = the mean return on asset j;

r_f = the risk-free rate;

β_j = asset j's beta, which measures the contribution of the asset to the risk, measured by standard deviation of return, of the market portfolio; and

$\mathrm{E}(r_m)$ = the mean return to the market portfolio of risky assets.

The pricing model (1) is particularly simple because the assumptions that Sharpe and Lintner make are strong. We examine the importance of each of these assumptions below.

2.1.1. Investors care only about mean and variance

The first assumption that Sharpe and Lintner make is that investors are risk averse, choose between portfolios on the basis of the mean and variance of their returns and plan only for a single period ahead.

It is generally accepted that to all intents and purposes investors are risk averse. On the other hand, even casual observation indicates that investors plan more than a single period ahead. If investors plan more than a single period ahead, then, in general, they will not choose between portfolios on the basis of solely the mean and variance of the returns to the portfolios. [32]

If investors do plan only a single period ahead, then they will choose between portfolios on the basis of the mean and variance of the returns to the portfolios if:

- investors display quadratic utility; or
- the returns to individual risky assets are multivariate normal.

[32] Merton, R.C., *An intertemporal capital asset pricing model*, Econometrica 41, 1973, pages 867-887.

The assumption that investors display quadratic utility implies that they will display increasing absolute risk aversion. [33] This means that in a world in which a single risk-free asset and a single risky asset exist, investors will choose to hold less of the risky asset as their wealth rises. This is not the kind of behaviour one would expect to see and so the more commonly adopted justification for the assumption that investors choose between portfolios on the basis of the mean and variance of their returns in a single-period framework is that the returns to individual risky assets are multivariate normal. [34]

Harvey and Siddique (2000) provide evidence against the hypothesis that the returns to risky assets are multivariate normal. [35] They, like Kraus and Litznberger (1976), show that if investors do not display quadratic utility and returns are not multivariate normal, then, in general, the predictions of the SL CAPM will not hold. Instead, the mean return to an asset will depend not solely on the beta of the asset but on its coskewness with the return to the market portfolio. [36]

The assumption that investors plan only for a single period ahead implies that investors will not attempt to hedge against changes in the investment opportunity set. Merton (1973) shows that in general if investors plan more than a single period ahead and can hedge against changes in the investment opportunity set, they will do so and, as a result, the predictions of the SL CAPM will not hold. [37] Intuitively, investors may view assets that pay off well when future investment opportunities are attractive as more valuable than assets that pay off badly because they will be better able to take advantage of the opportunities. So, all else constant, investors may be willing to accept a lower return on these assets. As Merton shows, this means that in general risks other than just the risk of an asset relative to the market, the asset's beta, will be priced.

2.1.2. Investors share the same beliefs

The second assumption that Sharpe and Lintner make is that investors share the same beliefs about the distribution of returns.

The dispersion in analyst forecasts for stock prices strongly suggests that even informed investors do not share the same beliefs about the distribution of returns.

Recent analyses of what impact heterogeneous beliefs will have on the way in which assets are priced typically use multi-period frameworks in which the investment opportunity set can shift through time. Fama (1976), however, examines the impact of heterogeneous beliefs on the way in which assets are priced in a single-period mean-variance framework. [38] With

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[33] Ingersoll, J., *Theory of financial decision making*, Rowman and Littlefield, New York, 1987, page 96.

[34] Ingersoll, J., *Theory of financial decision making*, Rowman and Littlefield, New York, 1987, page 96.

[35] Harvey, C. and A. Siddique, *Conditional skewness in asset pricing tests*, Journal of Finance, 2000, pages 1263-1295.

[36] Kraus, A. and R. Litzenberger, *Skewness preference and the valuation of risk assets*, Journal of Finance, 1976, pages 1085-1100.

[37] Merton, R.C., *An intertemporal capital asset pricing model*, Econometrica 41, 1973, pages 867-887.

[38] Fama, E.F., *Foundations of finance*, Basic Books, New York, 1976, pages 314-319.

heterogeneous beliefs investors will typically disagree about the identity of portfolios that are efficient. So what may represent an efficient portfolio for one investor need not represent an efficient portfolio for another investor who has a different set of beliefs. As a result, the simple relation linking the mean return on an asset to its beta, given by (1), will no longer hold.

2.1.3. No taxes

The third assumption that Sharpe and Lintner make is that investors either face no taxes or the same taxes on all forms of income.

Investors do not in general face the same taxes on all forms of income.

Long (1977) assumes that investors face different rates of tax on capital gains and dividends but that all investors face the same rate of tax on capital gains and that all investors face the same rate of tax on dividends.[39] With these assumptions, he provides a necessary and sufficient condition under which portfolios that are mean-variance efficient on a before-tax basis are also efficient on an after-tax basis and vice versa. He concludes that the condition is unlikely to be satisfied. Thus, if the market portfolio is efficient on an after-tax basis, it is unlikely that it will be efficient on a before-tax basis and the simple relation linking the mean before-tax return on an asset to its beta, given by (1), is unlikely to hold.

2.1.4. Investors can borrow and lend at a single risk-free rate

The fourth assumption that Sharpe and Lintner make is that investors can borrow and lend unlimited amounts at a single risk-free rate of interest.

As a practical matter borrowing rates exceed lending rates. The extent by which they do will depend on the individual or institution and their credit worthiness.

Markowitz (2005) suggests that the assumption that investors can borrow or lend unlimited amounts at a single risk-free rate is unrealistic.[40] Markowitz won the Nobel Prize in Economics in 1990 for his work in examining how investors can construct efficient portfolios and his endeavours formed the basis for the work of Sharpe (1964) and Lintner (1965) in developing the SL CAPM.[41] Markowitz examines the impact of relaxing the assumption that investors can borrow or lend unlimited amounts at a single risk-free rate while retaining an assumption that investors cannot short sell. He shows that if one relaxes the assumption, the SL CAPM will no longer hold.

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[39] Long, J.B., *Efficient portfolio choice with differential taxation of dividends and capital gains*, Journal of Financial Economics, 1977, pages 25-53.

[40] Markowitz, H.M., *Market efficiency: A theoretical distinction and so what?* Financial Analysts Journal 61, 2005, pages 17-30.

[41] Lintner, John, *The valuation of risk assets and the selection of risky investments in stock portfolios and capital budgets*, Review of Economics and Statistics 47, 1965, pages 13-37.

Sharpe, William F., *Capital asset prices: A theory of market equilibrium under conditions of risk*, Journal of Finance 19, 1964, pages 425-442.

In particular, Markowitz states that: [42]

> 'The assumption that the investor can borrow without limit is crucial to the Sharpe-Lintner model's conclusions. As illustrated later in this article, if we accept the other three CAPM assumptions but assume limited (or no) borrowing, the Sharpe-Lintner conclusions no longer follow.'
>
> '(If) we assume the first three premises of the Sharpe-Lintner CAPM but take into account the fact that investors have limited borrowing capacity, then it no longer follows that the market portfolio is efficient. As this article will illustrate, this inefficiency of the market portfolio could be substantial and it would not be arbitraged away even if some investors could borrow without limit.'
>
> '(T)he original CAPM, with unlimited borrowing ... (implies) that the expected return of a stock depends in a simple (linear) way on its beta, and only on its beta. This conclusion has been used for estimating expected returns, but it has lost favor for this use because of poor predictive results. It is still used routinely in "risk adjustment," however, for valuing assets and analyzing investment strategies on a "risk-adjusted basis." I will show here that the conclusion that expected returns are linear functions of beta does not hold when real-world limits on permitted portfolio holdings are introduced into the CAPM. This discussion will call into question the frequent use of beta in risk adjustment.'

Also, Markowitz makes clear that he believes that the problems associated with empirical versions of the SL CAPM would *not* disappear were one to be provided with a series of returns to the market portfolio of *all* assets. For example, Markowitz states that: [43]

> 'A frequent explanation of why observed expected returns do not appear to be linearly related to betas is that the measures of market return used in the tests do not measure the true, universal market portfolio that appears in the CAPM. The conclusion is that to test the CAPM, we need to measure returns on a cap-weighted world portfolio. The preceding discussion implies, however, that before spending vast resources on ever finer approximations to returns on this cap-weighted universal portfolio, we should note that CAPM Conclusion 2 (that expected returns are linearly related to betas) is not likely to be true if real-world constraints are substituted for (the assumption that the Sharpe-Lintner CAPM makes of unlimited borrowing opportunities).'

2.2. Black CAPM

While the SL CAPM is an attractively simple theory, it has been known for well over 40 years that empirical versions of the model of the kind that the AER uses tend to underestimate the returns to low-beta assets and overestimate the returns to high-beta assets. Mehrling (2005), for example, reports that:[44]

> 'The very first [Wells Fargo] conference was held in August 1969 at the University of Rochester in New York State ... The focus of the first Wells Fargo conference was on empirical tests of the CAPM ... the most significant output of the first conference was the paper of Fischer Black, Michael Jensen, and Myron Scholes (BJS), titled "The Capital Asset Pricing

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[42] Markowitz, H.M., *Market efficiency: A theoretical distinction and so what?* Financial Analysts Journal 61, 2005, pages 17-18.

[43] Markowitz, H.M., *Market efficiency: A theoretical distinction and so what?* Financial Analysts Journal 61, 2005, pages 28.

[44] Mehrling, Perry, *Fischer Black and the revolutionary idea of finance*, Wiley, 2005, pages 104-105.

> Model: Some Empirical Tests," eventually published in 1972. ... One important consequence of the BJS tests was to confirm earlier suggestions that low-beta stocks tend to have higher returns and high-beta stocks tend to have lower returns than the theory predicts.'

This empirical regularity prompted Black (1972), Vasicek (1971) and Brennan (1971) to examine whether relaxing the assumption that investors can borrow or lend freely at a single rate can produce a model that better fits the data.[45]

Brennan (1971) shows that if one replaces assumption (iv) of the SL CAPM with:[46]

(v) investors can borrow at a risk-free rate r_b and lend at a risk-free rate $r_l < r_b$ and face no restrictions on short sales, then:

$$\mathrm{E}(r_j) = \mathrm{E}(r_z) + \beta_j[\mathrm{E}(r_m) - \mathrm{E}(r_z)], \qquad r_l < \mathrm{E}(r_z) < r_b \tag{2}$$

where:

$\mathrm{E}(r_z)$ = the mean return to a zero-beta portfolio.

Although three authors contributed to the development of the model, the model is generally known as the 'Black CAPM'.

If $\mathrm{E}(r_z) = r_f$, the model collapses to the SL CAPM, illustrating the fact that the Black CAPM is a more general model than the SL CAPM.

The Black CAPM replaces the fourth assumption that Sharpe and Lintner make, that investors can borrow and lend unlimited amounts at a single risk-free rate of interest, with the assumption that there are no restrictions on short sales. As a practical matter there are restrictions on short sales.

2.2.1. No restrictions on short sales

To sell short, one must pay a fee and there also legal and institutional constraints that inhibit investors from selling short (see, for example, Jones and Lamont (2002)). [47]

Markowitz (2005) suggests that the assumptions that the Black CAPM – what he labels an alternate version of the CAPM – makes are unrealistic and that the model is likely to be wrong.[48] For example, Markowitz states that:[49]

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[45] Black, Fischer, *Capital market equilibrium with restricted borrowing*, Journal of Business 45, 1972, pages 444-454.

Brennan, Michael, *Capital market equilibrium with divergent borrowing and lending rates*, Journal of Financial and Quantitative Analysis 6, 1971, pages 1197-1205.

Vasicek, Oldrich, *Capital market equilibrium with no riskless borrowing*, Memorandum, Wells Fargo Bank, 1971.

[46] Brennan, Michael, *Capital market equilibrium with divergent borrowing and lending rates*, Journal of Financial and Quantitative Analysis 6, 1971, pages 1197-1205.

[47] Jones, C.M. and O.A. Lamont, *Short-sale constraints and stock returns*, Journal of Financial Economics, 2002, pages 207-239.

> 'An alternate version of the CAPM speaks of investors holding short as well as long positions. But the portfolios this alternate CAPM permits are as unrealistic as those of the Sharpe-Lintner CAPM with unlimited borrowing.'
>
> '(T)he alternate CAPM, with unrealistic short rules, (implies) that the expected return of a stock depends in a simple (linear) way on its beta, and only on its beta. This conclusion has been used for estimating expected returns, but it has lost favor for this use because of poor predictive results. It is still used routinely in "risk adjustment," however, for valuing assets and analyzing investment strategies on a "risk-adjusted basis." I will show here that the conclusion that expected returns are linear functions of beta does not hold when real-world limits on permitted portfolio holdings are introduced into the CAPM. This discussion will call into question the frequent use of beta in risk adjustment.'

Markowitz also makes clear that he believes that the problems associated with empirical versions of the Black CAPM would *not* disappear were one to be provided with a series of returns to the market portfolio of *all* assets. Thus Markowitz believes that the assumptions that both the SL CAPM and Black CAPM make are unrealistic and that replacing these assumptions by more realistic assumptions would remove the implication of both models that there should be a positive linear relation between risk, measured by beta, and return.

2.3. FFM

A stock's price will depend on the cash flows that the stock is expected to provide and on the rate at which the market will discount the cash flows. So the cross-section of stock prices should contain useful information about the cross-section of mean returns to stocks. A stock whose price is low is, all else constant, a stock whose mean return is likely to be high. A stock whose price is high is, all else constant, a stock whose mean return is likely to be low. A stock's price, however, will also depend on factors like the number of shares of the stock that are outstanding. A stock's price, for example, will fall by approximately one half when a two-for-one stock split is executed. For this reason, financial ratios in which price sits either in the denominator or numerator are more likely to track variation across stocks in mean returns than are prices that have not been scaled in some way.

Ball (1978) emphasises that financial ratios may provide information about the cross-section of mean returns to stocks not provided by estimates of beta.[50] Similarly, Berk (1995) emphasises that the market value of a firm's equity may provide information about the cross-section of returns to stocks not provided by estimates of beta.[51] Fama and French (1992) show that the market value of a firm's equity and the ratio of the book value of the equity to

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[48] Markowitz, H.M., *Market efficiency: A theoretical distinction and so what?* Financial Analysts Journal 61, 2005, pages 17-30.

[49] Markowitz, H.M., *Market efficiency: A theoretical distinction and so what?* Financial Analysts Journal 61, 2005, page 18.

[50] Ball, R., *Anomalies in relationships between securities' yields and yield surrogates*, Journal of Financial Economics, 1978, pages 103-126.

[51] Berk, J., *A critique of size-related anomalies*, Review of Financial Studies, 1995, pages 275-286.

its market value do not just provide information about the equity's return not provided by an estimate of the equity's beta, but they provide information whereas the estimate does not.[52]

If there are factors besides the return to the market portfolio of stocks that are pervasive, then the Arbitrage Pricing Theory (APT) of Ross (1976) predicts that the additional risks associated with the factors should be priced.[53] The intuition behind the APT is that investors will be rewarded for risks that are pervasive and they cannot diversify away but will not be rewarded for risks that are idiosyncratic and that they can diversify away. If investors were not rewarded for bearing pervasive risks, arbitrage opportunities would arise.

Fama and French (1993) argue, therefore, that if assets are priced rationally, then variables, like the market value of a firm's equity and the ratio of the book value of equity to its market value, that can explain the cross-section of mean returns *must* be proxies for risks that cannot be diversified away.[54]

Fama and French (1993) suggest that there are three pervasive sources of risk or factors:[55]

(a) the excess return to the market portfolio;

(b) the difference between the return to a portfolio of high book-to-market stocks and the return to a portfolio of low book-to-market stocks (*HML*); and

(c) the difference between the return to a portfolio of small-cap stocks and the return to a portfolio of large-cap stocks (*SMB*).

If the following conditions are true:

(i) there are no arbitrage opportunities; and

(ii) the excess return to the market, *HML* and *SMB* are the only pervasive sources of risk and a risk-free asset exists,

then:

$$\mathrm{E}(r_j) = r_f + b_j[\mathrm{E}(r_m) - r_f] + h_j\mathrm{E}(HML) + s_j\mathrm{E}(SMB), \quad (3)$$

where:

b_j, h_j and s_j are the slope coefficients from a multivariate regression of r_j on r_m, *HML* and *SMB,* and E(*HML*) and E(*SMB*) are the *HML* and *SMB* premiums.

We explain below whether assumption (i) is likely to hold and whether Fama and French provide evidence to support (ii). We also explain why the two assumptions together imply

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52 Fama, Eugene and Kenneth French, *The cross-section of expected returns*, Journal of Finance 47, 1992, pages 427-465.

53 Ross, Stephen, *The arbitrage theory of capital asset pricing*, Journal of Economic Theory 13, 1976, pages 341-360.

54 Fama, Eugene and Kenneth French, *Common risk factors in the returns to stocks and bonds*, Journal of Financial Economics 33, 1993, pages 3-56.

55 Fama, Eugene and Kenneth French, *Common risk factors in the returns to stocks and bonds*, Journal of Financial Economics 33, 1993, pages 3-56.

that the pricing relation (3) should hold, at least approximately, in the data that Fama and French use.

2.3.1. No arbitrage opportunities

An arbitrage opportunity offers a positive return with no investment or risk undertaken. The idea that prices should be set so as to rule out arbitrage opportunities is one of the most basic and oldest in Finance. Rubinstein notes that Fisher used a no-arbitrage argument as early as 1907.[56] The no-arbitrage principle is also a cornerstone of modern finance and applications of the principle to corporate finance and to the pricing of derivatives have led to Nobel Prizes for Miller, Merton and Scholes.[57] If there is anything about which economists can agree, it is that arbitrage opportunities in the market place should be difficult to identify.

Of course, for an investor to be able to take full advantage of an arbitrage opportunity requires the investor face no short sale constraints. Whereas the Black CAPM, however, requires *all* investors face no short-sale constraints, for there to be no arbitrage opportunities it is only necessary that *some* investors face no short-sale constraints. Thus the assumptions necessary for there to be no arbitrage opportunities are less restrictive than the assumptions necessary for the Black CAPM to hold.

2.3.2. *HML* and *SMB* are the only pervasive sources of risk

Fama and French (1993) form 25 portfolios on the basis of the book-to-market ratios and market capitalisations of US stocks. Using data from July 1963 to December 1991 they regress the returns to these portfolios in excess of the one month risk-free rate on the three Fama-French factors.

The R^2 values attached to these time series regressions range from 0.83 to 0.97.[58] R^2, known as the coefficient of determination, represents the fraction of the variation in a dependent variable explained by variation in a set of independent variables. Thus a regression that has an R^2 that is close to one is a regression in which the set of independent variables comes close to fully explaining variation in the dependent variable. It follows that the high R^2 values that Fama and French report indicate that one could almost replicate the returns to the 25 portfolios using the three Fama-French factors. If the R^2 values were all equal to 1.00, one would be able to replicate the returns to the portfolios exactly.

Estimates of the Fama-French betas of the 25 portfolios relative to the excess return to the market range from 0.91 to 1.18. Thus the portfolios all have Fama-French betas relative to the market factor that are around one. In contrast, estimates of the betas of the 25 portfolios relative to the *HML* factor range from -0.52 to 0.76 and estimates of the betas relative to the *SMB* factor range from -0.23 to 1.46. Thus the 25 portfolios that Fama and French construct have a variety of exposures to the *HML* and *SMB* factors.

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[56] Rubinstein, M., *A history of the theory of investments*, Wiley, 2006, page 7.

[57] http://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/

[58] Fama, Eugene and Kenneth French, *Common risk factors in the returns to stocks and bonds*, Journal of Financial Economics 33, 1993, pages 3-56.

Together these pieces of evidence indicate that one can form up portfolios of US stocks with different exposures to the *HML* and *SMB* factors in which virtually all but an exposure to the three Fama-French factors is diversified away. In other words, the evidence that Fama and French provide suggests that the *HML* and *SMB* factors are indeed pervasive sources of risk – at least in US data.

It may be, on the other hand, that the excess return to the market portfolio, *HML* and *SMB* are not the only pervasive sources of risk. As Fama and French (2004) point out, another pervasive source of risk may be linked to momentum in stock returns.[59] They emphasise, however, that since momentum is short-lived, it is largely irrelevant for constructing estimates of the cost of capital.

2.3.3. Implications

The mean excess returns to the 25 portfolios, that Fama and French form, range from 4.68 per cent per annum to 12.60 per cent per annum while estimates of their Sharpe-Lintner betas range from 0.84 to 1.40. So the evidence that Fama and French provide suggests that an empirical version of the SL CAPM cannot describe the data that they assemble. Instead, as Cochrane (2001) points out, the evidence that Fama and French provide suggests that, to rule out near-arbitrage opportunities, their three-factor model must be approximately true. Cochrane states that:[60]

> 'extremely high Sharpe ratios for the residuals would have to be invoked for the [Fama-French] model *not* to fit well. Equivalently, given the average returns and the failure of the CAPM to explain those returns, there would be near-arbitrage opportunities if value and small stocks did not move together in the way described by the Fama-French model.'

The Sharpe ratio is the ratio of the return to a portfolio that one can expect to receive relative to the return that one would receive were one to bear no risk to the risk, measured by standard deviation of return, which one must bear in holding the portfolio.

To illustrate the point that Cochrane makes, we use a numerical example drawn from the results that Fama and French provide. In particular, we use various statistics for the small/high (low market capitalisation and high book-to-market) portfolio and the three factors, that Fama and French supply. These statistics appear in Table 2.1 below.

The argument that Cochrane makes is that if the FFM were not to hold for the 25 portfolios that Fama and French construct, but instead the mean returns to the portfolios were to be determined by the SL CAPM, there would be near-arbitrage opportunities. To see that this would be the case, consider an arbitrage strategy that is:

- short a zero-investment position that is long the small/high portfolio and short the risk-free asset; and

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[59] Fama, E. and K. French, *The Capital Asset Pricing Model: Theory and evidence*, Journal of Economic Perspectives, 2004 pages 25-46.

[60] The emphasis is Cochrane's.

Cochrane, John H., *Asset pricing*, Princeton University Press, 2001, page 442.

- long a synthetic version of the zero-investment position constructed from the three Fama-French factors.

The return to the arbitrage strategy will be:

$$\left[b_j(r_m - r_f) + h_j HML + s_j SMB\right] - \left[r_j - r_f\right] \tag{4}$$

The second term in brackets is the return to the zero-investment position that is long the small/high portfolio and short the risk-free asset. The first term is the return to a synthetic version of the zero-investment position constructed from the three Fama-French factors.

The results that Fama and French provide, summarised in Table 2.1, indicate that the mean return to the strategy, were the mean return to the small/high portfolio to be determined by the SL CAPM, would be in per cent per annum:

$$\begin{aligned}&\left[b_j \mathrm{E}(r_m - r_f) + h_j \mathrm{E}(HML) + s_j \mathrm{E}(SMB)\right] - \left[\beta_j \mathrm{E}(r_m - r_f)\right] \\ &= \left[0.96 \times 5.16 + 0.62 \times 4.80 + 1.23 \times 3.24\right] - \left[1.08 \times 5.16\right] = 6.34\end{aligned} \tag{5}$$

The standard deviation of the return to the strategy will be, in per cent per annum, again using the results that appear in Table 2.1:

$$= 21.72 \times \sqrt{1 - 0.96} = 4.34. \tag{6}$$

Thus if the mean return to the small/high portfolio were to be determined by the SL CAPM, the strategy would have a Sharpe ratio attached to it of 6.34 ÷ 4.34 = 1.46 – a high enough Sharpe ratio for the strategy to be described as a near-arbitrage opportunity. Other strategies that involve combining positions in a number of the 25 portfolios that Fama and French form may generate even larger Sharpe ratios. The Sharpe ratio for the market, in contrast, is, from Table 2.1, just 0.33, for the *HML* factor, 0.55, and for the *SMB* factor 0.32.

If, of course, the mean return to the small/high portfolio were to be determined by the FFM, the near-arbitrage opportunity that we describe would vanish.

2.3.4. Empirical motivation

A frequent criticism of the FFM is that Fama and French choose the additional factors *HML* and *SMB* based on their knowledge of the data. In other words, the claim is that Fama and French choose the *HML* and *SMB* factors because they know that the premiums attached to the factors are positive in the sample that they employ, that the SL CAPM cannot explain the premiums and that their alternative pricing model works well in the sample that they use.

Table 2.1
Statistics for the small/high portfolio and the three factors drawn from the results that Fama and French (1993) provide: US data from July 1963 to December 1991

	Excess returns		Factors	
Statistic	Small/high	Market	*HML*	*SMB*
Mean	12.12	5.16	4.80	3.24
Std. dev.	21.72	15.73	8.80	10.01
Sharpe ratio	0.56	0.33	0.55	0.32
β_j	1.08			
b_j	0.96			
h_j	0.62			
s_j	1.23			
Fama-French R^2	0.96			

Notes: Means are in per cent per annum and have been computed by multiplying the monthly data that Fama and French (1993) provide by 12. Standard deviations are also in per cent per annum and have been computed by multiplying the monthly data that Fama and French (1993) provide by √12.

Source: Fama, Eugene and Kenneth French, Common risk factors in the returns to stocks and bonds, Journal of Financial Economics 33, 1993, pages 3-56.

There are two responses to this criticism. First, the FFM passes two of the tests that Friedman (1953) proposes a model should pass. [61] As Friedman emphasises, the first task of a theory is to explain what we observe. Fama and French (1993) use data over a relatively short period, from 1963 to 1991, but find that over that period the model can explain variation in mean returns across stocks that an empirical version of the SL CAPM cannot explain. [62] So the FFM passes the first of Friedman's tests. Friedman emphasises that the second task of a theory is to explain facts that it was not originally designed to explain. Fama and French (1996) find the model can explain the tendency of five-year US returns to reverse while Davis, Fama and French (2000) find that the model works well in US data prior to 1963. [63]

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[61] The second task is to predict what we do not currently observe.

Friedman, Milton, *The methodology of positive economics*, in Positive Economics, University of Chicago Press, 1953, pages 12-14.

[62] Fama, Eugene and Kenneth French, *Common risk factors in the returns to stocks and bonds*, Journal of Financial Economics 33, 1993, pages 3-56.

NERA, Review of cost of equity models: A report for the Energy Networks Association, June 2013.

[63] Fama, Eugene and Kenneth French, *Multifactor explanations of asset-pricing anomalies*, Journal of Finance 47, 1996, pages 426-465.

Davis, James, Eugene Fama and Kenneth French, *Characteristics, covariances, and average returns: 1929-1997*, Journal of Finance 55, 2000, pages 389-406.

The data from before 1963 had not been assembled at the time Fama and French developed the FFM. So the FFM passes the second of Friedman's tests and can explain related facts it was not originally engineered to explain.

Second, the *HML* and *SMB* factors are not without theoretical motivation. As Ball (1978) points out, theory suggests that financial ratios in which price sits either in the denominator or numerator are likely to track variation across stocks in mean returns and may pick up variation not tracked by the SL CAPM. [64] Theory, as Berk (1995) points out, also suggests that the market value of a firm's equity is likely to track variation across stocks in mean returns and may pick up variation not tracked by the SL CAPM. [65] In later work, researchers have suggested that the Fama-French factors could be proxies for, among other risks, the risks of financial distress, the risks of an asymmetric exposure to market conditions or risks associated with arbitrage. [66]

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[64] Ball, R., *Anomalies in relationships between securities' yields and yield surrogates*, Journal of Financial Economics, 1978, pages 103-126.

[65] Berk, J., *A critique of size-related anomalies*, Review of Financial Studies, 1995, pages 275-286.

[66] Ali, A., L. Hwang, and M.A. Trombley, *Arbitrage risk and the book-to-market anomaly*, Journal of Financial Economics, 69, 2003, pages 355–373.

Petkova, R., and L. Zhang, *Is value riskier than growth?* Journal of Financial Economics, 78, 2005, pages 187–202.

Vassalou, M., and Y. Xing, *Default risk in equity returns*, Journal of Finance, 59, 2004, pages 831–868.

3. Data

Attached to each financial model are strengths and weaknesses. These strengths and weaknesses depend on the *bias* that may result from the use of a model and the *precision* with which the use of a model will allow one to estimate the cost of equity. An estimator of a parameter is said to be unbiased if the expected value of the estimator matches the parameter and is said to be biased if the expected value differs from the parameter.[67] The precision of a random variable is the reciprocal of its variance.[68]

All else constant an unbiased estimator will be preferred to a biased estimator and all else constant a more precise estimator will be preferred to a less precise estimator. In principle, one may be willing to trade off bias for precision. For example, one may be willing to use an estimator that is less precise than an alternative if the bias associated with the estimator is smaller than the bias associated with the alternative.

Since the bias attached to an estimator that uses a pricing model and the precision of the estimator are important parameters, we provide estimates of these parameters for each of the models that the ENA proposes the AER should use for a range of equities.

W also assess whether the parameters of each model are sufficiently stable that the model can be of practical use. Before we proceed to the evidence that we provide, however, we describe the data that we use.

3.1. Australian Data

We extract monthly returns for individual Australian stocks from SIRCA's Share Price and Price Relative (SPPR) database. We exclude foreign stocks listed in Australia. Thus, for example, we exclude Kraft Foods Inc. Also, to minimise the impact of market microstructure effects, we exclude stocks in each year that at the end of the previous year fell outside the top 500 by market capitalisation.[69] We choose the top 500 because the All Ordinaries Index is constructed from the top 500 stocks. From the stocks remaining, we form a number of value-weighted portfolios.

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[67] See, for example:

Hamilton, J.D., *Time series analysis*, Princeton University Press, Princeton, NJ, 1994, page 741.

[68] This definition, standard in the statistics literature, differs from the Oxford Dictionary definition of precision which is:

> 'accuracy or exactness.'

In statistics a precise estimator can be exact but inaccurate. As Davidson and MacKinnon note, however,

> 'it is sometimes more intuitive to think in terms of precision than in terms of variance.'

We agree and so use the terms precise and precision to render our discussion easier to follow.

Davidson, R. and J. G. MacKinnon, *Estimation and inference in econometrics*, Oxford University Press, Oxford, 1993, page 144.

Fowler, F.G. and H.W. Fowler, *Pocket Oxford Dictionary*, Oxford University Press, Oxford, 1966, page 623.

[69] These microstructure effects can include the problems associated with infrequent trading. Small-cap stocks can trade infrequently and this infrequent trading can create difficulties in generating unbiased estimates of their betas.

First, we form a value-weighted portfolio of the 500 stocks and use the portfolio as a proxy for the Australian market portfolio. Second, we form a value-weighted portfolio of small firms from the bottom 30 percent of firms and a value-weighted portfolio of big firms from the top 30 percent. We use the difference between the returns to these portfolios as the *SMB* (small minus big) factor in the FFM and rebalance the portfolios at the end of each year. We form the *SMB* factor in this way because we take the *HML* (high minus low) factor from Ken French's web site and French constructs the *HML* factor in this way.[70]

Third, we form value-weighted portfolios on the basis of past Sharpe-Lintner beta estimates. At the end of December each year we use data for the prior five years to estimate the Sharpe-Lintner betas of all stocks relative to the Australian market portfolio, dropping those that do not have a full 60 months of data. We then place the stocks into five portfolios on the basis of the estimates. Thus we form portfolios in a way that is similar to the manner in which Black, Jensen and Scholes (1972) form portfolios.[71] We also form portfolios in the same way using, in place of past Sharpe-Lintner beta estimates, estimates of the betas of individual stocks relative to the three Fama-French factors.

We extract the one-month risk-free rate from the SPPR, the returns to growth and value portfolios from Ken French's web site and the yield to a 10-year Commonwealth Government Security (CGS) from the Reserve Bank.[72] Since we use monthly data, we use as a proxy for the risk-free rate the one-month risk-free rate taken from the SPPR. We also assess, however, the sensitivity of our results to replacing this rate with the yield on a monthly basis to a 10-year CGS. French provides data for value and growth portfolios from January 1975 to December 2012, so we use this period in tests that use Australian data.

3.2. US Data

We extract monthly data for the three US Fama-French factors from Ken French's web site.[73] These data run from July 1926 to August 2013.

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[70] See Fama and French (1998) for a detailed description of how they construct the *HML* factors that we use.

Fama, E.F. and K.R. French, *Value versus growth: The international evidence*, Journal of Finance 53, 1998, pages 1975-1999.

http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

[71] Black, F., M. Jensen and M. Scholes, *The capital asset pricing model: Some empirical tests*, in Studies in the theory of capital markets, ed. M. Jensen, 1972.

[72] http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

[73] http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

4. Bias and Precision

Determining whether a pricing model is a relevant model for estimating the cost of equity for a regulated energy utility requires that one compare the model to the alternatives.

In this section we consider whether estimates of the cost of equity produced by each of the three pricing models that the ENA suggests that the AER should use are likely to be biased or unbiased. We also examine how precise estimates of the cost of equity that each model produces are likely to be. In principle, one may be willing to trade off bias for precision. Our aim in this section is to provide information about the costs and benefits of such tradeoffs.

4.1. Bias

We begin by considering whether estimates of the cost of equity that each model produces are likely to be biased or unbiased.

4.1.1. SL CAPM

We have emphasised on a number of previous occasions in reports to the AER that the use of an empirical version of the SL CAPM of the kind that the AER uses can generate estimates of the cost of equity that are biased. [74] An empirical version of the SL CAPM will typically underestimate the returns required on stocks or portfolios with low betas and overestimate the returns required on stocks or portfolios with high betas. Also, an empirical version of the SL CAPM will typically underestimate the returns required on value stocks or portfolios and overestimate the returns required on growth stocks or portfolios.

Table 4.1 illustrates these empirical regularities. Panel A shows the sample means of the returns to five portfolios, formed on the basis of past estimates of the Sharpe-Lintner betas of individual Australian stocks, in excess of the risk-free rate and estimates of the Sharpe-Lintner betas of the portfolios. The five portfolios are formed on the basis of past estimates of Sharpe-Lintner betas that use the most recent 60 months of returns. Thus the portfolios that are constructed at the end of 1979 are formed on the basis of estimates of Sharpe-Lintner betas that use data from January 1975 to December 1979. The portfolios that are constructed at the end of 2011 are formed on the basis of estimates of Sharpe-Lintner betas that use data from January 2007 to December 2011. The Sharpe-Lintner beta estimates that appear in Table 4.1, on the other hand, use the returns to the five portfolios from January 1980 to December 2012. In other words, they are not averages of the Sharpe-Lintner beta estimates used to construct the five portfolios.

Panel A also shows estimates of the mean excess return to each portfolio constructed using an empirical version of the SL CAPM and estimates of the bias attached to the estimates. An estimate of the bias is constructed for each portfolio by subtracting the Sharpe-Lintner estimate of the mean excess return to the portfolio from the sample mean excess return. Thus

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[74] NERA, *Jemena Access Arrangement Proposal for the NSW Gas Networks: AER Draft Decision: A report for Jemena*, March 2010, page 22.

NERA, Review of cost of equity models: A report for the Energy Networks Association, June 2013, pages 3-13.

an estimate of the bias is simply the estimate of the intercept from a regression of the excess return to a portfolio on the excess return to the market portfolio of stocks.

Panel B shows the corresponding estimates for the value and growth portfolios that French constructs and for the small-cap and large-cap portfolios that we construct.

Table 4.1
Bias associated with the use of an empirical version of the SL CAPM: Australian data from January 1980 to December 2012

Portfolio	Sample mean excess return	Beta estimate	Sharpe-Lintner mean excess return	Bias estimate
Panel A: Portfolios formed on past estimates of beta				
1	7.81	0.58	2.75	**5.06**
2	7.23	0.76	3.56	**3.67**
3	7.59	0.91	4.28	**3.32**
4	4.51	1.11	5.23	-0.73
5	2.48	1.29	6.08	-3.61
Panel B: Portfolios formed on book-to-market and size				
Value	8.48	0.93	4.36	**4.12**
Growth	2.10	1.15	5.40	**-3.30**
Small	4.56	0.93	4.37	0.20
Big	4.82	1.02	4.79	0.04

Notes: Data are from SIRCA's Share Price and Price Relative database and Ken French's web site. Mean excess returns are in per cent per annum and are the monthly mean returns in excess of the one-month risk-free rate in per cent multiplied by 12. Bias estimates that differ significantly from zero at the five per cent level are in bold.

The two panels together show that there is evidence that is significant at the five per cent level that an empirical version of the SL CAPM:

- underestimates the returns required on stocks with low betas; and
- underestimates the returns required on value stocks and overestimates the returns required on growth stocks.

4.1.2. Black CAPM

An empirical version of the Black CAPM, by construction, will not tend to underestimate the returns required on stocks or portfolios with low betas or overestimate the returns required on stocks or portfolios with high betas. As Table 4.1 indicates, though, an empirical version of

the Black CAPM will use an estimate of the mean return to a zero-beta portfolio in excess of the risk-free rate that exceeds the market risk premium (*MRP*). This is because the table shows that, empirically, there is a negative, rather than a positive, relation between return and risk, measured by a portfolio's Sharpe-Lintner beta. This result is consistent with evidence that we provide in a related report in June 2013. [75] The evidence that we provide in June 2013 indicates that an estimate of the zero-beta premium using individual security data is 11.05 per cent per annum with a standard error of 3.39. This result implies that one can reject at the five per cent level any hypothesis that states that the zero-beta premium does not exceed 4.40. This is because if $X \leq 4.40$, then $(11.05 - X)/3.39 > 1.96$, where 1.96 is the appropriate critical value for a two-sided test that uses the standard normal distribution. Thus our June 2013 results are not consistent with a version of the Black CAPM that would set the zero-beta rate no more than 4.40 per cent per annum above the risk-free rate.

The evidence that we provide in Table 4.1 suggests that value portfolios have low Sharpe-Lintner betas and growth portfolios have high Sharpe-Lintner betas. So an empirical version of the Black CAPM that allows the zero-beta premium to exceed the *MRP* may not underestimate the returns required on value stocks and overestimate the returns required on growth stocks. The US evidence, in contrast, indicates that an empirical version of the Black CAPM underestimates the returns required on value stocks and overestimates the returns required on growth stocks. [76]

4.1.3. FFM

The FFM is designed to eliminate the tendency of an empirical version of the SL CAPM to underestimate the cost of equity for value stocks and overestimate the cost of equity for growth stocks. The FFM is also designed to eliminate any tendency for the model to underestimate the cost of equity for small-cap stocks and overestimate the cost of equity for large-cap stocks. Brailsford, Gaunt and O'Brien (2012) provide evidence that in Australian data the FFM is largely successful in eliminating the tendency of an empirical version of the SL CAPM to either underestimate or overestimate the cost of equity for value, growth, small-cap or large-cap portfolios and we review this evidence in a June 2013 report.[77]

There is evidence, however, that the FFM underestimates the cost of equity for low-market-beta stocks and overestimates the cost of equity for high-market-beta stocks in exactly the same way that the SL CAPM does. We will illustrate this problem with the model when we assess the predictive ability of each model in the next section.

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[75] NERA, Estimates of the zero-beta premium: A report for the Energy Networks Association, June 2013.

[76] Fama, E. and K. French, *The Capital Asset Pricing Model: Theory and evidence*, Journal of Economic Perspectives, 2004 pages 25-46.

[77] Brailsford, T., C. Gaunt and M. O'Brien, *Size and book-to-market factors in Australia*, Australian Journal of Management, 2012, pages 261-281.

NERA, Review of cost of equity models: A report for the Energy Networks Association, June 2013.

4.2. Precision

While an unbiased estimator may be preferred to a biased estimator, unbiased estimators may be less precise. We now turn our attention to the precision of estimators of the cost of equity that use the three pricing models. We begin by deriving formulae for each estimator's variance.

4.2.1. SL CAPM

An estimator of the cost of equity in excess of the risk-free rate that uses an empirical version of the SL CAPM is the product of an estimator of beta and an estimator of the *MRP*. That is, an estimator of the cost of equity in excess of the risk-free rate that uses an empirical version of the SL CAPM can be written:

$$\hat{\beta}_j \, \hat{MRP} \ , \tag{7}$$

where a hat denotes an estimator. One can determine, approximately, the variance of the estimator using the delta method.[78] The variance will be, approximately:

$$MRP^2 \ \mathrm{Var}(\hat{\beta}_j) + \beta_j^2 \ \mathrm{Var}(\hat{MRP}) \ , \tag{8}$$

where we use the fact that the estimator of beta will be uncorrelated with the estimator for the *MRP*. The delta method drops terms that are an order of magnitude smaller than the terms that it retains. Thus the delta method drops the term

$$\mathrm{Var}(\hat{\beta}_j)\mathrm{Var}(\hat{MRP}) \tag{9}$$

because it is negligible. Dropping terms that are negligible greatly simplifies the task of determining the variance of an estimator for the cost for equity. Since the risk-free rate is non-stochastic, expression (8) is also the variance of an estimator of the cost of equity.

4.2.2. Black CAPM

An estimator of the cost of equity in excess of the risk-free rate that uses an empirical version of the Black CAPM can be written:

$$(1-\hat{\beta}_j)\hat{ZBP} + \hat{\beta}_j \, \hat{MRP} \ , \tag{10}$$

where *ZBP* denotes the zero-beta premium, $\mathrm{E}(r_z) - r_f$. The variance of this estimator, again using the delta method, will be approximately:

$$\left(MRP - ZBP \right)^2 \ \mathrm{Var}(\hat{\beta}_j) + (1-\beta_j)^2 \mathrm{Var}(\hat{ZBP}) + \beta_j^2 \ \mathrm{Var}(\hat{MRP}) \ , \tag{11}$$

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[78] Hayashi, F., Econometrics, Princeton University Press, 2000, pages 93-94.

where we use the fact that an estimator of the zero-beta premium will be uncorrelated with an estimator for the *MRP* and will be approximately uncorrelated with an estimator for beta. [79] The estimator for beta will be approximately uncorrelated with the estimator for the zero-beta premium because, in practice, the estimator for beta uses a much shorter time series than the estimator for the zero-beta premium. Again, because the risk-free rate is non-stochastic, the expression (11) is also the variance of an estimator of the cost of equity.

4.2.3. FFM

An estimator of the cost of equity in excess of the risk-free rate that uses the FFM can be written:

$$\hat{B}_j' \hat{FRP} \tag{12}$$

where B_j' is a 1 × 3 vector of Fama-French betas and *FRP* is a 3 × 1 vector of Fama-French factor premiums. Note that the first element of the vector *FRP* will be the *MRP*. The variance of the estimator will be, approximately:

$$FRP' \mathrm{Var}(\hat{B}_j) FRP + \hat{B}_j' \mathrm{Var}(\hat{FRP}) \hat{B}_j, \tag{13}$$

where we use the fact that that the estimator of the vector of betas will be uncorrelated with the estimator for the vector of factor risk premiums. The expression (13) is also the variance of an estimator of the cost of equity.

4.2.4. Estimates

To construct estimates of the standard deviation of an estimator of the cost of equity that uses each pricing model, we require estimates of the parameters that appear in the expressions (8), (11) and (13).

We use the following estimates:

$$FRP = \begin{pmatrix} 6.5 \\ 7.5 \\ 3.2 \end{pmatrix}, \quad \mathrm{Var}(\hat{FRP}) = \begin{pmatrix} 1.5^2 & 0 & 0 \\ 0 & 3.2^2 & 0 \\ 0 & 0 & 3.2^2 \end{pmatrix},$$

$$ZBP = 11.0, \quad \mathrm{Var}(\hat{ZBP}) = 3.4^2, \quad \mathrm{Var}(\hat{B}_j) = \begin{pmatrix} 0.1^2 & 0 & 0 \\ 0 & 0.1^2 & 0 \\ 0 & 0 & 0.1^2 \end{pmatrix} \tag{14}$$

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[79] For an explanation of why an estimator of the zero-beta premium will be uncorrelated with an estimator for the *MRP*, see:

Fama, E.F., Foundations of finance, Basic Books, 1976, pages 326-331.

These estimates are drawn from the following reports:

- $\text{Var}(\hat{MRP})$ from Handley, *An estimate of the historical equity risk premium for the period 1883 to 2011*, University of Melbourne, April 2012, page 5.

- *FRP* and the remaining elements of $\text{Var}(\hat{FRP})$ from NERA, *The market size and value premiums: A report for the Energy Networks Association*, June 2013, pages 17 and 86-87.

- *ZBP* and $\text{Var}(\hat{ZRP})$ from NERA, *Estimates of the zero-beta premium: A report for the Energy Networks Association, Ju*ne 2013, page 16.

- $\text{Var}(\hat{B}_j)$ from SFG, *Regression-based estimates of risk parameters for the benchmark firm*, 24 June 2013, pages 13-15.

There are a couple of points to note about these estimates. First, the vector *FRP* contains the three Fama-French factor risk premiums and the first of these is the *MRP*. Second, we assume, for simplicity, that the two covariance matrices in (14) are diagonal. For reasons that we will make clear, this assumption will have little impact on our results.

With these data, and also assumptions about the values for the Sharpe-Lintner and Fama-French betas, we can compute estimates of the standard deviation of an estimator of the cost of equity that uses each pricing model. Table 4.2 provides these estimates.

The first row of Table 4.2 shows that if the Sharpe-Lintner beta of a portfolio is 0.5 and the Fama-French market beta of the portfolio is also 0.5, but the Fama-French *HML* and *SMB* betas are both zero, then the SL CAPM will provide a more precise estimator of the return required on the portfolio than either the Black CAPM or the FFM. The difference between the precision of an estimator that uses the SL CAPM and the precision of an estimator that uses the FFM is small. The standard deviation of an estimator that uses the Black CAPM, though, is twice the standard deviation of an estimator that uses the SL CAPM.

To make the way in which we compute each standard deviation as clear as is possible, it will be worth going through how we compute each standard deviation in the first row of Table 4.2.

Using (8), the standard deviation of an estimator of the return required on the portfolio that uses an empirical version of the SL CAPM is:

$$\left[MRP^2 \ \text{Var}(\hat{\beta}_j) + \beta_j^2 \ \text{Var}(\hat{MRP}) \right]^{1/2}$$

$$= \left[6.5^2 \times 0.1^2 + 0.5^2 \times 1.5^2 \right]^{1/2} = \left[0.42 + 0.56 \right]^{1/2} = 0.99 \qquad (15)$$

Using (11), the standard deviation of an estimator of the return required on the portfolio that uses an empirical version of the Black CAPM is:

$$\left[(MRP - ZBP)^2 \ \mathrm{Var}(\hat{\beta}_j) + (1-\beta_j)^2 \mathrm{Var}(\hat{ZBP}) + \beta_j^2 \ \mathrm{Var}(\hat{MRP}) \right]^{1/2}$$

$$= \left[(6.5 - 11.0)^2 \times 0.1^2 + (1-0.5)^2 \times 3.4^2 + 0.5^2 \times 1.5^2 \right]^{1/2}$$

$$= \left[0.20 + 2.89 + 0.56 \right]^{1/2} = 1.91 \qquad (16)$$

Using (13) and the notation *HLP* and *SBP* to denote the *HML* and *SMB* premiums, the standard deviation of an estimator of the return required on the portfolio that uses an empirical version of the FFM is:

$$\left[MRP^2 \ \mathrm{Var}(\hat{b}_j) + HML^2 \ \mathrm{Var}(\hat{h}_j) + SMB^2 \ \mathrm{Var}(\hat{s}_j) \right.$$

$$\left. + b_j^2 \mathrm{Var}(\hat{MRP}) + h_j^2 \mathrm{Var}(\hat{HLP}) + b_j^2 \mathrm{Var}(\hat{SBP}) \right]^{1/2}$$

$$= \left[6.5^2 \times 0.1^2 + 7.5^2 \times 0.1^2 + 3.2^2 \times 0.1^2 + 0.5^2 \times 1.5^2 \right]^{1/2}$$

$$= \left[0.42 + 0.56 + 0.10 + 0.56 \right]^{1/2} = 1.28 \qquad (17)$$

The intuition behind these results is that if the beta of a portfolio is 0.5, an estimator for the return required on the portfolio in excess of the risk-free rate that uses either the SL CAPM or the Black CAPM is an equally weighted average of the zero-beta premium, *ZBP*, and the *MRP*. The SL CAPM presumes that the zero-beta premium is known to be zero while the Black CAPM requires one estimate the premium. Uncertainty about the size of the zero-beta premium is captured by the second term in expression (16). Thus, the Black CAPM, under these conditions, produces a less precise estimator for the cost of equity.

The FFM produces a less precise estimator for the cost of equity because it requires beta estimates relative to, not one, but three factors. Since the *HML* and *SMB* betas are both presumed to be zero, however, uncertainty over the magnitudes of the *HML* and *SMB* premiums has no impact on the precision of an estimator for the cost of equity that uses the FFM.

The second row of Table 4.2 shows that if the portfolio has an *HML* beta that is also 0.5, then the precision of an estimator of the return required on a portfolio that uses the FFM will rise and will match, approximately, the precision of an estimator that uses the Black CAPM. This is because, under these conditions, uncertainty over the magnitude of the *HML* premium will have an impact on the precision of a Fama-French estimator for the cost of equity.

Row 3 of Table 4.2 shows that if the Sharpe-Lintner beta of a portfolio is one and the Fama-French market beta of the portfolio is also one, but the Fama-French *HML* and *SMB* betas are both zero, then the Black CAPM will provide a marginally more precise estimator of the return required on the portfolio than either the SL CAPM or the FFM. This result arises because, with the assumptions made, an estimate of the cost of equity that uses the Black CAPM is less sensitive to a change in the estimate that one produces for the Sharpe-Lintner beta than is an estimate that uses the SL CAPM.

Table 4.2
Estimates of the precision with which each pricing model estimates the cost of equity

Betas				Standard deviation		
β_j	b_j	h_j	s_j	SL	Black	FF
0.50	0.50	0.00	0.00	0.99	1.91	1.28
0.50	0.50	0.50	0.00	0.99	1.91	2.05
1.00	1.00	0.00	0.00	1.63	1.57	1.83
1.00	1.00	0.50	0.00	1.63	1.57	2.43

Notes: Estimates of the standard deviation of an estimator for the cost of equity are in per cent per annum and are computed using (8), (10), (12), the beta assumptions and the estimates (13) provides.

Row 4 of Table 4.2 shows that if the portfolio also has an *HML* beta of 0.5, then an estimator for the cost of equity that uses the FFM will be less precise because uncertainty over the magnitude of the *HML* premium will have an impact on the precision of the estimator.

A glance at expression (17), that computes the last entry in row 1 of Table 4.2, indicates that assuming that the covariance matrices in (14) are diagonal removes $2 \times 3 = 6$ terms from the expression. The relative magnitudes of the three Fama-French risk premiums, though, indicates that only the covariance between an estimator for the *MRP* and an estimator for the *HML* premium will have any significant impact on the standard deviation that we compute.

Row 2 of Table 4.2 assumes that the Fama-French market and *HML* beta are both 0.5. By making this assumption, uncertainty about the *HML* premium contributes to the standard deviation of an estimator for the required return and if we were to relax the assumption that the covariance matrices in (14) are diagonal, the covariance between the estimator for the *MRP* and the estimator for the *HML* premium would also play a role.

This analysis indicates that it is only an assumption that the covariance between the estimator for the *MRP* and the estimator for the *HML* premium is zero that might have any noticeable impact on our calculations. We find that using the annual data that we employ in our June 2013 report, to compute estimates of the *MRP* and the *HML* premium, that the correlation coefficient between the return to the market portfolio in excess of the risk-free rate and the *HML* factor using data from 1975 to 2011 is 0.10.[80] Thus we conclude that assuming that the covariance matrices in (14) are diagonal will have little impact on our results.

4.3. Implications

The results that we produce indicate that while an empirical version of the SL CAPM delivers relatively precise estimates, this benefit of using the model is accompanied by a significant

[80] NERA, *The market size and value premiums: A report for the Energy Networks Association*, June 2013.

cost as the model has difficulty in tracking variation in the required returns across portfolios. In other words, an empirical version of the SL CAPM often provides estimates of the cost of equity that are substantially biased. The Black CAPM, while delivering estimates of the cost of equity that may be less precise, produces estimates that are less likely to be biased. The results suggest that it is likely that for low-beta portfolios the benefits of using the Black CAPM relative to the SL CAPM will outweigh the costs. Similarly, the FFM, while delivering estimates of the cost of equity that may be less precise, produces estimates that are less likely to be biased. The results suggest that for value portfolios the benefits of using the FFM relative to the SL CAPM will likely outweigh the costs.

Since in our examples the *SMB* beta is set to zero, uncertainty about the magnitude of the *SMB* premium has no impact on the precision of an estimator of the cost of equity. Thus it is not true that the FFM will be undermined for use in Australia if the *SMB* premium does not differ significantly from zero. We do not consider examples where a portfolio has a positive Fama-French *SMB* beta because SFG provide little evidence that the beta differs from zero. [81]

The analysis above assumes that the data are stationary. In practice, this assumption may not be true. To determine whether departures from this assumption are important, we next examine the ability of the models to track variation in mean returns across stocks out of sample. We also examine how stable are estimates of the premiums on the three Fama-French factors.

[81] SFG, *Regression-based estimates of risk parameters for the benchmark firm*, 24 June 2013.

5. Predictive Ability and Stability

In this section we examine the predictive ability of an empirical version of the SL CAPM and of the FFM. In particular, we examine whether portfolios sorted on the basis of past estimates of Sharpe-Lintner or Fama-French betas produce cross-sectional variation in realised returns out of sample. We also test whether there the Fama-French factor risk premiums are constant through time. In other words, we test whether the factor risk premiums are stable through time.

5.1. Predictability

5.1.1. Sharpe-Lintner beta estimates

Once more we form five value-weighted portfolios on the basis of past estimates of Sharpe-Lintner betas that use the most recent 60 months of returns. The portfolios that are constructed at the end of 1979 are formed on the basis of estimates of Sharpe-Lintner betas that use data from January 1975 to December 1979. The portfolios that are constructed at the end of 2011 are formed on the basis of estimates of Sharpe-Lintner betas that use data from January 2007 to December 2011. We then collect the monthly return to these portfolios for the period from January 1980 to December 2012.

Table 5.1 provides estimates of the mean returns to the five portfolios relative to the one-month risk-free rate. The table also provides estimates of the Sharpe-Lintner and Fama-French betas of the portfolios. These estimates are computed using the returns to the five portfolios from January 1980 to December 2012. They are not the averages of the past estimates that were used to form the portfolios.

Table 5.1
Sharpe-Lintner beta estimates as predictors of returns:
Australian data from January 1980 to December 2012

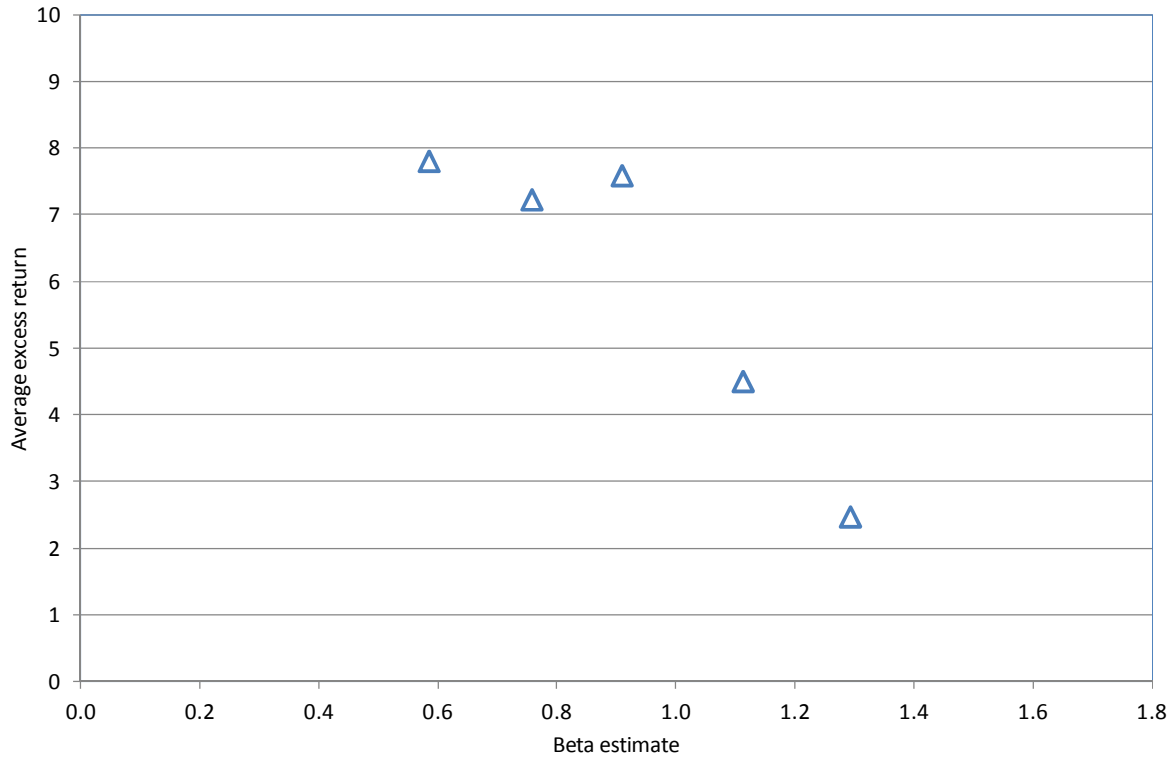
		Beta estimates			
	Sample mean excess return	Sharpe-Lintner	Fama-French		
Portfolio		Market	Market	*HML*	*SMB*
1	7.81	0.58	0.61	0.09	0.08
2	7.23	0.76	0.80	0.18	0.00
3	7.59	0.91	0.92	0.10	-0.12
4	4.51	1.11	1.12	0.04	0.02
5	2.48	1.29	1.28	-0.15	0.19

Notes: Data are from SIRCA's Share Price and Price Relative database and Ken French's web site. The five portfolios are formed on the basis of past estimates of Sharpe-Lintner betas. Sample mean excess returns are in per cent per annum and are the monthly mean returns in excess of the one-month risk-free rate in per cent multiplied by 12.

The results indicate that Sharpe-Lintner betas are sufficiently stable that sorting stocks into portfolios based on past Sharpe-Lintner beta estimates successfully sorts stocks into portfolios that also exhibit variation in estimates of their Sharpe-Lintner betas out of sample. On the other hand, the results indicate that past Sharpe-Lintner beta estimates are negatively, not positively, related to out-of-sample returns. In other words, Table 5.1 indicates that stocks with high estimates of past Sharpe-Lintner betas subsequently deliver on average low returns and stocks with low estimates of past Sharpe-Lintner betas subsequently deliver on average high returns.

Figure 5.1 below illustrates this empirical regularity. The figure plots the average out-of-sample average excess return for each of the five portfolios against an out-of-sample estimate of the portfolio Sharpe-Lintner beta.

Figure 5.1
Plot of average excess return against an estimate of beta for five portfolios formed on the basis of past Sharpe-Lintner beta estimates: Australian data from January 1980 to December 2012



Notes: Data are from SIRCA's SPPR and Ken French's web site. [82]

5.1.2. Fama-French market beta estimates

We also form five value-weighted portfolios on the basis of past Fama-French market beta estimates. Table 5.2 provides estimates of the mean returns to the five portfolios out of

[82] http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

sample relative to the one-month risk-free rate together with out-of-sample estimates of the Sharpe-Lintner and Fama-French betas of the portfolios.

The results indicate that Fama-French market betas are also sufficiently stable that sorting stocks into portfolios based on past Fama-French market beta estimates successfully sorts stocks into portfolios that also exhibit variation in estimates of their Fama-French market betas out of sample. On the other hand, the results indicate that past Fama-French market beta estimates are negatively, not positively, related to out-of-sample returns. In other words, Table 5.2 indicates that stocks with high estimates of past Fama-French market betas subsequently deliver on average low returns and stocks with low estimates of past Fama-French market betas subsequently deliver on average high returns.

Table 5.2
Fama-French market beta estimates as predictors of returns:
Australian data from January 1980 to December 2012

Portfolio	Sample mean excess return	Beta estimates			
		Sharpe-Lintner	Fama-French		
		Market	Market	*HML*	*SMB*
1	7.86	0.57	0.59	0.06	0.05
2	7.17	0.83	0.84	0.10	-0.05
3	6.72	0.95	0.96	0.08	-0.09
4	3.73	1.13	1.11	-0.07	-0.04
5	2.19	1.35	1.36	-0.02	0.23

Notes: Data are from SIRCA's Share Price and Price Relative database and Ken French's web site. The five portfolios are formed on the basis of past estimates of FFM market betas. Sample mean excess returns are in per cent per annum and are the monthly mean returns in excess of the one-month risk-free rate in per cent multiplied by 12.

Thus while the FFM does not suffer from all of the problems that afflict an empirical version of the SL CAPM, it does suffer from some of the same problems.

5.1.3. Fama-French *HML* beta estimates

We next form five value-weighted portfolios on the basis of past Fama-French *HML* beta estimates. Table 5.3 provides estimates of the mean returns to the five portfolios out of sample relative to the one-month risk-free rate together with out-of-sample estimates of the Sharpe-Lintner and Fama-French betas of the portfolios.

The results indicate that Fama-French *HML* betas are sufficiently stable that sorting stocks into portfolios based on past Fama-French *HML* beta estimates successfully sorts stocks into portfolios that also exhibit variation in estimates of their Fama-French *HML* betas out of sample. The results also indicate that past Fama-French *HML* beta estimates are positively related to out-of-sample returns. In other words, Table 5.2 indicates that stocks with high

estimates of past Fama-French *HML* betas subsequently deliver on average high returns and stocks with low estimates of past Fama-French *HML* betas subsequently deliver on average low returns.

Thus the FFM displays an ability, not shared by an empirical version of the SL CAPM, to sort stocks into portfolios that exhibit cross-sectional variation in realised returns out of sample in a way that is consistent with the theory underlying the model.

Table 5.3
Fama-French *HML* beta estimates as predictors of returns:
Australian data from January 1980 to December 2012

Portfolio	Sample mean excess return	Beta estimates			
		Sharpe-Lintner	Fama-French		
		Market	Market	*HML*	*SMB*
1	2.16	1.19	1.15	-0.19	0.07
2	5.33	1.03	1.04	0.04	-0.06
3	7.00	0.88	0.91	0.14	-0.09
4	7.08	0.84	0.88	0.19	-0.09
5	6.55	0.94	0.97	0.17	-0.01

Notes: Data are from SIRCA's Share Price and Price Relative database and Ken French's web site. The five portfolios are formed on the basis of past estimates of FFM HML betas. Sample mean excess returns are in per cent per annum and are the monthly mean returns in excess of the one-month risk-free rate in per cent multiplied by 12.

5.1.4. Fama-French *SMB* beta estimates

Finally, we form five value-weighted portfolios on the basis of past Fama-French *SMB* beta estimates. Table 5.4 provides estimates of the mean returns to the five portfolios out of sample relative to the one-month risk-free rate together with out-of-sample estimates of the Sharpe-Lintner and Fama-French betas of the portfolios.

The results indicate that Fama-French *SMB* betas are sufficiently stable that sorting stocks into portfolios based on past Fama-French *SMB* beta estimates successfully sorts stocks into portfolios that also exhibit variation in estimates of their Fama-French *SMB* betas out of sample. The results, though, also suggest that past Fama-French *SMB* beta estimates exhibit a negative relation with out-of-sample returns.

Finally, replacing the series of one-month risk-free rates that we extract from the SPPR with the yield on a monthly basis to a 10-year CGS has, as one would expect, little impact on our results.

Table 5.4
Fama-French *SMB* beta estimates as predictors of returns:
Australian data from January 1980 to December 2012

Portfolio	Sample mean excess return	Beta estimates			
		Sharpe-Lintner	Fama-French		
		Market	Market	*HML*	*SMB*
1	5.07	0.98	0.98	0.02	-0.13
2	7.05	0.97	0.96	0.00	-0.12
3	4.52	0.93	0.95	0.06	0.08
4	4.01	1.17	1.17	-0.08	0.29
5	0.79	1.34	1.36	-0.17	0.71

Notes: Data are from SIRCA's Share Price and Price Relative database and Ken French's web site. The five portfolios are formed on the basis of past estimates of FFM SMB betas. Sample mean excess returns are in per cent per annum and are the monthly mean returns in excess of the one-month risk-free rate in per cent multiplied by 12.

5.2. Stability

A frequent criticism of the Fama and French risk premiums is that they are unstable. This criticism is puzzling because tests of the null that an unconditional risk premium is a constant through time typically lack power. In other words, uncovering evidence of instability in risk premiums is generally difficult. This is because realised risk premiums are noisy. Constructing a test of the null that an unconditional risk premium is constant through time, using Australian data, which has an acceptable power to reject in favour of reasonable alternatives is even more challenging. This is because Australian time series are often short relative, for example, to their US counterparts.

Our June 2013 report uses annual Australian data from 1883 to 2011 to test the null that the unconditional *MRP* is a constant through time and is unable to reject the null.[83] In Table 5.5 below we use annual Australian data to test the null that the unconditional *HML* and *SMB* premiums are constant though time over the period from 1974 to 2012. Since there is no theory to guide us to do otherwise, we split these data into two roughly equal sub-periods: from 1974 to 1993 and from 1994 to 2012. The table provides no evidence that the *HML* premiums computed over the two sub-periods differ significantly from one another or that the *SMB* premiums computed over the two sub-periods differ significantly from one another.

[83] NERA, *Market, size and value premiums: A report for the Energy Networks Association*, June 2013.

Table 5.5
Stability tests for Australian *HML* and *SMB* premiums: annual Australian data from 1974 to 2012

Period	*HML*	Period	*SMB*
1975-2012	7.53	1974-2012	3.17
	(3.22)		(3.19)
1975-1993	11.14	1974-1993	3.91
	(5.63)		(4.39)
1994-2012	3.92	1994-2012	2.39
	(3.09)		(4.75)
Smith-Satterthwaite tests			
1975-1993	-1.12		-0.23
& 1994-2012	[0.27]		[0.82]

Notes: Data are from SIRCA's Share Price and Price Relative database and Ken French's web site. Estimates of the premiums are in per cent per annum. Standard errors are in parentheses while p-values for a two-sided test of the null that each unconditional premium is a constant through time are in brackets. To test whether the premiums differ significantly between the two sub-periods, we use the Smith-Satterthwaite test described by Miller and Freund (1965). [84]

Miller, I. and Freund, J.E., Probability and statistics for engineers, Prentice-Hall, Englewood Cliffs, NJ, 1965.

We also we use annual US data to test the null that the unconditional *HML* and *SMB* premiums are constant though time. We do so because the US time series span a much longer period – the annual data that French provides run from 1927 to 2012. Since Fama and French use data from 1963 to 1991 and we wish to examine whether the inferences that they draw about the significance of the premiums attached to the *HML* and *SMB* premiums are

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[84] The Smith-Satterthwaite statistic for a test of the null hypothesis that the mean of a normally distributed series x matches the mean of an independently normally distributed series y is:

$$\left(\frac{s_x^2}{n_x}+\frac{s_y^2}{n_y}\right)^{-1/2}(\bar{x}-\bar{y}),$$

where $\bar{x}$ and s_x are the sample mean and sample standard deviation of a sample of n_x observations on x and where $\bar{y}$ and s_y are the sample mean and sample standard deviation of a sample of n_y observations on y. Under the null, the statistic will be approximately t-distributed with

$$\left\lfloor\left(\frac{s_x^4}{n_x^2(n_x-1)}+\frac{s_y^4}{n_y^2(n_y-1)}\right)^{-1}\left(\frac{s_x^2}{n_x}+\frac{s_y^2}{n_y}\right)^2\right\rfloor$$

degrees of freedom, where $\lfloor . \rfloor$ is the floor function.

sensitive to the period that they use, we split the data into three sub-periods: from 1927 to 1962, from 1963 to 1991 and from 1992 to 2012. Table 5.6 provides no evidence that the *HML* premiums computed over the three sub-periods differ significantly from one another or that the *SMB* premiums computed over the three sub-periods differ significantly from one another. Indeed the estimates that Table 5.6 reports are remarkably stable over the three sub-periods.

Table 5.6
Stability tests for US *HML* and *SMB* premiums:
annual US data from 1927 to 2012

Period	*HML*	*SMB*
1927-2012	5.05	3.53
	(1.52)	(1.51)
1927-1962	4.67	3.46
	(2.44)	(2.37)
1963-1991	5.59	4.42
	(2.41)	(2.97)
1992-2012	4.93	2.43
	(3.32)	(2.42)
Smith-Satterthwaite tests		
1927-1962	0.27	0.25
& 1963-1991	[0.79]	[0.80]
1927-1962	0.06	0.30
& 1992-2012	[0.95]	[0.76]
1963-1991	-0.16	-0.52
& 1992-2012	[0.87]	[0.61]

Notes: Data are from Ken French's web site. Estimates of the premiums are in per cent per annum. Standard errors are in parentheses while p-values for a two-sided test of the null that each unconditional premium is a constant through time are in brackets. To test whether the premiums differ significantly between the two sub-periods, we use the Smith-Satterthwaite test described by Miller and Freund (1965).

Miller, I. and Freund, J.E., Probability and statistics for engineers, Prentice-Hall, Englewood Cliffs, NJ, 1965.

6. Conclusions

This report has been prepared for the Energy Networks Association (ENA) by NERA Economic Consulting (NERA). The ENA has asked NERA to provide and review evidence on the relevance of the Fama-French three-factor model (FFM) for the purpose of estimating the cost of equity for a benchmark regulated energy utility.

In particular, the ENA has asked NERA to:

- identify whether there is a theoretical basis for the Fama-French three factor model (FFM), and if so, briefly explain what that basis is and compare it to those of the Sharpe-Lintner (SL) Capital Asset Pricing Model (CAPM) and Black CAPM;
- investigate whether the three models are considered relevant by academics or practitioners for estimating the cost of equity;
- compare the ability of the SL CAPM, Black CAPM and FFM to predict the cost of equity in Australia;
- advise whether the model is undermined for use in Australia if one or both factors are not statistically significant;
- assess the statistical significance of premiums associated with the three Fama-French factors in Australia and assess the stability over time of the factors;
- assess the validity of the FFM relative to the obligations of the National Electricity Rules (NER) and National Gas Rules (NGR) and in comparison with the SL CAPM and the Black CAPM in terms of the criteria for assessment set out by the Australian Energy Regulator (AER); and
- conclude whether the FFM is a relevant financial model for the purpose of estimating the cost of equity for a benchmark regulated energy utility.

The full terms of reference are set out in Appendix A.

Framework

We address the terms of reference using as a fundamental guide the new NER and NGR. Under the previous NER, the AER was required to estimate the cost of equity for electricity network businesses using the SL CAPM. Although the previous NGR did not mandate the use of the SL CAPM, in practice, the AER also applied this approach in gas network decisions. The recently revised NER and NGR now require the AER to have regard to financial models generally, Clause 6.5.2 of the rules states:

> *(e) In determining the allowed rate of return, regard must be had to:*
>
> *(1) relevant estimation methods, financial models, market data and other evidence;*
>
> *(2) the desirability of using an approach that leads to the consistent application of any estimates of financial parameters that are relevant to the estimates of, and that are common to, the return on equity and the return on debt; and*

(3) any interrelationships between estimates of financial parameters that are relevant to the estimates of the return on equity and the return on debt.

Return on equity

(f) The return on equity for a regulatory control period must be estimated such that it contributes to the achievement of the allowed rate of return objective.

(g) In estimating the return on equity under paragraph (f), regard must be had to the prevailing conditions in the market for equity funds.

These clauses require the AER to consider all relevant financial models and therefore provide greater scope to look at cost of equity models beyond the traditionally adopted SL CAPM.

The NER and NGR say nothing about what sort of theoretical foundations a suitable financial model should have. The AER in its *Explanatory Statement* states that (amongst other things) it will consider whether a model is: [85]

> 'consistent with well accepted economic and finance principles and informed by sound empirical analysis and robust data'.

Later the AER states that: [86]

> 'The intention here is to ensure a method which is well grounded in economic theory would have wide-spread recognition and acceptability.'

In the body of the report, the AER proposes not to use the FFM in large part because the AER states that the FFM lacks an 'economic basis'. [87] In that context, we have been asked to explain the theoretical underpinnings of the FFM, and also of the SL CAPM and Black CAPM.

Attached to each financial model are strengths and weaknesses. These strengths and weaknesses depend on the *bias* that may result from the use of a model and the *precision* with which the use of a model will allow one to estimate the cost of equity. An estimator of a parameter is said to be unbiased if the expected value of the estimator matches the parameter and is said to be biased if the expected value differs from the parameter.[88] The precision of a random variable is the reciprocal of its variance.[89]

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[85] AER, *Explanatory statement: Draft rate of return guideline*, August 2013, page 27.

[86] AER, *Explanatory statement: Draft rate of return guideline*, August 2013, page 29.

[87] AER, *Explanatory statement: Draft rate of return guideline*, August 2013, page 191.

[88] See, for example:

Hamilton, J.D., *Time series analysis*, Princeton University Press, Princeton, NJ, 1994, page 741.

[89] This definition, standard in the statistics literature, differs from the Oxford Dictionary definition of precision which is:

'accuracy or exactness.'

In statistics a precise estimator can be exact but inaccurate. As Davidson and MacKinnon note, however,

'it is sometimes more intuitive to think in terms of precision than in terms of variance.'

All else constant an unbiased estimator will be preferred to a biased estimator and all else constant a more precise estimator will be preferred to a less precise estimator. In principle, one may be willing to trade off bias for precision. For example, one may be willing to use an estimator that is less precise than an alternative if the bias associated with the estimator is smaller than the bias associated with the alternative.

Since the bias attached to an estimator that uses a pricing model and the precision of the estimator are important parameters, we provide estimates of these parameters for each of the models that the ENA proposes the AER should use for a range of equities.

For a financial model to be of any practical use the parameters of the model must also be reasonably stable. So, in addition, we assess whether the parameters of each model are sufficiently stable that the model can be of practical use.

Finally, if a financial model is of practical use, there should be evidence that it is used in practice. We provide evidence that the models that the ENA proposes the AER should employ are used in practice.

Theoretical foundations

We show that the SL CAPM, Black CAPM and FFM all have theoretical foundations.

The SL CAPM and Black CAPM make assumptions about the behaviour of individuals, the distribution of returns, investor beliefs, the taxes that investors face and the ability of individuals to borrow and lend or to short sell. Both the SL CAPM and the Black CAPM predict that the market portfolio of all risky assets will be mean-variance efficient and that, consequently, there will be a simple linear relation between the cost of equity for a firm and the firm's equity beta computed relative to the portfolio. A portfolio that is mean-variance efficient is a portfolio that has the highest mean return for a given level of risk, measured by variance of return.

As Roll (1977) makes clear, the SL CAPM predicts that the market portfolio of all risky assets must be mean-variance efficient – it does not predict that the market portfolio of stocks must be mean-variance efficient.[90] The empirical version of the model that the AER and others use measures the risk of an asset relative to a portfolio of stocks alone. Stocks have readily available and transparent prices relative to other risky assets such as debt, property and human capital. Stocks, though, make up a relatively small fraction of all risky assets, so the return to a portfolio of stocks need not track closely the return to the market portfolio of

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We agree and so use the terms precise and precision to render our discussion easier to follow.

Davidson, R. and J. G. MacKinnon, *Estimation and inference in econometrics*, Oxford University Press, Oxford, 1993, page 144.

Fowler, F.G. and H.W. Fowler, *Pocket Oxford Dictionary*, Oxford University Press, Oxford, 1966, page 623.

[90] Roll, R., *A critique of the asset pricing theory's tests: Part I*, Journal of Financial Economics 4, 1977, pages 129-176.

all risky assets.[91] Thus the empirical version of the SL CAPM that the AER actually employs differs from the theoretical model proposed by Sharpe and Lintner.

The FFM is an example of the Arbitrage Pricing Theory (APT) of Ross (1976).[92] The APT assumes that there are a limited number of pervasive factors and that there are no arbitrage opportunities. Thus the APT does not make strict assumptions about the behaviour of individuals or the distribution of returns. The APT, though, does not specify what factors are pervasive or how many exist. The model states that, consistent with intuition, an investor will be compensated only for risk that he or she cannot diversify away.

Ball (1978) emphasises that theory indicates that financial ratios will provide information about the cross-section of mean returns to stocks.[93] Similarly, Berk (1995) emphasises that theory indicates that the market value of a firm's equity will provide information about the cross-section.[94] Empirically, Fama and French (1992) show that the market value of a firm's equity and the ratio of the book value of the equity to its market value are better predictors of the equity's return than is an estimate of the equity's beta.[95] So Fama and French (1993) assume that there are three pervasive sources of risk or factors:[96]

(d) the excess return to the market portfolio;

(e) the difference between the return to a portfolio of high book-to-market stocks and the return to a portfolio of low book-to-market stocks (*HML*); and

(f) the difference between the return to a portfolio of small-cap stocks and the return to a portfolio of large-cap stocks (*SMB*).

If the assumption is correct, then the APT will imply that there will be a simple linear relation between the cost of equity for a firm and the firm's equity betas computed relative to the three Fama-French factors.

Cochrane (2001) emphasises, in his popular graduate-level text, that if the three-factor model did not hold, there would be near-arbitrage opportunities.[97] We provide a numerical example, which is based on the results that Fama and French (1993) report, of a near-

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[91] The mean value of an Australian household's direct investment in stocks in 2010 was $37,505 and the mean value of the household's superannuation account – part of which would have been invested in stocks – was $142,429. The mean net wealth of a household in 2010 was $683,805. Thus the average Australian household in 2010 invested no more than 100 × (37,505 + 142,429)/683,805 = 26 per cent of its net wealth in stocks. See:

Melbourne Institute, *A statistical report on waves 1 to 10 of the Household, Income and Labour Dynamics in Australia Survey*, 2013, page 83.

[92] Ross, Stephen, *The arbitrage theory of capital asset pricing*, Journal of Economic Theory 13, 1976, pages 341-360.

[93] Ball, R., *Anomalies in relationships between securities' yields and yield surrogates*, Journal of Financial Economics, 1978, pages 103-126.

[94] Berk, J., *A critique of size-related anomalies*, Review of Financial Studies, 1995, pages 275-286.

[95] Fama, Eugene and Kenneth French, *The cross-section of expected returns*, Journal of Finance 47, 1992, pages 427-465.

[96] Fama, Eugene and Kenneth French, *Common risk factors in the returns to stocks and bonds*, Journal of Financial Economics 33, 1993, pages 3-56.

[97] Cochrane, John H., *Asset pricing*, Princeton University Press, 2001, page 442.

arbitrage opportunity that would hold were an empirical version of the SL CAPM of the kind that the AER employs to hold instead of the FFM. [98]

Subsequent to the introduction of the FFM in 1993, researchers have developed theories to explain why the Fama-French factors might be pervasive. These theories should not be discounted, of course, merely because they were developed to explain what we observe or because there may be debate over whether the factors capture one risk or multiple risks. As Friedman (1953) emphasises, the first task of a theory is to explain what we observe. [99] Researchers have suggested that the Fama-French factors could be proxies for, among other risks, the risks of financial distress, the risks of an asymmetric exposure to market conditions or risks associated with arbitrage. [100]

Bias and precision

We use Australian data to show that an empirical version of the SL CAPM of the kind that the AER uses can substantially underestimate (overestimate) the returns required on stocks with low (high) betas and substantially underestimate (overestimate) the returns required on value (growth) stocks. These important problems associated with an empirical version of the SL CAPM have been widely documented elsewhere. [101]

An empirical version of the Black CAPM will, by construction, neither underestimate the returns required on stocks with low betas nor overestimate the returns required on stocks with high betas. An empirical version of the Black CAPM, though, may underestimate (overestimate) the returns required on value (growth) stocks. Similarly, the FFM, by construction, will not underestimate the returns required on value stocks or overestimate the returns required on growth stocks. The FFM, though, like an empirical version of the SL CAPM, can underestimate (overestimate) the returns required on stocks with low (high) betas.

It follows that there can be costs associated with using an empirical version of the SL CAPM relative to using an empirical version of the Black CAPM or relative to using the FFM. There will, however, be costs to using an empirical version of the Black CAPM or to using the FFM because the estimates of the cost of equity that they will deliver will be less precise

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[98] Fama, Eugene and Kenneth French, *Common risk factors in the returns to stocks and bonds*, Journal of Financial Economics 33, 1993, pages 3-56.

[99] The second task is to predict what we do not currently observe.

Friedman, Milton, *The methodology of positive economics*, in Positive Economics, University of Chicago Press, 1953, pages 12-14.

[100] Ali, A., L. Hwang, and M.A. Trombley, *Arbitrage risk and the book-to-market anomaly*, Journal of Financial Economics, 69, 2003, pages 355–373.

Petkova, R., and L. Zhang, *Is value riskier than growth?* Journal of Financial Economics, 78, 2005, pages 187–202.

Vassalou, M., and Y. Xing, *Default risk in equity returns*, Journal of Finance, 59, 2004, pages 831–868.

[101] Brailsford, T., C. Gaunt and M. O'Brien, *Size and book-to-market factors in Australia*, Australian Journal of Management, 2012, pages 261-281.

Fama, Eugene and Kenneth French, *Common risk factors in the returns to stocks and bonds*, Journal of Financial Economics 33, 1993, pages 3-56.

than the estimates that an empirical version of the SL CAPM will deliver. So determining which models are to be preferred and under what conditions requires one assess not only the bias attached to estimates of the cost of equity that each model delivers but also the precision of the estimates.

We show, using estimates from a variety of recent submissions, that the precision with which one can estimate the cost of a firm's equity largely depends on the firm's equity beta or betas and the precision with which one can estimate the market risk premium and the two Fama-French factor risk premiums. The precision with one can estimate the cost of a firm's equity also depends on the market risk premium and the two Fama-French factor risk premiums and the precision with which one can estimate the firm's equity beta or betas, but to a lesser extent.

We show that an empirical version of the SL CAPM will deliver a relatively precise estimate of the return required on a stock with a low Sharpe-Lintner beta, the Black CAPM will deliver a relatively imprecise estimate of the return required on a stock with a low Sharpe-Lintner beta and the FFM will deliver a relatively imprecise estimate of the return required on a value stock.

We also show, however, as others have documented, that an empirical version of the SL CAPM will underestimate the return required on a stock with a low Sharpe-Lintner beta and underestimate the return required on a value stock. [102] In other words, for those stocks for which there may be benefits from using an empirical version of the SL CAPM, there also costs.

Our results suggest that it is likely that for low-beta stocks the benefits of using the Black CAPM relative to the SL CAPM will outweigh the costs. Similarly, our results suggest that for value stocks the benefits of using the FFM relative to the SL CAPM will likely outweigh the costs. This is despite the fact that an estimate of the *SMB* premium does not differ significantly from zero in Australian data.

Predictability and stability

A very basic test of the predictive ability of a model is whether portfolios sorted on the basis of past estimates of Sharpe-Lintner or Fama-French betas produce cross-sectional variation in realised returns out of sample. We find that portfolios formed from stocks that have low past estimates of Sharpe-Lintner betas or Fama-French market betas generate high, rather than low, returns out of sample. On the other hand, we find that portfolios formed from stocks that have low past estimates of Fama-French *HML* betas generate low returns out of sample, as the FFM would predict should be the case. Portfolios formed from stocks that have low past estimates of Fama-French *SMB* betas generate returns out of sample that are higher, but not significantly so, than the FFM would predict should be the case.

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[102] Brailsford, T., C. Gaunt and M. O'Brien, *Size and book-to-market factors in Australia*, Australian Journal of Management, 2012, pages 261-281.

Fama, Eugene and Kenneth French, *Common risk factors in the returns to stocks and bonds*, Journal of Financial Economics 33, 1993, pages 3-56.

We also test whether there is evidence that the *HML* and *SMB* premiums change through time. We find no evidence of a change in either Australian data or US data. We note, however, that uncovering evidence of a change through time will be difficult because realised premiums are noisy relative to their means.

Implications

Determining whether the FFM is a relevant financial model for the purpose of estimating the cost of equity for the benchmark firm requires one assess the alternatives.

An empirical version of the SL CAPM of the kind that the AER uses can provide estimates of the cost of equity for a firm that are relatively precise. The bias associated with the estimates if the firm's equity beta differs from one or if the firm's equity behaves like a value stock, though, can be substantial.

An empirical version of the Black CAPM is designed to eliminate the bias associated with estimates of the cost of equity generated by an empirical version of the SL CAPM for firms with equity betas that differ from one. An empirical version of the Black CAPM, on the other hand, delivers estimates that are less precise than estimates generated by an empirical version of the SL CAPM. Estimates of the bias associated with the estimates of the cost of equity that an empirical version of the SL CAPM produces, though, are sufficiently large that for low-beta and high-beta stocks the benefits of using an empirical version of the Black CAPM relative to an empirical version of the SL CAPM are likely to outweigh the costs.

The FFM, alone among the three models that we consider, is designed not to underestimate the cost of equity for a firm whose equity behaves like a value stock. The FFM, on the other hand, delivers estimates that are less precise than estimates generated by an empirical version of the SL CAPM. Estimates of the bias associated with the estimates of the cost of equity that an empirical version of the SL CAPM produces, though, are sufficiently large that for a firm whose equity behaves like a value stock the benefits of using the FFM relative to an empirical version of the SL CAPM are likely to outweigh the costs. SFG (2013) provide some evidence that a regulated energy utility behaves like a value stock. Consequently, we believe that the FFM is a relevant financial model for the purpose of estimating the cost of equity for a benchmark regulated energy utility.

Practical use

Finally, we note that there is evidence that the models that the ENA proposes the AER should employ for the purpose of estimating the cost of equity are used in practice.

SFG (2013) document that independent experts use the SL CAPM to estimate the return required on equity. It notes, however, that the evidence shows that independent expert valuation professionals do not use the model in the way that the AER does.[103] Practitioners are aware of the imprecision associated with regression-based estimates of beta derived from small samples. They are also aware that the Fama-French factors are likely to proxy for risk,

[103] SFG, *Evidence on the required return on equity from independent expert reports: Report for the Energy Networks Association*, June 2013.

and that there could be one or more risks associated with these factors. So practitioners do not mechanically incorporate regression-based estimates of beta into the SL CAPM.[104] Some practitioners adopt beta estimates which are adjusted towards one on the basis of estimation error.[105] Other practitioners make adjustments to their estimates of the cost of equity on the basis of considerations other than regression-based estimates of beta, which include risks.

The Brattle Group (2013) emphasise that it is well known that empirical versions of the SL CAPM tend to underestimate the returns required on low-beta stocks and overestimate the returns required on high-beta stocks.[106] They note that regulators in both Canada and the US, as a result, have made explicit use of an empirical version of the Black CAPM – what the Brattle Group describe as the 'Empirical' CAPM.[107] It is also likely that many market practitioners make implicit use of an empirical version of the Black CAPM by adjusting beta estimates further towards one than can be justified by estimation error or a tendency for beta to revert to a mean of one over time.

Morningstar provides betas relative to the three Fama-French factors for a wide range of companies.[108] These betas can be used to compute equity costs of capital. Morningstar is a source for information on stocks, mutual funds, variable annuities, closed-end funds, exchange-traded funds, separate accounts, hedge funds, and college savings plans and offers an extensive line of Internet, software, and print-based products for individual investors, financial advisors, and institutional clients. It has operations in 27 countries and provides data on more than 433,000 investment offerings worldwide.

The Chartered Financial Analysts (CFA) Institute requires practitioners seeking the CFA designation to understand how to use the FFM to compute the cost of equity. The CFA is the most widely accepted professional qualification for finance practitioners worldwide. To pass the CFA exams, practitioners must have a thorough understanding of the tools most widely used in finance. One such tool is the FFM. Study session 10, for examines:[109]

> 'the well-established methodologies of security analysis'

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[104] In particular, SFG (2013) note that in half of independent experts reports reviewed there was an additional uplift to the cost of equity above the estimate implied by the SL CAPM.

SFG, *Evidence on the required return on equity from independent expert reports: Report for the Energy Networks Association*, June 2013, page 12.

[105] For the theoretical and empirical genesis of this adjustment, see:

Blume, M.E., *On the assessment of risk*, Journal of Finance, 26, 1971, pages 1–10.

Blume, M.E., *Betas and their regression tendencies*, Journal of Finance, 30, 1975, pages 785–795.

Vasicek, O., *A note on using cross-sectional information in Bayesian estimation of security betas*, Journal of Finance, 28, 1973, pages 1233–1239;

[106] The Brattle Group, Estimating the cost of equity for regulated companies, February 2013, page 18.

[107] The Brattle Group, Estimating the cost of equity for regulated companies, February 2013, page 20.

[108] http://corporate.morningstar.com/IB/asp/subject.aspx?xmlfile=5532.xml

[109] CFA, Program Curriculum – Volume 4: Equity, Level II 2010, page 3.

and provides a review of the theory behind the FFM and an illustration of how to use the FFM. CFA course participants:[110]

> 'demonstrate the use of the capital asset pricing model (CAPM), the Fama-French model (FFM)'

We conclude from this evidence that the FFM is used as a practical tool for estimating the cost of equity.

[110] http://www.cfainstitute.org/cfaprog/resources/pdf/LII_SS10.pdf

Appendix A. Terms of Reference

TERMS OF REFERENCE – Review of theoretical support and stability of the Fama-French Three Factor Model

Background

The Australian Energy Regulator (AER) published its draft rate of return guideline that will form the basis of the regulated rate of return applied in energy network decisions. Previously the AER published an Issues Paper on 10 December 2012 and a Consultation Paper on 10 May 2013.

Under the previous National Electricity Rules (NER), the AER was required to estimate the cost of equity for electricity network businesses using the Sharpe-Lintner version of the capital asset pricing model (CAPM). Although the previous National Gas Rules (NGR) did not mandate the use of the Sharpe-Lintner CAPM, in practice, the AER also applied this approach in gas network decisions. The recently revised NER and NGR now require the AER to have regard to financial models generally, Clause 6.5.2 of the rules states:

> *(e) In determining the allowed rate of return, regard must be had to:*
>
> *(1) relevant estimation methods, financial models, market data and other evidence;*
>
> *(2) the desirability of using an approach that leads to the consistent application of any estimates of financial parameters that are relevant to the estimates of, and that are common to, the return on equity and the return on debt; and*
>
> *(3) any interrelationships between estimates of financial parameters that are relevant to the estimates of the return on equity and the return on debt.*
>
> ***Return on equity***
>
> *(f) The return on equity for a regulatory control period must be estimated such that it contributes to the achievement of the allowed rate of return objective.*
>
> *(g) In estimating the return on equity under paragraph (f), regard must be had to the prevailing conditions in the market for equity funds.*

These clauses require the AER to consider all relevant financial models and therefore provide greater scope to look at cost of equity models beyond the traditionally adopted Sharpe-Lintner CAPM.

In its draft guideline the AER allows no role for the Fama-French three factor model (FFM), stating that "it may not meet most of the criteria set out in chapter 2" [Explanatory Statement, p207].

The ENA is looking for expert consultants to provide a review of academic literature and the arguments presented by the AER and its consultants on the Fama-French model, including that it "does not have a strong theoretical underpinning". This will necessarily involve comparisons of the model with the previously used Sharpe-Lintner CAPM and the Black CAPM.

Scope of work

The consultant is to respond to the criticisms and concerns raised by the AER in the draft guideline, explanatory statement and other supporting material. The consultant should:

- Identify whether there is any theoretical basis for the Fama-French three factor model, and if so, briefly explain the basis of the model;
    - Compare the theoretical basis with that of the SL-CAPM as previously applied by the AER, and the proposed use of the Black CAPM;
- Investigate whether the three models are considered relevant by academics or practitioners for estimating the cost of equity;
- Assess the statistical significance of the SMB and/or HML factors in Australia and assess the stability over time of the factors;
    - Advise whether the model is undermined for use in Australia if one or both factors are not statistically significant and/or unstable
- Compare the models' ability to predict the cost of equity in Australia;
- Assess the validity of the FFM relative to the obligations of the Rules and in comparison with the SL-CAPM and the Black CAPM in terms of the AER's criteria for assessment;
- Conclude whether the FFM is a relevant financial model for the purpose of estimating the cost of equity for the benchmark firm.

In addition, relevant documents the consultant will be required to consider include:

- Academic literature on the Fama-French three factor model
- The draft rate of return guideline and its supporting explanatory note
- Expert consultant reports commissioned by the AER and released with the draft guideline:

  - McKenzie Partington (2013 June) 'Risk, asset pricing models and the WACC'
  - Frontier Economics (2013, July) 'Assessing risk when determining the appropriate rate of return'
- The AER's draft and final decisions for Jemena Gas Networks' 2010 access arrangement review

The consultant should document the methods, data, adjustments and assumptions used and made. Specific estimates of the cost of capital for regulated utilities will not be required, however establishing relevance of the model and response to AER criticisms will call for statistical testing and data analysis.

A draft report will be required for ENA's subgroup to review and comment on. The final report must be of a standard such that it can be submitted to the AER as part of the draft guideline consultation.

Timeframe

The consultant is to provide a draft report by 24 September 2013.

A final report addressing any ENA comments is to be provided by 4 October 2013.

Reporting

Iftekhar Omar, Blair Alexander and Eli Grace-Webb will provide the primary interface to the ENA Cost of Capital Subgroup for the duration of the engagement. The consultant will report on work progress on a regular basis. The consultant will make periodic presentations on analysis and advice when appropriate.

The consultant is likely to be called on to present analysis and advice to the ENA Cost of Capital Subgroup.

Conflicts

The consultant is to identify any current or future potential conflicts.

Fees

The consultant is requested to propose:

- A fixed total cost of the project and hourly rates for the proposed project team should additional work be required;
- the staff who will provide the strategic analysis and advice;
- declare the absence of any relevant conflict of interest in undertaking the project; and

- indicate preparedness to enter into a confidentiality agreement regarding research and findings.

Any changes to the scope of the consultancy must be agreed with the ENA before the quotation is submitted. Miscellaneous costs such as travel and accommodation will be reimbursed, provided that they are agreed with the ENA beforehand.

Contacts

Any questions regarding this terms of reference should be directed to:

Iftekhar Omar, IOmar@ausgrid.com.au , 02 9269 2695

Blair Alexander, blair.alexander@actewagl.com.au, 02 6248 2522

Eli Grace-Webb, Eli.Grace-Webb@jemena.com.au, 03 8544 9164

Appendix B. Federal Court Guidelines

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[111], 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[112]

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.

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[111] 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].

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

2. The Form of the Expert's Report[113]

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[114]; 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[115].

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.

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[113] Rule 23.13.

[114] See also *Dasreef Pty Limited v Nawaf Hawchar* [2011] HCA 21.

[115] The *"Ikarian Reefer"* [1993] 20 FSR 563 at 565

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[116].

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

[116] The *"Ikarian Reefer"* [1993] 20 FSR 563 at 565-566. See also Ormrod *"Scientific Evidence in Court"* [1968] Crim LR 240

Appendix C. Curricula Vitae

Simon M. Wheatley

5 Maple Street
Blackburn VIC 3130
Tel: +61 3 9878 7985
E-mail: swhe4155@bigpond.net.au

Overview

Simon is a consultant and was until 2008 a Professor of Finance at the University of Melbourne. Since 2008, Simon has applied his finance expertise in investment management and consulting outside the university sector. Simon's interests and expertise are in individual portfolio choice theory, testing asset-pricing models and determining the extent to which returns are predictable. Prior to joining the University of Melbourne, Simon taught finance at the Universities of British Columbia, Chicago, New South Wales, Rochester and Washington.

Personal

Nationalities:	U.K. and U.S.
Permanent residency:	Australia

Employment

- Special Consultant, NERA Economic Consulting, 2009-present
- External Consultant, NERA Economic Consulting, 2008-2009
- Quantitative Analyst, Victorian Funds Management Corporation, 2008-2009
- Adjunct, Melbourne Business School, 2008
- Professor, Department of Finance, University of Melbourne, 2001-2008
- Associate Professor, Department of Finance, University of Melbourne, 1999-2001
- Associate Professor, Australian Graduate School of Management, 1994-1999
- Visiting Assistant Professor, Graduate School of Business, University of Chicago, 1993-1994
- Visiting Assistant Professor, Faculty of Commerce, University of British Columbia, 1986

- Assistant Professor, Graduate School of Business, University of Washington, 1984-1993

Education

- Ph.D., University of Rochester, USA, 1986; Major area: Finance; Minor area: Applied statistics; Thesis topic: Some tests of international equity market integration; Dissertation committee: Charles I. Plosser (chairman), Peter Garber, Clifford W. Smith, Rene M. Stulz
- M.A., Economics, Simon Fraser University, Canada, 1979
- M.A., Economics, Aberdeen University, Scotland, 1977

Publicly Available Reports

The Market, Size and Value Premiums: A report for the Energy Networks Association, June 2013, http://www.aer.gov.au/sites/default/files/Report%2015%20-%20ENAMRPReport28062013%20Final.pdf

Estimates of the Zero-Beta Premium: A report for the Energy Networks Association, June 2013, http://www.aer.gov.au/sites/default/files/Report%202%20-%20Black%20CAPM%20Zero%20Beta%20Estimate%20(Final)%20-%2027%20June..pdf

The Payout Ratio: A report for the Energy Networks Association, June 2013, http://www.aer.gov.au/sites/default/files/Report%2012%20-%20Payout%20Ratio%20(Final)%20-%20June%202013.pdf

Review of Cost of Equity Models: A report for the Energy Networks Association, June 2013, http://www.aer.gov.au/sites/default/files/Report%201%20-%20Alternative%20Cost%20of%20Equity%20Models%20(Final)%20-%2026%20June.pdf

The Cost of Equity for a Regulated Energy Utility: A Response to the QCA Discussion Paper on the Risk-Free Rate and the MRP: A report for United Energy and Multinet Gas, March 2013, http://www.qca.org.au/files/CI-UEM-SubNERA-CCR1213-0413.pdf

The Cost of Equity for a Regulated Energy Utility: A report for Multinet, February 2013, http://www.erawa.com.au/cproot/11197/2/20130312%20-%20D103642%20-%20Guidelines%20for%20the%20Rate%20of%20Return%20for%20Gas%20Transmission%20and%20Distribution%20Networks%20-%20United%20Energy%20and%20Multinet%20Gas.pdf

The Black CAPM: A report for APA Group, Envestra, Multinet & SP AusNet, March 2012, http://www.aer.gov.au/sites/default/files/Attachment%209.6%20NERA%20-%20Black%20CAPM%20Report%20March%202012.pdf

Prevailing Conditions and the Market Risk Premium: A report for APA Group, Envestra,

Multinet & SP AusNet, March 2012,
http://www.aer.gov.au/content/item.phtml?itemId=753605&nodeId=418ee68d5b881d58515e4f39d9d3aee3&fn=G-5%20NERA%20%20Prevailing%20Conditions%20and%20the%20Market%20Risk%20Premium%20March%202012.pdf

The Market Risk Premium: A report for CitiPower, Jemena, Powercor, SP AusNet and United Energy, 20 February 2012,
http://www.aer.gov.au/content/item.phtml?itemId=752660&nodeId=fe0280e7e2113c467dfc4b3b076e1623&fn=Vic%20DNSPs%20(NERA)%20-%2020%20February%202012.pdf

Cost of Equity in the ERA DBNGP Draft Decision: A report for DBNGP, 17 May 2011,
http://www.erawa.com.au/cproot/9669/2/20110620%20-%20DBNGP%20(WA)%20%20-%20Sub%2055%20-%20Att%207%20-%20NERA%20Economic%20Consulting%20Cost%20of%20equity%20in%20the%20draft%20decision.pdf

The Market Risk Premium: A report for Multinet Gas and SP AusNet, 29 April 2011,
http://www.aer.gov.au/content/index.phtml/itemId/745782

Cost of Capital for Water Infrastructure Company Report for the Queensland Competition Authority, 28 March 2011,
http://www.qca.org.au/files/W-NERA-EconomicConsulting-FinalReport-WACC-0411.pdf

The Cost of Equity: A report for Orion, 2 September 2010,
http://www.comcom.govt.nz/assets/Pan-Industry/Input-Methodologies/Draft-Reasons-Papers/Draft-Reasons-EDBs/Draft-Determination-X-Sub/Orion-Cross-Submission-Attachment-on-EDBs-and-GPBs-Input-Methodologies-Draft-Determination-and-Reasons-Paper-NERA-Report-2-September-2010.pdf

New Gamma Issues Raised by AER Expert Consultants: A report for JGN, 17 May 2010,
http://www.aer.gov.au/content/item.phtml?itemId=736652&nodeId=dea014515519350384275dccc6b56018&fn=JGN%20further%20submission%20on%20gamma%20(18%20May%202010).pdf

The Required Rate of Return on Equity for a Gas Transmission Pipeline: A Report for DBP, 31 March 2010,
http://www.erawa.com.au/cproot/8512/2/20100503%20D29252%20DBNGP%20-%20Submission%208%20-%20Annexure%201%20-%20The%20Required%20Rate%20of%20Return%20on%20Equity%20for%20a%20Gas%20Transmission%20Pipeline.pdf

Jemena Access Arrangement Proposal for the NSW Gas Networks: AER Draft Decision: A report for Jemena, 19 March 2010,
http://www.aer.gov.au/content/item.phtml?itemId=735229&nodeId=4dc041cfe6e30a2c2b91e833cad31191&fn=Appendix%205.1%20-%20NERA%20-%20FAMA%20French%20Report.pdf

Payout Ratio of Regulated Firms: A report for Gilbert + Tobin, 5 January 2010, http://www.aer.gov.au/content/item.phtml?itemId=735236&nodeId=10e87413b13d1da23cd55faf20a6918d&fn=Appendix%206.3D%20-%20NERA%20(4%20Jan%2010,%20ETSA)%20Payout%20ratio%20of%20regulated%20firms.pdf

Review of Da, Guo and Jagannathan Empirical Evidence on the CAPM: A report for Jemena Gas Networks, 21 December 2009, http://www.ipart.nsw.gov.au/files/Submission%20-%20Alternative%20approaches%20to%20the%20determination%20of%20the%20cost%20of%20equity%20-%20Jemena%20-%20Sandra%20Gamble%20-%2022%20December%202009%20-%20APD%20-%20Website.PDF

The Value of Imputation Credits for a Regulated Gas Distribution Business: A report for WA Gas Networks, 18 August 2009, summarized in: http://www.erawa.com.au/cproot/8357/2/20100215%20WAGN%20-%20Proposed%20Revisions%20to%20the%20AA%20for%20the%20WAGN%20Gas%20Distribution%20Systems%20Submission%20-%20Public%20Version.pdf

Cost Of Equity - Fama-French Three-Factor Model Jemena Gas Networks (NSW), 12 August 2009, http://www.aer.gov.au/content/item.phtml?itemId=730699&nodeId=4fcc57398775fe84685434e0b749d76a&fn=Appendix%209.1%20-%20NERA%20-%20Cost%20of%20equity%20-%20Fama-French%20Model.pdf

Estimates of the Cost of Equity: A report for WAGN, 22 April 2009, summarized in: http://www.erawa.com.au/cproot/8357/2/20100215%20WAGN%20-%20Proposed%20Revisions%20to%20the%20AA%20for%20the%20WAGN%20Gas%20Distribution%20Systems%20Submission%20-%20Public%20Version.pdf

AER's Proposed WACC Statement – Gamma: A report for the Joint Industry Associations, 30 January 2009, http://www.aer.gov.au/content/item.phtml?itemId=726698&nodeId=80cf978278d317e99c34ae1878525573&fn=JIA%20Appendix%20Q%20-%20NERA%20-%20AER's%20proposed%20WACC%20statement-Gamma.pdf

The Value of Imputation Credits: A report for the ENA, Grid Australia and APIA, 11 September 2008, http://www.ena.asn.au/udocs/24092008aersub/Appendix%20K%20-%20The%20value%20of%20imputation%20credits%20-%20NERA.pdf

Consulting Experience

NERA, 2008-present

Lumina Foundation, Indianapolis, 2009

Industry Funds Management, 2010

Academic Publications

Imputation credits and equity returns, (with Paul Lajbcygier), 2012, *Economic Record* 88, 476-494.

Do measures of investor sentiment predict returns? (with Robert Neal), 1998, *Journal of Financial and Quantitative Analysis* 33, 523-547.

Adverse selection and bid-ask spreads: Evidence from closed-end funds (with Robert Neal), 1998, *Journal of Financial Markets* 1, 121-149.

Shifts in the interest-rate response to money announcements: What can we say about when they occur? (with V. Vance Roley), 1996, *Journal of Business and Economic Statistics* 14, 135-138.

International investment restrictions and closed-end country fund prices, (with Catherine Bonser-Neal, Greggory Brauer, and Robert Neal), 1990, *Journal of Finance* 45, 523-547 (reprinted in International Capital Markets Volume III, 2003, G. Andrew Karolyi and Rene M. Stulz, editors, Edward Elgar Publishing, Cheltenham, Glos).

A critique of latent variable tests of asset pricing models, 1989, *Journal of Financial Economics* 21, 177-212.

Some tests of international equity market integration, 1988, *Journal of Financial Economics* 21, 177-212 (reprinted in International Capital Markets Volume I, 2003, G. Andrew Karolyi and Rene M. Stulz, editors, Edward Elgar Publishing, Cheltenham, Glos).

Some tests of the consumption-based asset pricing model, 1988, *Journal of Monetary Economics* 22, 193-215.

Working Papers

An evaluation of some alternative models for pricing Australian stocks (with Paul Lajbcygier), 2009.

Intertemporal substitution, small-sample bias, and the behaviour of U.S. household consumption (with Kogulakrishnan Maheswaran and Robert Porter), 2007.

Keeping up with the Joneses, human capital, and the home-equity bias (with En Te Chen), 2003.

Evaluating asset pricing models, 1998.

Time-non-separable preferences or artifact of temporal aggregation? (with Robert Porter), 2002.

Testing asset pricing models with infrequently measured factors, 1989.

Refereeing Experience

Referee for Accounting and Finance, the Australian Journal of Management, Economic Letters, Financial Analysts Journal, Financial Management, Journal of Accounting and Economics, Journal of Business, Journal of Empirical Finance, Journal of Finance, Journal of Financial and Quantitative Analysis, Journal of Financial Economics, Journal of Futures Markets, Journal of International Economics, Journal of International Money and Finance, Journal of Money, Credit, and Banking, Journal of Monetary Economics, Management Science, National Science Foundation, Pacific-Basin Finance Journal, and the Review of Financial Studies.

Program Committee for the Western Finance Association in 1989 and 2000.

Teaching Experience

International Finance, Melbourne Business School, 2008

Corporate Finance, International Finance, Investments, University of Melbourne, 1999-2008

Corporate Finance, International Finance, Investments, Australian Graduate School of Management, 1994-1999

Investments, University of Chicago, 1993-1994

Investments, University of British Columbia, 1986

International Finance, Investments, University of Washington, 1984-1993

Investments, Macroeconomics, Statistics, University of Rochester, 1982

Accounting, 1981, Australian Graduate School of Management, 1981

Teaching Awards

MBA Professor of the Quarter, Summer 1991, University of Washington

Computing Skills

User of SAS since 1980. EViews, Excel, EXP, LaTex, Matlab, Powerpoint, Visual Basic. Familiar with the Australian School of Business, Compustat and CRSP databases. Some familiarity with Bloomberg, FactSet and IRESS.

Board Membership

Anglican Funds Committee, Melbourne, 2008-2011

Honours

Elected a member of Beta Gamma Sigma, June 1986.

Fellowships

Earhart Foundation Award, 1982-1983

University of Rochester Fellowship, 1979-1984

Simon Fraser University Fellowship, 1979

Inner London Education Authority Award, 1973-1977

Brendan Quach

Senior Consultant

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201 Sussex Street
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Fax: +61 2 8864 6549
E-mail: brendan.quach@nera.com
Website: www.nera.com

Overview

Brendan Quach has eleven years' experience as an economist, specialising in network economics, and competition policy in Australia, New Zealand and Asia Pacific. Since joining NERA in 2001, Brendan has advised clients on the application of competition policy in Australia, in such industries as aviation, airports, electricity, rail and natural gas. Brendan specialises in regulatory and financial modelling and the cost of capital for network businesses. Prior to joining NERA, Brendan worked at the Australian Chamber of Commerce and Industry, advising on a number of business issues including tax policy, national wage claims and small business reforms.

Qualifications

1991-1995 **AUSTRALIAN NATIONAL UNIVERSITY**
Bachelor of Economics.
(High Second Class Honours)

1991-1997 **AUSTRALIAN NATIONAL UNIVERSITY**
Bachelor of Laws.

Career Details

2001 - **NERA ECONOMIC CONSULTING**
Economist, Sydney

1998-1999 **AUSTRALIAN CHAMBER OF COMMERCE AND INDUSTRY**
Economist, Canberra

1996 **AUSTRALIAN BUREAU OF STATISTICS**
Research Officer, Canberra

Project Experience

Industry Analysis

2011 **Energy Networks Association**
Review of the regulatory frameworks for energy networks
Brendan is currently advising the ENA on the Australian Energy Regulator's (AER's) potential Rule change proposal. Advice currently focuses on a range of issues including the propose-respond framework, expenditure incentives, the cost of capital and the potential role of judicial reviews.

2011 **MSAR Office for the Development of the Energy Sector**
Development of a New Tariff Structure
Brendan is currently leading a team reviewing Macau's current electricity tariffs. This requires NERA to model and analyse long- and short-run marginal costs, sunk costs and generation dispatch. Our work for the Macau Government will be incorporated into the potential development of new tariffs for residential, commercial and casino customers.

2010 **Industry Funds Management/Queensland Investment Corporation**
Due diligence, Port of Brisbane
Brendan was retained to advise on various regulatory and competition matters likely to affect the future financial and business performance of the Port of Brisbane, in the context of its sale by the Queensland government.

2010-2011 **Minter Ellison /UNELCO**
Review of regulatory decision by the Vanuatu regulator
Assisted in the development of an expert report on a range of matters arising from the Vanuatu regulator's decision to reset electricity prices under four concession contracts held by UNELCO. The matters considered included the methodology employed to calculate the new base price, the appropriateness of the rate of return, the decision by the regulator to reset future prices having regard to past gains/losses.

2010 **Gilbert + Tobin/Confidential – Telecommunications**
Incentive Arrangements for Regulated Telecommunications Services
Brendan provided strategic advice to Gilbert + Tobin on possible regulatory arrangements that allow for the efficient delivery of fixed line telecommunications services in the context of the government mandated roll out the National Broadband Network.

2009-10 **EnergyAustralia – NSW Electricity Distribution**
Review of Public Lighting Services
Brendan provided advice to EnergyAustralia during its electricity distribution price review on the provision of public lighting services. Our work provided strategic and regulatory advice to EnergyAustralia during the appeal of the AER's revenue determination for the 2009-2014 period.

2009 **CitiPower/Powercor**
Efficiency carryover mechanisms
Assisted in the development of an expert report submitted to the AER on the consistency of carrying-forward accrued negative amounts arising from the application of the ESC's efficiency carryover mechanism with the National Electricity Law and the National Electricity Rules.

2009 **Prime Infrastructure**
Sale of Dalrymple Bay Coal Terminal (DBCT)
Brendan provided regulatory advice to a number of potential bidders for the assets of DBCT. Advice included an assessment of the rate of return parameters, depreciation, regulatory modelling and the regulatory arrangements in Queensland.

2008-09 **MSAR Office for the Development of the Energy Sector**
Review of Electricity Cost and Tariff Structures
Review of current and projected costs of electricity provision in Macau, including modelling and analysis of marginal costs and sunk cost attribution to various consumer classes. Our work for the Macau Government has incorporated the development of potential tariff structures (specifically rising block tariff structures) and scenarios, including modelling revenue recovery and cross subsidies.

2008 **Singaporean Ministry for Trade and Industry**
Electricity Industry Review
NERA was retained by the Singaporean Ministry for Trade and Industry (MTI) to provide a comprehensive review of the Singaporean electricity market. Brendan was involved in the analysis of the costs and benefits arising from the restructuring and reform of the Singaporean electricity industry since the mid 1990's, the estimated costs and benefits of future security of supply and energy diversification approaches. The project required NERA to undertake quantitative dispatch modelling of the Singaporean electricity market.

2008 **Ministerial Council Energy**
Retailer of Last Resort
Assisted in the development of a joint expert report with Allens Arthur Robinson (AAR) that: reviewed the existing jurisdictional retailer of last resort (RoLR) frameworks; advised the MCE on the development of an appropriate national policy framework for RoLR and developed a suggested base set of proposals for a national RoLR scheme.

2005-06 **Freehills/South Australian Gas Producers, NSW and South Australia**
Gas supply agreement arbitration
Assisted in the development of an economic expert report in the arbitration of the price to apply following review of a major gas supply agreement between the South Australian gas producers and a large retailer in NSW and South Australia.

2005-2006 **Australian Energy Market Commission (AEMC), Australia**
Advised the AEMC on its review of the Electricity Rules relating to transmission revenue determination and pricing, which included providing briefing papers to the Commission on specific issues raised by the review.

2005-2006 **Minter Ellison/ South West Queensland Gas Producers, Queensland**
Gas supply agreement arbitration
Advised Minter Ellison and the Producers in an arbitration of the price to apply following review of a major gas supply agreement between the South West Queensland gas producers and a large industrial customer.

2005 **International Utility, Queensland**
Generator sale, due diligence
Part of the due diligence team acting on behalf of a large international utility in the purchase of two coal fired generators in Queensland, Australia. Provided advice on the features of the Australian electricity market and regulatory environment.

2003 **Auckland City Council, New Zealand**
Rationalisation Options Study
Conducting a rationalisation options study to examine alternative business models for Metrowater. Our report assessed different vertical and horizontal integration options for Metrowater.

2003 **Metrowater, New Zealand**
Institutional Restructuring
Prepared advice for the board of the Auckland City Water and wastewater service provider, Metrowater on options for institutional and regulatory reform of the entire Auckland regional water sector.

2002 - 2003 **Rail Infrastructure Corporation, Australia**
Research to RIC on their proposed access undertaking.
Provided research and advice into various components of RICs proposed access undertaking with the ACCC including the cost of capital, asset valuation and pricing principles.

2002 **Argus Telecommunications, Australia**
Critique of CIE's bandwidth pricing principles.
Provided a critique of a CIE report on bandwidth pricing principles for the fibre optic networked run owned by Argus Telecommunications.

2001 **Screenrights, Australia**
Advice on valuing retransmission of local TV
A review and analysis of different methodologies in valuing retransmission of local television on pay TV services.

Regulatory and Financial Analysis

2012 **Queensland Competition Authority**
Review of the retail water regulatory models
Brendan undertook an independent quality assurance assessment of the financial models relied on by the QCA to set the regulated revenues of SunWater. The review considered: SunWater's Financial model, a model used by SunWater to calculate future electricity prices, an renewals annuity model, as well as the QCA's regulatory model. These models established a set of recommended prices for each of the 30 irrigation schemes operated by SunWater for the period 2014 to 2019.

2011 **Queensland Competition Authority**
Review of the retail water regulatory models
Undertook an independent quality assurance assessment of the models used to calculate regulated revenues for Queensland Urban Utilities, Allconnex Water, and Unitywater. The review considered: the formulation of the WACC; the intra year timing of cashflows; and the structural, computational and economic integrity of the models.

2011 **Queensland Competition Authority**
Review of the wholesale water regulatory models
Undertook an independent quality assurance assessment of the models used to calculate regulated revenues for LinkWater, Seqwater; and

WaterSecure. The review considered: the formulation of the WACC; the intra year timing of cashflows; and the structural, computational and economic integrity of the models.

2011 **Multinet Gas and SP AusNet - Gas Distribution**
Report on the market risk premium
Co-authored a report that examined a number of issues arising from the draft decision on Envestra's access proposal for the SA gas network. The report considered whether: the historical evidence supported the use of a long term average of 6 per cent; there is any evidence to warrant a MRP at it long term average; and the evidence relied on by the AER to justify its return to a MRP of 6 per cent.

2011 **Dampier to Bunbury Natural Gas Pipeline - Gas Transmission**
Cost of Equity
Co-authored two reports that updated the cost of equity for a gas transmission business and responded to issues raised by the regulator in its draft decision. The report re-estimated the cost of equity of a gas distribution business using the Sharpe Lintner CAPM, Black CAPM, Fama-French three-factor model and a zero beta version of the Fama-French three-factor model.

2010-2011 **Queensland Competition Authority**
Weighted Average Cost of Capital (WACC) for SunWater
Retained to provide two expert reports on the WACC for SunWater a Queensland rural infrastructure business. The first report considered issues pertaining to whether a single or multiple rates of return can be applied across SunWater's network segments. The second report focuses market evidence on the appropriate rate of return for SunWater.

2011 **Mallesons Stephens Jaques, on behalf of ActewAGL Distribution**
Determining the averaging period
Assisted in the development of an expert report that considered the economic and financial matters arising from the Australian Energy Regulator's decision to reject ActewAGL's proposed risk free rate averaging period.

2010 **Orion Energy, New Zealand**
Information disclosure regime
Provided advice and assistance in preparing submissions by Orion to the New Zealand Commerce Commission, in relation to the Commission's proposed weighted average cost of capital for an electricity lines businesses. Issues addressed included the financial model used to calculate the required return on equity, the appropriate term for the risk free rate and the WACC parameter values proposed by the Commission.

2010 **Ministerial Council on Energy, Smart Meter Working Group, The costs and benefits of electricity smart metering infrastructure in rural and remote communities**

This report extends NERA's earlier analysis of the costs and benefits of a mandatory roll out of smart meters, by consider the implications of a roll out in rural and remote communities in the Northern Territory, Western Australia and Queensland. The project has focused on eight case study communities and has examined the implications of prepayment metering and remoteness on the overall costs and benefits of a roll out.

2010 **Grid Australia, Submission to the AER on the proposed amendments to the transmission revenue and asset value models**

Developed and drafted a submission to the AER on the proposed amendments to the AER's post-tax revenue model (PTRM) and roll forward model (RFM). The proposal focused on a number of suggestions to simplify and increase the usability of the existing models.

2010 **Dampier to Bunbury Natural Gas Pipeline (DBNGP) - Gas Transmission**

Cost of Equity

Co-authored a report that examined four well accepted financial models to estimate the cost of equity for a gas transmission business. The report of estimating the cost of equity of a gas distribution business using the Sharpe Lintner CAPM, Black CAPM, Fama-French three-factor model and a zero beta version of the Fama-French three-factor model.

2009-10 **Jemena - Gas Distribution**

Cost of Equity

Co-authored two reports on the use of the Fama-French three-factor model to estimate the cost of equity for regulated gas distribution business. The report examined whether the Fama-French three-factor model met the dual requirements of the National Gas Code to provide an accurate estimate of the cost of equity and be a well accepted financial model. Using Australian financial data the report also provided a current estimate of the cost of equity for Jemena.

2009 **WA Gas Networks - Gas Distribution**

Cost of Equity

Co-authored a report that examined a range of financial models that could be used to estimate the cost of equity for a gas distribution business. The report of estimating the cost of equity of a gas distribution business using the Sharpe Lintner CAPM, Black CAPM, Fama-French three-factor model and Fama-French two-factor model. The report examined both the domestic and international data.

2009 **CitiPower and Powercor – Victorian Electricity Distribution**
Network Reliability Incentive Mechanism (S-factor)
Brendan provided advice to CitiPower and Powercor on the proposed changes to the operation of the reliability incentive mechanism. The advice considered the effects of the proposed changes to the operation of the two distribution network service providers. Specifically, how the 'S-factors' would be changed and implications this has to the revenue streams of the two businesses. A comparison was also made with the current ESC arrangements to highlight the changes to the mechanism.

2009 **CitiPower and Powercor – Victorian Electricity Distribution**
Network Reliability Incentive Mechanism (S-factor)
Brendan provided advice to CitiPower and Powercor on the proposed changes to the operation of the reliability incentive mechanism. The advice considered the effects of the new arrangements on the business case for undertaking a series of reliability projects. Specifically, the project estimated the net benefit to the businesses of three reliability programs.

2009 **Jemena and ActewAGL - Gas Distribution**
Cost of Equity
Co-authored a report on alternative financial models for estimating the cost of equity. The report examined the implication of estimating the cost of equity of a gas distribution business using the Sharpe Lintner CAPM, Black CAPM and Fama-French models. The report examined both the domestic and international data.

2008 **Joint Industry Associations - APIA, ENA and Grid Australia**
Weighted Average Cost of Capital
Assisted in the drafting of the Joint Industry Associations submission to the Australian Energy Regulator's weighted average cost of capital review. The submission examined the current market evidence of the cost of capital for Australian regulated electricity transmission and distribution businesses.

2008 **Joint Industry Associations - APIA, ENA and Grid Australia**
Weighted Average Cost of Capital
Expert report for the Joint Industry Associations on the value of imputation credits. The expert report was attached to their submission to the Australian Energy Regulator's weighted average cost of capital review. The report examined the current evidence of the market value of imputation credits (gamma) created by Australian regulated electricity transmission and distribution businesses.

2007-2008 **Smart Meter Working Group, Ministerial Council on Energy – Assessment of the costs and benefits of a national mandated rollout of smart metering and direct load control**

Part of a project team that considered the costs and benefits of a national mandated rollout of electricity smart meters. Brendan was primarily responsible for the collection of data and the modelling of the overall costs and benefits of smart metering functions and scenarios. The analysis also considering the likely costs and benefits associated with the likely demand responses from consumers and impacts on vulnerable customers.

2007 **Electricity Transmission Network Owners Forum (ETNOF), Submission to the AER on the proposed transmission revenue and asset value models**

Developed and drafted a submission to the AER on the proposed post-tax revenue model (PTRM) and roll forward model (RFM) that would apply to all electricity transmission network service providers (TNSPs). The proposal focused ensuring that the regulatory models gave effect to the AER's regulatory decisions and insures that TNSPs have a reasonable opportunity to recover their efficient costs.

2007 **Victorian Electricity Distribution Business**
Review of Smart Meter model

Reviewed the smart meter model developed by a Victorian distributor and submitted to the Victorian Essential Service Commission (ESC). The smart meter model supported the business' regulatory proposal that quantified the revenue required to meet the mandated roll out of smart meters in Victoria. The smart meter model the quantified the expected, meter, installation, communications, IT and project management costs associated with the introduction of smart meters. Further, the estimated the expected change in the business' meter reading and other ongoing costs attributed with the introduction of smart meter infrastructure.

2007 **Energy Trade Associations - APIA, ENA and Grid Australia**
Weighted Average Cost of Capital

Expert reports submitted to the Victorian Essential Services Commission evaluating its draft decision to set the equity beta at 0.7, and its methodology for determining the appropriate real risk free rate of interest, for the purpose of determining the allowed rate of return for gas distribution businesses.

2007 **Babcock and Brown Infrastructure, Qld**
Review of Regulatory Modelling

Provided advice to Babcock and Brown Infrastructure on the regulatory modelling of revenues and asset values of the Dalrymple Bay Coal Terminal (DBCT). DBCT has undertaken a substantial

capital investment to increase the capacity of the port. Brendan's role was to advise DBCT on variety of issues including the calculation of interest during construction, appropriate finance charges, cost of capital and regulatory revenues which were submitted to the Queensland Competition Authority (QCA).

2007- **ActewAGL, ACT**

Transition to National Electricity Regulation

Providing on-going advice to ActewAGL, the ACT electricity distribution network service provider, on its move to the national energy regulation. The advice covers the revenue and asset modelling, the development of a tax asset base, the new incentives for efficient operating and capital expenditure and processes for compliance, monitoring and reporting of its regulatory activities.

2007 - 2008 **Smart Meter Working Group, Ministerial Council on Energy – Assessment of the costs and benefits of a national mandated rollout of smart metering and direct load control**

Brendan was a member of NERA team that investigated the costs and benefits of a national mandated rollout of electricity smart meters. Brendan's prime responsibility was to undertake the modelling of the costs and benefits of smart metering. NERA's assignment required an assessment of smart metering functions and scenarios, and also considering the likely demand responses from consumers and impacts on vulnerable customers.

2005- **TransGrid, NSW**

Review of Regulatory Systems

Providing strategic advice to TransGrid, the NSW electricity transmission network service provider, on its current regulatory processes. The advice covers TransGrid's internal systems and processes for compliance, monitoring and reporting of its regulatory activities.

2006 **Grid Australia, National**

Submission to application by Stanwell to change the national Electricity Rules (Replacement and Reconfiguration investments)

Developed and drafted a submission to the AEMC on the appropriateness of the draft Rule change that extended the application of the regulatory test to replacement and reconfiguration investments.

2006 **Grid Australia, National**

Submission to application by MCE to change the national Electricity Rules (Regulatory Test)

Developed and drafted a submission to the AEMC on the appropriateness of the draft Rule change which changed the

Regulatory Test as it applies to investments made under the market benefits limb.

2006 **Office of the Tasmanian Energy Regulator**
Implications of the pre-tax or post-tax WACC
Provided a report to OTTER on the potential implications of changing from a pre-tax to a post-tax regulatory framework.

2006 **Babcock Brown Infrastructure**
Regulatory Modelling of Dalrymple Bay Coal Terminal
Developed the economic model used to determine revenues at Dalrymple Bay Coal Terminal. This included updating the model for capital expenditure to upgrade capacity at the terminal, account for intra-year cash flows, and the proper formulation of the weighted average cost of capital and inflation.

2006 **Queensland Competition Authority, Queensland**
Review of Regulatory Revenue Models
Advised the QCA on the financial and economic logic of its revenue building block model that projects the required revenue for the Queensland gas distribution businesses and tariffs for the next 5 years.

2006 **Envestra, South Australia**
Review of RAB Roll Forward Approach
Assisted Envestra in responding to the Essential Services Commission of South Australia's consultation paper on Envestra's 2006/07 to 2010/11 gas access proposal. This involved reviewing Envestra's RAB roll forward modelling and the Allen Consulting Group's critique thereof.

2006 **Transpower, New Zealand**
Review of Regulatory Systems
Provided assistance to Transpower, the sole electricity company in New Zealand, in responding to the New Zealand Commerce Commission's announcement of its intention to declare control of Transpower. This involved developing an expert report commenting on the Commission's methodology for analysing whether Transpower's has earned excess profits in the context of New Zealand's "threshold and control" regime.

2006 **Pacific National**
Rail industry structure and efficiency
Assisted with the development of a report which examined options for addressing issues arising in vertically-separated rail industries. This involved examining a number of case study countries including the UK, US and Canada.

2005 **Australian Energy Markets Commission, Australia**
Transmission pricing regime
Advisor to the AEMC's review of the transmission revenue and pricing rules as required by the new National Electricity Law.

2005 **Queensland Rail, Australia**
Weighted Average Cost of Capital
Provided a report for Queensland Rail on the appropriate weighted average cost of capital for its regulated below rail activities.

2004-2005 **ETSA Utilities**
Review of Regulatory Modelling
Advised ETSA Utilities on the financial and economic logic of ESCOSA's regulatory models used to determine the regulatory asset base, the weighted average cost of capital, regulatory revenues and distribution prices.

2003- 2005 **TransGrid, NSW**
Review of Regulatory Revenues
Assisted TransGrid in relation to its application to the ACCC for the forthcoming regulatory review which focused on asset valuation and roll forward, cost of capital and financial/regulatory modelling.

2004 **Prime Infrastructure, Australia**
Weighted Average Cost of Capital
Provided a report for Prime Infrastructure on the appropriate weighted average cost of capital for its regulated activities (coal shipping terminal).

2004 **PowerGas, Singapore**
Review of Transmission Tariff Model
Advised the Singaporean gas transmission network owner on the financial and economic logic of its revenue building block model that projects PowerGas' revenue requirements and tariffs for the next 5 years.

2003 **ActewAGL, ACT**
Review of Regulatory Revenues
Provided strategic advice to ActewAGL in developing cost of capital principles, asset valuation and incentive mechanisms as part of their current pricing reviews for their electricity and water businesses.

2003 **Orion Energy, New Zealand**
Threshold and Control Regime in the Electricity Sector
Provided advice and assistance in preparing submissions by Orion to the Commerce Commission, in relation to the Commission's proposed

changes to the regulatory regime for electricity lines businesses. Issues addressed included asset valuation, and the form of regulatory control.

2003 **EnergyAustralia, NSW**
Pricing Strategy Under a Price Cap
Advised EnergyAustralia on IPART's financial modelling of both regulated revenues and the weighted average price cap.

2002-03 **TransGrid, NSW,**
Advice in Relation to the Regulatory Test
Modelled the net present value of a range of investment options aimed at addressing a potential reliability issue in the Western Area of New South Wales. This work was undertaken in the context of the application of the ACCC's "regulatory test" which is intended to ensure only *efficient* investment projects are included in the regulatory asset base.

2002 **Rail Infrastructure Corporation (RIC), Australia**
Review of the Cost of Capital Model
Provided advice to RIC and assisted in drafting RIC's submission to the Australian Competition and Consumer Commission (ACCC) on the appropriate cost of capital. This included building a post-tax revenue model of RIC's revenues in the regulatory period.

2002 **PowerGrid, Singapore**
Review of Transmission Tariff Model
Advised the Singaporean electricity transmission network owner on the financial and economic logic of its revenue building block model that projects PowerGrid's revenue requirements and tariffs for the next 10 years.

2002 **EnergyAustralia, Australia**
Review of IPART's Distribution Tariff Model
Advised EnergyAustralia, a NSW distribution service provider, on the economic logic of the revenue model that projects EnergyAustralia's revenue requirements and tariffs for the 2004-2009 regulatory period.

2002 **Essential Services Commission of South Australia**
Review Model to Estimating Energy Costs
Reviewed and critiqued a model for estimating retail electricity costs for retail customers in South Australia for 2002-2003.

2002 **National Competition Council (NCC), Australia**
Exploitation of Market Power by a Gas Pipeline
Provided a report to the NCC in which we developed a number of tests for whether current transmission prices were evidence of the

exploitation of market power by a gas transmission pipeline. Also provided a separate report that applied each of the tests developed. This analysis was relied on by the NCC in determining whether to recommend the pipeline in question be subject to regulation under the Australian Gas Code.

2002 **Australian Gas and Lighting, Australia**
Report on South Australian Retail Tariffs
An independent assessment on the cost components of regulated retail tariffs in South Australia that will be used by AGL in the next review.

2002 **New Zealand Telecom, New Zealand**
Report on the application of wholesale benchmarks in NZ
A report on the application of international benchmarks of wholesale discounts to New Zealand Telecom.

2002 **ENEL, Italy**
Survey of Retailer of Last Resort in NSW
Provided research into the retailer of last resort provisions in the NSW gas sector of an international review for the Italian incumbent utility.

2002 **ENEL, Italy**
Survey of Quality of Service provisions in Victoria and South Australia
Provided research into quality of service regulation for electricity distribution businesses in Victoria and South Australia of an international review for the Italian incumbent utility.

2002 **Integral Energy, Australia**
Provided Advice on the Cost of Capital for the 2004 – 2008 Distribution Network Review
Provided analysis and strategic advice to Integral Energy on the possible methodologies that IPART may use to calculate the cost of capital in the next regulatory period.

2001 **IPART, Australia**
Minimum Standards in Regulation of Gas and Electricity Distribution
Advised the NSW regulator on the appropriate role of minimum standards in regulatory regimes and how this could be practically implemented in NSW.

2001 **TransGrid, Australia**
Advice on ACCC's Powerlink WACC decision
Provided a report critically appraising the ACCC's decision regarding Powerlink's weighted average cost of capital (WACC).

Competition Policy

2005 **Confidential, Australia**
Merger Analysis
Provided expert opinion as well as strategic guidance to the merging firms on the competitive implications of that merger.

2004 **Mallesons Stephen Jaques / Sydney Airports Corporation, Australia**
Appeal to declare under Part IIIA
Provided strategic and economic advice on aspects of Virgin Blue's appeal for the declaration of airside facilities at Sydney Airport under Part IIIA of the Trade Practices Act. This cumulated in the production of an expert witness statement by Gregory Houston.

2003 **Sydney Airports Corporation, Australia**
Application to declare under Part IIIA
Expert report to the National Competition Council in connection with the application by Virgin Blue to declare airside facilities at Sydney Airport under Part IIIA of the Trade Practices Act, and the potential impact on competition in the market for air travel to and from Sydney.

2002 - 2003 **Blake Dawson Waldron/ Qantas Airways, Australia**
Alleged predatory conduct
NERA was commissioned to provide advice in relation to potential allegations of anticompetitive behaviour. Developed a paper examining the economic theory behind predation and the way courts in various jurisdictions determine whether a firm has breached competition law.

2002 **Phillips Fox and AWB Limited**
Declaration of the Victorian Intra-State Rail Network
Advised law firm Phillips Fox (and AWB Limited) in its preparation for an appeal (in the Australian Competition Tribunal) of the Minister's decision not to declare the Victorian intra-state rail network, pursuant to Part IIIA of the Trade Practices Act. This included assisting in the preparation of testimony relating to pricing arrangements for third party access to the rail network and their likely impact on competition in related markets, including the bulk freight transportation services market.

2002 **Singapore Power International (SPI)**
Impact of acquisition of a Victorian distributor on competition
Provided analysis to a company interested in acquiring CitiPower (a Victorian electricity distribution/retail business). Including an assessment of the extent to which the acquisition of CitiPower would

lead to a 'substantial lessening of competition' in a relevant energy markets, given the company's existing Australian electricity sector assets. The NERA report was submitted to the ACCC as part of the pre-bid acquisition clearance process.

Other

1999-2000 **Australian Chamber of Commerce and Industry, Australia**
Alienation of Personal Service Income
Involved in analysing the effects of the proposed business tax reform package had on a number of industries which advocated a number of recommendations to the Federal Government. The package also included the provisions to change the definition of personal service income.

1998-2000 **Australian Chamber of Commerce and Industry, Australia**
Various economic policy issues
Provided analysis on economic trends and Government policies to business groups. This covered issues such as industrial relations reform, taxation changes, business initiatives, and fiscal and monetary settings. Also compiled ACCI surveys on business conditions and expectations.

1996 **Australian Bureau of Statistics, Australia**
Productivity Measures in the Public Health Sector
Involved in a team that reported on the current methods used to measure output in the public health sector and analysed alternative methods used internationally. This was in response to the ABS investigating the inclusion of productivity changes in the public health sector.

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