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Empirical Performance of Sharpe-Lintner and Black CAPMs

A report for Jemena Gas Networks, Jemena Electricity Networks, ActewAGL, AusNet Services, CitiPower, Energex, Powercor, SA Power Networks, and United Energy

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Project Team

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Executive Summary

This report has been prepared for Jemena Gas Networks (JGN), Jemena Electricity Networks (JEN), ActewAGL, AusNet Services, CitiPower, Energex, Powercor, SA Power Networks, and United Energy (UE) by NERA Economic Consulting (NERA). JGN, JEN, ActewAGL, AusNet Services, CitiPower, Energex, Powercor, SA Power Networks, and UE have asked NERA to assess the empirical performance of two forms of the Capital Asset Pricing Model (CAPM) and to respond to issues raised by the Australian Energy Regulator (AER) in its recently published *Draft decision Jemena Gas Networks (NSW) Ltd Access arrangement 2015-20*, other recent AER decisions and recent reports written by the AER's advisors.

Models for estimating the return on equity

We have been asked to assess the two well recognised forms of the CAPM:

- the Sharpe-Lintner (SL) CAPM; and

- the Black CAPM.

These two models have been widely used by finance academics over the last 50 years. It has been known for well over 40 years that there is empirical evidence against the SL CAPM. [1] Thus finance academics use the model primarily as a teaching device rather than in research. They use it as a teaching device because of its simplicity. The Black CAPM was widely used in research until the early 1980s when it was discovered that it tended to misprice low-cap and value stocks (an issue that subsequently led to development of the Fama-French model).

It is useful to add to these two models a naïve model that states that the mean returns to all equities are identical. A pricing model should at least be able to outperform, empirically, a naïve model of this kind.

We use both in-sample tests and out-of-sample tests to determine whether there is evidence against the restrictions that each model imposes. If the restrictions that an asset pricing

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[1] 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. 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 *all* risky assets. Thus the empirical version of the SL CAPM that the AER actually employs differs from the theoretical model proposed by Sharpe and Lintner. The empirical version of the model that the AER employs does closely resemble, though, the version that academic work tests.

Roll (1977) emphasises that difficulties in measuring the return to the market portfolio of *all* risky assets mean that it is not possible to test the SL CAPM. One may be able to reject an empirical version of the model that uses the market portfolio of stocks as a proxy for the market portfolio of all risky assets, but this rejection will not imply that the theoretical model itself is wrong. The issue that concerns us, though, is not whether the SL CAPM itself is correct, but whether the empirical version of the SL CAPM applied by the AER works.

Since our interest is in whether the empirical version of the SL CAPM applied by the AER works and not in whether the SL CAPM itself is true, all references to the SL CAPM in the report will be to the empirical version of the model that the AER uses unless stated otherwise.

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

model imposes do not hold, then the model will, in general, produce biased estimates of the return required on equity. Thus evidence against a model is evidence that the model will generate biased estimates of the return required on equity.

In-sample tests are full-sample tests whereas out-of-sample tests split the full sample up, typically in a recursive manner, into data used to estimate a model and data used to evaluate forecasts generated by the model. Inoue and Kilian (2004) and Diebold (2014) emphasise that in-sample tests of models are to be preferred and out-of-sample tests of models in general represent an inefficient use of data. [2] In other words, they emphasise that in-sample tests are more likely to detect that a null hypothesis is untrue than are out-of-sample tests. Out-of-sample tests, on the other hand, are simple to interpret. Also, as Diebold notes, out-of-sample tests can be useful in summarising the performance of forecasts that models would have generated over a particular historical period.

In-sample tests

We begin our assessment of these models by using in-sample tests to determine whether there is evidence against the restrictions that each model imposes.

Using 10 portfolios formed on the basis of past estimates of beta and monthly data taken from SIRCA from January 1974 to December 2013, we find:

- little evidence of bias in the naïve model;

- statistically significant evidence of bias in the SL CAPM; and

- little evidence of bias in the Black CAPM.

The data indicate that there is a negative rather than a positive relation between returns and estimates of beta. As a result, the evidence indicates that the SL CAPM significantly underestimates the returns generated by low-beta portfolios and overestimates the returns generated by high-beta portfolios. In other words, the model has a low-beta bias. The extent to which the SL CAPM underestimates the returns to low-beta portfolios is both statistically and economically significant.

As an example, we estimate the lowest-beta portfolio of the 10 portfolios that we construct to have a beta of 0.54 – marginally below the midpoint of the AER's range for the equity beta of a regulated energy utility of 0.4 to 0.7. Our in-sample results suggest that the SL CAPM underestimates the return to the portfolio by 4.90 per cent per annum.

While we find little evidence against the restrictions that the Black CAPM imposes on the mean returns to the 10 portfolios formed on the basis of past estimates of beta, the negative relation between returns and estimates of beta – which in some tests is statistically significant – is not consistent with the theory that underpins the model. If we were to impose the

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[2]   Diebold, F., *Comparing predictive accuracy, twenty years later: A personal perspective on the use and abuse of Diebold-Mariano tests*, University of Pennsylvania, December 2013.

    Inoue, A. and L. Kilian, In-*sample or out-of-sample tests of predictability: Which one should we use*? Econometric Reviews, 2004, pages 371-402.

restriction that the relation be nonnegative, then estimates generated by the Black CAPM would match estimates generated by the naïve model. We do not impose this restriction and instead allow the data to determine what relation exists between returns and estimates of beta.

Out-of-sample tests

An alternative way of evaluating the empirical performance of pricing models is to assess their out-of-sample performance. Rule 74 (2) (b) of the National Gas Rules, relating generally to forecasts and estimates, states that:

> 'A forecast or estimate ... must represent the best forecast or estimate possible in the circumstances.'

Evaluating the out-of-sample performance of a pricing model is an excellent way of demonstrating whether estimates of the cost of equity produced using the model are likely to satisfy this important rule because they are straightforward to interpret.

Our out-of-sample tests examine the SLCAPM and the Black CAPM, as well as an alternative version of the CAPM used by the AER. '

The AER states that: [3]

> 'we use the theoretical principles underpinning the Black CAPM to inform the equity beta point estimate from within our empirical range.'

The AER also states that it places some weight on foreign estimates of beta. While it sees: [4]

> 'there are inherent uncertainties when relating foreign estimates to Australian conditions'

the AER concludes that foreign estimates of beta: [5]

> 'provide some limited support for an equity beta point estimate towards the upper end of our range.'

The AER chooses an equity beta estimate for use with the SL CAPM of 0.7 from a range of 0.4 to 0.7. This choice amounts to placing a weight of two thirds on the midpoint of this range, 0.55, and a weight of one third on one. We label a policy of placing a weight of two

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[3]   AER, *Draft decision Jemena Gas Networks (NSW) Ltd Access arrangement 2015–20: Attachment 3: Rate of return*, November 2014, page 265.

[4]   AER, *Draft decision Jemena Gas Networks (NSW) Ltd Access arrangement 2015–20: Attachment 3: Rate of return*, November 2014, page 268.

[5]   AER, *Draft decision Jemena Gas Networks (NSW) Ltd Access arrangement 2015–20: Attachment 3: Rate of return*, November 2014, page 269.

thirds on an unadjusted estimate of beta and one third on one and then using the SL CAPM to estimate the return required on equity a policy of using the 'AER CAPM'. [6]

Using the 10 portfolios formed on the basis of past estimates of beta and monthly data from January 1979 to December 2013, we find:

- little evidence of bias in the naïve model;

- statistically significant evidence of bias in the SL CAPM;

- statistically significant evidence of bias in the AER CAPM; and

- little evidence of bias in the Black CAPM.

The evidence indicates that the SL CAPM and the AER CAPM significantly underestimate the returns generated by low-beta portfolios and overestimate the returns generated by high-beta portfolios. The extent to which they underestimate the returns to low-beta portfolios is both statistically and economically significant.

Issues raised by the AER and its advisors

The AER and its advisors raise a number of issues in recent decisions and reports to which we respond. A recurring theme is that the AER's advisers cite selectively from the work that they discuss.

As an example, McKenzie and Partington (2014) note that Da, Guo and Jagannathan (2012) argue that growth options that firms possess may be largely responsible for the weak relation between return and beta and that the inability of the SL CAPM to explain the cross-section of mean return to stocks need not prohibit its use in project evaluation. [7] McKenzie and Partington do not, however, make it clear that Da, Guo and Jagannathan do not suggest that the SL CAPM be used in the same way that the AER has been using the model. To construct estimates of beta that can be used in project evaluation, Da, Guo and Jagannathan emphasise that unadjusted ordinary least squares estimates of beta have to be adjusted and since beta is a relative measure of risk, even the betas of firms that have no growth options have to be adjusted.

Another recurring theme is that the AER dismisses as irrelevant academic work that rejects the SL CAPM because the work makes choices that might conceivably lead to the model being rejected – even though the AER in using the SL CAPM makes the same choices.

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[6]　The choice of label is unimportant. What is important is that we specify clearly a method that a regulator might use in estimating a return required on equity for a regulated energy utility and that we use time series of returns to evaluate the method. Methods that we cannot specify clearly, we cannot evaluate. We cannot, for example, evaluate the use by a regulator of its discretion in a way that is not specified and in a way that may vary through time.

[7]　Da, Z., R-J. Guo and R. Jagannathan, CAPM for estimating the cost of equity capital: Interpreting the empirical evidence, Journal of Financial Economics, 2012, pages 204-220.

McKenzie, M. and G. Partington, Report to the AER Part A: Return on equity, October 2014, pages 9-10.

As an example, the AER in the *Appendices* to its Rate *of Return Guidelines* argues that tests of the SL CAPM that use as a proxy a value-weighted index of stocks are of limited relevance because the SL CAPM requires one use instead a value-weighted index of all assets.[8] The AER in using the SL CAPM employs a value-weighted index of stocks.

As another example, the AER also in the *Appendices* to its Rate *of Return Guidelines* argues that tests of the SL CAPM typically use returns measured over one month or less whereas it believes a longer horizon may be more appropriate.[9] The AER makes this argument even though it relies itself on estimates of the equity beta of a regulated energy utility computed from weekly and monthly data.

Summary

The central empirical result is that models like the SL CAPM and AER CAPM that use market beta as a measure of risk and a restriction that a zero-beta portfolio earn either the risk-free rate or a rate that sits only a small distance above the risk-free rate provide poor estimates of the return required on equity. In particular, the models tend to underestimate the returns required on low-beta equity portfolios and overestimate the returns required on high-beta equity portfolios.[10] In other words, models that use market beta as a measure of risk and a restriction that a zero-beta portfolio earn either the risk-free rate or a rate that sits only a small distance above the risk-free rate produce estimates of required returns that are biased – especially for low-beta equities and high-beta equities.

The SL CAPM and the AER CAPM perform so badly that even a naïve model that states that the mean returns to all equities are identical performs better. Thus estimates of the return required on equity that use the SL CAPM, and the AER CAPM will not, for example, satisfy Rule 74 (2) of the National Gas Rules, relating generally to forecasts and estimates, which states that:

> (2) A forecast or estimate:
>
>> (a) must be arrived at on a reasonable basis; and
>>
>> (b) must represent the best forecast or estimate possible in the circumstances.

Estimates of the return required on equity that use the SL CAPM or the AER CAPM do not represent the best forecasts possible in the circumstances.

Table 1 below summarises the results of our tests and shows that there is little to choose between the naïve model and the Black CAPM in terms of the performance of the models in estimating the return required on an equity portfolio. One cannot reject the hypothesis that each of these models generates estimates of the return on equity that are unbiased.[11] Thus

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[8]   AER, Better Regulation Explanatory Statement Rate of Return Guideline (Appendices), December 2013, pages 11-12.

[9]   AER, Better Regulation Explanatory Statement Rate of Return Guideline (Appendices), December 2013, pages 11-12.

[10]   By construction, of course, the SL CAPM will correctly estimate the return required on a risk-free asset.

[11]   While the naïve model and the Black CAPM provide estimates of the return required on equity that are unbiased, the models will overestimate the return required on a risk-free asset.

estimates of the return required on equity that use the naïve model or the Black CAPM will satisfy Rule 74 (2) of the National Gas Rules.

We conclude that estimates of the return required on equity that use the naïve model or the Black CAPM will be relevant for estimating a cost of equity that is:

    (a) consistent with the allowed rate of return objective; and

    (b) reflective of prevailing conditions in the market for equity funds.

We have not examined the issue of how best to combine estimates from different pricing models. We note, however, that an estimator that relies solely on the SL CAPM or the AER CAPM to the exclusion of other asset pricing models, as the AER has done in its recent draft decisions, will produce a materially worse estimate of the cost of equity in terms of bias than an approach that combines estimates that these models provide with estimates provided by other models that are not similarly affected by bias, such as the Black CAPM.

Table 1
Summary of test results

	Portfolios formed on the basis of past estimates of beta		Portfolios formed on the basis of dividend yield and size	
	In-sample	Out-of-sample	In-sample	Out-of-sample
Naïve model	Accept	Accept	Accept	Accept
SL CAPM	Reject	Reject	Reject	Reject
AER CAPM		Reject		Reject
Black CAPM	Accept	Accept	Accept	Accept

Notes: The table indicates whether a Wald test of each model accepts or rejects the model. The tests use monthly data from January 1974 to December 2013. A Wald statistic uses unrestricted parameter estimates and an estimate of the covariance matrix of the unrestricted parameter estimates to test whether a set of restrictions are true. [28]

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[28]   Davidson, R. and J.G. MacKinnon, *Estimation and inference in econometrics*, Oxford University Press, 1993, page 89.

1.   Introduction

This report has been prepared for Jemena Gas Networks (JGN), Jemena Electricity Networks (JEN), ActewAGL, AusNet Services, CitiPower, Energex, Powercor, SA Power Networks, and United Energy (UE) by NERA Economic Consulting (NERA). JGN, JEN, ActewAGL, AusNet Services, CitiPower, Energex, Powercor, SA Power Networks, and UE have asked NERA to assess the empirical performance of two forms of the Capital Asset Pricing Model (CAPM) and to respond to issues raised by the Australian Energy Regulator (AER) in its recently published *Draft decision Jemena Gas Networks (NSW) Ltd Access arrangement 2015-20*, other recent AER decisions and recent reports written by the AER's advisors.

Under the previous National Electricity Rules, the AER was required to estimate the cost of equity for electricity network businesses using the Sharpe-Lintner (SL) CAPM. Although the previous National Gas Rules did not mandate the use of the SL CAPM, in practice, the AER also applied this approach in gas network decisions. The recently revised National Electricity Rules and National Gas Rules now 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.

Two of the key rules relevant to an access arrangement and its assessment are Rules 74 and 87 of the National Gas Rules.

Rule 74 of the National Gas Rules, relating generally to forecasts and estimates, states:

(1) Information in the nature of a forecast or estimate must be supported by a statement of the basis of the forecast or estimate.

(2) A forecast or estimate:

   (a) must be arrived at on a reasonable basis; and

   (b) must represent the best forecast or estimate possible in the circumstances.

Rule 87 of the National Gas Rules, relating to the allowed rate of return, states:

(1) Subject to rule 82(3), the return on the projected capital base for each regulatory year of the access arrangement period is to be calculated by applying a rate of return that is determined in accordance with this rule 87 (the allowed rate of return).

(2) The allowed rate of return is to be determined such that it achieves the allowed rate of return objective.

(3) The allowed rate of return objective is that the rate of return for a service provider is to be commensurate with the efficient financing costs of a benchmark efficient entity with a similar degree of risk as that which applies to the service provider in respect of the provision of reference services (the allowed rate of return objective).

(4) Subject to subrule (2), the allowed rate of return for a regulatory year is to be:

   (a) a weighted average of the return on equity for the access arrangement period in which that regulatory year occurs (as estimated under subrule (6)) and the return on debt for that regulatory year (as estimated under subrule (8)); and

   (b) determined on a nominal vanilla basis that is consistent with the estimate of the value of imputation credits referred to in rule 87A.

 (5) In determining the allowed rate of return, regard must be had to:

   (a) relevant estimation methods, financial models, market data and other evidence;

   (b) 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

   (c) 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

 (6) The return on equity for an access arrangement period is to be estimated such that it contributes to the achievement of the allowed rate of return objective.

 (7) In estimating the return on equity under subrule (6), regard must be had to the prevailing conditions in the market for equity funds.

[Subrules (8) – (19) omitted].

The equivalent National Electricity Rules are in clauses 6A.6.2 (for electricity transmission) and 6.5.2 (for electricity distribution).

JGN, JEN, ActewAGL, AusNet Services, CitiPower, Energex, Powercor, SA Power Networks, and UE have asked NERA to assess the empirical performance of two forms of the CAPM that might be used to estimate the return on equity component of the rate of return, in a way that complies with the requirements of the National Gas Law and Rules and National Electricity Law and Rules. In particular, the companies have asked NERA to assess the empirical performance, both in-sample and out-of-sample, of:

- the SL CAPM; and

- the Black CAPM.

JGN, JEN, ActewAGL, AusNet Services, CitiPower, Energex, Powercor, SA Power Networks, and UE have also asked that NERA respond to issues that the AER raises in its *Jemena Draft Decision*, in other decisions and issues raised by its advisors.

The remainder of this report is structured as follows:

- section 2 lists the models that we consider, describes the theory underlying each model and summarises the existing empirical evidence on their performance;

- section 3 describes the data that we employ to assess the pricing models that we consider;

- section 4 provides in-sample tests of the models;

- section 5 provides out-of-sample tests of the models;

- section 6 responds to a number of issues raised in recent AER decisions and reports authored by the AER's advisors; and

- Section 7 offers conclusions.

In addition:

- Appendix A provides the results of simulations;

- Appendix B provides the terms of reference for this report;

- Appendix C provides a copy of the Federal Court of Australia's *Guidelines for Expert Witnesses in Proceeding in the Federal Court of Australia*; and

- Appendix D provides the curriculum vitae of the author of the report.

Statement of Credentials

This report has been prepared by **Simon Wheatley**.

Simon Wheatley is an Affiliated Industry Expert 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.

In preparing this report, the author (herein after referred to as 'I' or 'my' or 'me') confirms that I have made all the inquiries that I believe are desirable and appropriate and that no matters of significance that I regard as relevant have, to my knowledge, been withheld from this report. I acknowledge that I 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*. I 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 my report has been prepared in accordance with those guidelines.

I have undertaken consultancy assignments for Jemena in the past. However, I remain at arm's length, and as an independent consultant.

2.   Models for Estimating the Return on Equity

Asset pricing models are theoretical models that place restrictions on the returns required on assets – including equities. Pricing models are, in principle, useful because they allow one to sharpen the precision of estimates of the returns required on assets. If the restrictions that a model imposes, however, do not hold, the pricing model will, in general, produce biased estimates of the returns required on assets.

We have been asked to assess two pricing models:

- the Sharpe-Lintner CAPM; and

- the Black CAPM.

It is useful to add to these two models a naïve model that states that the mean returns to all equities are identical. A pricing model should at least be able to outperform, empirically, a naïve model of this kind.

In this section we describe the theory that lies behind the models and summarise the existing evidence on their empirical performance.

2.1.   A Naïve Model

Risky assets will on average earn the same return if investors are risk neutral or if the risks of the assets – measured in some way – are identical. Casual observation suggests that investors are risk averse. Also, it is unlikely that the risks of all risky assets will be identical. So it is unlikely that a model that states that all risky assets will on average earn the same return will be literally true and deliver estimates of the cost of equity that are free from bias.

Nevertheless, we examine whether there is evidence against a naïve model and whether forecasts of the return on equity that use a naïve model are more or less biased than those generated by more sophisticated models.

The naïve model that we examine implies that:

$$E_{t-1}(z_{jt}) = E_{t-1}(z_{mt}) \tag{1}$$

where:

$E_{t-1}(z_{jt})$ =   the mean return on risky asset j in excess of the risk-free rate from $t-1$ to t conditional on what is known at $t-1$; and

$E_{t-1}(z_{mt})$ =   the mean return to the market portfolio of risky assets in excess of the risk-free rate conditional on what is known at $t-1$.

2.1.1. Evidence

Shanken (1985) tests the hypothesis that 20 portfolios of US stocks formed on the basis of market capitalisation share the same mean return and the hypothesis that the market portfolio of stocks is mean-variance efficient relative to the portfolios. [30] He finds weak evidence against the hypothesis that the 20 portfolios share the same mean return but stronger evidence against the hypothesis that the market portfolio of stocks is mean-variance efficient.

2.2. Sharpe-Lintner CAPM

2.2.1. Theory

The AER has chosen the Sharpe-Lintner (SL) CAPM as its 'foundation' model.[31]

Sharpe (1964) and Lintner (1965) show that if risk-averse investors:

(i)   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;

(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,

then the market portfolio of risky assets must be mean-variance efficient.[32] 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:

$$E_{t-1}(z_{jt}) = \beta_{jt} E_{t-1}(z_{mt}), \qquad \beta_{jt} = \frac{\text{Cov}_{t-1}(z_{jt}, z_{mt})}{\text{Var}_{t-1}(z_{mt})}, \qquad (2)$$

where:

$\text{Cov}_{t-1}(z_{jt}, z_{mt})$ =   the covariance between z_{jt} and z_{mt} conditional on what is known at $t-1$; and

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[30]   Shanken, J., *Multivariate tests of the zero-beta CAPM*, Journal of Financial Economics, 1985, pages 327-348.

[31]   AER, *Better Regulation Rate of Return Guideline*, December 2013, page 13.

[32]   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.

$$\mathrm{Var}_{t-1}(z_{mt}) \qquad = \qquad \text{the variance of } z_{mt} \text{ conditional on what is known}$$
$$\text{at } t-1.$$

The beta of asset j measures the contribution of asset j to the risk, measured by standard deviation of return, of the market portfolio. The SL CAPM predicts that:

- there should be a positive linear relation between risk, measured by beta, and return;

- the price of risk should be the market risk premium $\mathrm{E}_{t-1}(z_{mt})$; and

- the return required on a zero-beta asset should be the risk-free rate.

In the SL CAPM, a risk-averse investor will never invest solely in a single risky asset but rather will hold a share of the market portfolio. So, in the model, an investor cares not about how risky an individual asset would be if held alone, but by how the asset contributes to the risk of the market portfolio. Beta measures this contribution.

2.2.2. Evidence

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.[33] 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 *all* risky assets.[34] Thus the empirical version of the SL CAPM that the AER actually employs differs from the theoretical model proposed by Sharpe and Lintner. The empirical version of the model that the AER employs does closely resemble, though, the version that academic work tests.[35]

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

[34] 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 $100 \times (37,505 + 142,429)/683,805 = 26$ per cent of its net non-human wealth in stocks. Baxter and Jermann (1997), however, estimate that human capital for a nation as a whole represents around 60 per cent of total wealth. Thus an estimate of the proportion of total wealth that is invested in stocks will be no more than $(1 - 0.6) \times 26 = 10.4$ per cent.

Baxter, M. and U. Jermann, *The international diversification puzzle is worse than you think*, American Economic Review, 1997, pages 17-180.

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

[35] The only differences between the version of the model that the AER employs and the version that academic work typically tests are that (i) academic work typically employs a one-month bill rate as a measure of the risk-free rate whereas the AER uses a 10-year bond yield and (ii) academic work typically assigns no value to imputation credits whereas the AER assigns a value to imputation credits distributed. An exception to this rule is a paper by Lajbcygier and Wheatley (2012) that tests the model that the AER uses and finds evidence against the proposition that the market places a value on credits distributed and against the hypothesis that a zero-beta portfolio earns the risk-free rate.

Lajbcygier, P. and S.M. Wheatley, *Imputation credits and equity returns*, Economic Record, 2012, page 487.

Roll (1977) emphasises that difficulties in measuring the return to the market portfolio of *all* risky assets mean that it is not possible to test the SL CAPM.[36] One may be able to reject an empirical version of the model that uses the market portfolio of stocks as a proxy for the market portfolio of all risky assets, but this rejection will not imply that the theoretical model itself is wrong. The issue that concerns us, though, is not whether the SL CAPM itself is correct, but whether the empirical version of the SL CAPM applied by the AER works.

Since our interest is in whether the empirical version of the SL CAPM applied by the AER works and not in whether the SL CAPM itself is true, all references to the SL CAPM from here onwards will be to the empirical version of the model that the AER uses unless stated otherwise. Again, the AER and its advisors use a value-weighted portfolio of stocks as a proxy for the market portfolio. [37]

While the SL CAPM is an attractively simple theory, it has been known for well over 40 years that empirical versions of the model tend to underestimate the returns to low-beta assets and overestimate the returns to high-beta assets. Mehrling (2005), for example, reports that:[38]

> '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 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.'

As another example, President of the American Association Finance Association (2005) John Campbell and his co-author Tuomo Vuolteenah state that:[39]

> 'It is well known that the CAPM fails to describe average realized stock returns since the early 1960s, if a value-weighted equity index is used as a proxy for the market portfolio. In particular, small stocks and value stocks have delivered higher average returns than their betas can justify. Adding insult to injury, stocks with high past betas have had average returns no higher than stocks of the same size with low past betas.'

There are two possible explanations for why the performance of an empirical version of the SL CAPM appears to be poor:

- the model is wrong; and

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

[37]   See, for example,

Henry, Ólan T., *Econometric advice and beta estimation*, Attachment C to the AER's *Explanatory Statement: Electricity transmission and distribution network service provider, review of the weighted average cost of capital (WACC) parameters*, 2008.

Henry, Ólan T., *Estimating beta*, Attachment C to the AER's *Final Decision: Electricity transmission and distribution network service providers, review of the weighted average cost of capital (WACC) parameters*, 2009.

Henry, Ólan T., *Estimating β: An update*, University of Liverpool, April 2014.

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

[39]   Campbell, J. and T. Vuolteenaho, *Bad beta, good beta*, American Economic Review 94, page 1249.

- the model is right but the proxies employed for the market portfolio are poor.

As Fama and French (2004) point out, however, the idea that poor proxies are responsible for the evidence against the model will be of little assistance because it is these proxies that one will have to use. In particular, Fama and French state that: [40]

> 'It is always possible that researchers will redeem the CAPM by finding a reasonable proxy for the market portfolio that is on the minimum variance frontier. We emphasize, however, that this possibility cannot be used to justify the way the CAPM is currently applied. The problem is that applications typically use the same market proxies, like the value-weight portfolio of U.S. stocks, that lead to rejections of the model in empirical tests. The contradictions of the CAPM observed when such proxies are used in tests of the model show up as bad estimates of expected returns in applications; for example, estimates of the cost of equity capital that are too low (relative to historical average returns) for small stocks and for stocks with high book-to-market equity ratios. In short, if a market proxy does not work in tests of the CAPM, it does not work in applications.'

The observation that the SL CAPM tends to underestimate the returns to low-beta assets and overestimate the returns to high-beta assets prompted Black (1972), Vasicek (1971) and Brennan (1971) to examine whether relaxing the assumption that investors can borrow or lend freely at a single risk-free rate can produce a model that better fits the data.[41, 42]

2.3. Black CAPM

Black (1972) examines a world in which investors face no short-sale restrictions but cannot borrow or lend, Vasicek (1971) examines a world in which investors face no short-sale constraints but cannot borrow and Brennan (1971) examines a world in which investors face no short-sale restrictions and can borrow and lend at risk-free rates that differ from one another. [43] In addition, Black summarises the results that Vasicek produces. All three models predict that the market portfolio of risky assets will be mean-variance efficient relative to

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[40] Fama, E.F. and K.R. French, *The Capital Asset Pricing Model: Theory and evidence*, Journal of Economic Perspectives, 2004, pages 42-43.

[41] 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.

[42] The problems associated with the SL CAPM were highlighted by the Economic Sciences Prize Committee of the Royal Swedish Academy of Sciences when awarding the Nobel Prize to Eugene Fama, one the founders of an alternative to the SL CAPM, the Fama-French three-factor model.

Economic Sciences Prize Committee of the Royal Swedish Academy of Sciences, *Understanding Asset Prices: Scientific Background on the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2013*, 14 October 2013, page 39.

[43] 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.

portfolios constructed solely from risky assets. If the market portfolio of risky assets is mean-variance efficient relative to portfolios constructed solely from risky assets, then:

$$E_{t-1}(r_{jt}) = (1 - \beta_{jt})E_{t-1}(r_{zt}) + \beta_{jt}E_{t-1}(r_{mt}), \tag{3}$$

where:

$E_{t-1}(r_{jt})$ =   the mean return on risky asset j from $t-1$ to t conditional on what is known at $t-1$; and

$E_{t-1}(r_{zt})$ =   the mean return on a zero-beta portfolio conditional on what is known at $t-1$; and

$E_{t-1}(r_{mt})$ =   the mean return to the market portfolio of risky assets conditional on what is known at $t-1$.

If a risk-free rate exists – for example, a single rate at which the government can borrow or lend – then, like Ferson and Harvey (1991) and Lewellen, Nagel and Shanken (2010), we can express (3) alternatively as: [44, 45]

$$E_{t-1}(z_{jt}) = (1 - \beta_{jt})\gamma_{0t} + \beta_{jt}E_{t-1}(z_{mt}), \tag{4}$$

where:

γ_{0t} =   the mean return in excess of the risk-free rate on a portfolio that has a zero beta relative to the market portfolio of risky assets – the zero-beta premium.

Although three authors contributed to the development of (3), the model is generally known simply as the 'Black CAPM'. For example, Ingersoll (1987), in his widely cited text for doctoral-level courses in finance, states at the start of Chapter 4 'Mean-Variance Portfolio Analysis' that: [46, 47]

'Mean-variance analysis provides a basis for the derivation of the equilibrium model known variously as the capital asset pricing model (CAPM), Sharpe-Lintner model, Black model, and two-factor model.'

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[44]   Ferson, W. and C. Harvey, *The variation of economic risk premiums*, Journal of Political Economy, 1991, pages 385-415.

     Lewellen, J., S. Nagel and J. Shanken, *A skeptical appraisal of asset pricing tests*, Journal of Financial Economics, 2010, pages 175–194.

[45]   Note that expressing the model in terms of excess returns does not presume that all investors can borrow or lend at a single risk-free rate.

[46]   Google scholar reports that the book has been cited 2,309 times.

     http://scholar.google.com.au/citations?user=WetRd_cAAAAJ&hl=en

[47]   Ingersoll, *Theory of financial decision making*, Rowman and Littlefield, Maryland, 1987, page 82.

Ingersoll goes on, in his Chapter 4, to examine Black's (1972) world in which investors cannot borrow or lend but face no short-sale restrictions, Vasicek's (1971) world in which investors cannot borrow but face no short-sale constraints and Brennan's (1971) world in which investors face no short-sale restrictions and can borrow and lend at risk-free rates that differ from one another. [48]

Ingersoll (1987) derives (3) under the assumption that investors cannot borrow or lend – expressing it in raw returns – and states: [49]

> '(t)his is the Black CAPM or the "two-factor" model'

and goes on to note that: [50]

> '(w)hen there are restrictions on the riskless asset, such as only lending permitted or there is a higher borrowing than lending rate, but no restrictions on the other assets, then the zero-beta version of the CAPM is still valid.'

Nowhere in his Chapter 4 does Ingersoll refer by name to Vasicek or Brennan – even though he refers to the conclusions that they draw. [51]

Similarly, Bodie, Kane and Marcus (2002) in their widely used Investments text state that: [52]

> 'the Black model can be applied to any of several variations: no risk-free asset at all, risk-free lending but no risk-free borrowing, and borrowing at a higher rate than (the risk-free lending rate).'

Bodie, Kane and Marcus do not, though, make any reference to the work of Vasicek (1971) or Brennan (1972) anywhere in their book.

While each of the models that Black (1972), Vasicek (1971) and Brennan (1971) derive predicts that the cross-section of mean returns to risky assets will be described by (3), the models place different restrictions on the mean return to a zero-beta portfolio: [53]

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[48] 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.

[49] Ingersoll, *Theory of financial decision making*, Rowman and Littlefield, Maryland, 1987, page 94.

[50] Ingersoll, *Theory of financial decision making*, Rowman and Littlefield, Maryland, 1987, page 94.

[51] He does, as one would expect, include their papers in the references, at the rear of his text, for Chapter 4.

[52] While this quotation is from the fifth edition of their text, a 10th edition now exists.

Bodie, Z., A. Kane and A.J. Marcus, *Investments*, McGraw-Hill Irwin, New York, 2002, page 277.

http://highered.mheducation.com/sites/0077861671/information_center_view0/index.html

[53] 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.

- Black's model places no restriction on the zero-beta rate other than it must lie below the mean return to the market portfolio;

- Vasicek's model places the additional restriction on the zero-beta rate that it must lie above the risk-free lending rate; and

- Brennan's model places the additional restriction on the zero-beta rate that it must lie below the risk-free borrowing rate.

Note, however, of the three models, Brennan's model is the most general – Black's model and Vasicek's model are special cases of Brennan's model. In Brennan's model, all risk-free borrowing will cease when the borrowing rate is set sufficiently high. In other words, if the borrowing rate is set sufficiently high, Brennan's model will collapse to the simpler model that Vasicek examines. Similarly, in Brennan's model, both risk-free borrowing and lending will cease when the borrowing rate is set sufficiently high and the lending rate is set sufficiently low. [54] In other words, if the borrowing rate is set sufficiently high and the lending rate is set sufficiently low, Brennan's model will collapse to the simpler model that Black examines – and the constraint that the zero-beta rate lie between the borrowing and lending rates will not bind.

This discussion indicates that if, wanting to conserve space, a consultant were to choose to discuss the properties of just one of the three models, the consultant would do best to pick Brennan's model because the other two models – Black's model and Vasicek's model – are special cases of Brennan's more general model. This is the choice that NERA (2012, 2013) makes. [55]

McKenzie and Partington (2014) are critical of this choice and ask in their recent report for the AER: [56]

> 'why (do) NERA (2012, p.4) and NERA (2013b, p. 6) appear to be treating the Brennan and Black models as substitutes?'

NERA (2012, 2013), to conserve space, chooses to briefly describe only one of the Black, Vasicek and Brennan models. [57] Since Brennan's model includes the other two models as special cases NERA chooses to describe his model while noting – correctly, as we demonstrate – that all three models are often labelled the Black model.

Ingersoll, *Theory of financial decision making*, Rowman and Littlefield, Maryland, 1987, pages 82-95.

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

[54]   An example of a low lending rate would be minus 90 per cent per day.

[55]   NERA, The Black CAPM: A report for APA Group, Envestra, Multinet & SP AusNet, March 2012, page 4.

NERA, Estimates of the zero-beta premium: A report for the Energy Networks Association, June 2013, page 6.

[56]   McKenzie, M. and G. Partington, Report to the AER Part A: Return on equity, October 2014, page 22.

[57]   NERA, The Black CAPM: A report for APA Group, Envestra, Multinet & SP AusNet, March 2012, page 4.

NERA, Estimates of the zero-beta premium: A report for the Energy Networks Association, June 2013, page 6.

McKenzie and Partington (2014) go on to state that: [58]

> 'The implication of the Black model under either of his two scenarios is that borrowing cost (sic) are higher when there are restrictions on trading the riskless asset. This differs from the proposition "that investors would have to pay a premium above the risk-free rate when borrowing" as in the scenario where there is no risk-free security, such a statement is meaningless. Only under the Brennan (1971) model is the proposition that restrictions on trading in the riskless security result in the investor having to pay a premium above the risk-free rate when borrowing.
>
> Returning to the arguments of SFG ...'

In this passage McKenzie and Partington appear to suggest that the quote "that investors would have to pay a premium above the risk-free rate when borrowing" is from one of NERA's reports. It is not but is a quote from SFG's (2014) report. [59] SFG quite reasonably, like Bodie, Kane and Marcus (2005), uses the label 'Black CAPM' to describe the three very similar models that Black (1972), Vasicek (1971) and Brennan (1971) derive. On a more substantive note, the first and second sentences of the passage above, viewed together, make little sense. The first sentence says that in Black's model borrowing costs are higher while the second sentence says that this is not the same as paying more when borrowing. The third sentence is correct but note that there is nothing to prevent the borrowing and lending rates in Brennan's model from being sufficiently high and sufficiently low that all borrowing and lending will cease.

In what follows, we will continue to label (3) and (4) as the Black CAPM even though we are aware – and have previously made it clear that we are aware – that Fischer Black was not solely responsible for the derivation of the model. [60, 61]

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[58]   McKenzie, M. and G. Partington, Report to the AER Part A: Return on equity, October 2014, page 22.

[59]   SFG, *Cost of equity in the Black Capital Asset Pricing Model: Report for Jemena Gas Networks, ActewAGL, Networks NSW, Transend, Ergon and SA Power Networks*, May 2014, page 12.

[60]   Besides Vasicek and Brennan, there is evidence that others contributed to the development of the model. Mehrling (2005) notes that:

'In Financial Note No. 15A (August 26, 1970), the first draft of what would become the zero-beta model, Black thanks John Long (of the University of Rochester) and Robert Merton (of MIT) for drawing his attention to (the two-fund theorem).'

Mehrling, Perry, *Fischer Black and the revolutionary idea of finance*, Wiley, 2005, page 311.

[61]   Similarly, we, in this report, and McKenzie and Partington (2014) refer to the Sharpe-Lintner CAPM even though it is known that Treynor (1962) developed a similar model independently at around the same time as Sharpe and Lintner. See Mehrling (2005) for a discussion of the development of the model.

Mehrling, Perry, *Fischer Black and the revolutionary idea of finance*, Wiley, 2005, page 57.

Treynor, J., *Toward a theory of market value of risky assets*, 1962.

2.3.1. Evidence

By construction, the Black CAPM eliminates the tendency of the SL CAPM to underestimate the returns to low-beta assets and overestimate the returns to high-beta assets. The model does not, though, eliminate the tendency of the SL CAPM to underestimate the returns to value stocks and, in the US and some other countries, low-cap stocks. [62] Fama and French (2004), for example, note that: [63]

> 'Ratios involving stock prices have information about expected returns missed by market betas. On reflection, this is not surprising. A stock's price depends not only on the expected cash flows it will provide, but also on the expected returns that discount expected cash flows back to the present. Thus, in principle, the cross-section of prices has information about the cross-section of expected returns. (A high expected return implies a high discount rate and a low price.) The cross-section of stock prices is, however, arbitrarily affected by differences in scale (or units). But with a judicious choice of scaling variable X, the ratio X/P can reveal differences in the cross-section of expected stock returns. Such ratios are thus prime candidates to expose shortcomings of asset pricing models-in the case of the CAPM, short-comings of the prediction that market betas suffice to explain expected returns (Ball, 1978). The contradictions of the CAPM summarized above suggest that earnings-price, debt-equity and book-to-market ratios indeed play this role.
>
> Fama and French (1992) update and synthesize the evidence on the empirical failures of the CAPM. Using the cross-section regression approach, they confirm that size, earnings-price, debt-equity and book-to-market ratios add to the explanation of expected stock returns provided by market beta. Fama and French (1996) reach the same conclusion using the time-series regression approach applied to portfolios of stocks sorted on price ratios. They also find that different price ratios have much the same information about expected returns. This is not surprising given that price is the common driving force in the price ratios, and the numerators are just scaling variables used to extract the information in price about expected returns.'

As with the SL CAPM, there are two possible explanations for why the performance of an empirical version of the Black CAPM appears to be poor:

- the model is wrong; and

- the model is right but the proxies employed for the market portfolio are poor.

The Black CAPM states that the risk of an asset should be measured relative to the market portfolio of *all* risky assets whereas empirical versions of the model measure the risk of an asset relative to a portfolio of stocks alone. It follows that one should not expect the cross-

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[62]   A value stock is a stock that has a high book value relative to its market value or, identically, a low market value relative to its book value. A growth stock is a stock that has a low book value relative to its market value or, identically, a high market value relative to its book value.

[63]   Fama, E.F. and K.R. French, *The Capital Asset Pricing Model: Theory and evidence*, Journal of Economic Perspectives, 2004, page 36.

section of mean returns to be completely explained by empirical estimates of beta nor should one expect empirical estimates of the zero-beta rate computed relative to a value-weighted portfolio of stocks to necessarily lie between the risk-free borrowing and lending rates. This is because the Black CAPM does not impose the restriction that the mean return to a portfolio that has a zero beta relative to the market portfolio of stocks must lie between the risk-free borrowing and lending rates.

Again, the idea that poor proxies are responsible for any evidence against the model will be of little assistance because it is these proxies that one will have to use in employing the model.

3. Data

We use monthly data from January 1969 to December 2013 from SIRCA's Share Price and Price Relative (SPPR) database to evaluate the empirical performance of a number of different pricing models. These data are the longest reliable series of returns on a large cross-section of Australian stocks that are available. SIRCA constructs the database from data provided by the Australian Stock Exchange (ASX).

3.1. Portfolio Returns

Like Black, Jensen and Scholes (1972), Fama and MacBeth (1973), Campbell and Vuolteenaho (2004) and Lewellen, Nagel and Shanken (2010), we test pricing models using the returns to portfolios of stocks. [81]

3.1.1. Portfolios formed on the basis of past estimates of beta

The model that the AER chooses as its 'foundation' model is the SL CAPM. This model implies that variation across equities in their mean returns will be completely explained by variation in their betas. So a sensible way of constructing portfolios to be used in evaluating the empirical performance of the model is to form portfolios, like Black, Jensen and Scholes (1972) and Fama and MacBeth (1973), on the basis of past estimates of beta. [82]

To form portfolios on the basis of past estimates of beta, we begin by extracting data from January 1969 to December 2013 for individual stocks from the SPPR database. The SPPR database does not provide market capitalisations before December 1973 and so we do not begin to record the returns to the portfolios that we construct until January 1974. We use past estimates of betas to allocate stocks to portfolios, however, and so we use data from before January 1974 to determine in which portfolios to place stocks in the early years of the time series that we construct. To minimise the impact of market microstructure effects, at the end of each year we use past data to estimate the betas only of stocks that are in the top 500 by market capitalisation. We choose the top 500 because the All Ordinaries Index is constructed from the top 500 stocks.

We form value-weighted portfolios on the basis of past beta estimates in the following way. At the end of December each year we use data for the prior five years to estimate the betas of

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[81] 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, Praeger, New York, 1972.

Campbell, J. and T. Vuolteenaho, *Bad beta, good beta*, American Economic Review 94, page 1249.

Fama, E. F. and J. D. Macbeth, *Risk, return and equilibrium: Empirical tests*, Journal of Political Economy, 1973, pages 607-636.

Lewellen, J., S. Nagel and J. Shanken, *A skeptical appraisal of asset pricing tests*, Journal of Financial Economics, 2010, pages 175–194.

[82] 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, Praeger, New York, 1972.

Fama, E. F. and J. D. Macbeth, *Risk, return and equilibrium: Empirical tests*, Journal of Political Economy, 1973, pages 607-636.

all stocks relative to the market portfolio, dropping those that do not have a full 60 months of data. We then place the stocks into 10 portfolios on the basis of the estimates and record the returns to these portfolios for each month of the following year. So, for example, we compute beta estimates using data from January 1969 to December 1973 for stocks that are in the top 500 by market capitalisation at the end of December 1973. We allocate these stocks to 10 portfolios on the basis of these estimates and then record the returns to the portfolios for each month of 1974. Next, we compute beta estimates using data from January 1970 to December 1974 for stocks that are in the top 500 by market capitalisation at the end of December 1974, allocate these stocks to 10 portfolios on the basis of the estimates and then record the returns to the portfolios for each month of 1975. And so on. We also form a value-weighted portfolio of the top 500 stocks by market capitalisation and use the portfolio as a proxy for the market portfolio.

Some of the stocks that are in the SPPR database are headquartered abroad. In previous submissions to the AER that use earlier versions of the SPPR database, we have used our best efforts to remove stocks that are foreign. [83] We used our best efforts to remove foreign stocks because the market capitalisations of the stocks recorded by SIRCA include the value of stocks traded on other exchanges besides the ASX. For example, we eliminated stocks that were Chess Units of Foreign Securities and stocks whose company name included the acronym 'plc'. We may not have eliminated all foreign stocks in this way but we are confident that we eliminated a significant proportion of the stocks and that we induced no survivorship bias in doing so. [84]

SIRCA has included in the most recent version of the SPPR database a flag that indicates whether the stock is likely to be incorporated outside Australia. Unfortunately, the way in which the flag has been constructed implies that there is a possibility that survivorship bias will be induced by using the flag. SIRCA states in its SPPR guide that: [85]

> '(the flag) is generated from two ASX sources. The most recent ASX source distinguishes between: 1) 'f' which are companies incorporated outside Australia that comply with ASX listing rules; and 2) 'x' which are also foreign incorporated companies that are exempt from listing rule compliance. 'f' and 'x' codes first became available in July 1996. Prior to this time, a separate field identified companies reporting in currencies other than Australian dollars. This field initially appeared in January 1988 and is recorded here as 'c'. In order to extend this identifier further back in time than January 1988, companies that are later labelled as 'c' companies are imputed to have been always reporting in currencies other than Australian dollars. A label of 'b' is applied for such companies during intervals before January 1988. Please be aware this imputation process creates a

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[83]   For example, see:

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

    NERA, *Imputation credits and equity prices and returns: A report for the Energy Networks Association*, October 2013.

[84]   We are confident that we did so because using the 2013 SIRCA database we find that using the 2012 database we eliminated a significant proportion of the stocks that SIRCA now deems to be foreign. See below for a discussion of SIRCA's newly introduced flag that indicates foreign ownership.

[85]   SIRCA, *Share price and price relative database*, 2014, page 20.

survivorship bias because companies that reported in foreign currencies before January 1988 and did not survive until January 1988, where this practice first becomes observable in our archives, are not recognised as such. In effect, we can only 'see' foreign currency companies (which) are listed in January 1988.   This survivorship bias can be expected to increase the further back in time a study uses data before January 1988. 'b' is adopted to distinguish between legitimate 'c' records and our estimated categorisation, 'b'. '

We address this issue by examining the sensitivity of our results to the exclusion of stocks contained in the SPPR database that SIRCA deems to be foreign. We find the results are not sensitive to the exclusion of stocks that SIRCA deems to be foreign.

3.1.2.   Data input errors

In a recent report, Lally (2013) expresses concern over the possible effects of data entry errors. [90] It is almost certain that the SIRCA database contains some errors – although we suspect that they are very few. The database contains 686,964 nonnegative price relatives and nine negative price relatives. A price relative is one plus the rate of return to a stock. Limited liability constrains price relatives to be nonnegative and so the negative price relatives must be errors of some kind. We exclude these observations and have done so in past work. There are also 859 occasions on which a return of no more than -50 per cent is followed by a return of at least 100 per cent or on which a return of at least 100 per cent is followed by a return of no more than -50 per cent. The mean (median) closing price associated with these observations is 22.1 (2.0) cents. In contrast, the mean (median) closing price associated with observations that do not exhibit these wide swings is 199.8 (52.5) cents. So, many of these 859 large return reversals may not represent data entry errors. Some of them, however, may represent data entry errors. We find that our results are not sensitive, however, to the exclusion of these observations. Thus we conclude that it is unlikely that data entry errors are responsible for the results that we report.

3.2.   Imputation Credits

We compute the returns to the portfolios that we use inclusive of a value assigned to imputation credits. In particular, we assign a value of 35 cents to each dollar of imputation credits distributed. Thus the partially franked returns that we use are the unfranked returns plus 35 percent of the difference between the fully franked and unfranked returns.

3.3.   Risk-Free Rate

We use as a measure of the risk-free rate the yield, computed on a monthly basis, on a 10-year Commonwealth Government bond. We do so because the AER uses the 10-year yield as its measure of the risk-free rate. [92]   We extract the end-of-month yields on these bonds from the Reserve Bank of Australia.

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[90]   Lally, M., *The estimation of gamma*, Victoria University of Wellington, November 2013, page 25.

[92]   AER, *Draft decision Jemena Gas Networks (NSW) Ltd Access arrangement 2015–20: Attachment 3: Rate of return*, November 2014, page 28.

4.   In-Sample Tests

We use both in-sample tests and out-of-sample tests to determine whether there is evidence against the restrictions that each model imposes. If the restrictions that an asset pricing model imposes do not hold, then the model will, in general, produce biased estimates of the return required on equity. Thus evidence against a model is evidence that the model will generate biased estimates of the return required on equity.

In-sample tests are full-sample tests whereas out-of-sample tests split the full sample up, typically in a recursive manner, into data used to estimate a model and data used to evaluate forecasts generated by the model. Inoue and Kilian (2004) and Diebold (2014) emphasise that in-sample tests of models are to be preferred and out-of-sample tests of models in general represent an inefficient use of data. [93] In other words, they emphasise that in-sample tests are more likely to detect that a null hypothesis is untrue than are out-of-sample tests. Out-of-sample tests, on the other hand, are simple to interpret. Also, as Diebold notes, out-of-sample tests can be useful in summarising the performance of forecasts that models would have generated over a particular historical period.

We begin by using in-sample tests to determine whether there is evidence against the restrictions that each model imposes.

Using 10 portfolios formed on the basis of past estimates of beta and monthly data from January 1974 to December 2013, we find:

- little evidence of bias in a naïve model;

- evidence of bias in the SL CAPM; and

- little evidence of bias in the Black CAPM.

The data indicate that there is a negative rather than a positive relation between returns and estimates of beta. As a result, the evidence indicates that the SL CAPM significantly underestimates the returns generated by low-beta portfolios and overestimates the returns generated by high-beta portfolios.

4.1.   Methodology

We use the generalised method of moments of Hansen (1982) to estimate the parameters of each model and to test the restrictions that the models impose. [94] The ordinary method of moments uses sample moments as estimates of the corresponding population moments. Under the assumption that the data are independently and identically distributed the

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[93]   Diebold, F., *Comparing predictive accuracy, twenty years later: A personal perspective on the use and abuse of Diebold-Mariano tests*, University of Pennsylvania, December 2013.

   Inoue, A. and L. Kilian, In-*sample or out-of-sample tests of predictability: Which one should we use*? Econometric Reviews, 2004, pages 371-402.

[94]   Hansen, L.P., *Large sample properties of Generalized Method of Moments estimators*, Econometrica, 1982, pages 1029-1054.

procedure can be justified by invoking the law of large numbers. The generalised method of moments (GMM) relaxes the assumption. The ordinary least squares (OLS) estimator can be regarded as a GMM estimator. [95] OLS is the most commonly used technique in econometrics. [96]

To test the naïve model, we estimate the system:

$$z_{jt} = \alpha_j + z_{mt} + \varepsilon_{jt}, \qquad j = 1, 2, ..., N, \tag{5}$$

> where:

> α_j =   the error with which the naïve model measures the mean return to portfolio j;

> ε_{jt} =   a disturbance; and

> N =   the number of portfolios.

The error α_j is merely the difference between the mean return to portfolio j and the mean return to the market. The naïve model says that this error should be zero for every portfolio. Thus the model imposes N restrictions on the system of N equations.

To test the SL CAPM, we estimate the system:

$$z_{jt} = \alpha_j + \beta_j z_{mt} + \varepsilon_{jt}, \qquad j = 1, 2, ..., N, \tag{6}$$

> where here:

> α_j =   the error with which the SL CAPM measures the mean return to portfolio j.

The SL CAPM says that each pricing error α_j must be zero and so also imposes N restrictions on the system of N equations.

To test the Black CAPM, we estimate the system:

$$z_{jt} = (1 - \beta_j)\gamma + \beta_j z_{mt} + \varepsilon_{jt}, \qquad j = 1, 2, ..., N, \tag{7}$$

> where:

> γ =   the zero-beta premium.

The Black CAPM reduces the number of parameters to be estimated by $N - 1$ and so imposes $N - 1$ restrictions.

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[95]   Davidson, R. and J.G. MacKinnon, *Estimation and inference in econometrics*, Oxford University Press, 1993, pages 583-584.

[96]   Davidson, R. and J.G. MacKinnon, *Estimation and inference in econometrics*, Oxford University Press, 1993, page 3.

We use individual *t*-test statistics and Wald statistics to test the restrictions that each model imposes. A Wald statistic uses unrestricted parameter estimates and an estimate of the covariance matrix of the unrestricted parameter estimates to test whether a set of restrictions are true. [97]

4.2. Results

4.2.1. Tests that use portfolios formed on the basis of past estimates of beta

Table 4.1 provides the results of tests of the naïve model, the SL CAPM and the Black CAPM that use the 10 portfolios formed on the basis of past estimates of beta.

The results indicate that there is little evidence against the naïve model. A Wald test of the restrictions that the model imposes does not come close to rejecting them and there is only evidence that one of the portfolios – portfolio 4 – is mispriced.

On the other hand, Table 4.1 indicates that there is evidence against the SL CAPM. A Wald test of the restrictions that the model imposes rejects them and there is evidence that six of the portfolios are mispriced. Recall that the SL CAPM restricts each α to be zero. The evidence is particularly strong for low-beta portfolios – the SL CAPM underestimates the returns to the five lowest-beta portfolios by around three to five per cent per annum. Thus the evidence against the model is both economically and statistically significant.

The AER (2013) and McKenzie and Partington (2014) refer to the work of Ray, Savin and Tiwari (2009) who show that the finite-sample distribution of the Wald statistic for a test of the SL CAPM need not conform closely to its theoretical asymptotic distribution. [98] The finite-sample distribution refers to the distribution in samples that are not very, very large while the asymptotic distribution refers to the distribution in very, very large samples. Asymptotic results are ones that are strictly true only in the limit as the sample size tends to infinity. [99] As a result of the differences that can occur between the finite-sample and asymptotic distributions of the Wald statistics used to test the SL CAPM, Ray, Savin and Tiwari note that tests of pricing models that rely on the asymptotic distributions of the statistics can reject more frequently than the stated sizes (significance levels) of the tests would suggest. To examine the extent to which the finite-sample distribution of the Wald statistic that we use to test the SL CAPM differs from its theoretical asymptotic distribution, we conduct bootstrap simulations.

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[97] Davidson, R. and J.G. MacKinnon, *Estimation and inference in econometrics*, Oxford University Press, 1993, page 89.

[98] AER, *Better Regulation Explanatory Statement Rate of Return Guideline (Appendices)*, December 2013, page 12.

McKenzie, M. and G. Partington, Report to the AER Part A: Return on equity, October 2014, page 9.

Ray, S., N.E. Savin and A. Tiwari, Testing the CAPM revisited, Journal of Empirical Finance, 2009, pages 721-733.

[99] Davidson, R. and J.G. MacKinnon, *Estimation and inference in econometrics*, Oxford University Press, 1993, page 42.

Table 4.1
In-sample tests of a naïve model, the Sharpe-Lintner CAPM and the Black CAPM
that use portfolios formed on the basis of past estimates of beta

Portfolio	Naïve model α	Sharpe-Lintner CAPM α	Sharpe-Lintner CAPM β	Black CAPM β	Black CAPM γ
					10.75
					(2.86)
1	2.59	**4.90**	**0.54**	**0.54**	
	(2.05)	(1.76)	(0.04)	(0.04)	
2	2.27	**4.16**	**0.62**	**0.62**	
	(1.99)	(1.74)	(0.05)	(0.05)	
3	2.11	**3.86**	**0.65**	**0.66**	
	(1.87)	(1.72)	(0.06)	(0.06)	
4	**3.95**	**4.99**	**0.79**	**0.79**	
	(1.67)	(1.63)	(0.03)	(0.03)	
5	2.90	**3.25**	**0.93**	**0.93**	
	(1.64)	(1.64)	(0.03)	(0.03)	
6	1.15	1.42	**0.95**	**0.96**	
	(1.40)	(1.42)	(0.04)	(0.03)	
7	-1.20	-1.44	**1.05**	**1.06**	
	(1.64)	(1.68)	(0.04)	(0.04)	
8	-0.17	-1.26	**1.22**	**1.21**	
	(1.88)	(1.78)	(0.03)	(0.03)	
9	-3.17	**-4.91**	**1.35**	**1.35**	
	(2.27)	(2.11)	(0.04)	(0.03)	
10	-1.61	-3.55	**1.39**	**1.39**	
	(3.78)	(3.66)	(0.06)	(0.06)	
Wald	11.58	**22.61**		8.33	
	[0.31]	[0.01]		[0.50]	

Notes: The results are for the period January 1974 to December 2013. GMM estimates are outside of parentheses while the standard errors of the estimates are in parentheses. Estimates of α and γ and their standard errors have been annualised and are in per cent per annum. Wald statistics for tests of each model are outside of brackets while the p-values associated with the statistics are in brackets. Estimates that differ significantly from zero at the five per cent level are in bold. Wald statistics that lead to a rejection of a set of restrictions at the five per cent level are also in bold.

We briefly explain here how we conduct these simulations but consign the details of how we do so to Appendix A. The simulations involve four steps.

- We estimate the unrestricted model (6). We place the residuals into the first block of a partitioned matrix and beside this block we place the column vector of market excess returns. Each row of this partitioned matrix corresponds to a particular month.

Each column of the first block of the matrix corresponds to one of the 10 portfolios. [100]

- We sample with replacement from the rows of this matrix and use the unrestricted estimate of the vector of betas from the first step of the procedure, (6) and an assumption that the vector of alphas is a vector of zeros, consistent with the SL CAPM, to generate simulated excess returns to the market portfolio and to the 10 portfolios. [101]

- We use these simulated excess returns to construct a Wald statistic for a test of the 10 restrictions that the SL CAPM imposes.

We repeat steps 2 and 3 10,000 times and assess the probability, from the simulated values of the Wald statistic, that a Wald statistic as high as 22.61 (taken from Table 4.1) would have been produced were the SL CAPM to have been true.

The result of this exercise is that we find, consistent with what Ray, Savin and Tiwari (2009) find, that the finite-sample behaviour of the Wald statistic for a test of the SL CAPM differs from its theoretical asymptotic distribution. From Table 4.1, a p-value computed using the statistic's theoretical asymptotic distribution is 0.01. A p-value computed from the results of the simulations is higher – it is 0.02. While this marginal difference may be of some academic interest, however, it is of no practical importance. The inference that we draw from the results is unaffected because we follow convention and use a five per cent rather than a one per cent level of significance. We must still conclude that there is evidence against the SL CAPM. The model tends to underestimate the returns required on low-beta portfolios.

Figure 4.1 provides a plot of the sample mean excess returns to the 10 portfolios against estimates of their betas. This figure reveals the difficulty that the SL CAPM has in describing the data. There is a negative relation between the sample mean excess return to a portfolio and an estimate of its beta, rather than the positive relation that one would expect to see were the SL CAPM to be true.

Figure 4.1 suggests that, in tests of the Black CAPM, an estimate of the zero-beta premium will exceed an estimate of the market risk premium (*MRP*) and this is indeed what we find. Table 4.1 provides an estimate of the zero-beta premium of 10.75 per cent per annum that is both economically and statistically significant. The SL CAPM says that the zero-beta premium should be zero but this evidence suggests that one can easily reject the hypothesis. An estimate of the *MRP* for the period January 1974 to December 2013 is 5.04 per cent per annum and the standard error attached to this estimate is 2.77 per cent. [103] Thus an

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[100] Let $A = \begin{bmatrix} A_1 & A_2 \end{bmatrix}$, where A_1 and A_2 are $n \times m_1$ and $n \times m_2$ matrices. Then A is said to be a partitioned matrix and A_1 and A_2 are the blocks or submatrices that are created by partitioning the matrix. See:

   Davidson, R. and J.G. MacKinnon, *Estimation and inference in econometrics*, Oxford University Press, 1993, page 779.

[101] The statement that the vector of alphas is a vector of zeros means that $\begin{bmatrix} \alpha_1 & \alpha_2 & ... & \alpha_N \end{bmatrix} = \begin{bmatrix} 0 & 0 & ... & 0 \end{bmatrix}$, that is, $\alpha_j = 0, \quad j = 1, 2, ..., N$.

[103] SFG (2014) provide lower estimates of the zero-beta premium that also use portfolios formed on the basis of past estimates of beta. The portfolios that SFG form, however, are constructed in such a way as to minimise any differences

estimate of the difference between the *MRP* and the zero-beta premium is 5.04 – 10.75 = -5.72 per cent per annum. The standard error attached to this estimate will be:

$$\sqrt{2.77^2 + 2.86^2} = 3.98 \text{ per cent}$$

Thus one cannot reject the hypothesis that the difference between the *MRP* and the zero-beta premium is positive at the five per cent level of significance. In addition, Wald tests of the restrictions imposed by the Black CAPM do not reject the model.

Figure 4.1
Sample mean excess return against beta estimate for portfolios formed on the basis of past estimates of beta
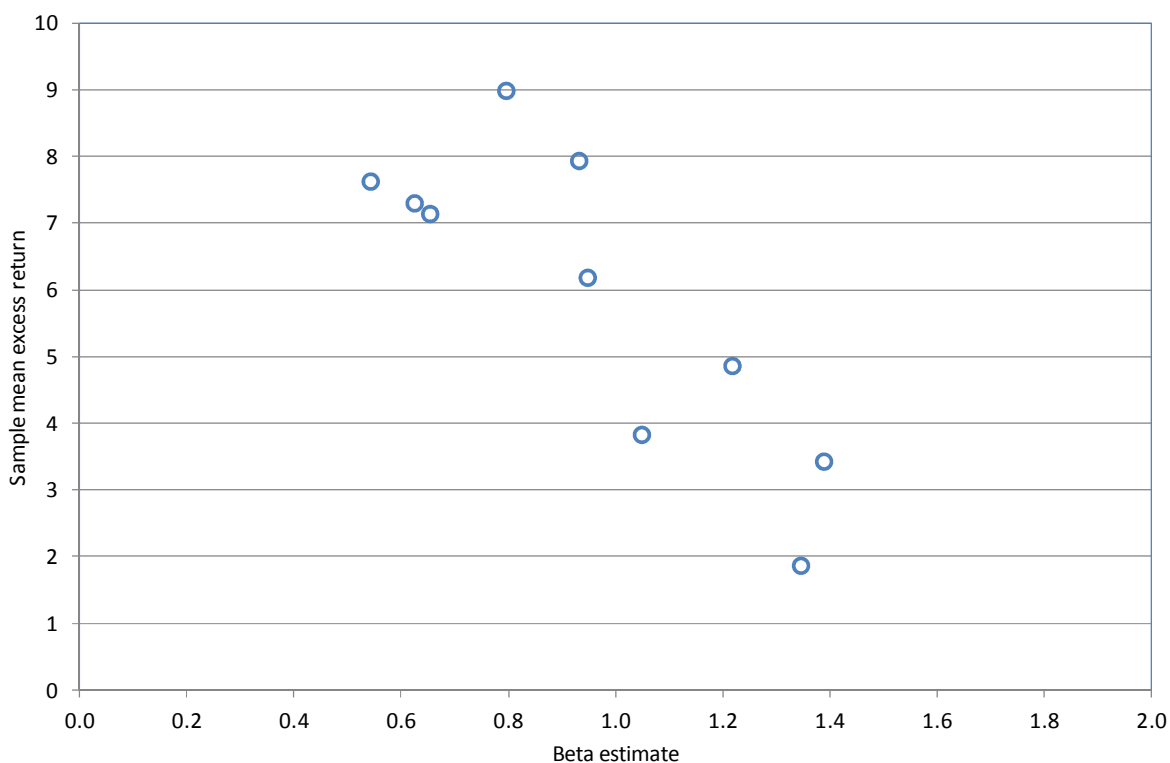
Notes: The plot uses monthly returns from January 1974 to December 2013.

The results of tests of the naïve model, the SL CAPM and the Black CAPM that use the 10 portfolios formed on the basis of past estimates of beta are not particularly sensitive to the exclusion of stocks that SIRCA deems to be foreign. The Wald statistics (p-values) for tests

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in average book-to-market, industry membership and size between the portfolios. It is well known that value stocks tend to have low betas relative to the market portfolio of stocks while growth stocks tend to have high betas. Value stocks tend to earn high returns while growth stocks tend to earn low returns. Consequently, were one to compute an estimate of the zero-beta premium using just two portfolios – a value portfolio and a growth portfolio – the estimate would likely exceed the *MRP*. SFG tries to eliminate the impact of this empirical relation between beta and book-to-market on its results. We, on the other hand, do not attempt to do so because we do not wish to prevent beta from behaving as a proxy for missing measures of risk. Allowing beta to proxy for missing measures of risk will lead to estimates generated by the Black Model that are less likely to be biased.

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

of the restrictions that the naïve model, the SL CAPM and the Black CAPM impose, computed with stocks that SIRCA deems to be foreign excluded, are 17.00 (0.07), 32.36 (0.00) and 12.85 (0.17). On the other hand, an estimate of the difference between the *MRP* and the zero-beta premium is -7.35 per cent per annum and the standard error attached to this estimate is 4.18 per cent per annum. Thus, one can reject the hypothesis that the difference between the *MRP* and the zero-beta premium is positive at the five per cent level.

The results of tests of these models that use the 10 portfolios are also not sensitive to the exclusion of observations that may represent data entry errors. We exclude – in addition to negative price relatives – the 859 occasions on which a return of no more than -50 per cent is followed by a return of at least 100 per cent or on which a return of at least 100 per cent is followed by a return of no more than -50 per cent. The Wald statistics (p-values) for tests of the restrictions that the naïve model, the SL CAPM and the Black CAPM impose are 11.55 (0.32), 22.45 (0.01) and 8.22 (0.51). An estimate of the difference between the *MRP* and the zero-beta premium is -5.80 per cent per annum and the standard error attached to this estimate is 4.00 per cent per annum. Thus, one cannot reject the hypothesis that the difference between the *MRP* and the zero-beta premium is positive at the five per cent level.

While we find little evidence against the restrictions that the Black CAPM imposes on the mean returns to the 10 portfolios formed on the basis of past estimates of beta, the negative relation between returns and estimates of beta – which in some tests is statistically significant – is not consistent with the theory that underpins the model. If we were to impose the restriction that the relation be nonnegative, then estimates generated by the Black CAPM would match estimates generated by the naïve model. We do not impose this restriction and instead allow the data to determine what relation exists between returns and estimates of beta.

5.   Out-of-Sample Tests

An alternative way of evaluating the empirical performance of pricing models is to assess their out-of-sample performance. Rule 74 (2) (b) of the National Gas Rules, relating generally to forecasts and estimates, states that:

> 'A forecast or estimate ... must represent the best forecast or estimate possible in the circumstances.'

Evaluating the out-of-sample performance of a pricing model is an excellent way of demonstrating whether estimates of the cost of equity produced using the model are likely to satisfy this important rule because the tests are straightforward to interpret.

Using 10 portfolios formed on the basis of past estimates of beta and monthly data from January 1979 to December 2013, we find:

- little evidence of bias in the naïve model;

- evidence of bias in the SL CAPM;

- evidence of bias in the AER's implementation of the CAPM; and

- little evidence of bias in the Black CAPM.

The data indicate that forecasts of the return on equity that use the SL CAPM and the AER's implementation of the CAPM are downwardly biased for low-beta portfolios and upwardly biased for high-beta portfolios and the bias is not only statistically significant but economically significant.

5.1.   Forecasts

We note that in using the SL CAPM, the AER uses what it calls the 'theory' behind the Black CAPM to influence its choice of an equity beta. For example, the AER states that: [112]

> 'we use the theoretical principles underpinning the Black CAPM to inform the equity beta point estimate from within our empirical range.'

The AER also states that it places some weight on foreign estimates of beta. While it sees: [113]

> 'there are inherent uncertainties when relating foreign estimates to Australian conditions'

the AER concludes that foreign estimates of beta: [114]

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[112]   AER, *Draft decision Jemena Gas Networks (NSW) Ltd Access arrangement 2015–20: Attachment 3: Rate of return*, November 2014, page 265.

[113]   AER, *Draft decision Jemena Gas Networks (NSW) Ltd Access arrangement 2015–20: Attachment 3: Rate of return*, November 2014, page 268.

'provide some limited support for an equity beta point estimate towards the upper end of our range.'

We cannot be sure what weight the AER places on the principles underpinning the Black CAPM and what weight the AER places on foreign estimates of beta because the AER does not reveal this information.

We assume in what follows that the AER acts as if it adjusts an estimate of the equity beta of a regulated energy utility solely on the basis of the principles underpinning the Black CAPM. We do so, because to evaluate a method for estimating the return required on equity, we must clearly specify the method. Methods that we cannot clearly specify, we cannot evaluate. We cannot, for example, evaluate the use by a regulator of its discretion in a way that is not specified and in a way that may vary through time.

To understand how a regulator might adjust an estimate of the equity beta of a regulated energy utility on the basis of the principles underpinning the Black CAPM, recall that the SL CAPM implies that:

$$\mathrm{E}_{t-1}(z_{jt}) = \beta_{jt}\mathrm{E}_{t-1}(z_{mt}) \tag{8}$$

while the Black CAPM implies that:

$$\mathrm{E}_{t-1}(z_{jt}) = (1 - \beta_{jt})\gamma_{0t} + \beta_{jt}\mathrm{E}_{t-1}(z_{mt}) \tag{9}$$

A regulator using the Black CAPM explicitly would set the cost of equity for a firm equal to:

$$(1 - \hat{\beta}_{jt})\hat{\gamma}_{0t} + \hat{\beta}_{jt}\hat{z}_{mt}, \tag{10}$$

where a hat denotes a forecast generated from data prior to month t. The expression (10), however, can also be rewritten as:

$$\beta_{jt}^{*}\hat{z}_{mt}, \tag{11}$$

where

$$\beta_{jt}^{*} = \left(1 - \frac{\hat{\gamma}_{0t}}{\hat{z}_{mt}}\right)\hat{\beta}_{jt} + \left(\frac{\hat{\gamma}_{0t}}{\hat{z}_{mt}}\right) \tag{12}$$

Thus a regulator using the Black CAPM implicitly could use (11) to set the cost of equity for a firm instead of (10) and would come up with exactly the same result. In other words, the regulator could use the SL CAPM together with an adjusted estimate of the equity beta of a firm to compute the estimate that would have been generated by an explicit use of the Black CAPM. The adjusted estimate of beta is, from (12), a weighted average of the unadjusted estimate of beta and one.

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[114]   AER, *Draft decision Jemena Gas Networks (NSW) Ltd Access arrangement 2015–20: Attachment 3: Rate of return*, November 2014, page 269.

To be able to evaluate forecasts of the cost of equity that a regulator would have generated using this scheme, we need to know what weight the regulator places on an unadjusted estimate of beta.

In its recent Jemena Draft Decision, the AER states that: [115]

'We adopt an equity beta point estimate of 0.7 from a range of 0.4 to 0.7.'

Thus it is reasonable to assume that the AER adjusts upwards an estimate of 0.55 – the midpoint of the range of 0.4 to 0.7 – to 0.7. Simple arithmetic indicates that the AER places a weight of two thirds on an unadjusted estimate of beta and one third on one in deriving its adjusted point estimate of beta. That is:

$$\frac{2}{3} \times 0.55 + \frac{1}{3} \times 1 = 0.7 \tag{13}$$

From (16), the use of a weight of two thirds on an unadjusted estimate of beta implies that the AER currently acts as if it believes that the zero-beta premium should be one third of the value of the *MRP*. That is:

$$\left(1 - \frac{\hat{\gamma}_{0t}}{\hat{z}_{mt}}\right) = \frac{2}{3} \Rightarrow \hat{\gamma}_{0t} = \frac{1}{3}\hat{z}_{mt} \tag{14}$$

Since the AER chooses a value for the *MRP* of 6.5 per cent per annum, then, with the assumptions made, the AER currently acts as if it believes that the zero-beta premium is 2.17 per cent per annum.

We label forecasts generated using the SL CAPM and an estimate of beta that is one third plus two thirds of an unadjusted estimate forecasts generated by the AER CAPM.

We also examine forecasts generated by an empirical version of the Black CAPM. We follow the scheme outlined above and compute an adjusted estimate of beta for use with the SL CAPM – but instead of relying on 'theory' we rely on past empirical evidence.

We use the recursive estimates of the monthly zero-beta premium that NERA (2013) graphs that we update to December 2013. [116] These estimates use the largest 100 stocks from 1963 to 1973, the largest 500 stocks from 1974 to 2013 and the two-pass methodology of Fama and MacBeth (1973) as modified by Litzenberger and Ramaswamy (1979). [117] For each month t

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[115]   AER, *Draft decision Jemena Gas Networks (NSW) Ltd Access arrangement 2015–20: Attachment 3: Rate of return*, November 2014, page 267.

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

[117]   Fama, E. F. and J. D. Macbeth, *Risk, return and equilibrium: Empirical tests*, Journal of Political Economy, 1973, pages 607-636.

Litzenberger, R. and K. Ramaswamy, *The effects of personal taxes and dividends on capital asset prices: Theory and empirical evidence*, Journal of Financial Economics, 1979, pages 163-195.

we compute a forecast for the month of the zero-beta premium as the average of all monthly zero-beta premium estimates up until month $t-1$.

We also use the time series of *MRP* estimates that NERA (2013) provides to generate estimates of the monthly *MRP*. Let $\hat{Z}_{mt}$ denote the most recent estimate of the annual *MRP* constructed from all data prior to month t. We use as a forecast of the monthly *MRP* for month t:

$$\hat{z}_{mt} = (1 + \hat{Z}_{mt})^{1/12} - 1 \tag{15}$$

We use these forecasts for simplicity – not because we believe that one cannot produce better forecasts of the *MRP* than forecasts based on historical averages. If there is variation through time in the *MRP* and the zero-beta premium that is not tracked by forecasts based on historical averages, then the empirical performance of an empirical version of the Black CAPM that uses the forecasts may be understated.

We use these forecasts of the *MRP* and of the zero beta premium in conjunction with OLS estimates of beta and the SL CAPM to produce forecasts generated by the Black CAPM. [118] Intuitively, at each point in time this model looks back into the past and determines from the empirical evidence how best to use, in the future, the cross-sectional relation, if any, that has existed in the past between returns and estimates of beta.

Besides assessing the out-of-sample performance of forecasts of the return on equity provided by the AER CAPM and the Black CAPM, we also assess forecasts provided by the naïve model and the SL CAPM.

5.2.   Methodology

Again, Rule 74 (2) (b) of the National Gas Rules, relating generally to forecasts and estimates, states that:

> 'A forecast or estimate ... must represent the best forecast or estimate possible in the circumstances.'

It is difficult to see that a forecast of the return on equity that can be shown to be systematically biased could satisfy this rule and so we test for each pricing model whether forecasts of the return on equity are unbiased.

Our tests use two methods and we label these methods: Method A and Method B. Method A uses explicit forecasts of the *MRP*. Method B, on the other hand does not do so. [119] Method

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[118]   We do not use so-called robust regression estimates of beta because they can be biased when the distribution of the disturbance from (7) is not symmetric. See:

NERA, *Robust regression techniques: A report for DBP*, December 2014.

[119]   Aside from forecasts of the *MRP* required to compute an adjusted estimate of beta.

B merely assumes that a regulator will use rational forecasts, that is, forecasts that are unbiased.[120]

5.2.1. Method A

If forecasts generated by the SL CAPM are unbiased, then:

$$\text{E}(z_{jt} - \hat{\beta}_{jt}\hat{z}_{mt}) = 0, \tag{16}$$

where, again, a hat denotes a forecast generated from data prior to month t. Method A tests whether the restriction (14) holds true by examining whether its sample counterpart:

$$\frac{1}{T}\sum_{t=1}^{T}(z_{jt} - \hat{\beta}_{jt}\hat{z}_{mt}) \tag{17}$$

differs significantly from zero. The quantity (19) is the mean forecast error associated with forecasts of excess returns that use the SL CAPM.[121]

We test the AER CAPM and the Black CAPM in the same way. Thus we test whether forecasts generated by the AER CAPM and the Black CAPM are unbiased by examining whether the mean forecast error:

$$\frac{1}{T}\sum_{t=1}^{T}(z_{jt} - \beta_{jt}^{*}\hat{z}_{mt}) \tag{18}$$

differs significantly from zero.

5.2.2. Method B

If the regulator's assessment of the *MRP* is rational, that is, unbiased, then:

$$\text{E}\left(\hat{z}_{mt}\right) = \text{E}\left(z_{mt}\right) \tag{19}$$

It follows that if forecasts generated by the SL CAPM are unbiased and the regulator's assessment of the *MRP* is rational, then:

$$\text{E}(z_{jt} - \hat{\beta}_{jt}z_{mt}) = 0 \tag{20}$$

We test whether the restriction (20) holds true by examining whether its sample counterpart:

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[120] See Keane and Runkle (1989) for a discussion of what it means for a forecast to be rational.

Keane, M.P. and D.E. Runkle, *Are economic forecasts rational?* Federal Reserve Bank of Minneapolis Quarterly Review, 1989, pages 26-33.

[121] Since the risk-free rate for an investment made at the end of month $t-1$ that matures at the end of month t is known at the end of month $t-1$, it is also the mean forecast error associated with forecasts of raw returns that use the SL CAPM.

$$\frac{1}{T}\sum_{t=1}^{T}(z_{jt} - \hat{\beta}_{jt}z_{mt}) \tag{21}$$

differs significantly from zero.

The quantity (20) is the mean difference between two zero-investment strategies:

- the quantity z_{jt} is the return to a zero-investment strategy that is long portfolio j and short the risk-free asset.

- the quantity $\hat{\beta}_{jt}z_{mt}$ is the return to a zero-investment strategy that is long the market portfolio and short the risk-free asset.

If the SL CAPM generates forecasts that are unbiased and the regulator's assessment of the *MRP* is rational, then the mean difference between the returns to the two zero-investment strategies should be zero.

We test the AER CAPM and the Black CAPM in the same way. Thus we test whether forecasts generated by the AER CAPM and the Black CAPM are unbiased by examining whether the mean forecast error:

$$\frac{1}{T}\sum_{t=1}^{T}(z_{jt} - \beta_{jt}^{*}z_{mt}) \tag{22}$$

differs significantly from zero.

5.2.3. Power

We suspect that tests of the pricing models that use individual portfolios, *t*-statistics and Method B will have substantially more power than tests that use *t*-statistics and Method A. Uncertainty about what future realisations will be of the return to the market will raise the variability of the forecast errors that Method A uses. As Method B uses the realisations rather than forecasts of the realisations, the variability of the forecast errors that Method B employs will in general be smaller. As a result, tests that use individual portfolios, *t*-statistics and Method B should have more power than tests that use *t*-statistics and Method A.

In contrast, we suspect that a Wald test of the restrictions that a pricing model places that uses the portfolios together and Method A will have a power that is similar to a Wald test that uses Method B. This is because a Wald test that uses the portfolios together will take into account any variation in the forecast errors that is shared by the portfolios. Again, a Wald statistic uses unrestricted parameter estimates and an estimate of the covariance matrix of the unrestricted parameter estimates to test whether a set of restrictions are true.[122]

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[122]   Davidson, R. and J.G. MacKinnon, *Estimation and inference in econometrics*, Oxford University Press, 1993, page 89.

Appendix A provides the results of bootstrap simulations that confirm these suspicions. They also show that differences under the null hypothesis between the finite-sample and asymptotic distributions of the test statistics that we use are minor.

5.3.   Results

5.3.1.   Tests that use portfolios formed on the basis of past estimates of beta

We begin by presenting the results of out-of-sample tests that use the 10 portfolios formed on the basis of past estimates of beta. Like Fama and French (1997), we assess forecasts constructed using both rolling estimates of beta and recursive estimates of beta. [123] The rolling estimates of beta that we use each month employ data over the previous 60 months to compute a forecast of beta. The recursive estimates that we use each month employ all previously available data – and never less than 60 months of data – to compute a forecast of beta.

Table 5.1 provides the results of out-of-sample tests of the naïve model, SL CAPM, AER CAPM and Black CAPM that use the 10 portfolios, Method A and rolling estimates of beta. [124] Table 5.2 provides the results of out-of-sample tests of these models that use the 10 portfolios, rolling estimates of beta and Method B. The tables show that Wald tests of the restrictions that the SL CAPM and AER CAPM impose can be rejected at the five per cent level regardless of whether Method A or Method B is employed. The tables show, on the other hand, that Wald tests cannot reject either the naïve model or the Black CAPM.

Consistent with the results of our simulations, the standard errors attached to the individual sample mean forecast errors generated using Method B are smaller than their counterparts that use Method A. As a result, tests at the individual portfolio level that use Method B are able to reject the null hypothesis of no bias more frequently than tests that use Method A. Portfolios 1 through 4 – all low-beta portfolios – are significantly mispriced by the SL CAPM and AER CAPM. Both models significantly underestimate the returns to these four portfolios. The two models also significantly overestimate the return to portfolio 9 – a high-beta portfolio. The return to portfolio 4 is sufficiently high that even the naïve model and Black CAPM significantly underestimate its return.

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[123]   Fama, E. F. and K. R. French, *Industry costs of equity*, Journal of Financial Economics, 1997, pages 153-193.

[124]   We compute the returns to portfolios formed on the basis of past estimates of beta from January 1974 to December 2013 and we use 60 months of returns to compute a forecast of beta. Thus the first forecast that we evaluate is for January 1979.

Table 5.1

Out-of-sample tests of a naïve model, the SL CAPM, the AER CAPM and the Black CAPM that use Method A, rolling estimates of beta and portfolios formed on the basis of past estimates of beta

Portfolio	β	Mean forecast error			
		Naïve model	Sharpe-Lintner CAPM	AER CAPM	Black CAPM
1	0.55	1.81	**4.69**	3.73	1.48
		(2.38)	(2.39)	(2.39)	(2.39)
2	0.58	2.17	4.88	3.98	1.86
		(2.51)	(2.51)	(2.59)	(2.51)
3	0.67	1.48	3.60	2.89	1.33
		(2.56)	(2.56)	(2.56)	(2.56)
4	0.78	3.14	4.58	4.10	3.01
		(2.70)	(2.70)	(2.70)	(2.70)
5	0.95	1.51	1.85	1.74	1.57
		(3.05)	(3.06)	(3.05)	(3.05)
6	0.99	0.11	0.22	0.18	0.22
		(3.00)	(3.00)	(3.00)	(3.00)
7	1.10	-2.00	-2.65	-2.44	-1.76
		(3.31)	(3.31)	(3.31)	(3.31)
8	1.23	-1.26	-2.75	-2.24	-1.03
		(3.80)	(3.80)	(3.80)	(3.80)
9	1.33	-4.99	-7.13	-6.42	-4.75
		(4.27)	(4.27)	(4.27)	(4.27)
10	1.38	-3.71	-6.14	-5.33	-3.46
		(5.30)	(5.30)	(5.30)	(5.30)
Wald		10.01	**27.36**	**20.25**	8.62
		[0.44]	[0.00]	[0.03]	[0.57]

Notes: The results are for the period January 1979 to December 2013. Sample mean forecast errors in per cent per annum are outside of parentheses while the standard errors of the means are in parentheses. Estimates of β are the averages of the rolling estimates. Wald statistics for tests of each model are outside of brackets while the p-values associated with the statistics are in brackets. Mean forecast errors that differ significantly from zero at the five per cent level are in bold. Wald statistics that lead to a rejection of a model at the five per cent level are also in bold.

Table 5.2
Out-of-sample tests of a naïve model, the SL CAPM, the AER CAPM and the Black CAPM that use Method B, rolling estimates of beta and portfolios formed on the basis of past estimates of beta

Portfolio	β	Mean forecast error			
		Naïve model	Sharpe-Lintner CAPM	AER CAPM	Black CAPM
1	0.55	2.96	**5.98**	**4.97**	2.78
		(2.23)	(1.91)	(1.93)	(2.30)
2	0.58	3.32	**5.93**	**5.06**	3.02
		(2.09)	(1.85)	(1.86)	(2.10)
3	0.67	2.63	**4.49**	**3.86**	2.63
		(1.94)	(1.78)	(1.76)	(1.92)
4	0.78	**4.30**	**5.58**	**5.15**	**4.18**
		(1.80)	(1.70)	(1.70)	(1.78)
5	0.95	2.66	2.53	2.58	2.80
		(1.75)	(1.73)	(1.72)	(1.74)
6	0.99	1.26	1.27	1.27	1.40
		(1.50)	(1.49)	(1.48)	(1.49)
7	1.10	-0.85	-1.74	-1.45	-0.60
		(1.70)	(1.68)	(1.67)	(1.70)
8	1.23	-0.11	-1.55	-1.07	0.04
		(1.97)	(1.90)	(1.90)	(2.02)
9	1.33	-3.84	**-5.56**	**-4.98**	-3.74
		(2.45)	(2.29)	(2.30)	(2.47)
10	1.38	-2.56	-4.50	-3.85	-2.45
		(3.88)	(3.76)	(3.76)	(3.88)
Wald		9.99	**31.79**	**23.54**	9.85
		[0.44]	[0.00]	[0.01]	[0.45]

Notes: The results are for the period January 1979 to December 2013. Sample mean forecast errors in per cent per annum are outside of parentheses while the standard errors of the means are in parentheses. Estimates of β are the averages of the rolling estimates. Wald statistics for tests of each model are outside of brackets while the p-values associated with the statistics are in brackets. Mean forecast errors that differ significantly from zero at the five per cent level are in bold. Wald statistics that lead to a rejection of a model at the five per cent level are also in bold.

Table 5.3 provides the results of out-of-sample tests of the naïve model, SL CAPM, AER CAPM and Black CAPM that use the 10 portfolios, Method A and recursive estimates of beta. The results for the naïve model are identical to those in Tables 5.1 and 5.2 because the model does not use estimates of beta. Table 5.4 provides the results of out-of-sample tests of the models that use the 10 portfolios, recursive estimates of beta and Method B. Tables 5.3 and 5.4 show, like Tables 5.1 and 5.2, that Wald tests of the restrictions that the SL CAPM and AER CAPM impose can be rejected at the five per cent level regardless of whether Method A or Method B is employed and that Wald tests do not reject the Black CAPM.

Table 5.3
Out-of-sample tests of a naïve model, the SL CAPM, the AER CAPM and the Black CAPM that use Method A, recursive estimates of beta and portfolios formed on the basis of past estimates of beta

Portfolio	β	Mean forecast error			
		Naïve model	Sharpe-Lintner CAPM	AER CAPM	Black CAPM
1	0.54	1.81	**4.81**	3.80	1.44
		(2.38)	(2.38)	(2.38)	(2.39)
2	0.61	2.17	4.72	3.86	1.90
		(2.51)	(2.51)	(2.51)	(2.51)
3	0.58	1.48	4.22	3.31	1.20
		(2.56)	(2.56)	(2.56)	(2.56)
4	0.77	3.14	4.66	4.15	2.96
		(2.70)	(2.70)	(2.70)	(2.70)
5	0.86	1.51	2.44	2.12	1.40
		(3.05)	(3.05)	(3.05)	(3.05)
6	0.88	0.11	0.88	0.62	0.06
		(3.00)	(3.00)	(3.00)	(3.00)
7	0.97	-2.00	-1.79	-1.86	-2.00
		(3.31)	(3.31)	(3.31)	(3.31)
8	1.18	-1.26	-2.44	-2.04	-1.09
		(3.80)	(3.80)	(3.80)	(3.80)
9	1.36	-4.99	-7.34	-6.56	-4.72
		(4.27)	(4.27)	(4.27)	(4.27)
10	1.38	-3.71	-6.19	-5.36	-3.40
		(5.30)	(5.30)	(5.30)	(5.30)
Wald		10.01	**26.83**	**19.90**	8.75
		[0.44]	[0.00]	[0.03]	[0.56]

Notes: The results are for the period January 1979 to December 2013. Sample mean forecast errors in per cent per annum are outside of parentheses while the standard errors of the means are in parentheses. Estimates of β are the averages of the rolling estimates. Wald statistics for tests of each model are outside of brackets while the p-values associated with the statistics are in brackets. Mean forecast errors that differ significantly from zero at the five per cent level are in bold. Wald statistics that lead to a rejection of a model at the five per cent level are also in bold.

The standard errors attached to the individual sample mean forecast errors generated using Method B are again smaller than their counterparts that use Method A. The standard errors that appear in Tables 5.3 and 5.4 are also marginally lower – particularly for the high-beta portfolios – than their counterparts in Tables 5.1 and 5.2. Tests in Table 5.4 that use Method B and recursive estimates of beta reveal that the SL CAPM and AER CAPM significantly underestimate the returns to the low-beta portfolios 1 through 4. The two models also significantly overestimate the return to high-beta portfolio 9. The return to portfolio 4 is sufficiently high that, as in Table 5.2, the Black CAPM significantly underestimates its return.

Table 5.4
Out-of-sample tests of a naïve model, the SL CAPM, the AER CAPM and the Black CAPM that use Method B, recursive estimates of beta and portfolios formed on the basis of past estimates of beta

		Mean forecast error			
Portfolio	β	Naïve model	Sharpe-Lintner CAPM	AER CAPM	Black CAPM
1	0.54	2.96	**5.47**	**4.63**	2.78
		(2.23)	(1.87)	(1.91)	(2.32)
2	0.61	3.32	**5.45**	**4.74**	3.18
		(2.09)	(1.85)	(1.86)	(2.10)
3	0.58	2.63	**4.96**	**4.18**	2.51
		(1.94)	(1.79)	(1.75)	(1.93)
4	0.77	**4.30**	**5.47**	**5.09**	**4.16**
		(1.80)	(1.70)	(1.70)	(1.80)
5	0.86	2.66	3.32	3.10	2.58
		(1.75)	(1.75)	(1.74)	(1.74)
6	0.88	1.26	1.91	1.69	1.25
		(1.50)	(1.51)	(1.50)	(1.49)
7	0.97	-0.85	-0.76	-0.79	-0.86
		(1.70)	(1.70)	(1.70)	(1.69)
8	1.18	-0.11	-1.07	-0.74	0.00
		(1.97)	(1.87)	(1.90)	(2.00)
9	1.36	-3.84	**-5.74**	**-5.10**	-3.68
		(2.45)	(2.27)	(2.29)	(2.48)
10	1.38	-2.56	-4.55	-3.89	-2.35
		(3.88)	(3.73)	(3.74)	(3.89)
Wald		9.99	**29.86**	**23.09**	9.40
		[0.44]	[0.00]	[0.01]	[0.49]

Notes: The results are for the period January 1979 to December 2013. Sample mean forecast errors in per cent per annum are outside of parentheses while the standard errors of the means are in parentheses. Estimates of β are the averages of the rolling estimates. Wald statistics for tests of each model are outside of brackets while the p-values associated with the statistics are in brackets. Mean forecast errors that differ significantly from zero at the five per cent level are in bold. Wald statistics that lead to a rejection of a model at the five per cent level are also in bold.

6.   Issues Raised by the AER and its Advisors

In this section we address a number of issues raised by the AER and its advisors.

6.1.   Handley

We begin by addressing a number of issues that Handley raises in his 2014 report for the AER. [126]

6.1.1.   The past as a guide to the future and bad luck

Handley (2014) states that: [127]

> 'An apparent weakness of the Sharpe-CAPM is the empirical finding, for example
> by Black, Jensen and Scholes (1972) and Fama and French (2004), that the relation
> between beta and average stock returns is too flat compared to what would
> otherwise be predicted by the Sharpe-CAPM – a result often referred to as the low
> beta bias. In considering the relevance of this evidence, however, it is important to
> recognize that the current objective is to determine the fair rate of return given the
> risk of the benchmark efficient entity rather than to identify the model which best
> explains past stock returns.'

It is difficult to determine quite what point Handley intends to make but in the last sentence he
appears to argue either that the past performance of a model should not be viewed as a guide
to the future performance of a model or that because realisations in general differ from
expectations, one cannot rule out that the apparent evidence against the SL CAPM is the
result of bad luck.

There is evidence contained in the two papers that Handley cites against the proposition that
the past performance of a model should not be viewed as a guide to the future performance of
a model. Black, Jensen and Scholes (1972) provide evidence of a low-beta bias using data
from January 1931 to December 1965 while Fama and French (2004) summarise evidence
that they provide in Fama and French (1992) that a low-beta bias exists in an almost
completely non-overlapping set of data from July 1963 to December 1990. [128] As Fama and
French (2004) state, a low-betas bias is found: [129]

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[126]   Handley, J., *Report prepared for the Australian Energy Regulator: Advice on the return on equity*, University of Melbourne, October
2014.

[127]   Handley, J., *Report prepared for the Australian Energy Regulator: Advice on the return on equity*, University of Melbourne, October
2014, page 5.

[128]   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, Praeger, New York, 1972.

Fama, E.F. and K.R. French, *The cross-section of expected returns*, Journal of Finance 47, 1992, pages 427-465.

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

[129]   Fama, E.F. and K.R. French, *The Capital Asset Pricing Model: Theory and evidence*, Journal of Economic Perspectives, 2004, page 32.

'*in the early tests*, such as Douglas (1968), Black, Jensen and Scholes (1972), Miller and Scholes (1972), Blume and Friend (1973) and Fama and MacBeth (1973), *as well as in more recent cross-section regression tests*, like Fama and French (1992).'

[Emphasis added]

There is also evidence against the proposition that the apparent evidence against the SL CAPM is the result of bad luck. In this report, for example, we provide the results of tests to determine whether or not one would have expected to have seen mean forecast errors as large as we compute were the SL CAPM to have been true.

As an illustration, Table 5.2 reports that the sample mean forecast error associated with an estimate of the mean excess return to portfolio 1 that uses the SL CAPM is 5.98 per cent per annum and the standard error associated with the mean is 1.91 per cent. This implies that a p-value associated with a two-sided *t*-test of the null hypothesis that the true mean forecast error is zero will be 0.17 per cent. In other words, were the SL CAPM to be true, we would expect to see a *t*-test statistic as large in absolute value as $5.98 \div 1.91 = 3.13$ just one time in 574 (that is, $1 \div 0.0017$). Thus observing a *t*-test statistic as large in absolute value as 3.13 by chance would be very bad luck indeed. That is to say it is highly unlikely that our results can be attributed to bad luck. We note that Table A.1 in Appendix A, which contains the results of bootstrap simulations, provides no evidence that the finite-sample distribution of the *t*-test statistic for an out-of-sample test of the SL CAPM that uses Method B differs from its theoretical asymptotic distribution. In other words, there is no evidence that our reliance on asymptotic theory will mislead. Note also that portfolio1 has a beta estimated to be on average 0.55 – precisely the midpoint of the AER's range for the equity beta of a regulated energy utility.

As another illustration, Table 5.2 reports that the sample mean forecast error associated with an estimate of the mean excess return to portfolio 1 that uses the AER CAPM is 4.97 per cent per annum and the standard error associated with the mean is 1.93 per cent. This implies that a p-value associated with a two-sided *t*-test of the null hypothesis that the true mean forecast error is zero will be 1.00 per cent. In other words, were the AER CAPM to be true, we would expect to see a *t*-test statistic as large in absolute value as $4.97 \div 1.93 = 2.58$ just one time in 100 (that is, $1 \div 0.0100$). Thus observing a *t*-test statistic as large in absolute value as 2.58 by chance would also be very bad luck. That is to say it is unlikely that a test statistic that large can be attributed solely to bad luck.

6.1.2. Savor and Wilson (2014)

In recent work, Savor and Wilson (2014) examine the behaviour of returns on days when important announcements about economic aggregates are made and on days when no such announcements are made.[148] Handley notes that:[149]

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[148]   Savor, P. and M. Wilson, Asset pricing: A tale of two days, Journal of Financial Economics, 2014, pages 171-201.

[149]   Handley, J., *Report prepared for the Australian Energy Regulator: Advice on the return on equity*, University of Melbourne, October 2014, page 8.

'Savor and Wilson (2014) find that beta is positively related to average returns on days when employment, inflation, and interest rate news is scheduled to be announced but is unrelated or even negatively related to average returns on nonannouncement days. They suggest as one possible explanation that announcement day returns provide a much clearer signal of aggregate risk and expected future market returns, perhaps as a result of reduced noise or disagreement on announcement days:

> *"These results suggest that beta represents an important measure of systematic risk. At times when investors expect to learn important information about the economy, they demand higher returns to hold higher-beta assets."'*

Savor and Wilson (2014) also state that: [150]

> 'The non-announcement day points show a negative relation between average returns and beta: an increase in beta of one is associated with a reduction in average daily excess return of about 1.5 basis points (bps), with a t-statistic for the slope coefficient estimate above three.
>
> announcement days ... constitute just 13% of the sample period
>
> non-announcement days constitute the great majority of trading days in a given year, and consequently also cannot be ignored. A good theory should explain both where the majority of cumulative returns come from and what happens most of the time.'

Thus it would be difficult to view their work as an endorsement of the use of the SL CAPM. It is not an endorsement of the SL CAPM because Savor and Wilson note that 87 per cent of days are non-announcement days and on these days there is a significant negative relation between beta and return.

6.1.3.   Other issues

Handley states that: [151]

> 'NERA acknowledge that their finding that the zero beta premium is equal to the MRP appears implausible'

This not quite what NERA (2014) says. [152] What NERA actually says is that:

> 'our specification of the Black CAPM assumes that the zero-beta premium is equal to the *MRP*. In other words, our specification of the Black CAPM will result in the same mean return for all stocks. This result may appear implausible, but it merely reflects the inability of estimates of beta computed relative to the market portfolio of stocks to track variation in returns across stocks.'

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[150]   Savor, P. and M. Wilson, Asset pricing: A tale of two days, Journal of Financial Economics, 2014, pages 171-201.

[151]   Handley, J., *Report prepared for the Australian Energy Regulator: Advice on the return on equity*, University of Melbourne, October 2014, page 12.

[152]   NERA, *Return on capital of a regulated electricity network: A report for Ashurst*, May 2014, page 92.

The phrase 'may appear implausible, but' is commonly used to explain why a result, rather than being implausible, is – when thought about carefully – plausible.

6.2.   McKenzie and Partington

We next address issues that McKenzie and Partington raise in their 2014 report. [153]

6.2.1.   Regulators and the cost of equity

McKenzie and Partington (2014) examine the use of models by regulators in a number of countries and state that:[154]

> 'It remains that (sic) case that the majority of international regulators currently base their decisions primarily on the CAPM framework. (see Table 1).'

Their Table 1 provides a list of the primary and secondary models used by a single regulator in each of six countries. One of the countries is the US and the single regulator chosen is the New York State Public Services Commission. Each state in the US, however, has a public utilities commission as does the District of Columbia and so the table is missing data for 50 US public utilities commissions. Without data for these other public utilities commissions and for regulators from other countries that are also missing it is difficult to see that much weight should be attached to the conclusion that McKenzie and Partington draw.

Another way of assessing the importance to be placed on the choice by regulators in each country of primary and secondary models is to examine the GDP of each country – which should provide a guide as to the relative sizes of the businesses being regulated on aggregate in each country. The CIA Factbook reports that US GDP in 2013 is estimated to be US $16.72 trillion while New Zealand GDP in 2013 is estimated to be US $181.1 billion. [155] This evidence suggests that more weight should be placed on the choices made by US regulators than on regulators in New Zealand. We note that the primary model used by US public utilities commissions is the dividend growth model while the primary model used in New Zealand is the SL CAPM.

6.2.2.   Da, Guo and Jagannathan (2012)

In recent work, Da, Guo and Jagannathan (2012) argue that growth options that firms possess may be largely responsible for the weak relation between return and beta. [156] McKenzie and Partington (2014) state that:[157]

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[153]   McKenzie, M. and G. Partington, Report to the AER Part A: Return on equity, October 2014.

[154]   McKenzie, M. and G. Partington, Report to the AER Part A: Return on equity, October 2014, page 9.

[155]   https://www.cia.gov/library/publications/the-world-factbook/index.html

[156]   Da, Z., R-J. Guo and R. Jagannathan, CAPM for estimating the cost of equity capital: Interpreting the empirical evidence, Journal of Financial Economics, 2012, pages 204-220.

[157]   McKenzie, M. and G. Partington, Report to the AER Part A: Return on equity, October 2014, pages 9-10.

'Da, Guo and Jagannathan (2012) argue that the empirical evidence against the capital asset pricing model (CAPM) based on stock returns does not invalidate its use for estimating the cost of capital for projects in making capital budgeting decisions. Their argument is that stocks are backed not only by projects in place, but also by the options to modify current projects and even undertake new ones. Consequently, the expected returns on equity need not satisfy the CAPM even when expected returns of projects do. Thus, their findings justify the continued use of the CAPM irrespective as to one's interpretation of the empirical literature on asset pricing.'

What McKenzie and Partington do not explain is that Da, Guo and Jagannathan do not suggest that the SL CAPM be used in the same way that the AER has been using the model. To construct estimates of beta that can be used in project evaluation, unadjusted common or garden estimates of beta have to be adjusted. Da, Guo and Jagannathan (2012) state that: [158]

'In general, both the equity risk premium and the equity beta of a firm are complex functions of the firm's project beta and real option characteristics. If we project them on a set of variables capturing the features of real options using linear regressions, the residual risk premium and the residual beta are option-adjusted and more closely resemble the underlying project risk premium and project beta.'

Since beta is a relative measure of risk, an adjustment must be made even to the betas of firms that have no growth options. Da, Guo and Jagannathan construct option-adjusted betas as the residuals from a cross-sectional regression, without an intercept, of unadjusted betas on book-to-market, idiosyncratic volatility and the return on assets where the three regressors are measured relative to averages for the market. Neither the AER nor its advisers construct estimates of beta in this way.

While Da, Guo and Jagannathan provide some interesting results, there are some obvious practical problems that would arise in trying to use their procedure. First, their data suggest that, in the cross-sectional regression used to adjust betas, the coefficient on book-to-market will be negative, the coefficient on idiosyncratic volatility will be positive and the coefficient on return on assets will be negative. It follows that an option-adjusted beta for a risk-free asset will likely be positive because its idiosyncratic volatility will be zero in absolute terms and negative relative to the average for the market. This implies that for some firms there may be a negative rather than a positive relation between the adjusted equity beta of the firm and leverage. Second, as the idiosyncratic volatility of two firms that merge can be expected, all else constant, to fall below the idiosyncratic volatilities of the unmerged firms, one can expect the adjusted betas of merged firms to be higher than a weighted average of the adjusted betas of the unmerged firms. The idiosyncratic volatility of two firms that merge will be likely to fall below the idiosyncratic volatilities of the unmerged firms if the idiosyncratic returns to the two firms are less than perfectly positively correlated.

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[158] Da, Z., R-J. Guo and R. Jagannathan, CAPM for estimating the cost of equity capital: Interpreting the empirical evidence, Journal of Financial Economics, 2012, pages 204-220.

6.2.3.   The Black CAPM

McKenzie and Partington (2014) state that:[161]

> 'McKenzie and Partington (2012b) present a numerical example, which was
> designed to highlight the sensitivity of the Black model to the choice of proxy for
> the market portfolio. NERA (2013b) go to great lengths to critically examine each
> aspect of the example. We find this approach somewhat unnecessary since we
> clearly state at the beginning of our analysis,
>
> "… that the lessons we draw from our analysis do not depend upon the specific
> values we have chosen for the data." (p. 11) '

The statement that the analysis does not depend on the specific values chosen for the data is
incorrect as we emphasise in our 2013 report.[162] McKenzie and Partington argue in their
2012 report that the zero-beta rate will be sensitive to the choice of a proxy for the market
portfolio and to back up their claim they examine a number of portfolios that are close to
being globally minimum variance.[163] The zero-beta rate relative to a proxy for the market
portfolio is the mean return to a portfolio that has a zero beta relative to the proxy. There can
be no argument that were a proxy to be chosen for the market portfolio that was close to being
globally minimum variance an estimate of the zero-beta rate would be sensitive to the precise
makeup of the portfolio. There is, however, as we point out in our 2013 report, abundant
evidence that the market portfolio is far from being globally minimum variance. Thus it is
unclear that the examples that McKenzie and Partington choose to examine are of any
practical significance.

McKenzie and Partington (2014) go on to state that:[164]

> 'NERA (2013b, p. 31) argue that:
>
> "Although there are a number of different value-weighted indices of Australian
> stocks, their composition does not vary greatly. As a result, an estimate of the beta
> of a security will not in general be sensitive to the choice of an index and,
> consequently, an estimate of the zero-beta rate will also not be sensitive to the
> choice of an index. Thus this issue that McKenzie and Partington (2012) raise is
> also of no practical significance."
>
> This is contradicted by, Roll's (1977, p. 130) fifth conclusion which states that with
> reference to the market portfolio, [24]
>
> " … most reasonable proxies will be very highly correlated with each other and
> with the true market whether or not they are mean-variance efficient. This high

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[161]   McKenzie, M. and G. Partington, Report to the AER Part A: Return on equity, October 2014, page 23.

[162]   NERA, Estimates of the zero-beta premium: A report for the Energy Networks, June 2013, pages 24-37.

[163]   McKenzie, M. and G. Partington, Report to the AER: Review of NERA report on the Black CAPM, August 2012.

[164]   McKenzie, M. and G. Partington, Report to the AER Part A: Return on equity, October 2014, pages 23-24.

correlation will make it seem that the exact composition is unimportant, whereas it can cause quite different inferences.'"

The statement that NERA's (2013) argument is contradicted by Roll's (1977) fifth conclusion is also incorrect. [165] NERA state that because there is little variation in the composition of different value-weighted indices of Australian stocks an estimate of the zero-beta rate will not be sensitive to which of the indices is chosen. Roll makes a different point – as a careful reading of his paper will confirm. Roll emphasises that the compositions of portfolios that belong to the set of portfolios whose returns are highly correlated with one another can differ and so an estimate of the zero-beta rate can be sensitive to which portfolio is chosen from the set.

An illustration of the point that Roll (1977) makes can be provided using the numerical example that McKenzie and Partington (2012) provide. [166] Using the mathematics of the mean-variance framework it is straightforward to identify a portfolio 5 that lies above McKenzie and Partington's portfolio 2 on the efficient frontier and that satisfies the condition that the correlation between its return and the return to portfolio 2 is 0.95. Figure 6.1 below plots – again using the numbers that McKenzie and Partington provide – the two portfolios together with the zero-beta rates associated with the portfolios and the efficient frontier. The two zero-beta rates differ by 8.8 per cent – thus demonstrating the point that Roll makes. Importantly, the composition of portfolio 5 also differs substantially from the composition of portfolio 2. Portfolio 5 invests 85.47, 16.94 and -2.40 per cent in risky assets A, B and C while portfolio 2 invests 53.73, 41.86 and 4.41 per cent in A, B and C. As commonsense would suggest, it is the large difference between the compositions of the two portfolios that is responsible for the large difference between the two zero-beta rates associated with the portfolios.

SFG (2014) forms portfolios designed to have different betas but the same average book-to-market, market capitalisation and industry membership and reports estimates of the zero-beta premium that are lower than those that we report here and in our 2013 report. [167] SFG explains why the two sets of estimates differ in the following way: [168]

> 'The portfolios relied upon by NERA do not necessarily have the same industry, size and book-to-market ratio. The portfolios are formed only on the basis of beta estimates. So differences in returns across portfolios will be, in part, due to differences in risks associated with industry, size and book-to-market ratio.
>
> To examine this conjecture, we repeated our analysis after forming portfolios only on the basis of beta estimates. Recall that in our sample, beta estimates were higher for small firms compared to large firms, higher for low book-to-market firms

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[165]   NERA, Estimates of the zero-beta premium: A report for the Energy Networks, June 2013, page 31.

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

[166]   McKenzie, M. and G. Partington, Report to the AER: Review of NERA report on the Black CAPM, August 2012.

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

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

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

[168]   SFG, *Cost of equity in the Black Capital Asset Pricing Model: Report for Jemena Gas Networks, ActewAGL, Networks NSW, Transend, Ergon and SA Power Networks*, May 2014, page 30.

compared to high book-to-market firms, and varied across industry. Results are presented in Table 4.

Under this alternative portfolio composition, the estimate of the zero beta return is 1.097% over four weeks (15.29% per year) as shown in Panel A. In comparison to the average yield on 20-year government bonds over the sample period (0.449%), this is a zero beta premium of 0.648% over four weeks and 9.28% per year.

As shown in Panels B, C and D there is no material change in the estimates of the zero beta return and the zero beta premium under alternative regression specifications.

The zero beta premium estimate of 9.28% per year can be compared to the figure of 9.12% reported by NERA (2013).

This is the zero beta premium estimate formed from portfolios over a time period which is one year different to the time period we analyse (1994 to 2012 for NERA and 1994 to 2013 in our sample). The standard errors of the zero beta premium are also similar (4.20% per year in our sample compared to 4.69% per year reported by NERA).

So when portfolios are constructed using only beta estimates there is a high degree of correspondence in the estimate of the zero beta premium across the two sets of analysis.'

Figure 6.1
Example of sensitivity of the zero-beta rate to the choice between two portfolios whose returns are highly correlated with one another but whose compositions are very different
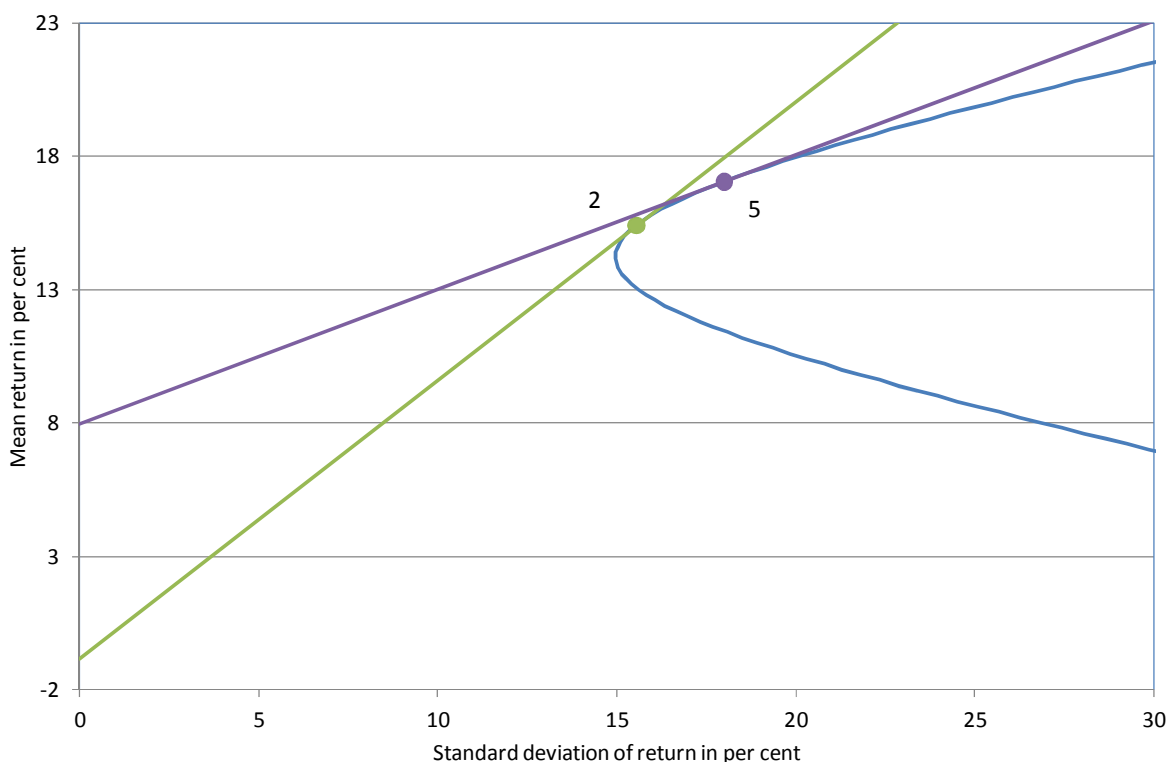
McKenzie and Partington (2014) state immediately after their discussion of the sensitivity of the zero-beta rate to the choice of a proxy that:[171]

> 'Our point that 'what you get depends very heavily on what you do' is well illustrated by the SFG estimate of the zero beta premium, which is quite different to the NERA estimate (see SFG, 2014e, and NERA, 2012, 2013b).'

This appears to suggest that the reason that (some of) SFG's estimates differ from those that NERA report has to do with the choice that each consultant makes of a series of market returns – which is not the case as both sets of consultants use a series of returns to a value-weighted index of stocks. [172]

The portfolios that SFG form are constructed in such a way as to minimise any differences in average book-to-market, industry membership and size between the portfolios. It is well known that value stocks tend to have low betas relative to the market portfolio of stocks while growth stocks tend to have high betas. Value stocks tend to earn high returns while growth stocks tend to earn low returns. Consequently, were one to compute an estimate of the zero-beta premium using just two portfolios – a value portfolio and a growth portfolio – the estimate would likely exceed the *MRP*. SFG tries to eliminate the impact of this empirical relation between beta and book-to-market on its results. We do not attempt to do so because we do not wish to prevent beta from behaving as a proxy for missing measures of risk. Allowing beta to proxy for missing measures of risk will lead to estimates generated by the Black Model that are less likely to be biased.

Finally, McKenzie and Partington (2014) state:[173]

> We do acknowledge the error in our labelling of the figures in McKenzie and Partington (2012b). As NERA correctly point out, Figure 1 corresponds to portfolio 2 and Figure 2 corresponds to portfolio 1. This does not, however, serve to alter any of the conclusions. That is to say the discussion of the sensitivity of the intercept to the portfolios remains valid. Further, the comparison of efficient portfolio 2 with an intercept of -0.85% (presented in the incorrectly labelled 'Figure 1') and the inefficient portfolios (presented in Figures 3 and 4) still shows that we move from a negative intercept to a positive intercept.

The makeup of portfolio 2 and the makeup of portfolio 4 are very different and so it is no surprise that the zero-beta rates associated with portfolios differ substantially. The makeup of portfolio 2 and the makeup of portfolio 3 do not differ as dramatically and so the difference between the zero-beta rates associated with the two portfolios is smaller – it is 3.27 per cent. That the difference is nonetheless this high can be attributed again to the choice by McKenzie and Partington of portfolios that are close to being globally minimum variance. There is no evidence of which we are aware that a value-weighted index of stocks is close to being globally minimum variance.

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[171] McKenzie, M. and G. Partington, Report to the AER Part A: Return on equity, October 2014, page 24.

[172] SFG, *Cost of equity in the Black Capital Asset Pricing Model: Report for Jemena Gas Networks, ActewAGL, Networks NSW, Transend, Ergon and SA Power Networks*, May 2014, page 30.

[173] McKenzie, M. and G. Partington, Report to the AER Part A: Return on equity, October 2014, page 24.

6.3.   AER

Finally, we address some issues that the AER raises in the *Appendices* to its Rate *of Return Guidelines*.[174] In these appendices, the AER states that:

> 'Many of the empirical tests of the Sharpe–Lintner CAPM, however, are themselves the subject of ongoing academic debate. For example, a common test used to demonstrate low beta bias is to plot the average beta of share portfolios against the realised returns on these portfolios. Indeed, similar evidence was included in the report by NERA, and submitted by ENA. In previous decisions we have highlighted the limitations of these tests, as suggested in the academic literature. These limitations include:
>
> - They use a market proxy that does not accord with the Sharpe–Lintner CAPM market.
>
> - They consider realised returns, whereas the Sharpe–Lintner CAPM requires expected returns.
>
> - They use short–term intervals (less than one month), whereas the Sharpe–Lintner CAPM uses a long–term investment horizon.
>
> - They use inappropriate statistical tests or procedures.'

The argument that tests of the SL CAPM 'use a market proxy that does not accord' with the model is irrelevant as we have already pointed out. The AER and its advisors use estimates of beta computed relative to the value-weighted market portfolio of stocks and so do the vast majority of empirical tests. Again, as Fama and French (2004) emphasise:[175]

> 'It is always possible that researchers will redeem the CAPM by finding a reasonable proxy for the market portfolio that is on the minimum variance frontier. We emphasize, however, that this possibility cannot be used to justify the way the CAPM is currently applied. The problem is that applications typically use the same market proxies, like the value-weight portfolio of U.S. stocks, that lead to rejections of the model in empirical tests. The contradictions of the CAPM observed when such proxies are used in tests of the model show up as bad estimates of expected returns in applications; for example, estimates of the cost of equity capital that are too low (relative to historical average returns) for small stocks and for stocks with high book-to-market equity ratios. In short, if a market proxy does not work in tests of the CAPM, it does not work in applications.'

Whether the SL CAPM itself is true is irrelevant. What matters is whether or not the version of the model that the AER uses works and the evidence is that it does not. In particular, the model underestimates the returns to low-beta portfolios.

The AER argues that tests of pricing models typically use realised returns and not expected returns. This is correct but one can draw inferences about expected returns from realised returns – and indeed the AER does so when it uses historical averages of the excess return to

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[174]   AER, Better Regulation Explanatory Statement Rate of Return Guideline (Appendices), December 2013, pages 11-12.

[175]   Fama, E.F. and K.R. French, *The Capital Asset Pricing Model: Theory and evidence*, Journal of Economic Perspectives, 2004, pages 42-43.

the market portfolio to guide its choice for the *MRP*. In the same way, one can draw inferences about whether a die is loaded. One might not know whether the die is loaded – but one can soon find out by throwing the die a sufficient number of times – and tests exist that will allow one to test the hypothesis that the die is fair.

The AER criticises tests of the SL CAPM for using returns realised over short term intervals – but itself relies on estimates of beta computed over the same intervals. [176] If the aim is to discover whether the model that the AER uses generates unbiased estimates of the cost of equity, then it is surely appropriate for the tests to use estimates of beta that have been computed using the method that the regulator and its advisors have adopted.

The AER claim that existing tests use 'inappropriate ... procedures' and so cannot be relied upon. In particular, they cite the work of Ray, Savin and Tiwari (2009). [177] As we have already made clear, we address the issue that Ray, Savin and Tiwari raise.

Ray, Savin and Tiwari (2009) show that the finite-sample distribution of the Wald statistic for a test of the SL CAPM need not conform closely to its theoretical asymptotic distribution. [178] The finite-sample distribution refers to the distribution in samples that are not very, very large while the asymptotic distribution refers to the distribution in very, very large samples. Asymptotic results are ones that are strictly true only in the limit as the sample size tends to infinity. [179] As a result of the differences that can occur between the finite-sample and asymptotic distributions of the Wald statistics used to test the SL CAPM, Ray, Savin and Tiwari note that tests of pricing models that rely on the asymptotic distributions of the statistics can reject more frequently than the stated sizes (significance levels) of the tests would suggest. We examine the extent to which the finite-sample distribution of the Wald statistic that we employ to test the SL CAPM differs from its theoretical asymptotic distribution, using bootstrap simulations, and find little evidence that a reliance on asymptotic theory will mislead.

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[176]   AER, *Draft decision Jemena Gas Networks (NSW) Ltd Access arrangement 2015–20: Attachment 3: Rate of return*, November 2014, pages 241-262.

[177]   Ray, S., N. E. Savin and A. Tiwari, Testing the CAPM revisited, Journal of Empirical Finance, 2009, pages 721–733.

[178]   AER, *Better Regulation Explanatory Statement Rate of Return Guideline (Appendices)*, December 2013, page 12.

McKenzie, M. and G. Partington, Report to the AER Part A: Return on equity, October 2014, page 9.

Ray, S., N.E. Savin and A. Tiwari, Testing the CAPM revisited, Journal of Empirical Finance, 2009, pages 721-733.

[179]   Davidson, R. and J.G. MacKinnon, *Estimation and inference in econometrics*, Oxford University Press, 1993, page 42.

7.   Conclusions

This report has been prepared for Jemena Gas Networks (JGN), Jemena Electricity Networks (JEN), ActewAGL, AusNet Services, CitiPower, Energex, Powercor, SA Power Networks, and United Energy (UE) by NERA Economic Consulting (NERA). JGN, JEN, ActewAGL, AusNet Services, CitiPower, Energex, Powercor, SA Power Networks, and UE have asked NERA to assess the empirical performance of two forms of the Capital Asset Pricing Model (CAPM) and to respond to issues raised by the Australian Energy Regulator (AER) in its recently published *Draft decision Jemena Gas Networks (NSW) Ltd Access arrangement 2015-20*, other recent AER decisions and recent reports written by the AER's advisors.

Models for estimating the return on equity

We have been asked to assess the two well recognised forms of the CAPM:

- the Sharpe-Lintner (SL) CAPM; and

- the Black CAPM.

These two models have been widely used by finance academics over the last 50 years. It has been known for well over 40 years that there is empirical evidence against the SL CAPM. [180] Thus finance academics use the model primarily as a teaching device rather than in research. They use it as a teaching device because of its simplicity. The Black CAPM was widely used in research until the early 1980s when it was discovered that it tended to misprice low-cap and value stocks (an issue that subsequently led to development of the Fama-French model).

It is useful to add to these two models a naïve model that states that the mean returns to all equities are identical. A pricing model should at least be able to outperform, empirically, a naïve model of this kind.

We use both in-sample tests and out-of-sample tests to determine whether there is evidence against the restrictions that each model imposes. If the restrictions that an asset pricing

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[180]   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. 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 *all* risky assets. Thus the empirical version of the SL CAPM that the AER actually employs differs from the theoretical model proposed by Sharpe and Lintner. The empirical version of the model that the AER employs does closely resemble, though, the version that academic work tests.

Roll (1977) emphasises that difficulties in measuring the return to the market portfolio of *all* risky assets mean that it is not possible to test the SL CAPM. One may be able to reject an empirical version of the model that uses the market portfolio of stocks as a proxy for the market portfolio of all risky assets, but this rejection will not imply that the theoretical model itself is wrong. The issue that concerns us, though, is not whether the SL CAPM itself is correct, but whether the empirical version of the SL CAPM applied by the AER works.

Since our interest is in whether the empirical version of the SL CAPM applied by the AER works and not in whether the SL CAPM itself is true, all references to the SL CAPM in the report will be to the empirical version of the model that the AER uses unless stated otherwise.

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

model imposes do not hold, then the model will, in general, produce biased estimates of the return required on equity. Thus evidence against a model is evidence that the model will generate biased estimates of the return required on equity.

In-sample tests are full-sample tests whereas out-of-sample tests split the full sample up, typically in a recursive manner, into data used to estimate a model and data used to evaluate forecasts generated by the model. Inoue and Kilian (2004) and Diebold (2014) emphasise that in-sample tests of models are to be preferred and out-of-sample tests of models in general represent an inefficient use of data. [181] In other words, they emphasise that in-sample tests are more likely to detect that a null hypothesis is untrue than are out-of-sample tests. Out-of-sample tests, on the other hand, are simple to interpret. Also, as Diebold notes, out-of-sample tests can be useful in summarising the performance of forecasts that models would have generated over a particular historical period.

In-sample tests

We begin our assessment of these models by using in-sample tests to determine whether there is evidence against the restrictions that each model imposes.

Using 10 portfolios formed on the basis of past estimates of beta and monthly data taken from SIRCA from January 1974 to December 2013, we find:

- little evidence of bias in the naïve model;

- statistically significant evidence of bias in the SL CAPM; and

- little evidence of bias in the Black CAPM.

The data indicate that there is a negative rather than a positive relation between returns and estimates of beta. As a result, the evidence indicates that the SL CAPM significantly underestimates the returns generated by low-beta portfolios and overestimates the returns generated by high-beta portfolios. In other words, the model has a low-beta bias. The extent to which the SL CAPM underestimates the returns to low-beta portfolios is both statistically and economically significant.

As an example, we estimate the lowest-beta portfolio of the 10 portfolios that we construct to have a beta of 0.54 – marginally below the midpoint of the AER's range for the equity beta of a regulated energy utility of 0.4 to 0.7. Our in-sample results suggest that the SL CAPM underestimates the return to the portfolio by 4.90 per cent per annum.

While we find little evidence against the restrictions that the Black CAPM imposes on the mean returns to the 10 portfolios formed on the basis of past estimates of beta, the negative relation between returns and estimates of beta – which in some tests is statistically significant – is not consistent with the theory that underpins the model. If we were to impose the

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[181]   Diebold, F., *Comparing predictive accuracy, twenty years later: A personal perspective on the use and abuse of Diebold-Mariano tests*, University of Pennsylvania, December 2013.

Inoue, A. and L. Kilian, In-*sample or out-of-sample tests of predictability: Which one should we use*? Econometric Reviews, 2004, pages 371-402.

restriction that the relation be nonnegative, then estimates generated by the Black CAPM would match estimates generated by the naïve model. We do not impose this restriction and instead allow the data to determine what relation exists between returns and estimates of beta.

Out-of-sample tests

An alternative way of evaluating the empirical performance of pricing models is to assess their out-of-sample performance. Rule 74 (2) (b) of the National Gas Rules, relating generally to forecasts and estimates, states that:

> 'A forecast or estimate ... must represent the best forecast or estimate possible in the circumstances.'

Evaluating the out-of-sample performance of a pricing model is an excellent way of demonstrating whether estimates of the cost of equity produced using the model are likely to satisfy this important rule because they are straightforward to interpret.

Our out-of-sample tests examine the SLCAPM and the Black CAPM, as well as an alternative version of the CAPM used by the AER. '

The AER states that: [182]

> 'we use the theoretical principles underpinning the Black CAPM to inform the equity beta point estimate from within our empirical range.'

The AER also states that it places some weight on foreign estimates of beta. While it sees: [183]

> 'there are inherent uncertainties when relating foreign estimates to Australian conditions'

the AER concludes that foreign estimates of beta: [184]

> 'provide some limited support for an equity beta point estimate towards the upper end of our range.'

The AER chooses an equity beta estimate for use with the SL CAPM of 0.7 from a range of 0.4 to 0.7. This choice amounts to placing a weight of two thirds on the midpoint of this range, 0.55, and a weight of one third on one. We label a policy of placing a weight of two

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[182]   AER, *Draft decision Jemena Gas Networks (NSW) Ltd Access arrangement 2015–20: Attachment 3: Rate of return*, November 2014, page 265.

[183]   AER, *Draft decision Jemena Gas Networks (NSW) Ltd Access arrangement 2015–20: Attachment 3: Rate of return*, November 2014, page 268.

[184]   AER, *Draft decision Jemena Gas Networks (NSW) Ltd Access arrangement 2015–20: Attachment 3: Rate of return*, November 2014, page 269.

thirds on an unadjusted estimate of beta and one third on one and then using the SL CAPM to estimate the return required on equity a policy of using the 'AER CAPM'. [185]

Using the 10 portfolios formed on the basis of past estimates of beta and monthly data from January 1979 to December 2013, we find:

- little evidence of bias in the naïve model;

- statistically significant evidence of bias in the SL CAPM;

- statistically significant evidence of bias in the AER CAPM; and

- little evidence of bias in the Black CAPM.

The evidence indicates that the SL CAPM and the AER CAPM significantly underestimate the returns generated by low-beta portfolios and overestimate the returns generated by high-beta portfolios. The extent to which they underestimate the returns to low-beta portfolios is both statistically and economically significant.

Issues raised by the AER and its advisors

The AER and its advisors raise a number of issues in recent decisions and reports to which we respond. A recurring theme is that the AER's advisers cite selectively from the work that they discuss.

As an example, McKenzie and Partington (2014) note that Da, Guo and Jagannathan (2012) argue that growth options that firms possess may be largely responsible for the weak relation between return and beta and that the inability of the SL CAPM to explain the cross-section of mean return to stocks need not prohibit its use in project evaluation. [186] McKenzie and Partington do not, however, make it clear that Da, Guo and Jagannathan do not suggest that the SL CAPM be used in the same way that the AER has been using the model. To construct estimates of beta that can be used in project evaluation, Da, Guo and Jagannathan emphasise that unadjusted ordinary least squares estimates of beta have to be adjusted and since beta is a relative measure of risk, even the betas of firms that have no growth options have to be adjusted.

Another recurring theme is that the AER dismisses as irrelevant academic work that rejects the SL CAPM because the work makes choices that might conceivably lead to the model being rejected – even though the AER in using the SL CAPM makes the same choices.

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[185]   The choice of label is unimportant. What is important is that we specify clearly a method that a regulator might use in estimating a return required on equity for a regulated energy utility and that we use time series of returns to evaluate the method. Methods that we cannot specify clearly, we cannot evaluate. We cannot, for example, evaluate the use by a regulator of its discretion in a way that is not specified and in a way that may vary through time.

[186]   Da, Z., R-J. Guo and R. Jagannathan, CAPM for estimating the cost of equity capital: Interpreting the empirical evidence, Journal of Financial Economics, 2012, pages 204-220.

McKenzie, M. and G. Partington, Report to the AER Part A: Return on equity, October 2014, pages 9-10.

As an example, the AER in the *Appendices* to its Rate *of Return Guidelines* argues that tests of the SL CAPM that use as a proxy a value-weighted index of stocks are of limited relevance because the SL CAPM requires one use instead a value-weighted index of all assets.[187] The AER in using the SL CAPM employs a value-weighted index of stocks.

As another example, the AER also in the *Appendices* to its Rate *of Return Guidelines* argues that tests of the SL CAPM typically use returns measured over one month or less whereas it believes a longer horizon may be more appropriate.[188] The AER makes this argument even though it relies itself on estimates of the equity beta of a regulated energy utility computed from weekly and monthly data.

Summary

The central empirical result is that models like the SL CAPM and AER CAPM that use market beta as a measure of risk and a restriction that a zero-beta portfolio earn either the risk-free rate or a rate that sits only a small distance above the risk-free rate provide poor estimates of the return required on equity. In particular, the models tend to underestimate the returns required on low-beta equity portfolios and overestimate the returns required on high-beta equity portfolios.[189] In other words, models that use market beta as a measure of risk and a restriction that a zero-beta portfolio earn either the risk-free rate or a rate that sits only a small distance above the risk-free rate produce estimates of required returns that are biased – especially for low-beta equities and high-beta equities.

The SL CAPM and the AER CAPM perform so badly that even a naïve model that states that the mean returns to all equities are identical performs better. Thus estimates of the return required on equity that use the SL CAPM, and the AER CAPM will not, for example, satisfy Rule 74 (2) of the National Gas Rules, relating generally to forecasts and estimates, which states that:

> (2) A forecast or estimate:
>
>   (a)   must be arrived at on a reasonable basis; and
>
>   (b)   must represent the best forecast or estimate possible in the circumstances.

Estimates of the return required on equity that use the SL CAPM or the AER CAPM do not represent the best forecasts possible in the circumstances.

Table 1 below summarises the results of our tests and shows that there is little to choose between the naïve model and the Black CAPM in terms of the performance of the models in estimating the return required on an equity portfolio. One cannot reject the hypothesis that each of these models generates estimates of the return on equity that are unbiased.[190] Thus

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[187]   AER, Better Regulation Explanatory Statement Rate of Return Guideline (Appendices), December 2013, pages 11-12.

[188]   AER, Better Regulation Explanatory Statement Rate of Return Guideline (Appendices), December 2013, pages 11-12.

[189]   By construction, of course, the SL CAPM will correctly estimate the return required on a risk-free asset.

[190]   While the naïve model and the Black CAPM provide estimates of the return required on equity that are unbiased, the models will overestimate the return required on a risk-free asset.

estimates of the return required on equity that use the naïve model or the Black CAPM will satisfy Rule 74 (2) of the National Gas Rules.

We conclude that estimates of the return required on equity that use the naïve model or the Black CAPM will be relevant for estimating a cost of equity that is:

    (a) consistent with the allowed rate of return objective; and

    (b) reflective of prevailing conditions in the market for equity funds.

We have not examined the issue of how best to combine estimates from different pricing models. We note, however, that an estimator that relies solely on the SL CAPM or the AER CAPM to the exclusion of other asset pricing models, as the AER has done in its recent draft decisions, will produce a materially worse estimate of the cost of equity in terms of bias than an approach that combines estimates that these models provide with estimates provided by other models that are not similarly affected by bias, such as the Black CAPM.

Appendix A.   Simulations

We conduct bootstrap simulations using the 10 portfolios formed on the basis of past estimates of beta to examine the behaviour of the test statistics that we employ and the power of our tests. The power of a test is the probability that the test will reject the null hypothesis when the null is not true. [196]

To begin with, we use OLS to estimate for each of the 10 portfolios the time series regression:

$$z_{jt} = \alpha_j + \beta_j z_{mt} + \varepsilon_{jt}, \qquad j = 1, 2, ..., 10, \quad t = 1, 2, ..., T \tag{A.1}$$

We place in each row of a $T \times 11$ matrix E the vector $(\hat{\varepsilon}_{1t}, \hat{\varepsilon}_{2t}, ..., \hat{\varepsilon}_{10t}, z_{mt})$ where $\hat{\varepsilon}_{jt}$ is an OLS residual.

We simulate data for T months using the fitted regression, random drawings with replacement from the rows of the matrix E and, initially, the restriction that:

$$\alpha_j = 0, \qquad j = 1, 2, ..., 10 \tag{A.2}$$

In this way we create data that may display heteroskedasticity but are drawn from a model in which the SL CAPM is true. Heteroskedasticity occurs when the variance of a disturbance is not constant. [197]

A.1.   In-Sample Tests

We examine the behaviour of the Wald statistics that we use for in-sample tests under the null hypothesis that the SL CAPM is true. Again, a Wald statistic uses unrestricted parameter estimates and an estimate of the covariance matrix of the unrestricted parameter estimates. [198] Thus a Wald statistic tests the restrictions that (A.2) imposes on the regression (A.1) but uses unrestricted estimates of the parameters of the regression.

The results of the simulations for the 10 portfolios formed on the basis of past estimates of beta appear in Table A.1 below and indicate that while the finite-sample distribution of the Wald statistic differs, under the null hypothesis, from its theoretical asymptotic counterpart, the differences between the distributions are minor. The finite-sample distribution refers to the distribution in samples that are not very, very large while the asymptotic distribution refers to the distribution in very, very large samples. Asymptotic results are ones that are strictly true only in the limit as the sample size tends to infinity. [199]

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[196]   Davidson, R. and J.G. MacKinnon, *Estimation and inference in econometrics*, Oxford University Press, 1993, page 79.

[197]   Davidson, R. and J.G. MacKinnon, *Estimation and inference in econometrics*, Oxford University Press, 1993, page 60.

[198]   Davidson, R. and J.G. MacKinnon, *Estimation and inference in econometrics*, Oxford University Press, 1993, page 89.

[199]   Davidson, R. and J.G. MacKinnon, *Estimation and inference in econometrics*, Oxford University Press, 1993, page 42.

The fact that the differences between the finite-sample distribution of the Wald statistic and the theoretical asymptotic distribution are minor implies that the inferences that we draw in section 4 of the report that are based on the theoretical asymptotic distribution are valid.

Table A.1
Distribution under the null of the Wald statistic used to test the SL CAPM:
10 portfolios formed on the basis of past estimates of beta

	Probability that null is rejected at a significance level of			
	0.500	0.100	0.050	0.010
Wald	0.540	0.124	0.065	0.017

Notes: The results are generated using bootstrap simulations, 10, 000 replications and the returns to 10 portfolios formed on the basis of past estimates of beta from January 1974 to December 2013. The theoretical asymptotic distribution of the Wald statistic used to test whether the SL CAPM is true, that is, whether $\alpha_j = 0$, $j = 1, 2, ..., 10$, is chi-squared with 10 degrees of freedom.

A.2.   Out-of-Sample Tests

We also examine the behaviour of the *t*-test statistics and Wald statistics that we use in out-of-sample tests. To begin with, we examine their behaviour under the null hypothesis that the SL CAPM is true. We then examine their behaviour under the alternative that the SL CAPM is false.

The in-sample results of the simulations for the 10 portfolios formed on the basis of past estimates of beta appear in Table A.2 below and indicate that while the finite-sample distributions of the test statistics that we use differ, under the null hypothesis, from their theoretical asymptotic counterparts, the differences are small.

The fact that the differences between the finite-sample distribution of the Wald statistic and the theoretical asymptotic distribution are small implies that the inferences that we draw in section 5 of the report that are based on the theoretical asymptotic distribution are valid.

We next examine the behaviour of the test statistics that we use under the alternative that:

$$\alpha_j = 0.005 \times (1 - \beta_j), \qquad j = 1, 2, ..., N. \tag{A.3}$$

In other words, we examine the behaviour of the test statistics under the alternative that the Black CAPM is true but the SL CAPM is false and the zero-beta premium is 0.5 percent per month.

The results of these simulations for the 10 portfolios formed on the basis of past estimates of beta appear in Table A.2 below.

Table A.2

Distribution under the null of statistics used to test the SL CAPM out of sample using 10 portfolios formed on the basis of past estimates of beta and rolling estimates of beta

	Method A				Method B			
	Probability that null is rejected at a significance level of				Probability that null is rejected at a significance level of			
Portfolio	0.995	0.975	0.025	0.005	0.995	0.975	0.025	0.005
1	0.996	0.975	0.028	0.007	0.994	0.972	0.025	0.005
2	0.996	0.978	0.036	0.010	0.994	0.971	0.032	0.007
3	0.997	0.980	0.037	0.011	0.995	0.979	0.029	0.007
4	0.996	0.976	0.028	0.006	0.992	0.970	0.026	0.004
5	0.995	0.977	0.031	0.007	0.993	0.974	0.025	0.004
6	0.996	0.977	0.032	0.009	0.994	0.973	0.025	0.005
7	0.996	0.976	0.034	0.008	0.995	0.972	0.027	0.005
8	0.996	0.976	0.031	0.007	0.994	0.972	0.022	0.004
9	0.996	0.975	0.027	0.007	0.994	0.975	0.024	0.004
10	0.995	0.974	0.028	0.006	0.995	0.971	0.024	0.006
	Method A				Method B			
	Probability that null is rejected at a significance level of				Probability that null is rejected at a significance level of			
	0.500	0.100	0.050	0.010	0.500	0.100	0.050	0.010
Wald	0.528	0.125	0.067	0.017	0.532	0.124	0.070	0.017

Notes: The results are generated using bootstrap simulations, 10, 000 replications and the returns to 10 portfolios formed on the basis of past estimates of beta from January 1974 to December 2013. The theoretical asymptotic distribution of the t-test statistic used to test whether the mean forecast error for an individual portfolio differs from zero is standard normal. The theoretical asymptotic distribution of the Wald statistic used to test whether the mean forecast errors for all 10 portfolios are zero is chi-squared with 10 degrees of freedom.

Table A.3

Power of out-of-sample tests that use 10 portfolios formed on the basis of past estimates of beta and rolling estimates of beta

	Method A			Method B		
	Probability that null is rejected at a significance level of			Probability that null is rejected at a significance level of		
Portfolio	0.100	0.050	0.010	0.100	0.050	0.010
1	0.301	0.200	0.070	0.416	0.298	0.117
2	0.219	0.126	0.040	0.308	0.202	0.076
3	0.198	0.122	0.033	0.311	0.216	0.068
4	0.137	0.075	0.017	0.179	0.106	0.038
5	0.108	0.056	0.010	0.118	0.060	0.014
6	0.108	0.049	0.008	0.104	0.054	0.014
7	0.102	0.052	0.009	0.103	0.054	0.012
8	0.124	0.059	0.017	0.181	0.106	0.028
9	0.139	0.076	0.021	0.238	0.154	0.045
10	0.131	0.069	0.020	0.164	0.097	0.032
Wald	0.357	0.227	0.086	0.337	0.223	0.078

Notes: The results are generated using bootstrap simulations, 10, 000 replications and the returns to 10 portfolios formed on the basis of past estimates of beta from January 1974 to December 2013. Inference is drawn by comparing the t-test statistics and Wald statistic to their simulated distributions.

Appendix B.   Terms of Reference

Expert Terms of Reference

Empirical performance of Sharpe-Lintner and Black CAPMs

Jemena Gas Networks
2015-20 Access Arrangement Review

AA15-570-0068   **13 February 2015**

1.   Background

Jemena Gas Networks (**JGN**) is the major gas distribution service provider in New South Wales (**NSW**).   JGN owns more than 25,000 kilometres of natural gas distribution system, delivering approximately 100 petajoules of natural gas to over one million homes, businesses and large industrial consumers across NSW.

JGN submitted its revised Access Arrangement proposal (**proposal**) with supporting information for the consideration of the Australian Energy Regulator (**AER**) on 30 June 2014. The revised access arrangement will cover the period 1 July 2015 to 30 June 2020 (July to June financial years). The AER published its draft decision on this proposal on 27 November 2014. JGN must submit any additions or other amendments to its proposal by 27 February 2015.

As with all of its economic regulatory functions and powers, when assessing JGN's revised Access Arrangement under the National Gas Rules and the National Gas Law, the AER is required to do so in a manner that will or is likely to contribute to the achievement of the National Gas Objective, which is:

> "to promote efficient investment in, and efficient operation and use of, natural gas services for the long term interests of consumers of natural gas with respect to price, quality, safety, reliability and security of supply of natural gas."

For electricity networks, the AER must assess regulatory proposals under the National Electricity Rules and the National Electricity Law in a manner that will or is likely to achieve the National Electricity Objective, as stated in section 7 of the National Electricity Law.

Where there are two or more possible decisions in relation to JGN's revised Access Arrangement that will or are likely to contribute to the achievement of the National Gas Objective, the AER is required to make the decision that the AER is satisfied will or is likely to contribute to the achievement of the National Gas Objective to the greatest degree.

The AER must also take into account the revenue and pricing principles in section 24 of the National Gas Law and section 7A of the National Electricity Law, when exercising a discretion related to reference tariffs. The revenue and pricing principles include the following:

"(2) A service provider should be provided with a reasonable opportunity to recover at least the efficient costs the service provider incurs in—

   a) providing reference services; and

   b) complying with a regulatory obligation or requirement or making a regulatory payment.

(3) A service provider should be provided with effective incentives in order to promote economic efficiency with respect to reference services the service provider provides. The economic efficiency that should be promoted includes—

   (a) efficient investment in, or in connection with, a pipeline with which the service provider provides reference services…

[…]

(5) A reference tariff should allow for a return commensurate with the regulatory and commercial risks involved in providing the reference service to which that tariff relates.

(6) Regard should be had to the economic costs and risks of the potential for under and over investment by a service provider in a pipeline with which the service provider provides pipeline services."

Some of the key rules that are relevant to an access arrangement and its assessment are set out below.

Rule 74 of the National Gas Rules, relating generally to forecasts and estimates, states:

   (1) Information in the nature of a forecast or estimate must be supported by a statement of the basis of the forecast or estimate.

   (2) A forecast or estimate:

      (a) must be arrived at on a reasonable basis; and

      (b) must represent the best forecast or estimate possible in the circumstances.

Rule 87 of the National Gas Rules, relating to the allowed rate of return, states:

   (1) Subject to rule 82(3), the return on the projected capital base for each regulatory year of the access arrangement period is to be calculated by applying a rate of return that is determined in accordance with this rule 87 (the allowed rate of return).

   (2) The allowed rate of return is to be determined such that it achieves the allowed rate of return objective.

   (3) The allowed rate of return objective is that the rate of return for a service provider is to be commensurate with the efficient financing costs of a benchmark efficient entity with a similar degree of risk as that which applies to the service provider in respect of the provision of reference services (the allowed rate of return objective).

(3) Subject to subrule (2), the allowed rate of return for a regulatory year is to be:

   (a) a weighted average of the return on equity for the access arrangement period in which that regulatory year occurs (as estimated under subrule (6)) and the return on debt for that regulatory year (as estimated under subrule (8)); and

   (b) determined on a nominal vanilla basis that is consistent with the estimate of the value of imputation credits referred to in rule 87A.

(4) In determining the allowed rate of return, regard must be had to:

   (a) relevant estimation methods, financial models, market data and other evidence;

   (b) 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

   (c) 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

(5) The return on equity for an access arrangement period is to be estimated such that it contributes to the achievement of the allowed rate of return objective.

(6) In estimating the return on equity under subrule (6), regard must be had to the prevailing conditions in the market for equity funds.

[Subrules (8)–(19) omitted].

The equivalent National Electricity Rules are in clauses 6A.6.2 (for electricity transmission) and 6.5.2 (for electricity distribution).

In this context, JGN seeks a report from NERA, as a suitable qualified independent expert (**Expert**), on the empirical performance of relevant financial models used to estimate the return on equity component of the rate of return, in a way that complies with the requirements of the National Gas Law and Rules and National Electricity Law and Rules, including as highlighted above. JGN seeks this report on behalf of itself, Jemena Electricity Networks, ActewAGL, AusNet Services, CitiPower, Energex, Powercor, SA Power Networks, and United Energy.

2.   **Scope of Work**

In its Rate of Return Guideline (and again in its Draft Decisions for JGN and ActewAGL), the AER relies on two asset pricing models to estimate the return on equity:

• Sharpe-Lintner CAPM; and

• Black CAPM.

The AER states in the Draft Decisions for JGN and ActewAGL that it considers the Sharpe-Lintner CAPM to be superior to the others, and therefore decides to use it as the 'foundation model' for determining the return on equity. The AER also considers that there is no compelling evidence that

the return on equity estimate from this model will be downward biased, given the AER's selection of input parameters.

Having regard to the AER's position on relevant return on equity models, as set out in the Rate of Return Guideline and the Draft Decisions for JGN and ActewAGL, the Expert will provide an opinion report that:

1. Describes methods used to test the empirical performance of asset pricing models and the usefulness for determining a cost of equity that is:

   (a) consistent with the allowed rate of return objective; and

   (b) reflective of prevailing conditions in the market for equity funds.

2. Recommends one or more methods for testing the empirical performance of the asset pricing models in Australia.

3. Using the method or methods in (2), tests the empirical performance of the asset pricing models in Australia (including the potential for bias in any of these models) and concludes on their relevance for estimating a cost of equity that is:

   (a) consistent with the allowed rate of return objective; and

   (b) reflective of prevailing conditions in the market for equity funds.

In preparing the report, the Expert will:

A. consider different approaches to applying each of the financial models, including any theoretical restrictions on empirical estimates;

B. consider different methods for testing empirical performance, including both within sample and out of sample tests;

C. consider the availability of data to test performance, and the reliability of that data;

D. consider any comments raised by the AER, its experts and other regulators, including on (but not limited) to (a) whether each of the financial models applies in Australia; (b) the statistical reliability of the parameter estimates produced by those models; and (c) evidence of bias in the return on equity estimates produced by any of these models.

3.   Information to be Considered

The Expert is also expected to consider the following additional information:

- such information that, in Expert's opinion, should be taken into account to address the questions outlined above;

- relevant literature on the rate of return;

- the AER's rate of return guideline, including explanatory statements and supporting expert material;

- material submitted to the AER as part of its consultation on the rate of return guideline; and

- previous decisions of the AER, other relevant regulators and the Australian Competition Tribunal on the rate of return and any supporting expert material, including the recent draft decisions for JGN and electricity networks in ACT, NSW and Tasmania.

4.   Deliverables

At the completion of its review the Expert will provide an independent expert report which:

- is of a professional standard capable of being submitted to the AER;

- is prepared in accordance with the Federal Court Practice Note on Expert Witnesses in Proceedings in the Federal Court of Australia (CM 7) set out in Attachment 1, and includes an acknowledgement that the Expert has read the guidelines [200];

- contains a section summarising the Expert's experience and qualifications, and attaches the Expert's curriculum vitae (preferably in a schedule or annexure);

- identifies any person and their qualifications, who assists the Expert in preparing the report or in carrying out any research or test for the purposes of the report;

- summarises JGN's instructions and attaches these term of reference;

- includes an executive summary which highlights key aspects of the Expert's work and conclusions; and

- (without limiting the points above) carefully sets out the facts that the Expert has assumed in putting together his or her report, as well as identifying any other assumptions made, and the basis for those assumptions.

The Expert's report will include the findings for each of the items defined in the scope of works (Section 2).

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[200] Available at: http://www.federalcourt.gov.au/law-and-practice/practice-documents/practice-notes/cm7.

5.   **Timetable**

The Expert will deliver the final report to Jemena Regulation by13 February 2015.

6.   **Terms of Engagement**

The terms on which the Expert will be engaged to provide the requested advice shall be:

as provided in accordance with the Jemena Regulatory Consultancy Services Panel arrangements applicable to the Expert.

Appendix C.   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[202], 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[203]

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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[202] 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].

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

2.   The Form of the Expert's Report[204]

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[205]; 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[206].

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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[204] Rule 23.13.

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

[206] 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[207].

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

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

Appendix D. Curriculum Vitae

Simon M. Wheatley

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Blackburn VIC 3130
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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

- Affiliated Industry Expert, NERA Economic Consulting, 2014-

- Special Consultant, NERA Economic Consulting, 2009-2014

- 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

Imputation Credits and Equity Returns: A report for the Energy Networks Association, October 2013, http://www.aer.gov.au/sites/default/files/ENA,%20Attachment%204%20-%20NERA%20Report%20-%20Imputation%20Credits%20and%20Equity%20Prices,%20Submission%20to%20draft%20AER%20rate%20of%20return%20guideline%20-%2011%20Oct%202013.pdf

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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

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