ESQUANT
Statistical Consulting

A Review of Measures of Australian Corporate Credit Spreads published by the Reserve Bank of Australia

Submission to the issues paper (Return on debt: Choice of third party data service provider) released by the Australian Energy Regulator (April 2014)

A report prepared for United Energy and Multinet Gas.

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1 Executive Summary

1.1 Background

In December 2013, the Reserve Bank of Australia (RBA) commenced the publication of monthly, kernel-smoothing based estimates of bond spreads. The RBA published an article to explain the methods that had been employed (Arsov et al., 2013).

ESQUANT Statistical Consulting was engaged by United Energy and Multinet Gas to evaluate the data series that had been generated by the RBA and to assess the statistical properties of kernel based methods. ESQUANT was asked to review non-parametric techniques such as kernel smoothing, and to assess the merits of the approach relative to other methods such as the development of yield curves. The brief that was given to ESQUANT asked that a comprehensive analysis be undertaken. Accordingly, ESQUANT has documented the particular methods, has performed empirical analysis, and has examined other practicalities.

In response to the brief, ESQUANT has examined data on corporate bonds, has undertaken a literature review, and has applied kernel smoothing techniques. We have compared our results to those obtained by the RBA, and have also estimated Nelson-Siegel yield curves. We have been informed by the work that we did previously on the development of yield curves, zero coupon yields, and par value yields for corporate bonds (Diamond et al., 2013b). This report describes the outcomes of our assignment.

We acknowledge that we have read, understood and complied with the Federal Court of Australia's Practice Note CM7, Expert Witnesses in Proceedings in the Federal Court of Australia.

The RBA has published aggregate measures of Australian corporate bond spreads and yields for non-financial corporations. The data is available on a monthly basis, though the results produced are for a single day each month, generally at the end of the month, and presumably for the last working day (although the RBA has not been explicit) . The RBA has, in effect, constructed composite, corporate bond indices, for securities of different tenors (3, 5, 7, and 10 years). While the RBA reports on the outputs, comparatively little information has been provided about the inputs. The RBA has not supplied data about the actual, individual bond issues that have been used to compile the indices from one month to the next.

The Competition Economists Group (CEG) has undertaken a separate exercise to replicate the calculations and intermediate steps that have been applied by the RBA. CEG noted the filtering criteria that had been used by the RBA, and extracted data on corporate bonds from Bloomberg, covering a sampling period from 1st November 2013 to 28th February 2014. CEG retrieved daily data on option-adjusted spreads (for bonds with embedded options), and simple spreads over swap (for plain vanilla bonds), and then applied transformations as appropriate. CEG calculated weights for the individual bonds using the Gaussian kernel method, while making use of actual tenors (the remaining term to maturity for each bond) and the target tenor. A weighted average spread-over-swap rates was computed for each of the target tenors, incorporating the face values of the bonds (measured in Australian dollars) into the calculation. The resulting values for the aggregate corporate bond spreads matched those obtained by the RBA relatively closely (see Table 1 below). CEG has not published a report of its analysis but has made spread sheet workbooks containing the input and output data available to ESQUANT[1].

CEG provided data for A rated and BBB rated bonds for 28th February 2014, and supplied daily data for BBB-rated bonds, in respect of the period from 1st November 2013 to 28th February 2014. The CEG data was structured so as to form the most accurate proxy for the RBA data that could be obtained. ESQUANT has been able to verify the results obtained by CEG for 28th February 2014. In other words, using the data on individual bonds that has been provided, we have reproduced the results for the aggregate corporate bond spreads derived by CEG in the A-rated and BBB-rated credit bands (refer to Table 1 and to Table 2).

[1] The data supplied by CEG will be provided to the AER upon request, subject to confidentiality considerations governing, *inter alia*, the release of Bloomberg data.

1.2 Smoothing methods

A smoothing parameter, σ (sigma), is one of the components of the weighting function used in Gaussian kernel estimation. The RBA has set σ equal to 1.5, which is marginally away from the optimal value. The Gaussian kernel technique that has been used by the RBA is also described as local constant smoothing, because it gives rise to a locally weighted average of bond yields for each target term to maturity. ESQUANT contends that if a smoothing method is to be used, then there are advantages in using local linear smoothing (an alternative to local constant smoothing), particularly for estimating the spread at a maturity of ten years. The empirical work conducted by ESQUANT has shown that local constant smoothing is biased to first order when the effective tenor does not match the target tenor, whereas the local linear smoother corrects for this bias.

1.3 Nelson-Siegel models

An alternative to smoothing methods is to fit Nelson-Siegel yield curves to the data. Such curves show fewer discontinuities than those produced using smoothing methods and enforce some basic constraints from financial economic theory which the smoothing methods cannot do. An analysis of daily data from November 2013 to February 2014 shows that the Gaussian Kernel method gives negatively biased results, relative to the Nelson-Siegel results and those obtained by local linear smoothing.

1.4 Effect of Interpolating monthly estimates and selecting an averaging period

A time series, ARIMA model of the estimated spread at a 10-year term to maturity was determined from the daily results. The ARIMA model was fitted to the spreads-over-swap obtained using a number of estimation methods, including a Gaussian kernel (the RBA approach), local linear smoothing, Nelson-Siegel yield curves, and the extrapolated values of the Bloomberg BBB fair value curve. The longest time series of data available was for the Bloomberg BBB fair value curve, and the ARIMA model obtained had a significant integrated moving average component. An integrated moving average process represents time series observations for the spread-to-swap which are a weighted average of current and past random disturbances. A simulation was then undertaken, using the parameters from the fitted ARIMA model, but based on a draw of only one observation from every 20 (corresponding to one per month). A new ARIMA model was then fitted to the much shorter time series data, and it delivered a markedly different set of parameter estimates. The new parameter estimates gave a much higher weight to current values of the random disturbance in the integrated moving average process.

The implication of these findings is that values of the spread-to-swap from previous months are likely to be an unsatisfactory predictor of the spread-to-swap during the current month. If the cost of debt, evaluated as a margin over swap rates, is measured on a daily basis, then current values of the integrated moving average process have a 50% influence on current spread levels, whilst past values of the process also exert an influence which amounts to 50%. If, however, the Bloomberg fair value curve (or its successor, the Bloomberg BBB BVAL curve) were only released once a month, then current values of the integrated moving average process would have a 92% influence on current spread levels, whilst past values of the process would have a much lesser effect, amounting to 8%. Fair value spreads from, say, a period two months prior, would not serve as a useful guide as to current or recent values of the spread-over-swap. The AER has proposed to create a daily series by interpolating between consecutive end-of-month observations of the RBA's corporate bond spreads. However, there is no empirical justification for such an approach. The ARIMA models produced by ESQUANT suggest that the spreads-over-swap for, say, the month of March, cannot be inferred by taking an average of the results recorded at the end of January and at the end of February. Similarly, the spreads-over-swap in the middle of the month of March cannot be accurately estimated by taking an average of the spreads reported, respectively, at the end of February and at the end of March. There are substantial advantages in using daily data.

1.5 Using a third party service provider

Finally, we offer some comments on the arguments, advanced by the AER about the benefits of using a third party provider of financial data. ESQUANT considers that, even if a third party provider of data is used, consideration will still need to be given to the suitability of the results from the particular data source during the period for assessment of the cost of debt. In order to assess the results against market evidence, there will need to be an analysis of yield curves and averaging methods, while choices will have to be exercised about debt instruments and methods of handling the data. The third party provider may have different objectives to those of the AER and the results obtained for the cost of debt are heavily influenced by the sample chosen and the methods applied to that sample.

Declaration by Dr Neil Diamond and Professor Rob Brooks

We have made all the inquiries that we believe are desirable and appropriate, and no matters of significance that we regard as relevant have, to our knowledge, been withheld from the report.

2 TERMS OF REFERENCE: REVIEW OF RBA CORPORATE BOND SPREADS IN RESPONSE TO AER ISSUES PAPER ON THIRD PARTY DATA PROVIDERS

2.1 Background

In April 2014, the Australian Energy Regulator, (AER), published an Issues Paper in which it set out its considerations about the methods that it would employ to estimate the return on debt. The AER noted that there were aspects of the estimation of the spot cost of debt which hadn't been adequately addressed in the rate of return guideline. The AER therefore sought to explain:

- The attributes of the third party data series which are currently available to be used for estimating the return on debt. The available cost of debt information includes data series published by the Reserve Bank of Australia (RBA) and by Bloomberg.
- The particular matters that would need to be addressed if the RBA corporate bond spread series were to be used to estimate the return on debt. Those matters would include the interpolation of monthly estimates, and the selection of an averaging period over which the return on debt would be calculated.

The AER stated in its Issues Paper that it wasn't proposing to use a specific data series or source, rather the decision about the sources of information would be made at the time of a regulatory determination.

The RBA published its new measures of corporate bond spreads in December 2013, with data initially available up to November 2013. The RBA has also endeavoured to back-cast its data, with historical corporate bond spreads having been produced back to January 2005. An article in the Reserve Bank Bulletin serves to explain the methods that have been used to create the composite corporate bond spreads and yields. The data from the RBA is currently produced as a set of monthly figures, with daily data releases not yet available.

2.2 Replication of RBA component bond yield information

The Competition Economists Group, (CEG), has attempted to re-create the source data that the RBA has used to calculate its summary measures of corporate bond spreads. CEG has also sought to repeat the exercise undertaken by the RBA, and to compile aggregate corporate bond indices, stratified by broad credit rating class. CEG has followed the methods which have been documented by the RBA in the Bulletin article. CEG has provided the results of its empirical work to United Energy and Multinet Gas, and has also supplied data. A number of spread sheet workbooks from CEG will be made available to the consultant that is appointed to undertake the current assignment for UE and MG. In summary, the data from CEG is made up as follows:

- A spread sheet workbook with separate worksheets for each business day recorded over the period from 1st November 2013 until 28th April 2014.
- Each worksheet contains a list of bonds with unique identifiers. The list has been determined through a screening process, using the filtering criteria applied by the AER.
- The data available for the individual bonds includes credit rating, remaining term to maturity, the spreads over swap rates, and the face value of the bond (or the amount issued). Foreign currency bonds are included in the sample, with their spreads or option-adjusted spreads having been converted into Australian dollar equivalent spreads, after implementing the transformations that are documented in the Bulletin article.

- A fully worked example of the application of the Gaussian kernel method, using data from a single day, 28th February 2014. The example shows the weighted average spreads for BBB rated bonds at target tenors of 3, 5, 7 and 10 years. The effective tenors, corresponding to each of the four categories, are also shown.

2.3 Scope of work

There are three broad dimensions to the work to be undertaken:

1. The consultant should investigate the properties of the data that has been put together by the RBA, and consider whether the methods that have been applied are appropriate and fit-for-purpose.

2. The series of corporate bond spreads derived by the RBA should be compared with other proxy measures for the cost of debt. Specifically, the variables to be considered should be those that have been assembled and condensed into composite indices or curves that can be regarded as "third party sources of data". The comparisons should be based on methodological differences and empirical results.

3. Evaluate alternative techniques for determining the cost of debt for a benchmark corporate bond with a BBB credit rating from Standard and Poors. Consider methodological rigour and empirical tractability.

When performing tasks that fall under category (1) above, the main question to be addressed is whether the RBA corporate bond spread series is amenable to the task of producing an unbiased, objective estimate of the return on debt. The National Electricity Rules provide the over-arching framework, with the most pertinent clauses being 6.5.2 (a) to 6.5.2 (l). The allowed rate of return objective is paramount:

> The allowed rate of return is to be determined such that it achieves the allowed rate of return objective;

and

> The return on debt for a regulatory year must be estimated such that it contributes to the achievement of the allowed rate of return objective.

2.4 Timeframe

The consultant is to provide a draft report which discusses the results of the analysis by Wednesday 7th May 2014. A final report should be provided by no later than Wednesday 14th May.

2.5 Reporting

Jeremy Rothfield will serve as the primary contact for the period of the engagement. The consultant will prepare reports showing the work-in-progress on a regular basis. The consultant will make periodic presentations on analysis and advice as appropriate.

2.6 Conflicts

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

2.7 Compliance with the Code of Conduct for Expert Witnesses

Attached is a copy of the Federal Courts Practice Note CM 7, entitled "Expert Witnesses in Proceedings in the Federal Court of Australia", which comprises the guidelines for expert witnesses in the Federal Court of Australia (Expert Witness Guidelines). Please read and familiarise yourself with the Expert Witness Guidelines, and comply with them at all times in the course of your engagement with United Energy and Multinet Gas.

In particular, your report prepared for United Energy and Multinet Gas should contain a statement at the beginning of the report to the effect that the author of the report has read, understood and complied with the Expert Witness Guidelines.

Your report must also:

1. Contain particulars of the training, study or experience by which the expert has acquired specialised knowledge.

2. Identify the questions that the expert has been asked to address.

3. Set out separately each of the factual findings or assumptions on which the experts opinion is based.

4. Set out each of the expert's opinions separately from the factual findings or assumptions.

5. Set out the reasons for each of the expert's opinions; and

6. Otherwise comply with the Expert Witness Guidelines. The expert is also required to state that each of the experts opinions is wholly or substantially based on the experts specialised knowledge.

The declaration contained within the report should be 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 report."

Please also attach a copy of these terms of reference to the report.

2.8 Fees

The consultant is requested to submit:

- A fixed total fee for the project and hourly rates for the proposed project team should additional work be required; and

- Details of the individuals who will provide the strategic analysis and advice.

2.9 Contacts

Any questions regarding this terms of reference should be directed to: Jeremy Rothfield, telephone (03) 8846 9854, or via email at `Jeremy.Rothfield@ue.com.au`

3 Smoothing methods

3.1 Kernel smoothing

Kernel estimation is a semi-parametric regression technique which fits a different, but simple model separately at each "query point", x_0. A kernel method fits the simple model by using only those observations that are close to the target point x_0. The model, or models, are fitted in such a way that the resulting estimated function, $\hat{f}(X)$ is smooth over the domain of observations. The localization in kernel estimation is achieved via a weighting function or kernel $K_\lambda(x_0, x_i)$, , which assigns a weight to x_i based on its distance from x_0. The kernels, K_λ, are typically indexed by a parameter, λ, which dictates the width of the "neighbourhood". If $h_\lambda(x_0)$ is a width function (indexed by λ) that determines the width of the neighbourhood at x_0, then the kernel function can be written as:

$$K_\lambda(x_0, x) = \frac{D(\|x - x_0]\|}{(h_\lambda(x_0)}.$$

For a Gaussian kernel, $h_\lambda(x_0) = \lambda$ with λ equal to a constant.

The smoothing parameter, λ, which determines the width of the local neighbourhood, has to be determined. A large value for λ implies a lower variance (with λ averaging over more observations), but a higher bias (because we essentially assume that the true function is constant within the window).

The Gaussian kernel employs a density function, $D(t) = \phi(t)$, with the standard deviation playing the role of the window size. The Reserve Bank of Australia (RBA) has employed a Gaussian density function.

Following Arsov et al. (2013), the RBA's Gaussian kernel average credit spread at a target tenor T is given by

$$S(T) = \sum_{i=1}^{N} w_i(T;\sigma) S_i$$

where $w_i(T;\sigma)$ is the weight defined below, S_i is the observed spread for the ith bond, and

$$w_i(T;\sigma) = \frac{K(T_i - T;\sigma)F_i}{\sum_{j=1}^{N} K(T_j - T;\sigma)F_j}$$

where T_i is the tenor of the ith bond, F_i is the face value of the ith bond and $K(T_i - T;\sigma)$ is the Gaussian kernel given by

$$K(T_i - T;\sigma) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left[-\frac{(T_i - T)^2}{2\sigma^2}\right].$$

where σ is the standard deviation of the Gaussian (Normal) distribution used in the Gaussian kernel. The query point here is the target tenor.

This is a solution of a least squares problem given by

$$\min_{S(T)} \sum_{i=1}^{N} F_i K(T_i - T;\sigma) \left[S_i - S(T)\right]^2.$$

The derivative of the function with respect to $S(T)$ is given by

$$2 \sum_{i=1}^{N} F_i K(T_i - T;\sigma) \left[S_i - S(T)\right].$$

and setting this to zero

$$\sum_{i=1}^{N} F_i K(T_i - T;\sigma) S_i = S(T) \sum_{i=1}^{N} F_i K(T_i - T;\sigma)$$

leading to

$$\begin{aligned} S(T) &= \frac{\sum_{i=1}^{N} F_i K(T_i - T;\sigma) S_i}{\sum_{i=1}^{N} F_i K(T_i - T;\sigma)} \\ &= \sum_{i=1}^{N} w_i(T;\sigma) S_i \end{aligned}$$

as given by Arsov et al. (2013).

There has been a long history of using smoothing methods to estimate yield curves, following McCulloch (1971) who used polynomial splines[2] to model a discount function from which the yield curve can be determined[3]. One problem is that with polynomial splines the discount curve can diverge from zero at long maturities. This defect was remedied to some extent by Vasicek and Fong (1982), who used exponential splines and applied a negative transformation of maturity. The authors therefore ensured that forward rates and yields converge to a fixed limit as maturity increases. There are still problems, however, as the implied forward rates are not necessarily positive.

CEG provided data for A rated and BBB rated bonds for 28/02/14 and for each business day from 1/11/13 to 28/02/14 for BBB rated bonds. The data provided includes the daily spreads over swap rates, years to maturity of the sampled bonds and corresponding credit ratings. The CEG sample matched the sample used by the RBA as closely as possible. In addition to supplying data on individual bonds, CEG also supplied its Gaussian kernel calculations for a single date, 28th February 2014. CEG had worked out aggregate bond spreads at tenors of 3, 5, 7 and 10 years. Below we replicate within rounding error the CEG results.

The CEG sample for A rated bonds has 101 securities for 28/02/2014. Figure 1 gives a plot of the spread to swap for 28 February 2014 against the term to maturity for A rated securities as well as the fitted line using the RBA methodology with a Gaussian kernel smoother, with standard deviation of 1.5.

Table 1 gives a comparison of the RBA's estimates, those obtained by CEG, and those which we calculated. There is good agreement for all target tenors.

	3 years	5 years	7 years	10 years
RBA estimates				
February 2014	66.36	88.07	107.37	118.84
CEG replication				
February 2014	64.55	88.05	106.09	118.87
ESQUANT replication				
February 2014	64.4	88.04	105.99	118.81

Table 1: Comparison of spread to swap, A rated securities. Sources: ESQUANT; CEG calculations; RBA Statistical Table F3.

The CEG sample for BBB rated bonds has 62 securities for 28/02/2014. Figure 2 gives a plot of the spread to swap for 28 February 2014 against the term to maturity for BBB rated securities as well as the fitted line using the RBA methodology with a Gaussian kernel smoother, with standard deviation of 1.5.

Table 2 gives a comparison of the RBA's estimates, those obtained by CEG, and those which we calculated. There is good agreement for all target tenors.

3.1.1 Appropriate Value of σ

The technique of "cross-validation" is used to measure the predictive performance of a statistical model[4]. The dataset should be split into two parts, a "test set" (which is out-of-sample) and a "training set" which is in-sample. The model is developed using the training set, and assessed using the test set, with the predictive accuracy measured by the mean squared error (MSE) over the latter. The

[2]A polynomial spline is a piecewise polynomial over the range of the data. The range of the data is divided into a set of continuous intervals and in each interval a polynomial of some degree is fitted. Usually, a requirement of continuity is specified while the most often used case, the cubic spline, also has continuous first and second degree derivatives.

[3]A discount function describes the present value of $1.00 repayable in m years. The discount function is continuously differentiable and is monotonically decreasing, that is, it is downwards sloping with the present value of one dollar shown on the y-axis, and years to maturity presented on the x-axis.

[4]Model fit statistics are not always a reliable guide as to how well a model will predict. A high R^2 need not necessarily imply that the model is good.

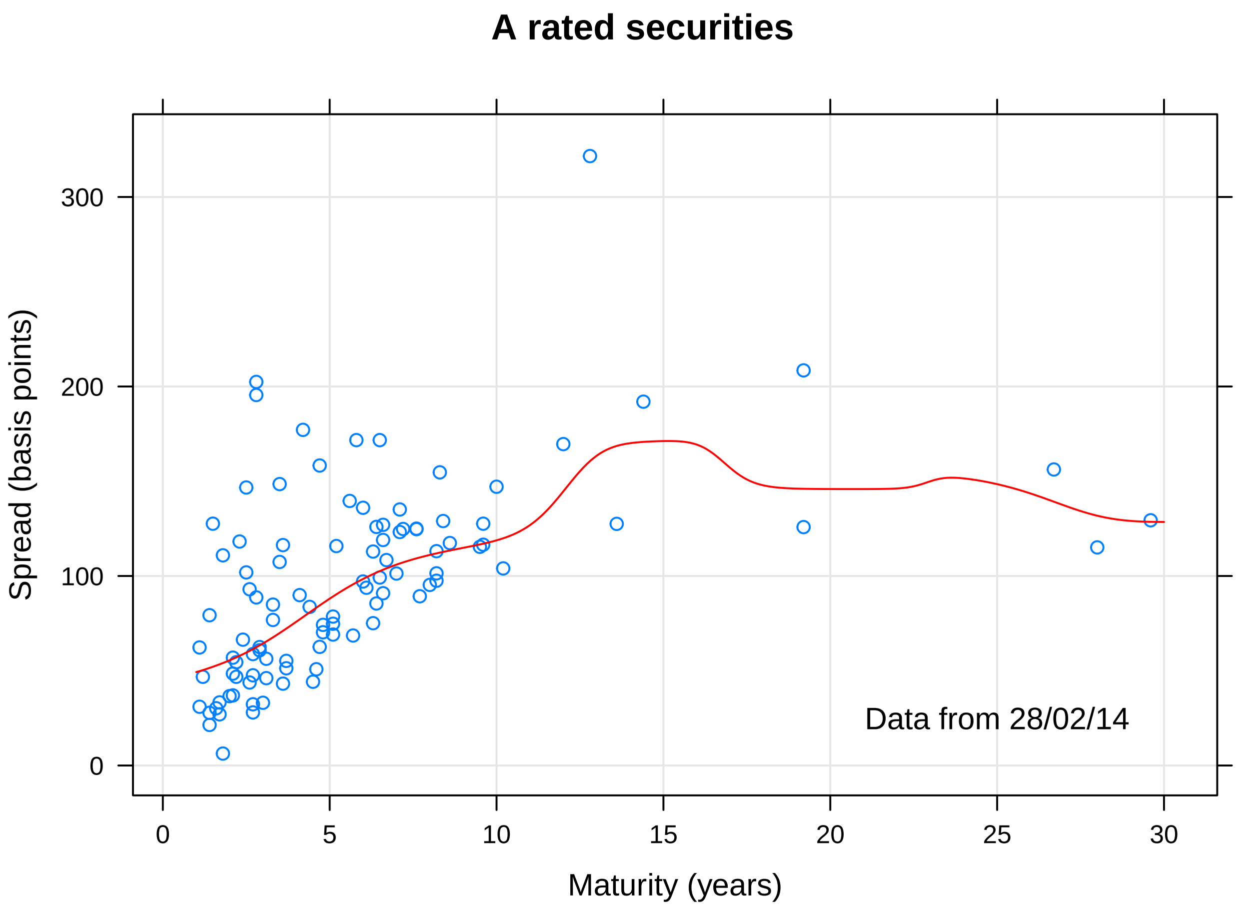

Figure 1: Spreads to swap for A rated securities with smoothing line using RBA methodology.

	3 years	5 years	7 years	10 years
RBA estimates				
February 2014	162.09	181.58	214.57	257.64
CEG replication				
February 2014	156.99	180.63	213.54	255.75
ESQUANT replication				
February 2014	156.77	180.52	213.69	255.35

Table 2: Comparison of spread to swap, BBB rated securities. Sources: ESQUANT; CEG calculations; RBA Statistical Table F3.

MSE inferred from the test data will generally be larger than the MSE derived using the training data, because the test data were not used for estimation.

Leave-one-out cross-validation (LOOCV) is a form of predictive testing in which the accuracy measures are obtained using the following method. Consider the n independent observations, $y_1, \ldots, y_n$.

- Let observation i form the test set, with the model to be fitted using the remaining data. An error term is computed for the omitted observation, $e_*^i = y_i - \hat{y}_i$. The error term is sometimes described as a "predicted residual" so as to distinguish it from an ordinary residual.
- The previous step is then repeated n times for each observation in the dataset, $i = 1, \ldots, n$.
- The mean-squared error (MSE) is then calculated using the results $e_*^1, \ldots, e_*^n$. The result for the MSE is referred to as the CV.

The method of leave-one-out cross validation makes efficient use of the available data because only

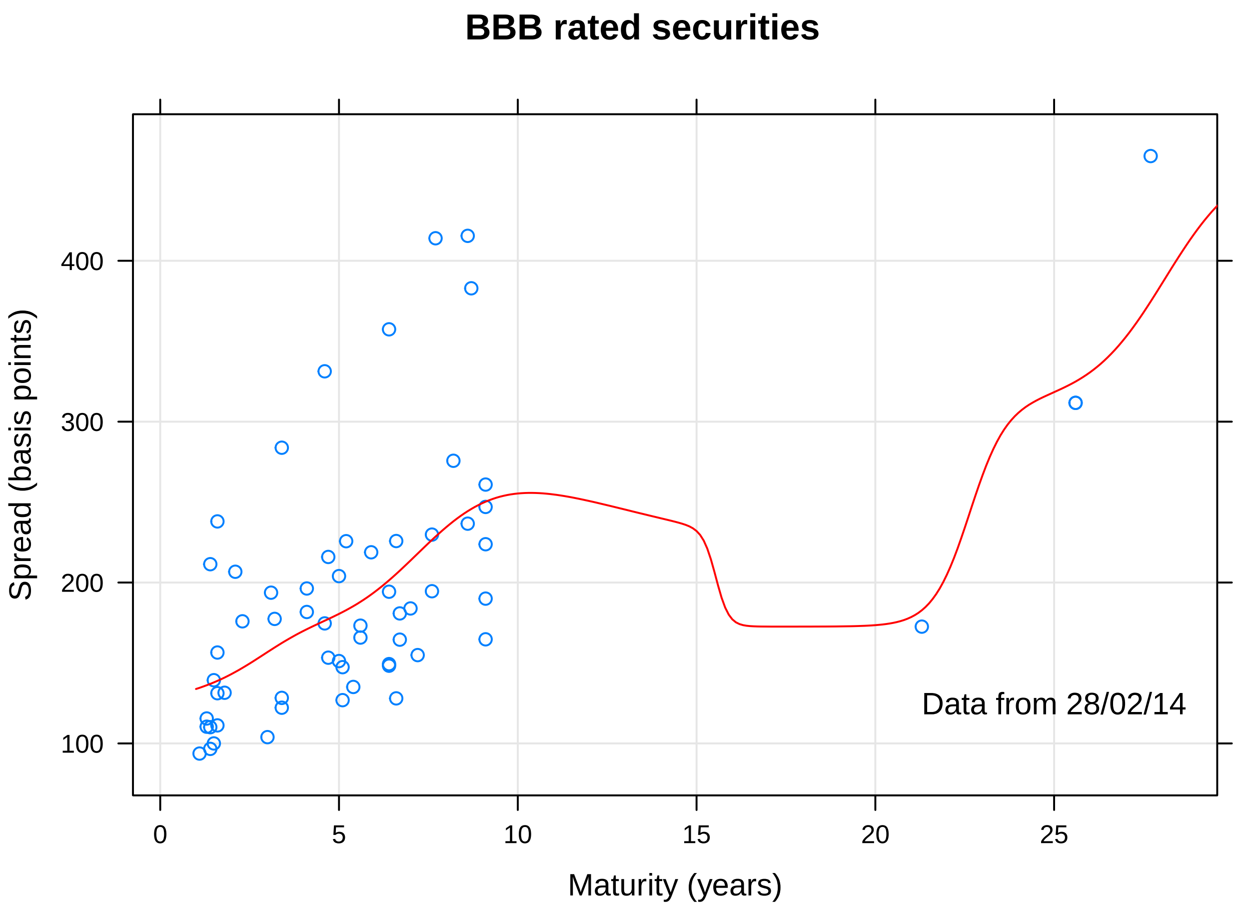

Figure 2: Spreads to swap for BBB rated securities with smoothing line using RBA methodology.

one observation is omitted at each step[5].

The RBA uses a Gaussian Kernel with $\sigma = 1.5$. LOOCV can be adapted to the task of determining an appropriate value for σ. In the current context, the cross validation error is given by

$$CV(\hat{f}_\sigma) = \frac{1}{N}\sum_{i=1}^{N}(y_i - \hat{f}_\sigma^{(-i)})^2.$$

where $\hat{f}_\sigma^{(-i)}$ is the estimated ith spread where the smoothing is done without the ith value included. Figures 3 and 4 give the plots of the cross validation error against σ, for A rated and BBB rated securities respectively, showing that the optimal value of sigma for A rated securities is $\sigma = 2$, on 28/02/2014, while the optimal value of sigma for BBB rated securities is $\sigma = 1.1$ on the same date. When bonds with a remaining term to maturity greater than 15 years are removed from the calculation of the cross-validation error, the optimal value of sigma for A rated securities is $\sigma = 1.8$, while the optimal value of sigma for BBB rated securities is $\sigma = 1.3$. All of these values are close to the value of $\sigma = 1.5$, chosen by the RBA.

3.1.2 Bias of the Local Constant Smoother

It should be pointed out that the model underlying the kernel estimator is that the local relationship is that of a constant. In other words, the Gaussian kernel estimator assumes that the relationship between the spread to swap and the remaining term to maturity of a bond is constant at each of the target tenors, and in the vicinity of each of the target tenors (3, 5, 7, and 10 years).

[5]Hastie et al. (2009) discuss leave-one-out cross-validation, see pages 160-161.

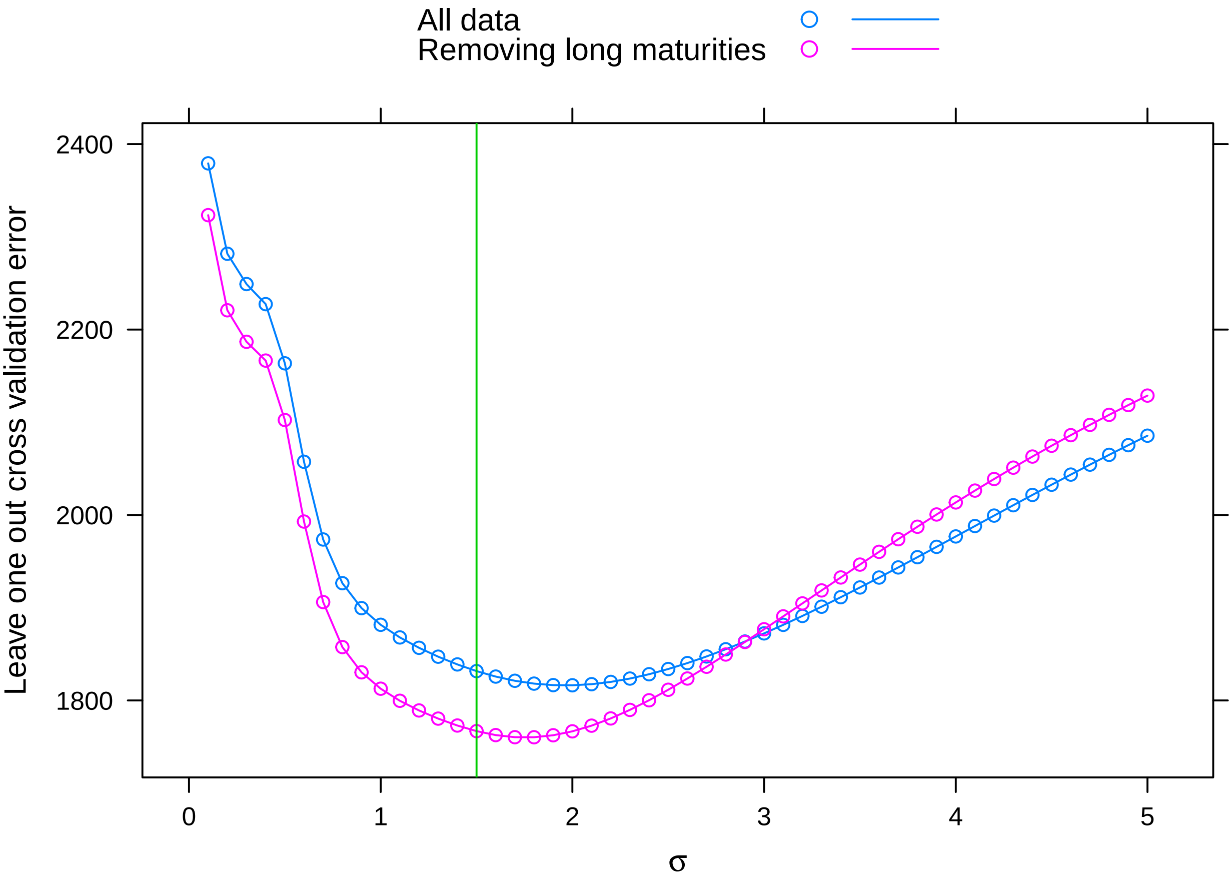

Figure 3: Leave one out cross validation error for A rated securities.

A problem with local constant smoothing is that there is bias at the boundaries, and this bias is apparent in Figure 2 above. Over much of the domain, the smooth fitted curve captures the main trend of the data, as is required. However, at the boundary regions, the curve will over- or under-estimate the spread to swap for bonds within a particular range of term to maturity. Therefore, when the Gaussian kernel estimate is applied at the right hand side boundary, at a target tenor of ten years, most of the observations used to construct the weighted average have a remaining term to maturity of less than ten years, and, correspondingly, the slope of the true relation induces boundary bias into the estimate of the spread to swap.

The RBA has itself acknowledged that there are problems at the boundaries. In commenting on the shape of the Australian, non-financial, credit spread curve, the Bulletin article (Arsov et al., 2013) reports that:

> “Overall, the Gaussian kernel method produces weighted average tenors that are very close to each of the target tenors (Graph 11). . . . The exception is the 10-year tenor where the effective tenor is closer to 9 years. This reflects the dearth of issuance of bonds with tenors of 10 years or more. Notwithstanding the slightly shorter effective tenor for the 10-year point, the estimates of the 10-year spread from the Gaussian kernel are distinct from the estimates of the 9-year spread as the two are estimated by applying different weights to the bonds in the sample.”

Hastie et al. (2009, pp 194-195) acknowledge that local constant smoothing may be subject to problems. They note that:

> “Locally weighted averages can be badly biased on the boundaries of the domain because of the asymmetry of the kernel in that region.”

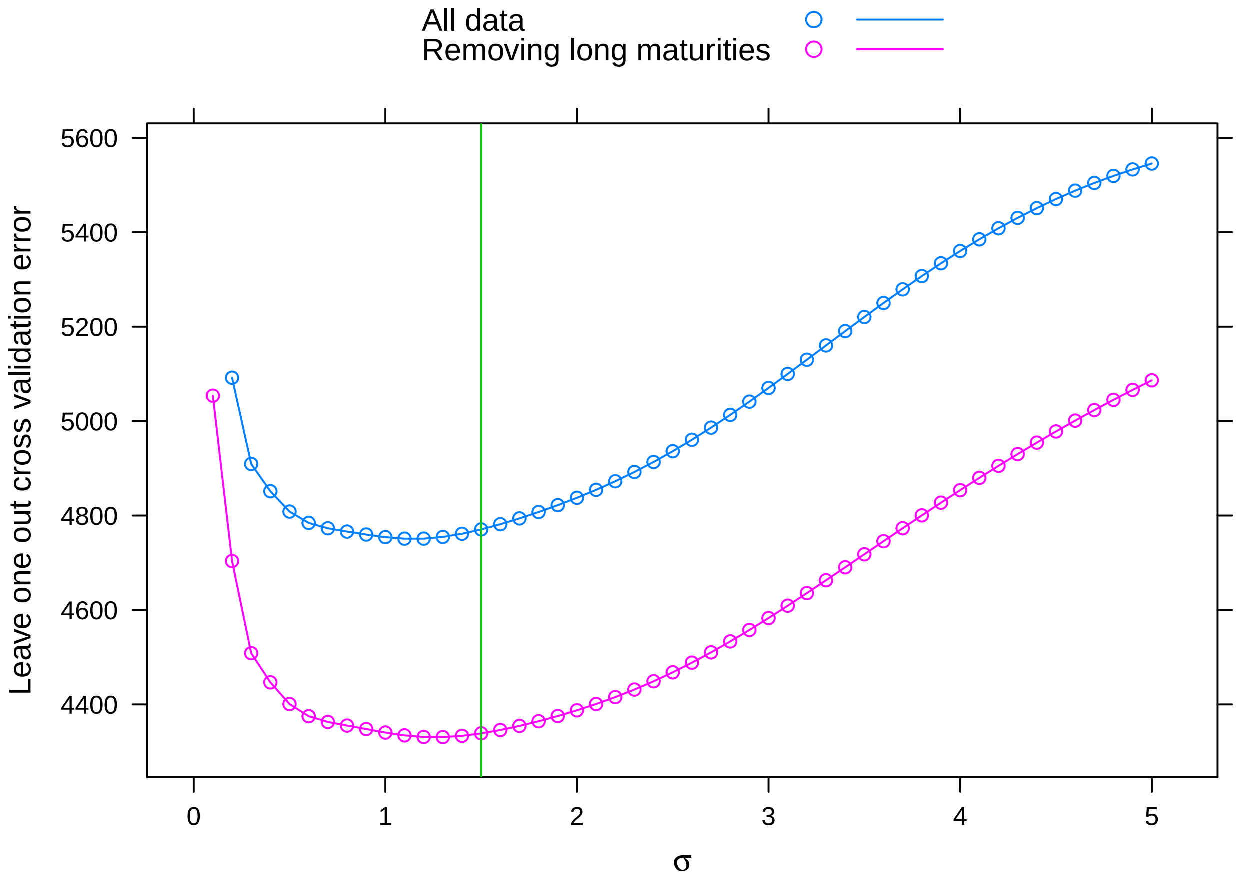

Figure 4: Leave one out cross validation error for BBB rated securities.

The authors report further that a bias may also be present in the interior of the domain, if the X values are not equally spaced. The bias also occurs because of the asymmetry of the kernel, but is generally less severe. The authors state further that by fitting straight lines rather than constants locally, then the bias can be remedied to first order. Locally weighted linear regression is the technique used to make a first order correction.

Let the true spread curve be $G(t)$ with derivative $g(t)$, where t denotes a term to maturity. The expected value of the local constant smoother at the target maturity T is given by

$$\begin{aligned} E[S(T)] &= \sum_{i=1}^{N} w_i(T;\sigma)G(T_i) \\ &= \sum_{i=1}^{N} w_i(T;\sigma)\left(G(T) + (T_i - T)g(T) + \text{higher order terms}\right) \\ &= G(T)\sum_{i=1}^{N} w_i(T;\sigma) + \sum_{i=1}^{N} w_i(T;\sigma)\,(T_i - T)\,g(T) + \text{higher order terms} \\ &= G(T) + \sum_{i=1}^{N} w_i(T;\sigma)\,(T_i - T)\,g(T) + \text{higher order terms} \\ &= G(T) + (\text{Effective Tenor} - \text{Target Tenor}) \times g(T) + \text{higher order terms} \end{aligned}$$

Hence the bias (to first order) is given by

$$(\text{Effective Tenor} - \text{Target Tenor}) \times (\text{Slope at Target Tenor})$$

The RBA estimate will be biased unless the Effective Tenor matches the Target Tenor or the slope of the spread curve at the target tenor is zero. For each target tenor in the RBA series, the effective tenor does not match the target tenor. By way of example, consider the result for the 10-year spread over swap as at the end of February 2014. The RBA has reported that the spread is 257.64 basis points for BBB-rated securities; however the effective tenor is shown to be 8.43 years (which is somewhat below 10 years).

In comparing the use of the RBA corporate bond index, for BBB-rated securities, with the Bloomberg BVAL curve for BBB bonds, which requires extrapolation from 7 years to 10 years maturity, the AER has stated (AER, 2014)[6]:

> In contrast, the RBA currently publishes a series with a 10 year term which would not require extrapolation.

The previous result for the bias of the Gaussian kernel smoother, demonstrates that the AER's assertion is not correct. Some adjustment is required to the RBA estimates at 10 years because of the mis-match between the effective tenor and the target tenor of 10 years.

3.2 Local Linear Smoothing

As indicated above, to overcome the bias, Hastie et al., (2009, p 198), show that local linear or quadratic smooths are superior to local constant smooths:

> "To summarise some collected wisdom on the issue:
>
> - Local linear fits can help reduce bias dramatically at the boundaries at a modest cost in variance. Local quadratic fits do little at the boundaries for bias, but increase the variance a lot.
> - Local quadratic fits tend to be most helpful in reducing the bias due to curvature in the domain."

Local linear regression is similar to local constant smoothing with a slightly different least squares problem to be solved. In local linear regression, the least squares problem is

$$\min_{\alpha(T),\beta(T)} \sum_{i=1}^{N} F_i K(T_i - T; \sigma) \left[S_i - \alpha(T) - \beta(T)T\right]^2$$

and the estimate is given by $S(T) = \alpha(T) + T\beta(T)$. For local linear regression, it remains the case, in the current analysis, that:

$$K(T_i - T; \sigma) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left[-\frac{(T_i - T)^2}{2\sigma^2}\right].$$

In Appendix A, we show algebraically that the spread at a target tenor, $S(T)$, is equal to a weighted average of the spreads of the component bonds. This is consistent with the proposition that has been advanced for local constant smoothing. In other words:

$$S(T) = \sum_{i=1}^{N} w_i(T; \sigma) S_i$$

but the weights are calculated differently with

$$w_i(T; \sigma) = \frac{K(T_i - T; \sigma) F_i (C - TB) + K(T_i - T; \sigma) F_i T_i (TA - B)}{AC - B^2}$$

[6] AER(2014), Section 4.3.

where

$$
\begin{aligned}
A &= \sum_{i=1}^{N} K(T_i - T;\sigma) F_i \\
B &= \sum_{i=1}^{N} K(T_i - T;\sigma) F_i T_i \\
C &= \sum_{i=1}^{N} K(T_i - T;\sigma) F_i T_i^2
\end{aligned}
$$

Appendix A also shows that

$$\sum_{i=1}^{N} w_i(T;\sigma) = 1$$

and

$$\sum_{i=1}^{N} (T_i - T) w_i(T;\sigma) = 0. \qquad (1)$$

Equation 1 is a formulation which shows deviations from a target tenor. For a target tenor, T, the weighted sum of the differences between the tenors of individual bonds, i, and the target tenor, should be equal to zero. The weights are as determined by local linear smoothing.

3.2.1 Bias of the Local Linear Smoother

Let the true spread curve be $G(t)$ with derivative $g(t)$, where t denotes a term to maturity. The expected value of the local linear smoother at the target maturity T is given by

$$
\begin{aligned}
E[S(T)] &= \sum_{i=1}^{N} w_i(T;\sigma) G(T_i) \\
&= \sum_{i=1}^{N} w_i(T;\sigma) \left(G(T) + (T_i - T) g(T) + \text{higher order terms} \right) \\
&= G(T) + \sum_{i=1}^{N} w_i(T;\sigma) \left(T_i - T \right) g(T) + \text{higher order terms} \\
&= G(T) + 0 g(T) + \text{higher order terms} \\
&= G(T) + \text{higher order terms}
\end{aligned}
$$

Hence, when measured to first order, the local linear smoother is unbiased. This unbiasedness is irrespective of whether the effective tenor matches the target tenor.

3.3 Comparison of Local Constant Smoothing to Local Linear Smoothing

The RBA has used a Gaussian kernel (local constant) smoother with $\sigma = 1.5$. There are advantages in using a local linear smoother. In this section, the appropriate value of σ for local linear smoothing is established.

The Gaussian kernel smoothers displayed in Figures 1 and 2 are relatively straight over the term to maturity range of 1 to 10 years. The smoothest curve possible is a straight regression line between the spread-to-swap and the remaining term to maturity, which has two degrees of freedom - one for the intercept and one for the slope. On the other hand, a curve with the least degree of smoothness would be an interpolating curve, which has N degrees of freedom - one for each of the data points. Clearly, the degrees of freedom for the smoothing lines shown in Figures 1 and 2 are somewhere between 2 and N.

Consider the $N \times N$ matrix S_σ, the ith row of which consists of the weights $\{w_i(Ti;\sigma), i = 1, \ldots, N\}$ for the target tenor given by $T_i, i = 1, \ldots, N$. Hastie et al. (2009, pp 153-154) define the effective degrees of freedom as the trace (the sum of the diagonal elements) of S_σ. Considering only bonds over the interval of 1 to 10 remaining years to maturity, the Gaussian kernel smoother has effective degrees of freedom of 3.89 for A rated securities and 2.79 for BBB rated securities.

For the local linear smoothers, numerical methods were used in order to determine the appropriate value of σ for the effective degrees of freedom to be the same as for the Gaussian kernel smoothers. For A rated securities, σ needs to be 2.26 for the effective degrees of freedom to be 3.89, while for BBB rated securities, σ needs to be 2.39 for the effective degrees of freedom to be 2.79.

In order to remove the variability that can be explained by the different credit ratings, the backfitting algorithm given by Hastie et al. (2009, p 297-298) was used to determine adjusted spreads. Using these spreads should improve the estimation of the smoother.

The steps of the backfitting algorithm are as follows:

1. Calculate the average spread across the whole sample and subtract the result from all of the data.

2. Set "oldd"=0 and "olds"=0. These are vectors of the adjustments for the credit ratings and the corrected smoothed value respectively.

3. Cycle the following steps until convergence:

   (a) Fit a linear model of (demeaned Credit Spread from step 1 minus olds) versus Credit rating. Save the demeaned fitted values and call them "newd".

   (b) Fit a smoother (We used the Gaussian kernel smoother with a standard deviation of 1.5) to the (demeaned Credit Spread minus oldd) versus Term to Maturity. Save the demeaned fitted values and call them "news".

   (c) Set oldd=newd and olds=news.

It only takes a small number of iterations for the algorithm to converge to a solution. The adjusted spreads are given by the (average spread − oldd).

Figures 5 and 6 show, for A rated securities and BBB rated securities, respectively, the adjusted spreads versus term to maturity as calculated by the backfitting algorithm.

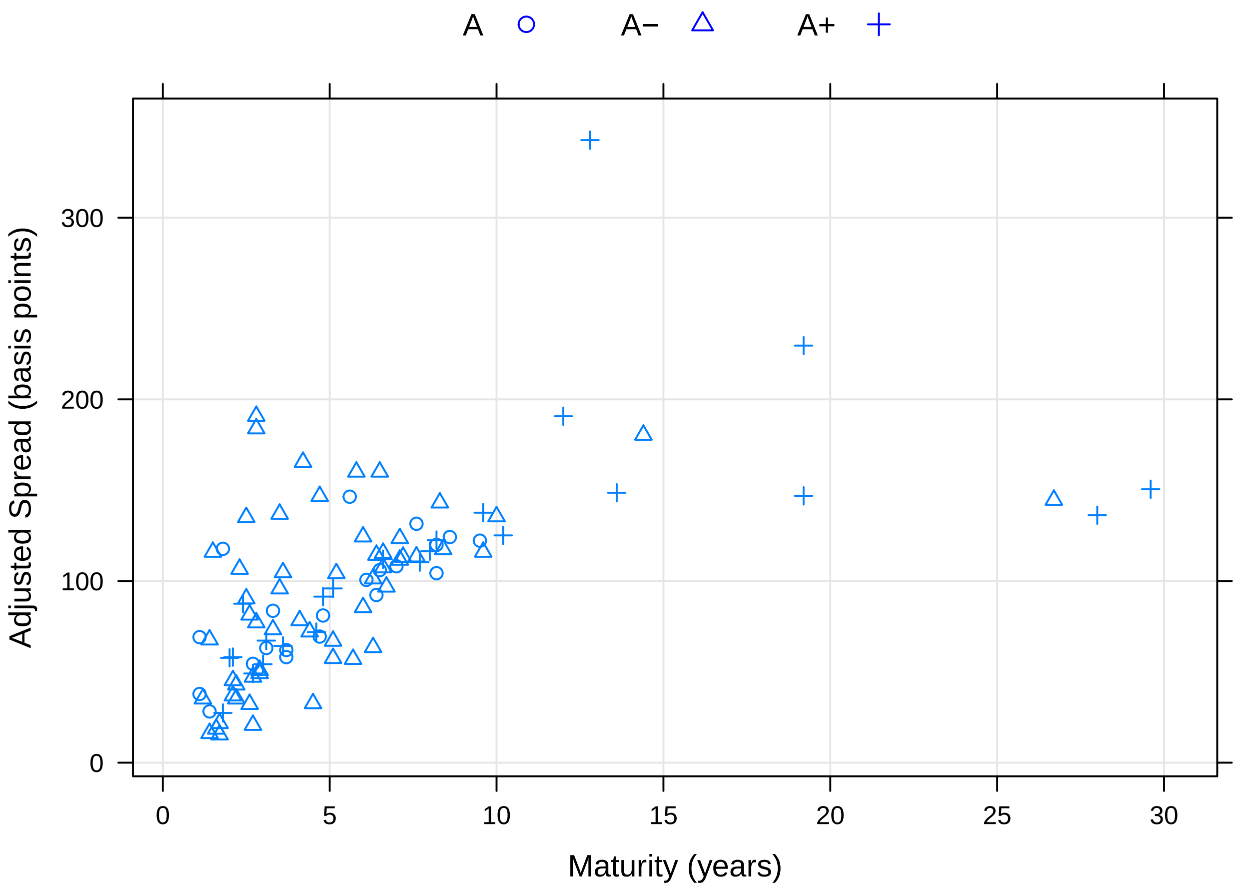

Figure 5: Adjusted spreads versus remaining term to maturity for A rated securities.

Using the adjusted BBB spreads, Figure 7 gives the estimated spread at 10 years maturity using the Gaussian kernel smoother, the local linear smoother using all the data, and the local linear smoother dropping long maturity securities (those with maturity greater than 15 years). Note that the Gaussian kernel smoother is not affected by dropping long maturity securities, while the local linear smoother is only affected if $\sigma > 1.5$.

Examination of the figure reveals the following insights:

- The removal, from the sample, of the long maturity bonds has only a minimal effect on the results from the local linear smoother.
- For values of σ greater than 1.5, the Gaussian kernel smoother gives lower estimates than the local linear smoother.
- The Gaussian kernel smoother is relatively insensitive to the value of σ.

Figures 8 and 9 give a comparison of the Gaussian kernel smoother and local linear smoother for A rated and BBB rated securities, respectively. The bias of the Gaussian kernel smoother is apparent for short maturities and at maturities in the vicinity of 10 years.

In conclusion, the analysis which has been undertaken in this section using bond spreads (over swaps), which have been controlled for differences in credit rating, has demonstrated that the Gaussian kernel method produces results for the spread-to-swap at 10 years which are below the results obtained from the application of local linear smoothing.

The empirical work has been performed using bond spread data for a single day (28th February 2014), however the RBA has also computed its results for February for a single day, probably also 28th February.

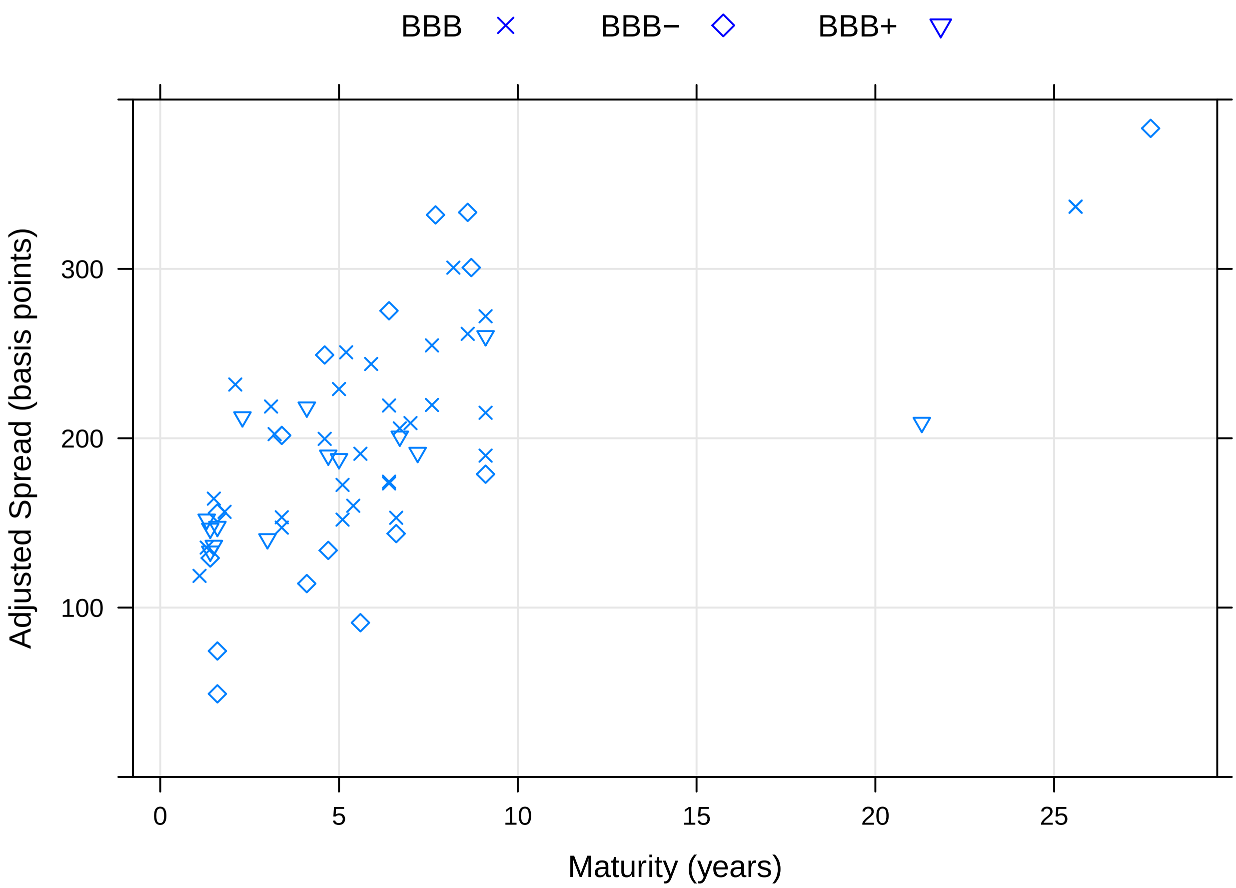

Figure 6: Adjusted spreads versus remaining term to maturity for BBB rated securities.

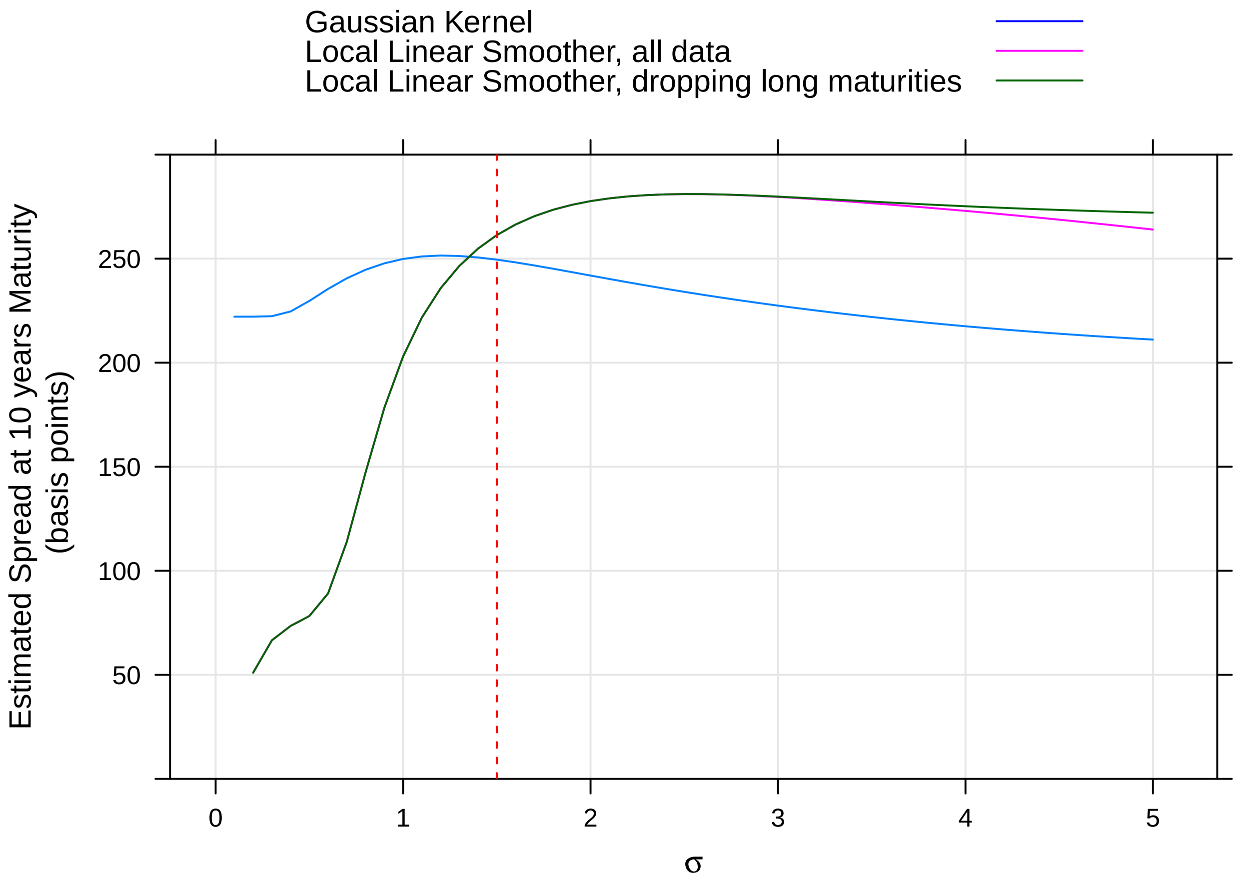

Figure 7: Estimated spread-to-swap at 10 years maturity for BBB bonds using various smoothing methods and values of σ.

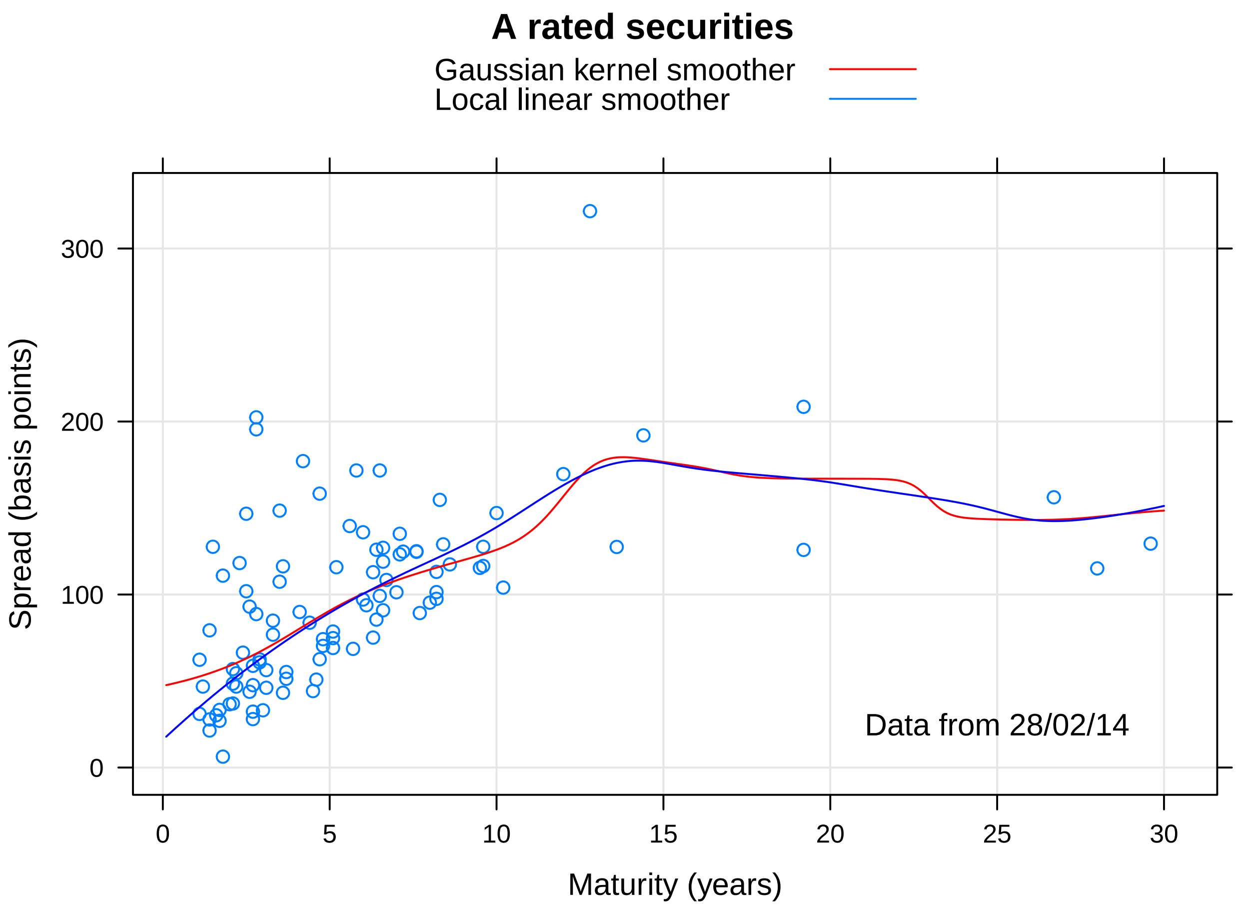

Figure 8: Spreads to swap for A rated securities with smoothing line using Gaussian kernel smoothing and local linear smoothing on adjusted spreads. Note: The fit of the smoothers has been controlled for the different credit ratings within the A band (A-, A, A+).

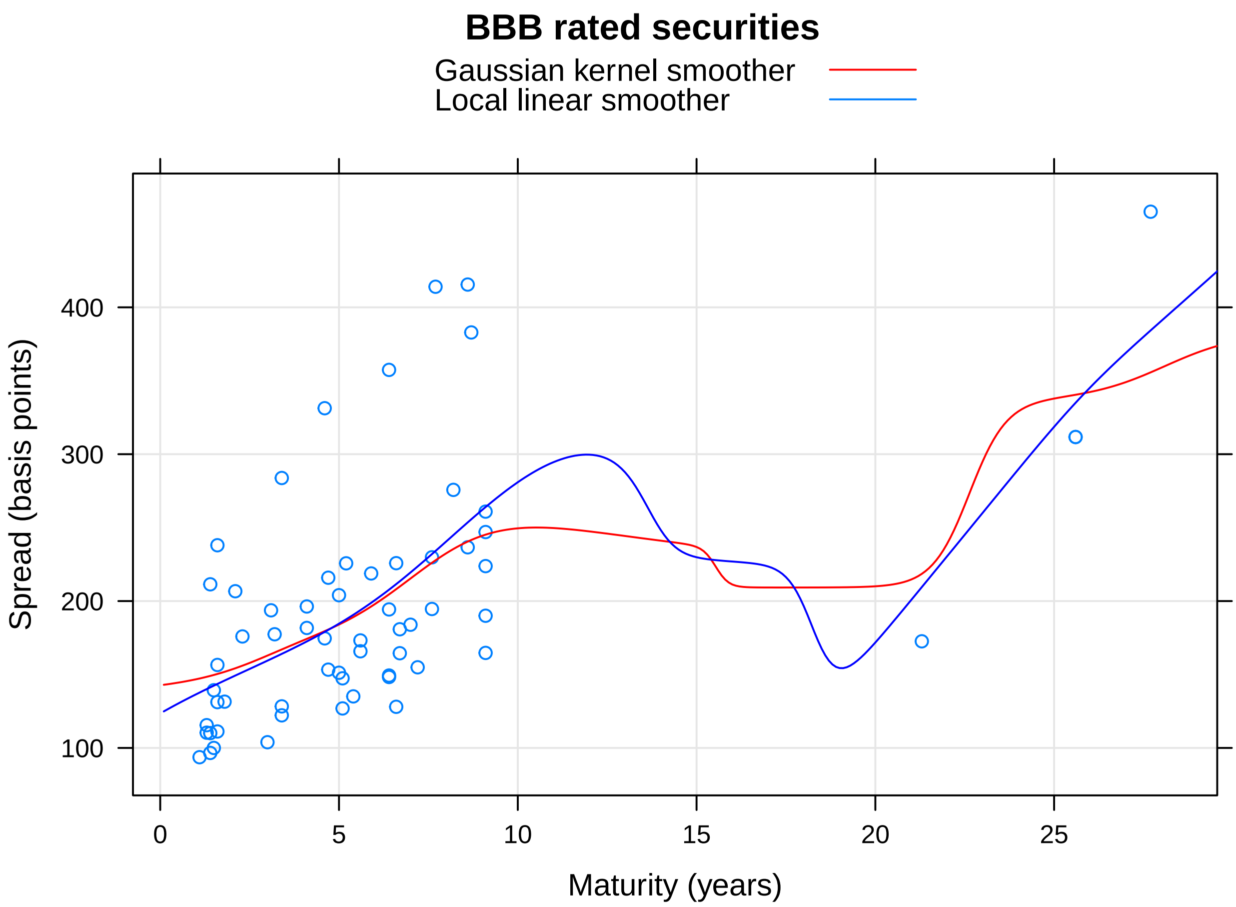

Figure 9: Spreads to swap for BBB rated securities with smoothing line using Gaussian kernel smoothing and local linear smoothing on adjusted spreads. Note: The fit of the smoothers has been controlled for the different credit ratings within the BBB band (BBB-, BBB, BBB+).

3.4 Nelson-Siegel Models

Non-parametric methods, such as the kernel smoothing method proposed by the RBA (Arsov et al., 2013) do not assume a functional form for the relationship between the dependent variable and the independent variable, in this case the average bond spread and term to maturity, respectively. Generally, non-parametric methods are not as precise as parametric methods but they do avoid the possible bias that can occur if the assumed parametric model is incorrect (See, for example, James et al., 2013, p 23).

The most commonly used parametric technique is that due to Nelson and Siegel (1987). The Nelson-Siegel model is non-linear and must generally be estimated using the method of maximum likelihood. Arsov et al. (2013) report difficulties with fitting the Nelson-Siegel model. Annaert et al. (2013) explain methods which can be used to help overcome these computational problems.

In separate exercises, CEG (Hird, 2013) and ESQUANT (Diamond et Brooks, 2013b) have successfully estimated Nelson-Siegel yield curves for large groups of corporate bonds in credit rating bands from A minus to BBB. The data samples were comprised of bonds issued by Australian corporations in Australian dollars and in foreign currencies, as well as Australian dollar bonds placed in the domestic market by foreign corporations. Fixed rate, bullet bonds were considered, as were bonds with optionality features, and floating rate notes. A number of different specifications of the Nelson-Siegel curve were trialled.

The Nelson-Siegel model (Nelson and Siegel, 1987) relates the expected yield of a bond, $R(m)$, to its remaining term to maturity, m, as

$$R(m) = \beta_0 + (\beta_1 + \beta_2)\left(\frac{1 - \exp(-m/\tau)}{m/\tau}\right) - \beta_2 \exp(-m/\tau)$$

where $\tau, \beta_0, \ldots, \beta_2$ are parameters to be estimated. The parameter τ is described as the shape parameter, with its value sometimes motivated by prior knowledge about the curvature of spot rates.

Diebold and Li (2006) suggest an alternative parameterization:

$$y(\tau) = \beta_1 + \beta_2\left(\frac{1 - e^{-\lambda\tau}}{\lambda\tau}\right) + \beta_3\left(\frac{1 - e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau}\right)$$

where $y(\tau)$ is the expected yield of a bond with maturity τ, β_1 is interpreted as the loading on the "long-term" factor, β_2 is interpreted as the loading on the "short-term" factor, and β_3 is interpreted as the loading on the "medium-term" factor.

The equivalence between the two specifications are given below:

Nelson-Siegel	Diebold and Li
$R(m)$	$y(\tau)$
β_0	β_1
β_1	β_2
β_2	β_3
m	τ
τ	$\frac{1}{\lambda}$

Note that τ is used as a parameter in the Nelson and Siegel formulation but as the Maturity in the Diebold and Li formulation.

Diebold and Li's (2006) specification can be written as a function of three components, F_1, F_2, and F_3, called the 'long-term', 'short-term', and 'medium-term' components with

$$\begin{aligned} y(\tau) &= \beta_1 F_1 + \beta_2 F_2 + \beta_3 F_3 \\ F_1 &= 1 \\ F_2 &= \left(\frac{1 - e^{-\lambda\tau}}{\lambda\tau}\right) \\ F_3 &= \left(\frac{1 - e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau}\right) \end{aligned}$$

Diebold and Li (2006) suggest that, if the maturity is measured in months, that λ be set at 0.0609, since at that value the medium term factor (denoted by F_2) is at a maximum when the maturity is 30 months[7]. Diebold and Li (2006) stated that most of the humps and troughs in the spot rate function are between the second and third years. Fixing λ allows the Nelson-Siegel model to be fitted by Ordinary Least Squares.

If λ is estimated, then non-linear least squares is required. Figures 10 and 11 give the fitted Nelson-Siegel curves for A rated and BBB rated securities, respectively. Both curves were estimated using the `nlsLM` command in the `minpack.lm` (Elzhov et al. 2013) package in R. The curves were fitted to yield data rather than to the spreads-to-swap data that was provided by CEG. In order to obtain yields, swap rates with a commensurate term to maturity were added to the spread-over-swap for each bond. The swap rates for specific tenors were themselves calculated by applying an interpolation method to

[7] Dr Li has confirmed that the correct number should be 0.0598, rather than the value 0.0609 quoted in the paper and the following literature. For daily data, the maximum was in fact 0.001964-this was rounded to 0.002. Multiplying 0.002 by 365.25/12, the value 0.0609 was obtained. For maturities measured in years the implied value of λ is 0.7176 using the correct 0.0598.

the observed data on vanilla interest rate swaps (as reported by Bloomberg)[8]. When the yields had been calculated, the Nelson-Siegel curve could then be econometrically estimated. Thereafter, the fitted values for yield at a 10-year tenor could be converted back into spreads-to-swap by subtracting 10-year tenor swap rates from the predicted yields.

Annaert et al. (2013) discuss and apply particular methods which can assist in overcoming estimation difficulties associated with Nelson-Siegel yield curves. The authors integrated grid search methods with a conditional ridge regression. They followed Nelson and Siegel (1987) by combining a grid search with an OLS regression so as to free up the shape parameter. Conditional on the value of λ that gave rise to the highest value of R^2, the parameters were then re-estimated by using ridge regression whenever the degree of multi-collinearity among the regressors was deemed to be too high.

There are many advantages in using the Nelson-Siegel curves by comparison with the alternative of applying kernel smoothing methods:

- The formulation provides a parsimonious approximation (Diebold and Rudebusch, 2013).
- Empirically, the Nelson-Siegel formulation is simple and stable to estimate (Christensen et al., 2011).
- The curve is quite flexible and fits both the cross section and time series of yields remarkably well, in many countries and periods, and for many grades of bonds (Christensen et al., 2011); and
- The curve forecasts well. Theoretically, for example, the Nelson-Siegel functional form imposes economically desirable properties, such as requiring the discount function to approach zero with maturity, while the dynamic Nelson-Siegel can be shown to correspond to a modern, linear three-factor model with level, slope and curvature factors. (Diebold and Rudebusch, 2013).

4 Comparison of results over time

CEG supplied a dataset for each day over the period 1/11/13 to 28/02/14. In this section I have used the Gaussian kernel smoother, the local linear smoother and the Nelson-Siegel model to predict the spread at 10 years maturity for each day. The models were fitted to the samples of BBB rated bonds provided by CEG. Recall that the samples were chosen to “mimic” those that would be compiled by the RBA.

Figure 12 presents a comparison of the estimated spreads at 10 years maturity using a Gaussian kernel smoother with $\sigma = 1.5$, a local linear smoother with $\sigma = 2.4$, and Nelson-Siegel estimates using all of the data. In addition, there are separate sets of Nelson-Siegel estimates which result, alternately, from the removal of an outlying bond[9], and from the elimination from the sample of “long maturity” bonds. Long maturity bonds are those with a remaining term to maturity in excess of 15 years. The figure shows that:

- The Gaussian kernel smoother estimates are lower than all of the other estimates.
- The Nelson-Siegel estimates are sensitive to the inclusion of the outlying bond and/or the long maturity bonds. The estimates for the spread-to-swap at 10 years change according to whether or not bonds in these categories are included. The daily data samples provided by CEG do not contain many bonds with a term to maturity in excess of 15 years, and this may partly be a consequence of the filtering criteria (attributable to the RBA) that CEG applied.
- The local linear smoother gives results that are similar to the estimates provided by the Nelson-Siegel approach when long maturity bonds are excluded.

---

[8]For the period under consideration, daily values of swap rates were obtained for the Australian dollar swaps curve. The relevant series in Bloomberg includes, as its constituents, variables such as “ADSWAP10 Curncy”.

[9]This bond had a spread of 172.62 basis points and a maturity of 21.29 years as at 28/02/14.

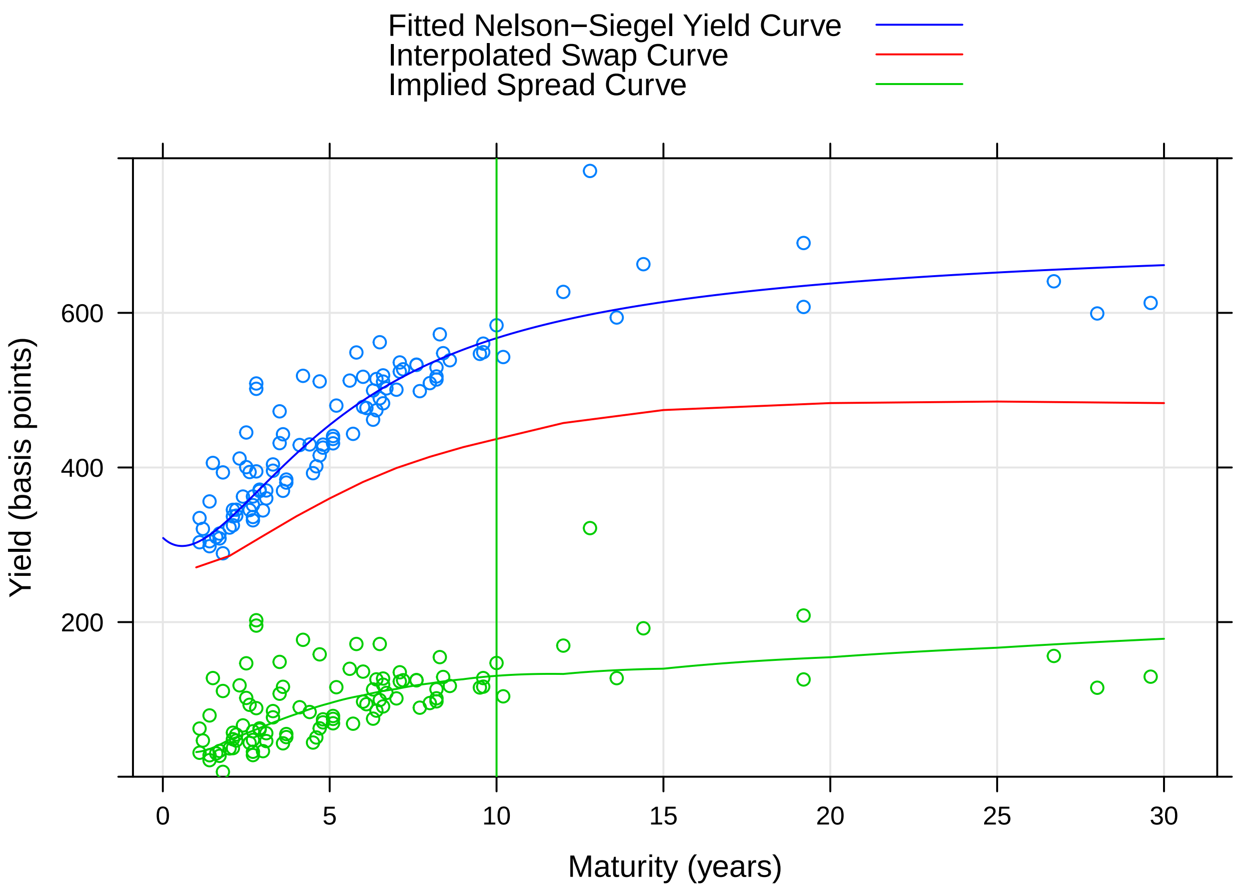

Figure 10: Yields versus Term to Maturity for A rated securities and fitted Nelson-Siegel curve, as at 28/02/2014.

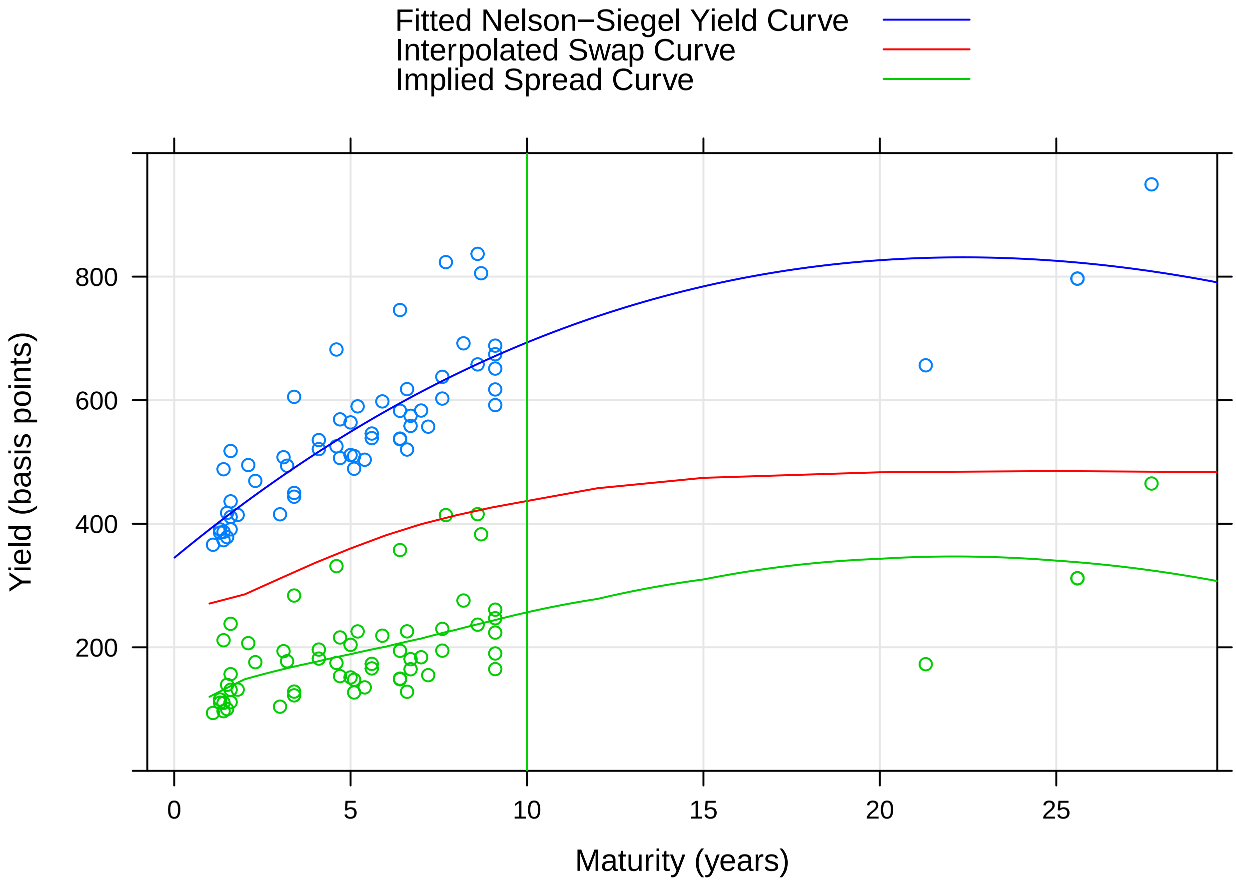

Figure 11: Yields versus Term to Maturity for BBB rated securities and fitted Nelson-Siegel curve, as at 28/02/2014.

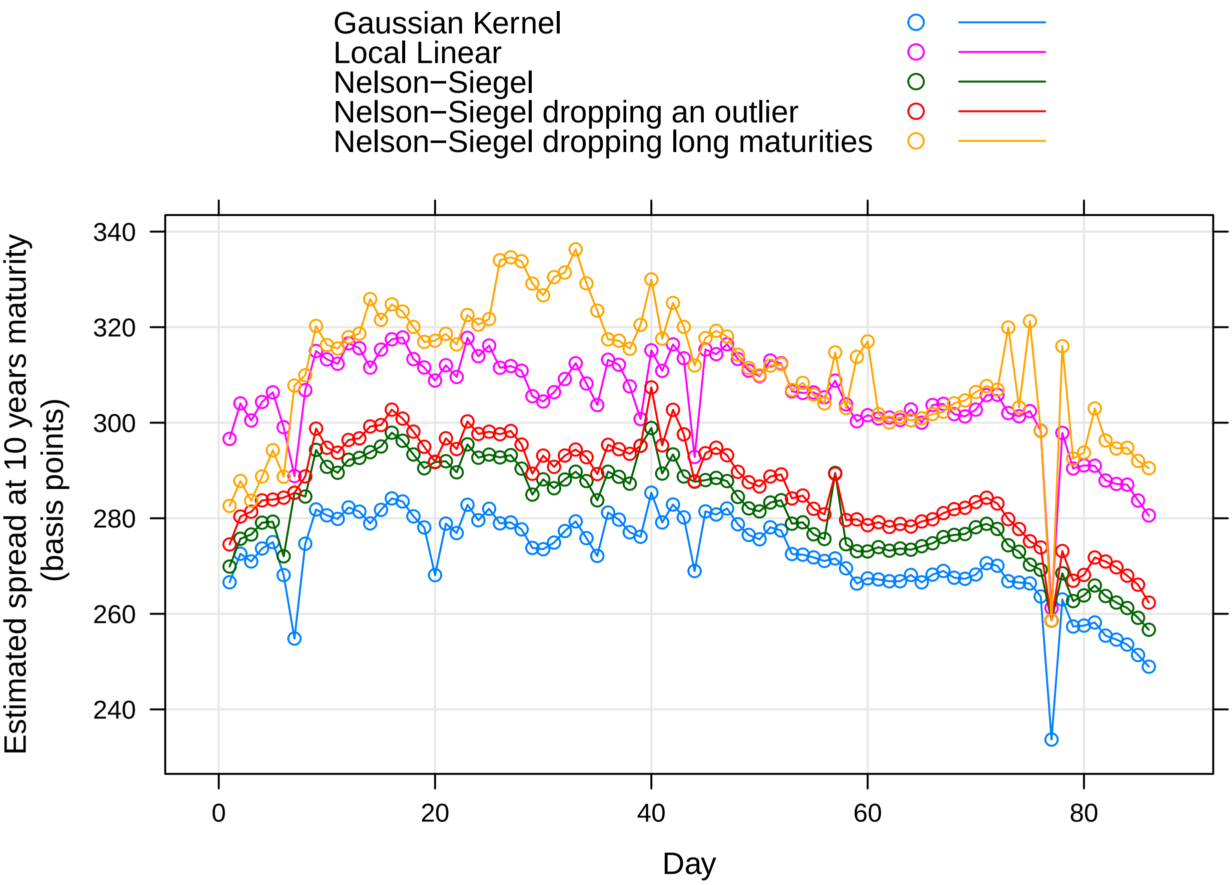

Figure 12: Comparison of Gaussian Smoothing, Local Linear Smoothing, and Nelson-Siegel Curve Fitting to BBB rated bonds over the period 01/11/13 to 28/02/14.

5 Effect of interpolating monthly estimates and selecting an averaging period

In regulatory proceedings, and in regulatory determinations made by the AER, it has generally been the case that an averaging period is defined in terms of consecutive business days. The cost of debt has then been assessed as an arithmetic mean of the outcomes recorded for each of the individual days. The AER is considering the possibility of interpolating between the end-of-month estimates of the RBAs corporate bond spread variable so as to produce daily observations. The daily results would then be used in an averaging period calculation (AER, 2014, section 5.1).

In this section the proposal by the AER to use monthly results from the RBA's corporate bond spread measure to generate daily observations will be evaluated. The RBA currently publishes corporate bond spreads (at tenors of 3, 5, 7 and 10 years) on a monthly basis, and may eventually produce the series on a daily basis.

The RBA currently produces spreads to swap for a 10-year tenor corporate bond. The periodicity of the RBA's series is monthly, though the results produced are for a single day each month, generally at the end of the month, and presumably for the last working day (although the RBA has not been explicit on this point)[10].

The Gaussian kernel daily estimates of the spread at a 10 year term to maturity, displayed in Figure 12, are well approximated by an ARIMA(0,1,1) model (see, for example, Box, Jenkins and Reinsel, 1994, pp 109-114.)

$$S_t - S_{t-1} = a_t - \theta a_{t-1} \tag{2}$$

The numbers in brackets correspond to the usual notation, ARIMA(p, d, q), and convey a message that the autoregressive part of the model was of order zero ($p = 0$), while differencing was of order one ($d = 1$), and the moving average component of the model was also of the first order ($q = 1$).

In equation (2) above, S_t denotes the spread at day t, θ is estimated to be 0.62, and a_t is a Normally distributed variable with mean 0 and variance 31.1. The local level of the process is then an exponentially weighted moving average of the current and previous estimated spreads and is given by

$$\lambda S_t + \lambda(1-\lambda)S_{t-1} + \lambda(1-\lambda)^2 S_{t-2} + \ldots \tag{3}$$

where $\lambda = 1 - \theta = 0.38$. The weights to be applied to the current and lagged values of the spread S_t are then 0.38, 0.24, 0.15, 0.09, 0.06, ..., and so on, indicating that there is some information about the process of evolution of corporate spreads which is over and above the current observation.

Box, Jenkins and Reinsel (1994, pp. 526-528) show that a sampled ARIMA(0,1,1) process also follows an ARIMA(0,1,1) model, but with different parameters. The results obtained from the ARIMA(0,1,1) model as applied to the daily Gaussian kernel estimates can be used in a sampling experiment. Simulating an ARIMA process with $\theta = 0.62$ and $\sigma^2 = 31.1$, and taking every 20th observation (corresponding to roughly a month) gives an ARIMA(0,1,1) with $\theta = 0.15$ and $\sigma^2 = 126.7$. The low estimate for the theta parameter indicates that past values of the spread to swap have little bearing on the current reading. Hence, 85% of the information about the process is summarised by the current observation.

The results are slightly different for the local linear smoothing daily estimates of the spread at a 10-year term to maturity and for the corresponding estimates using the Nelson-Siegel curve. Both of these series are again well-fitted by the ARIMA(0,1,1) model but with different parameters.

For local linear smoothing, θ is estimated to be 0.66, and a_t is a Normally distributed variable with mean 0 and variance 44.2. The weights are therefore 0.34, 0.23, 0.15, 0.1, 0.06, ... Simulating an ARIMA process with $\theta = 0.66$ and $\sigma^2 = 44.2$, and taking every 20th observation gives an ARIMA(0,1,1) with $\theta = 0.18$ and $\sigma^2 = 158.1$. Hence, 82% of the information about the process is summarised by the current observation.

For the Nelson-Siegel estimates, θ is estimated to be 0.37, and a_t is a Normally distributed variable with mean 0 and variance 15.7. The weights are therefore 0.63, 0.23, 0.09, 0.03, 0.01, ... Simulating an ARIMA process with $\theta = 0.37$ and $\sigma^2 = 15.7$, and taking every 20th observation gives an

[10] The RBA's corporate bond series is published as Table F3, Aggregate Measures of Corporate Bond Spreads and Yields: Non-financial Corporate (NFC) Bonds.

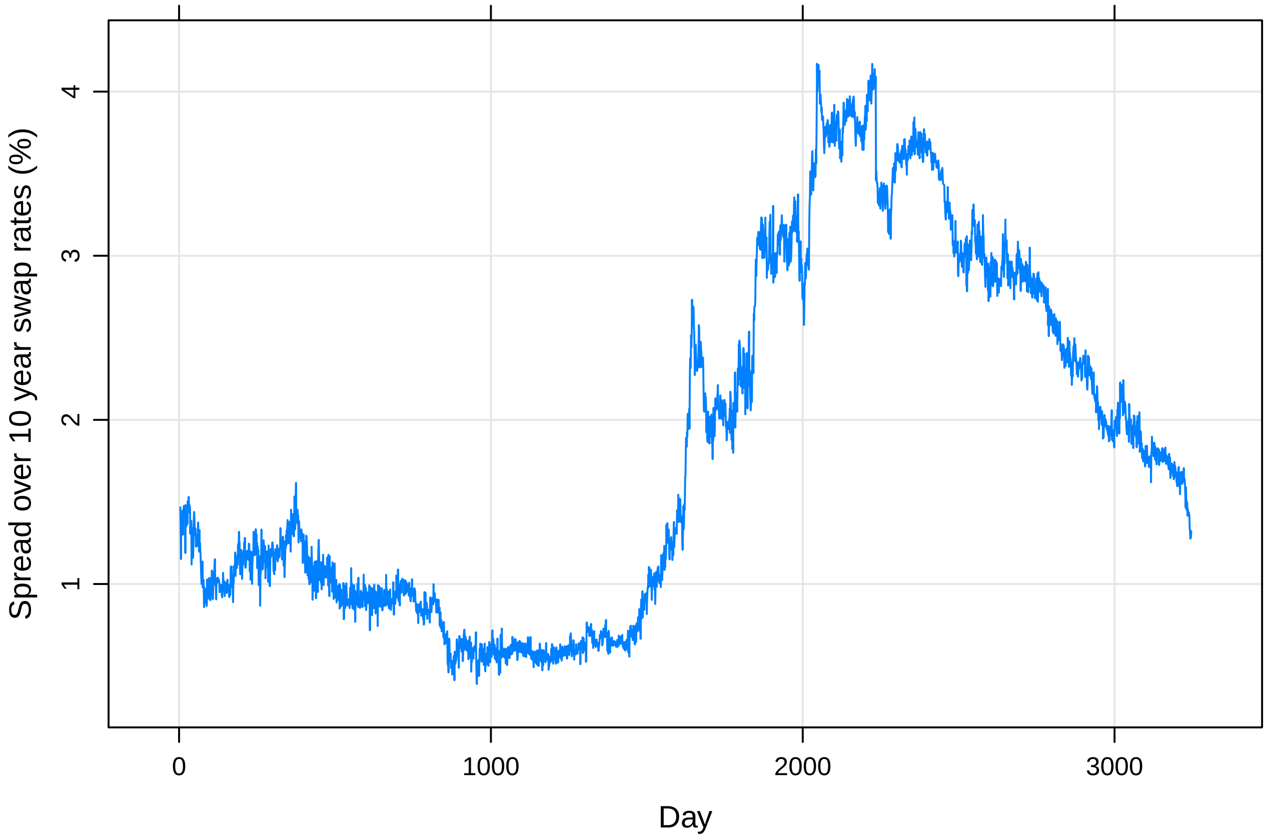

Figure 13: Daily Bloomberg BBB fair value spreads, 10 year tenor.

ARIMA(0,1,1) with $\theta = 0.04$ and $\sigma^2 = 135.7$. Hence, 96% of the information about the process is summarised by the current observation.

Although the parameter estimates have differed between the three series, they all show that most of the information about the current level is contained in the most recent observation and, accordingly, when formulating projections, there is no rationale for giving the same weight to the previous months' observation as to the current observation.

The time series of bond data that was provided by CEG for analysis was relatively short, although there was enough data available to permit estimates of the cost of debt (at a 10-year tenor) to be derived using a number of estimation methods (see Figure 12). The comparatively limited period of coverage may have had an impact on parameter estimates from the ARIMA models, however, causing some loss of precision. In order to investigate the results, daily data on Bloomberg BBB fair value spreads was used, with the series being checked for stationarity so that an ARIMA model could be identified and fitted. The spreads over swap for the Bloomberg BBB fair value curve were available on a daily basis, for each business day from 4th December 2001 to 301th April 2013 (N, the number of observations = 3,236). The Bloomberg BBB fair value spreads are shown in Figure 13, and an explanation of the derivation of these values is provided in Appendix B. Tests for stationarity revealed that the time series of spreads is nonstationary over the full sample period.

Again, an ARIMA(0,1,1) model fits well with θ estimated to be 0.5, while a_t is a Normally distributed variable distributed with mean 0 and variance 0.005. The weights are therefore 0.5, 0.25, 0.12, 0.06, 0.03, ..., and so on. Simulating an ARIMA process with $\theta = 0.5$ and $\sigma^2 = 0.005$, and taking every 20th observation gives an ARIMA(0,1,1) with $\theta = 0.08$ and $\sigma^2 = 0.03$. Hence, when using monthly data, 92% of the information about the process is summarised by the current observation. The process here is essentially the change in the spread from one day to the next.

The best estimate of the local level, and therefore the best projection going forward, is provided by an exponentially weighted moving average (EWMA)

		1 Month (20 days)	2 Months (40 days)	3 Months (60 days)	6 Months (120 days)	12 Months (240 days)
Daily	Average of 10 days	0.189	0.255	0.298	0.42	0.66
	Average of 20 days	0.203	0.262	0.303	0.428	0.67
	EWMA model	0.179	0.249	0.294	0.415	0.654
Monthly	Last two months	0.2	0.259	0.302	0.428	0.67
	Last month's value	0.183	0.251	0.297	0.416	0.653

Table 3: Comparison of MSE values obtained from alternative projection methods.

$$0.5S_t + 0.25S_{t-1} + 0.12S_{t-2} + 0.06S_{t-3} + 0.03S_{t-4} + \ldots$$

Using the actual Bloomberg BBB FV Spreads, Table 3 gives the performance of various estimates based on either daily or monthly data, projecting forward to a single day in n months' time, where n is equal to 1, 2, 3, 6, and 12. The comparison statistic is the Mean Square Error (MSE)

$$\text{MSE} = \sqrt{\text{Bias}^2 + \text{Standard Deviation}^2}$$

where

$$\text{Bias} = (\text{Actual Spread } n \text{ days later} - \text{Estimated Spread})$$

and

$$\text{Standard Deviation} = \text{Standard Deviation}(\text{Actual Spread } n \text{ days later} - \text{Estimated Spread}).$$

where a smaller MSE is better. All of the projections shown in Table 3 were made on a rolling basis using the entire available time series of Bloomberg fair value curve data (extrapolated to a 10-year term over those periods for which 10-year tenor data was not published). Consider, for instance, the forecasts which were calculated by taking an average over 10 days of the Bloomberg fair value spreads. The arithmetic mean thus obtained was then compared with the actual result for the fair value curve spread that was reported 20 days later. That particular approach to forecasting is repeated many times using the time series of fair value spread data. The mean square error obtained over all of the forecasts of that type is shown to be 0.189.

An examination of the results from Table 3 shows that:

- The EWMA (exponentially weighted moving average) estimate given by equation (3) provides the best estimate for all projection horizons. This is not surprising as the EWMA is the optimal model for an ARIMA(0,1,1) process, and the Bloomberg BBB FV spreads follow that model well.
- Calculating an arithmetic mean of daily results over a 10-day period produces forecasts which are fractionally better than those obtained by taking an arithmetic average of results over a 20-day period.
- The projections obtained by calculating average spreads using daily data are better than the forecasts derived by working out averages from a more limited set of monthly observations, however the difference in performance is not that great.
- If monthly data is being used to estimate the spread-to-swap at a future date, then the best approach is to use the most recent monthly result. There is no empirical support for the practice of linear interpolation, because linear interpolation essentially means that an average is being taken of the monthly values from the preceding two months.

5.1 Effect of interpolating

The AER is considering interpolating monthly estimates and selecting an appropriate averaging period. The interpolation will make use of observations for the two preceding months (the most recent

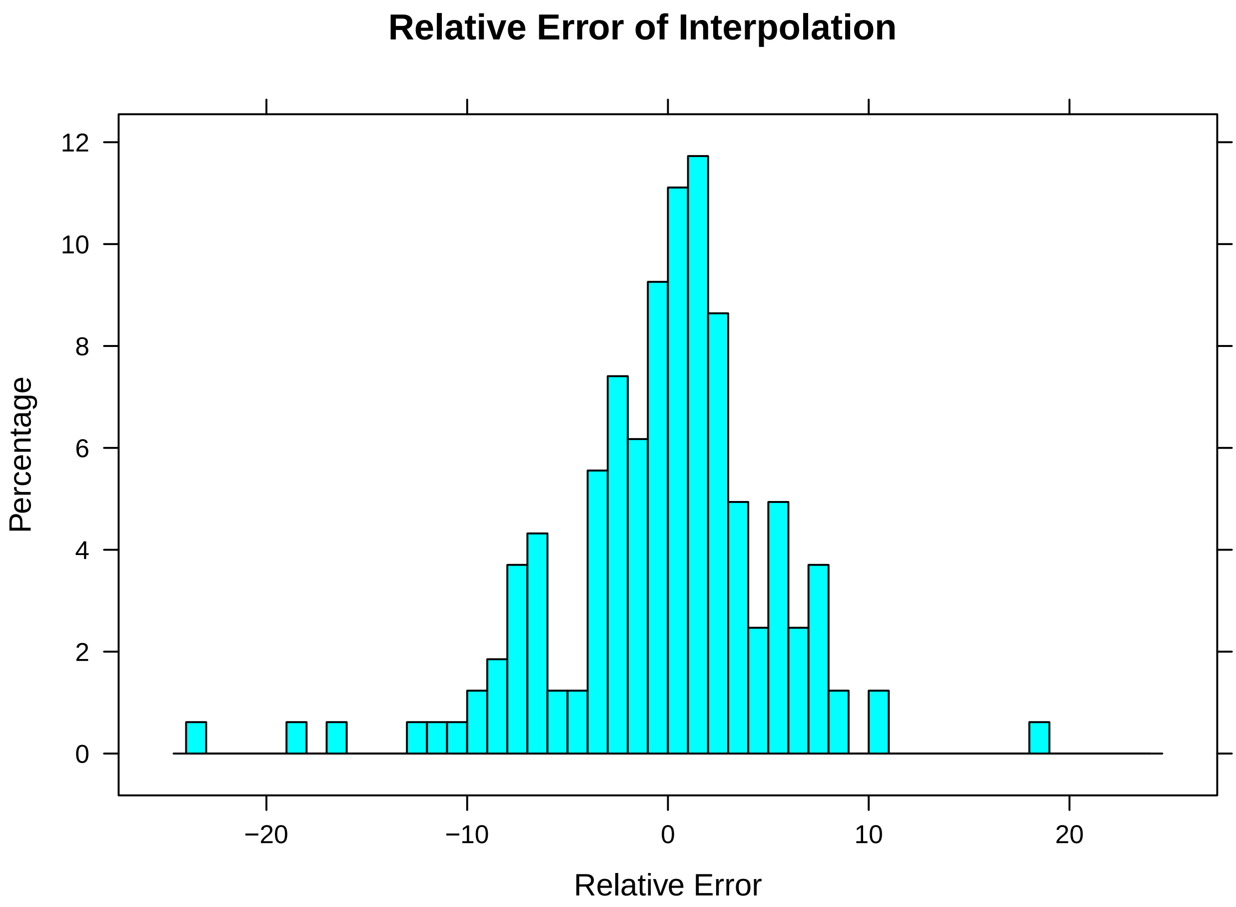

Figure 14: Relative error of interpolation method relative to daily averaging.

available). In this section we have used the Bloomberg BBB FV spreads to investigate this approach further.

The series consists of 3,246 observations. We broke the series into 162 blocks of 20 observations. For each block we averaged the first and last observations (i.e. the interpolation method), and also computed the average over all 20 observations. The relative error of the interpolation method was computed as

$$100 \times \frac{\text{Average of First and Last Observation} - \text{Average of All Observations}}{\text{Average of All Observations}}$$

A histogram of relative errors is given in Figure 14.

Of the 162 blocks of data, the absolute relative error is over 5% for 49 blocks, i.e. 30.2% of the time. The relative error is over 10% for 9 blocks, i.e. 5.6% of the time.

5.2 Concluding comments about the use of monthly data

The results from the empirical analysis of ARIMA models and from the assessment of the relative error of interpolation can be used to draw inferences about the merits of using monthly data for the cost of debt.

ARIMA models were fitted to the daily spread-over-swap data that had been produced using a variety of methods (including the Gaussian kernel estimation method used by the RBA). The results from estimation suggested that integrated moving average processes were dominant. An integrated moving average (IMA) series for an economic variable, y_t, is a weighted average of a current and a past random disturbance. The IMA model is one in which random shocks require more than one period to work themselves through the system. In general, an IMA process represents time series observations on the economic variable, y_t, as a weighted average of random disturbances extending back one, two or more time periods.

The daily ARIMA models showed that past observations for the random disturbance were influential in determining the change in spread from one time period to the next. However, when only monthly data was considered, meaning that one observation per month was sampled, the influence of past random disturbances (which affect the process that gives rise to the change in the spread) was significantly diminished. In the case of the Bloomberg BBB fair value curve spread, past values of the integrated moving average process, from the months preceding the current month, have a limited impact on current values of the spread to swap. The weight given to past observations is 8%.

Should the AER use the RBA's month end data to produce daily estimates by a process of linear interpolation?

The proposal by the AER is supported neither by economic theory nor by the results of empirical analysis.

If the Bloomberg fair value curve were released only once a month, then current values of the integrated moving average process would have a 92% influence on current spread levels, whilst past values of the process would have a much lesser effect, amounting to 8%. Fair value spreads from, say, a period two months prior, would not serve as a useful guide as to current or recent values of the spread-over-swap. The ARIMA models produced by ESQUANT suggest that the spreads-over-swap for, say, the month of March, cannot be inferred by taking an average of the results recorded at the end of January and at the end of February. Similarly, the spreads-over-swap in the middle of the month of March cannot be accurately estimated by taking an average of the spreads reported, respectively, at the end of February and at the end of March. There are substantial advantages in using daily data.

The daily spreads from the Bloomberg BBB fair value curve can also be used to calculate the relative interpolation error, which can be defined as the measurement error that is recorded when an average is taken of monthly values of the spread-to-swap, instead of taking an average of daily observations. The relative interpolation error was found to be above 5% almost one third of the time.

6 Using a third party provider of cost of debt information

The AER claim an advantage of using a third party service provider

> "Using an independent third party reduces the scope for debate on debt instrument selection issues, and curve fitting[11] or the use of some form of averaging methods to derive the estimate of the return on debt[12]."

It is important to stress that using a particular third party service provider implies that the AER is satisfied with the debt instruments selected by the supplier and with the statistical manipulations that the supplier uses, whether these statistical manipulations are curve fitting like Nelson-Siegel methods or Gaussian Kernel, or other averaging methods.

The AER has indicated that it would prefer not to develop an in-house method. However, irrespective of whether the method is in-house or otherwise, the AER should be satisfied that the debt instruments satisfy their requirements, and that the estimation methods are clearly explained and transparent.

The successful use of any statistical or econometric technique is a combination of subjective judgement and objective application. The subjective judgement part concerns the selection of the sample, the assessment of methods and the formation of a model. The objective application component is about ensuring that the methods chosen are applied rigorously and to the highest standards. ESQUANT considers that regulated businesses and the AER will need to be satisfied that the third party provider of data has performed the subjective and objective components of the task satisfactorily. The third party provider of cost of debt information may be motivated by other considerations, and may consider that the data series being published is better suited to other applications. ESQUANT considers that, even if a third party provider of data is used, consideration will still need to be given to the appropriateness of the results from the particular data source during the period for assessment of the cost of debt. In order to assess the results against market evidence, there will need to be an analysis of yield curves and averaging methods, while choices will have to be exercised about debt instruments and methods of handling the data.

[11] The AER describe curve fitting in the following terms: "Curve fitting is the process of constructing a curve, or mathematical function, that has the best fit to a series of data points, subject to constraints."

[12] In a footnote expanding on this point, the AER says:"Alternatively, developing an in-house solution would likely require detailed criteria for selecting debt instruments with appropriate specification of contingencies to allow automatic updating, and a detailed description of the estimation method (that is, a curve fitting technique or some form of averaging observed yields-for example, Nelson-Siegel, Svensson or spline-based approaches)".

A Estimation of the Local Linear Smoother

Define S_i as the observed spread for the ith bond, T_i as the tenor of the ith bond, F_i as the face value of the ith bond and $K(T_i - T; \sigma)$ is the Gaussian kernel given by

$$K(T_i - T; \sigma) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left[-\frac{(T_i - T)^2}{2\sigma^2}\right].$$

where σ is the standard deviation of the Gaussian (Normal) distribution used in the Gaussian kernel. As pointed out by Hastie et al. (2009, p 195) locally weighted regression solves a separate weighted least squares problem at each target tenor T:

$$\min_{\alpha(T),\beta(T)} \sum_{i=1}^{N} F_i K(T_i - T; \sigma)[S_i - \alpha(T) - \beta(T)T]^2$$

Hastie et al (2009, p195) make the following definitions: They define the vector-values function $b(T)' = (1, T)$, the $N \times 2$ "regression matrix" $\mathbf{B}$ with ith row $b(T_i)'$, and $\mathbf{W}(T)$ the $N \times N$ diagonal matrix with ith diagonal element $F_i K(T_i - T; \sigma)$. They give (equations 6.8 and 6.9) the estimate at T as

$$\sum_{i=1}^{n} w_i(T; \sigma) S_i$$

where

$$w_i(T; \sigma) = b(T)'(\mathbf{B}'\mathbf{W}(T)\mathbf{B}^{-1}\mathbf{B}'\mathbf{W}(T).$$

Denote $k_i = K(T_i - T; \sigma)$, then

$$\mathbf{B}'\mathbf{W}(T)\mathbf{B} = \begin{pmatrix} \sum_{i=1}^{n} F_i k_i & \sum_{i=1}^{n} F_i k_i T_i \\ \sum_{i=1}^{n} F_i k_i T_i & \sum_{i=1}^{n} F_i k_i T_i^2 \end{pmatrix} = \begin{pmatrix} A & B \\ B & C \end{pmatrix}.$$

The inverse is given by

$$\frac{1}{AC - B^2} \begin{pmatrix} C & -B \\ -B & A \end{pmatrix}$$

and therefore

$$b(T)'(\mathbf{B}'\mathbf{W}(T)\mathbf{B})^{-1} = \frac{1}{AC - B^2} \begin{pmatrix} C - TB & AT - B \end{pmatrix}.$$

Also

$$\mathbf{B}'\mathbf{W}(T) = \begin{pmatrix} F_1 k_1 & F_2 k_2 & \dots & F_N k_N \\ F_1 k_1 T_1 & F_2 k_2 T_2 & \dots & F_N k_N T_N \end{pmatrix}.$$

Hence

$$w_i(T; \sigma) = \frac{k_i F_i (C - TB) + k_i F_i T_i (TA - B)}{AC - B^2}$$

as given in the section.
The sum of the weights

$$\begin{aligned} \sum_{i=1}^{N} w_i(T; \sigma) &= \frac{1}{AC - B^2} \left((C - TB) \sum_{i=1}^{N} k_i F_i + (TA - B) \sum_{i=1}^{N} k_i F_i T_i \right) \\ &= \frac{(C - TB)A + (TA - B)B}{AC - B^2} \\ &= 1 \end{aligned}$$

Also,

$$\begin{aligned}
\sum_{i=1}^{N}(T_i - T)w_i(T;\sigma) &= \sum_{i=1}^{N} T_i w_i(T;\sigma) - T \\
&= \frac{1}{AC - B^2}\left((C - TB)\sum_{i=1}^{N} k_i F_i T_i + (TA - B)\sum_{i=1}^{N} k_i F_i T_i^2\right) - T \\
&= \frac{1}{AC - B^2}\left((C - TB)B + (TA - B)C\right) - T \\
&= \frac{1}{AC - B^2}\left(CB - TB^2 + TAC - BC\right) - T \\
&= \frac{1}{AC - B^2}\left(TAC - TB^2\right) - T \\
&= 0.
\end{aligned}$$

B Methods for extrapolating the Bloomberg fair value curve for BBB corporate bonds

The Bloomberg BBB fair value curve is used as a benchmark when assessing the cost of debt. However, for most of the curve's history, Bloomberg has not published fair value yield estimates which are commensurate with a 10-year term for the benchmark cost of debt. Hence, different techniques have been devised for extrapolating the curve so as to produce fair value estimates at 10-years. The application of the techniques has varied over time, depending upon the availability of other data series. A summary of the practices that have been employed to compile the historical data series is presented in the dot points below. The methods thus described have been adopted to create the Bloomberg fair value curve variable that has been used in the analysis undertaken for this report.

- The Bloomberg BBB fair value curve was first published with an effective date of 4th December 2001, and was initially available across a wide range of tenors from one to ten years, and also at a 15-year term to maturity.

- For those early periods for which BBB fair value yields are not available at a 10-year term to maturity, extrapolation has been achieved retrospectively using the A curve as the first choice, with the alternative selections being, in order, the AA and AAA curves.

- From 19th August 2009 to 22nd June 2010, Bloomberg did not report values for the BBB, A, and AA curves for a tenor, or term to maturity, in excess of 7 years. The AER therefore adopted the following approach to measurement of the cost of debt: Bloomberg BBB 7 year values + (Bloomberg AAA 10 year valuesBloomberg AAA 7 year values).

- Subsequent to 22 June 2010, the AER accepted a different formulation for the cost of debt, as presented here: Bloomberg BBB 7 year values + (10 year yields on CGS − 7 year yields on CGS) + (10 year AAA values averaged over 20 days − 10 year CGS averaged over 20 days) − (7 year AAA values averaged over 20 days − 7 year CGS averaged over 20 days). Note that averages were calculated over the 20 business days to 22nd June 2010. The resulting increment to the DRP was 47 basis points, from 7-years to 10-years.

- From 2nd January 2012 until 30th April 2014, an approach based on paired bonds has been applied. The increment to the debt risk premium, from 7-years to 10-years has been assumed to be 23 basis points[13]. The increment, which was derived from a report prepared by PWC for the Victorian gas distributors, has been held steady for analytical purposes, even though more current estimates of the DRP margin have become available[14].

Note that the Bloomberg fair value yields are reported on a semi-annual payment basis, and are transformed into annual equivalent rates at an early stage in the calculations. The transformation into annual equivalent rates applies to Bloomberg fair value yields at all tenors.

Calculating the spreads over swap from Bloomberg fair value yields

In order to calculate the fair value spreads over swap, data was retrieved from Bloomberg on 10-year swap rates and was transformed from being on a semi-annual payments basis into annual equivalent rates. The amended swaps data was then subtracted from the Bloomberg fair value yields at 10 years (either actual yields or estimated yields, depending upon the time period). The Bloomberg fair value

[13]The AER reports that it has used a fixed term spread of 30 basis points to extrapolate Bloomberg data from an underlying 7-year curve to a ten-year term to maturity. "The addition of a fixed term spread represents a simplification for illustrative purposes, but the magnitude of this spread reflects that applied in recent AER decisions". See AER (2014), Return on debt: Choice of third party data service provider, Issues Paper, Australian Energy Regulator, Apri l 2014; Figure 1.

[14]PWC(2012), Estimating the benchmark debt risk premium, a report prepared by PWC for SP AusNet, Multinet Gas, Envestra, and APA Group, March 2012. The increment to the DRP between 7-years and 10-years was reported to be 7.6 basis points per annum.

spread-over-swap series was thereby derived as a set of daily observations covering the period from 4th December 2001 until 30th April 2014.

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Neil Diamond CV

Neil Diamond CV

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Career History

1977-78	Statistician, ICI Explosives Factory, Deer Park
1979-86	Research Officer, Research Scientist, Senior Research Scientist And Statistics and Computing Team Leader, ICI Central Research Laboratories, Ascot Vale
1987-1989	Lecturer, Department of Mathematics, Computing and Operations Research, Footscray Institute of Technology
(1989)	Visiting Scientist, Center for Quality and Productivity Improvement, University of Wisconsin-Madison, USA.
1990-2003	Senior Lecturer, Department of Computer and Mathematical Sciences, Victoria University of Technology
(1995)	Visiting Fellow, Center for Quality and Productivity Improvement, University of Wisconsin-Madison, USA.
2003-2004	Senior Statistician, Insureware
2004-2006	Senior Lecturer and Deputy Director of Consulting, Department of Econometrics and Business Statistics, Monash University.
2007- 2012	Senior Lecturer and Director of Consulting, Department of Econometrics and Business Statistics, Monash University.
2011- 2012	Associate Professor and Co-ordinator of Statistical Support, Victoria University.
2012-	Director, ESQUANT Statistical Consulting

Research and Consulting Experience

- A Ph.D. from the University of Melbourne entitled "Two-factor interactions in non-regular foldover designs."
- Ten years with ICI Australia as an industrial statistician initially with the Explosives group and eventually with the research group.
- Two six month periods (Professional Experience Program and Outside Studies Program) at the Center for Quality and Productivity Improvement, at the University of Wisconsin-Madison. The Center, founded and directed by Professor George Box, conducts innovative practical research in modern methods of quality improvement and is an internationally recognised forum for the exchange of ideas between experts in various disciplines, from industry and government as well as academia.

- Extensive consulting and training on behalf of the Centre for Applied Computing and Decision Analysis based at VUT for the following companies:

Data Sciences	Initiating Explosives Systems
Analytical Science Consultants	Saftec
Glaxo Australia	Datacraft Australia
Enterprise Australia	ICI Australia
The LEK partnership	Kaolin Australia
BP Australia	AMCOR
Melbourne Water	Kinhill Group
Australian Pulp and Paper Institute	

- Operated the Statistical Consulting Service at Victoria University of Technology from 1992-2003.
- From 2003-2004 worked as a Senior Statistician with Insureware on the analysis of long-tailed liability data.
- From December 2004 to December 2006, Deputy Director of Consulting of Monash University Statistical Consulting Service based in the Department of Econometrics and Business Statistics.
- From January 2007 to December 2012, Director of Consulting of Monash University Statistical Consulting Service based in the Department of Econometrics and Business Statistics.
- Extensive consulting and training on behalf of the Monash University Statistical Consulting Service for the following companies and organisations:

Australian Tax Office	Department of Human Services
J D McDonald	IMI Research
Port of Melbourne Corporation	Incitec Pivot
Agricola, Wunderlich & Associates	Parks Victoria
Australian College of Consultant Physicians	ANZ
Department of Justice	CRF(Colac Otway)
Australian Football League Players' Association	United Energy
ETSA	ENA

- From May 2011 to February 2013, Associate Professor and Co-ordinator of Statistical Support, Victoria University.
- From February 2013, Extensive consulting and training as Research Director of ESQUANT Statistical Consulting for the following companies and organisations:

United Energy & Multinet Gas
Competition Economists Group
SFG Consulting
Engineered Wood Panels Association of Australasia
Monash University Department of Social Work
Choros
Electricity Networks Association
Victoria University Office for Research

Postgraduate Supervision

Principal Supervisor

Gregory Simmons (1994-1997). M.Sc. completed. "Properties of some minimum run resolution IV designs."

Tony Sahama (1995-2003). Ph.D. completed. "Some practical issues in the design and analysis of computer experiments."

Ewa Sztendur (1999-2005). Ph.D. completed. "Precision of the path of steepest ascent in response surface methodology." [As a result of this thesis, Ewa was awarded the 2006 Victoria University Vice-Chancellor's Peak Award for Research and Research Training-Research Degree Graduate.]

Co-supervisor

Keith Hart (1996-1997). M.Sc. completed. "Mean reversion in asset prices and asset allocations in funds management."

Jyoti Behera (1999-2000). M.Eng. completed. "Simulation of container terminals."

Ray Summit (2001-2004). Ph.D. completed. "Analysis of warranty data for automobile data."

Rob Moore (2001-2007). Ph.D. completed. "Computer recognition of musical instruments.

M.Sc. Minor Theses

Milena Shtifelman (1999). Completed. (Monash University Accident Research Centre). "Modelling interactions of factors influencing road trauma trends in Victoria."

Rohan Weliwita (2002). Completed. "Modelling road accident trauma data."

Theses Examination

One M.Sc. major thesis (University of Melbourne) and one M.Sc minor thesis (Victoria University).

Workshops

Victoria University

- Experimental Design.
- Longitudinal Data Analysis.
- Statistics for Biological Sciences.
- Introductory Statistics for Research.
- Software Packages for Statistics.
- Design and Analysis of Questionnaires and Sample Surveys.
- Introductory SPSS.
- Statistics for Biological Sciences using R.
- Statistics for Biological Sciences using SPSS.
- Research Design and Statistics.

Monash University

- Expert Stats Seminars for higher degree research students on Software Packages for Statistics, Questionnaire Design, Analysis of Survey Data, and Multivariate Statistics.
- Introduction to Statistics for Pharmacy (5 hours).
- Statistical Analysis for Social Workers.
- Statistical Methods for Social Workers.
- SPSS for Social Workers.

Other

- Design of Experiments for ICI Australia (One day course).
- Design of Experiments for Quality Assurance-including Taguchi Methods. A 2-day professional development short course on behalf of the Centre for Manufacturing Advanced Engineering Centre.

- Design of Experiments for the Australian Pulp and Paper Institute.
- Statistical Methods for ANZ Analytics.

Teaching Experience

Monash University

- Business Statistics (First Year), Marketing Research Analysis (Second Year), Survey Data Analysis (Third Year-Clayton and Caulfield).

Victoria University of Technology

- Applied Statistics (First Year), Linear Statistical Models, Sampling and Data Analysis (Second Year), Experimental Design (Third Year).
- Statistics for Engineers, Statistics for Nurses, Statistics for Occupational Health.
- Forecasting (Graduate Diploma in Business Science)

Sessional Teaching

- RMIT (1991, 1996-2002) Design of Experiments for Masters in Quality Management.
- AGSM (1993-1997): Total Quality Management for Graduate Management Qualification.
- Various other: The University of Melbourne, Enterprise Australia, Swinburne Institute of Technology.

Industry Projects

Over 30 projects for the following companies and organisations:

Gas and Fuel Corporation	Ford Australia
Mobil Australia	Fibremakers
ICI Australia	Western General Hospital
Data Sciences	Keilor City Council
AMCOR	Composite Buyers
Davids	Email Westinghouse
Craft Coverings	Australian Wheat Board
CSL	Holding Rubber
Viplas Olympic	Melbourne Water
Federal Airports Corporation	

Publications

Chapters in Books

1. Sztendur, E.M. and Diamond, N.T., (2001). "Inequalities for the precision of the path of steepest ascent in response surface methodology," in Cho, Y.J, Kim, J.K., and Dragomir, S.S. (eds.) *Inequality Theory and Applications Volume 1*, Nova Publications.

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6. Sahama, T. And Diamond, N.T. (2008). "Computer Experiment-A case study for modelling and simulation of Manufacturing Systems," 9th Global Conference on Manufacturing and Management.

7. Jackson, M.L., Diamond, N.T., Sztendur E.M., Bruck, D. (2013). "The Role of Sleep Difficulties in the Subsequent Development of Depression and Anxiety in a Longitudinal Study of Young Australian Women, " *American Professional Sleep Societies Scientific Meeting, Baltimore, MA* (Selected for an Honorable Mention Award) and *25th Annual Scientific Meeting of the Australasian Sleep Association, Brisbane, October.*

Reports

A number of confidential reports for ICI Australia from 1977-1987.

Victoria University

VU1. Diamond, N.T (1990). "Professional Experience Program at the Center for Quality and Productivity Improvement," Footscray Institute of Technology.

VU2. Bisgaard, S. and Diamond, N.T (1991). "A discussion of Taguchi's methods of confirmatory trials," Report No. 60. Center for Quality and Productivity Improvement, University of Wisconsin-Madison.

VU3. Diamond, N.T (1996). "Outside Studies Program at the Center for Quality and Productivity Improvement," Victoria University of Technology.

VU4. Diamond, N.T (1996). "Statistical Analysis of EPA compliance of the western treatment plant," prepared for Melbourne Water on behalf of Kinhill Engineers.

VU5. Diamond, N.T (1996). "Statistical Analysis of EPA compliance of the western treatment plant," prepared for Melbourne Water on behalf of Kinhill Engineers.

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Professional Service

- President, Victorian Branch, Statistical Society of Australia, 2001-2002.
  - Terms as Council Member, Vice-President, and Past President.
- Referee: *Australian and New Zealand Journal of Statistics*, *Biometrika*, *Journal of Statistical Software*, *Journal of Production Planning and Control*.

Professor Robert Brooks CV

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Robert obtained his honours and PhD degrees from Monash University and has previously worked at RMIT University.

His primary area of research interest is in financial econometrics, with a particular focus on beta risk estimation, volatility modelling and the analysis of the impacts of sovereign credit rating changes on financial markets. His research in the financial econometrics area has produced a number of publications in top-tier journals, along with research funding from ARC Discovery and ARC Linkage and industry sources.

Given his education management role, Robert also works in areas of educational research relating to pedagogy of teaching business statistics and in particular applications of problem based learning in that setting.

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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[1], 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.

<u>Guidelines</u>

1. General Duty to the Court[2]

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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[1] 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].

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

2. The Form of the Expert's Report[3]

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[4]; 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[5].

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

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

2.7 Where an expert's report refers to photographs, plans, calculations, analyses, measurements, survey reports or other extrinsic matter, these must be provided to the opposite party at the same time as the exchange of reports[6].

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

3. Experts’ Conference

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

J L B ALLSOP
Chief Justice
4 June 2013

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TERMS OF REFERENCE – REVIEW OF RBA CORPORATE BOND SPREADS IN RESPONSE TO AER ISSUES PAPER ON THIRD PARTY DATA PROVIDERS

Background

In April 2014, the Australian Energy Regulator, (AER), published an Issues Paper in which it set out its considerations about the methods that it would employ to estimate the return on debt. The AER noted that there were aspects of the estimation of the spot cost of debt which hadn't been adequately addressed in the rate of return guideline[1]. The AER therefore sought to explain:

- The attributes of the third party data series which are currently available to be used for estimating the return on debt. The available cost of debt information includes data series published by the Reserve Bank of Australia (RBA) and by Bloomberg.

- The particular matters that would need to be addressed if the RBA corporate bond spread series were to be used to estimate the return on debt. Those matters would include the interpolation of monthly estimates, and the selection of an averaging period over which the return on debt would be calculated.

The AER stated in its Issues Paper that it wasn't proposing to use a specific data series or source, rather the decision about the sources of information would be made at the time of a regulatory determination[2].

The RBA published its new measures of corporate bond spreads in December 2013, with data initially available up to November 2013[3]. The RBA has also endeavoured to back-cast its data, with historical corporate bond spreads having been produced back to January 2005. An article in the Reserve Bank Bulletin serves to explain the methods that have been used to create the composite corporate bond

[1] AER (2014), Return on debt: Choice of third party data service provider, Issues Paper, Australian Energy Regulator, April 2014, section 1.

[2] United Energy will be submitting a regulatory proposal in April 2015. The AER is currently expected to release a final determination for United Energy in April 2016.

[3] The RBA's corporate bond series is published as Table F3, Aggregate Measures of Corporate Bond Spreads and Yields: Non-financial Corporate (NFC) Bonds.

spreads and yields[4]. The data from the RBA is currently produced as a set of monthly figures, with daily data releases not yet available.

Replication of RBA component bond yield information

The Competition Economists Group, (CEG), has attempted to re-create the source data that the RBA has used to calculate its summary measures of corporate bond spreads. CEG has also sought to repeat the exercise undertaken by the RBA, and to compile aggregate corporate bond indices, stratified by broad credit rating class. CEG has followed the methods which have been documented by the RBA in the Bulletin article. CEG has provided the results of its empirical work to United Energy and Multinet Gas, and has also supplied data. A number of spread sheet workbooks from CEG will be made available to the consultant that is appointed to undertake the current assignment for UE and MG. In summary, the data from CEG is made up as follows:

- A spread sheet workbook with separate worksheets for each business day recorded over the period from 1st November 2013 until 28th April 2014.

- Each worksheet contains a list of bonds with unique identifiers. The list has been determined through a screening process, using the filtering criteria applied by the RBA.

- The data available for the individual bonds includes credit rating, remaining term to maturity, the spread over swap rates, and the face value of the bond (or the amount issued). Foreign currency bonds are included in the sample, with their spreads or option-adjusted spreads having been converted into Australian dollar equivalent spreads, after implementing the transformations that are documented in the Bulletin article.

- A fully worked example of the application of the Gaussian kernel method, using data from a single day, 28th February 2014. The example shows the weighted average spreads for BBB rated bonds at target tenors of 3, 5, 7 and 10 years. The effective tenors, corresponding to each of the four categories, are also shown.

Scope of work

There are three broad dimensions to the work to be undertaken:

(1) The consultant should investigate the properties of the data that has been put together by the RBA, and consider whether the methods that have been applied are appropriate and fit-for-purpose.

(2) The series of corporate bond spreads derived by the RBA should be compared with other proxy measures for the cost of debt. Specifically, the variables to be considered should be those that have been assembled and condensed into composite indices or curves that can be regarded as "third party sources of data". The comparisons should be based on methodological differences and empirical results.

(3) Evaluate alternative techniques for determining the cost of debt for a benchmark corporate bond

[4] Arsov, I., Brooks, M., and Kosev, M. (2013). 'New Measures of Australian Credit Spreads', Bulletin, Reserve Bank of Australia, December Quarter 2013.

with a BBB credit rating from Standard and Poor's. Consider methodological rigour and empirical tractability.

When performing tasks that fall under category (1) above, the main question to be addressed is whether the RBA corporate bond spread series is amenable to the task of producing an unbiased, objective estimate of the return on debt. The National Electricity Rules provide the over-arching framework, with the most pertinent clauses being 6.5.2 (a) to 6.5.2 (l). The allowed rate of return objective is paramount:

> The allowed rate of return is to be determined such that it achieves the allowed rate of return objective[5];

and

> The return on debt for a regulatory year must be estimated such that it contributes to the achievement of the allowed rate of return objective[6].

Timeframe

The consultant is to provide a draft report which discusses the results of the analysis by Wednesday 7th May 2014. A final report should be provided by no later than Wednesday 14th May.

Reporting

Jeremy Rothfield will serve as the primary contact for the period of the engagement. The consultant will prepare reports showing the work-in-progress on a regular basis. The consultant will make periodic presentations on analysis and advice as appropriate.

Conflicts

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

Compliance with the Code of Conduct for Expert Witnesses

Attached is a copy of the Federal Court's Practice Note CM 7, entitled "Expert Witnesses in Proceedings in the Federal Court of Australia", which comprises the guidelines for expert witnesses in the Federal Court of Australia (Expert Witness Guidelines).

Please read and familiarise yourself with the Expert Witness Guidelines, and comply with them at all times in the course of your engagement with United Energy and Multinet Gas.

In particular, your report prepared for United Energy and Multinet Gas should contain a statement at the beginning of the report to the effect that the author of the report has read, understood and complied with the Expert Witness Guidelines.

Your report must also:

[5] National Electricity Rules, clause 6.5.2 (b) (current since version 53).

[6] National Electricity Rules, clause 6.5.2 (h) (current since version 53).

1. Contain particulars of the training, study or experience by which the expert has acquired specialised knowledge.

2. Identify the questions that the expert has been asked to address.

3. Set out separately each of the factual findings or assumptions on which the expert's opinion is based.

4. Set out each of the expert's opinions separately from the factual findings or assumptions.

5. Set out the reasons for each of the expert's opinions; and

6. Otherwise comply with the Expert Witness Guidelines.

The expert is also required to state that each of the expert's opinions is wholly or substantially based on the expert's specialised knowledge.

The declaration contained within the report should be 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 report".

Please also attach a copy of these terms of reference to the report.

Fees

The consultant is requested to submit:

- A fixed total fee for the project and hourly rates for the proposed project team should additional work be required; and

- Details of the individuals who will provide the strategic analysis and advice.

Contacts

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

Jeremy Rothfield, telephone (03) 8846 9854, or via email at Jeremy.Rothfield@ue.com.au