

Estimation of Fair Value Curves

A REPORT FOR

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1 Introduction

We have been asked to review estimation of yield curves summarised in the CEG report¹ by Dr. Tom Hird (Hird, 2012). Specifically the questions we have been asked to address are:

- Are the methods that have been applied to estimate fair value curves reasonable and defensible?
- Is the equation given in paragraph 111² of the report that has been used to estimate par value yield curves appropriate and reasonable?
- Do regression diagnostics help to justify or otherwise support the use of the estimated equations given in the report?

We have been able to broadly reproduce the results using another package, which gives confidence in the findings given in the report. Some modifications to the results used in the report to accommodate outliers have given broadly the same results.

We raise two matters which need to be considered in interpreting the report.

- The length and representativeness of the sample period chosen.
- The weighting scheme used based on Macaulay durations.

Some comments on these issues are made in sections 3.1 and section 4, respectively.

2 Yield to Maturity Curves

The Nelson-Siegel formula (Nelson and Siegel, 1987), in the notation used in the report³, can be written as

$$\text{Yield}(t, \text{rank}) = \beta_{1, \text{rank}} + (\beta_2 + \beta_3) \frac{1 - \exp(-t/\beta_0)}{t/\beta_0} - \beta_3 \exp(-t/\beta_0)$$

The interpretation is that $\beta_{1, \text{rank}}$ is the long-term component, which depends on the credit rating of the bond, β_2 is the short-term component, β_3 is the medium term component, and β_0 is a parameter which governs the speed of the decay of the short term and medium term components. The model is non-linear because of the inclusion of the β_0 parameter.

In the report, the parameters were estimated by minimising the sum of squares of the predicted yield based on the equation above and the actual yield. This was accomplished using the Solver facility in Excel, which is based on a generalised reduced gradient optimisation.

We have used the `nls` (non-linear least squares) function in R (R Core Team, 2012) to estimate the parameters. Slightly different but essentially the same results were obtained.

Irrespective of whether Excel Solver was used or `nls` in R, both have the same objective function. As noted by Fox (2008, p. 463)

The general nonlinear model is given by the equation

$$Y_i = f(\beta, x_i^T) + \varepsilon_i$$

in which

- Y_i is the response-variable value for the i th of n observations;
- β is a vector of p parameters to be estimated from the data;
- x_i^T is a row vector of scores for observation i on the k explanatory variables (some of which may be qualitative); and

¹This is called the report in this document.

²This section of the report dealt with the estimation of the zero-coupon or spot curve.

³In the original paper, the equation was in fact $R(m) = \beta_0 + (\beta_1 + \beta_2) \frac{1 - \exp(-t/\tau)}{t/\tau} - \beta_2 \exp(-t/\tau)$ where $R(m)$ is the yield to maturity at maturity m

- ε_i is the error for the i th observation.

...

Under the assumption of independent and normally distributed errors, with zero means and common variance, the general nonlinear model has likelihood

$$\begin{aligned} L(\beta, \sigma_\varepsilon^2) &= \frac{1}{2\pi\sigma_\varepsilon^2} \exp \left\{ -\frac{\sum_{i=1}^n [Y_i - f(\beta, x_i^T)]^2}{2\sigma_\varepsilon^2} \right\} \\ &= \frac{1}{2\pi\sigma_\varepsilon^2} \exp \left\{ -\frac{1}{2\sigma_\varepsilon^2} S(\beta) \right\} \end{aligned}$$

where $S(\beta)$ is the sum of squares function

$$S(\beta) = \sum_{i=1}^n [Y_i - f(\beta, x_i^T)]^2$$

As for the general linear model, we therefore maximise the likelihood by minimising the sum of squares errors $S(\beta)$.

The above indicates that if the errors are Normally distributed then Least Squares corresponds to Maximum Likelihood estimation. It is also true that if the errors are not Normally distributed the least squares estimates are consistent, that is as the sample size increases the estimates get closer and closer to the “true” values of the parameters.

There are some outliers in the data. To see if the results depend only on a few observations, the analysis was repeated using a robust non-linear regression method in R, `nlrob` in the `robustbase` package (Rousseeuw, Crowx, Todorov, Rusckstuhl, Salibian-Barrera, Verbeke, Koller, and Maechler, 2012), which uses robust M-estimates, using iteratively re-weighted least squares to estimate the fitted model.

The name M-estimate derives from ‘MLE-like’ estimators (Venables and Ripley, 2008, p. 122). Consider the case where only a mean μ is to be estimated and it is known the standard deviation is 1. Assume the density of the data is f and $\rho = -\log f$. The MLE solves

$$\min_{\mu} \sum_i -\log f(y_i - \mu) = \min_{\mu} \sum_i \rho(y_i - \mu)$$

Let $\psi = \rho'$, the derivative with respect to μ . Then the MLE can be found by using the equations

$$\sum_i \psi(y_i - \mu) = 0 \text{ or } \sum_i w_i(y_i - \mu) = 0$$

where

$$w_i = \frac{\psi(y_i - \hat{\mu})}{y_i - \hat{\mu}}.$$

The estimate of μ is solved iteratively, with the weights being undated at each iteration. The mean corresponds to $\rho(x) = x^2$. In this case $\psi(x) = 2x$. The idea of a robust M-estimator is to choose a different function for ψ where outliers have less of an effect. A popular choice is metric Winsorizing with

$$\psi(x) = \begin{cases} -c & x < -c \\ x & |x| < c \\ c & x > c \end{cases}$$

shown in Figure 1. Here the effects of outliers are trimmed to $\pm c$. The results depend on the choice of c . By choosing $c = 1.345$, it can be shown that the relative efficiency of the robust M-estimator relative to least squares is 95%.⁴

The standard deviation is never known so a robust estimator is needed. The choice used in the `nlrob` function is the MAD (Median Absolute Deviation) estimator given by the median of the absolute values of the deviations from the mean, divided by 0.6475.

Extensions of the robust M-estimator methodology to multiple linear regression and non-linear estimation follow a similar logic.

⁴The variance of the least squares estimator is 95% of the variance of the robust M-estimator if there were no outliers.

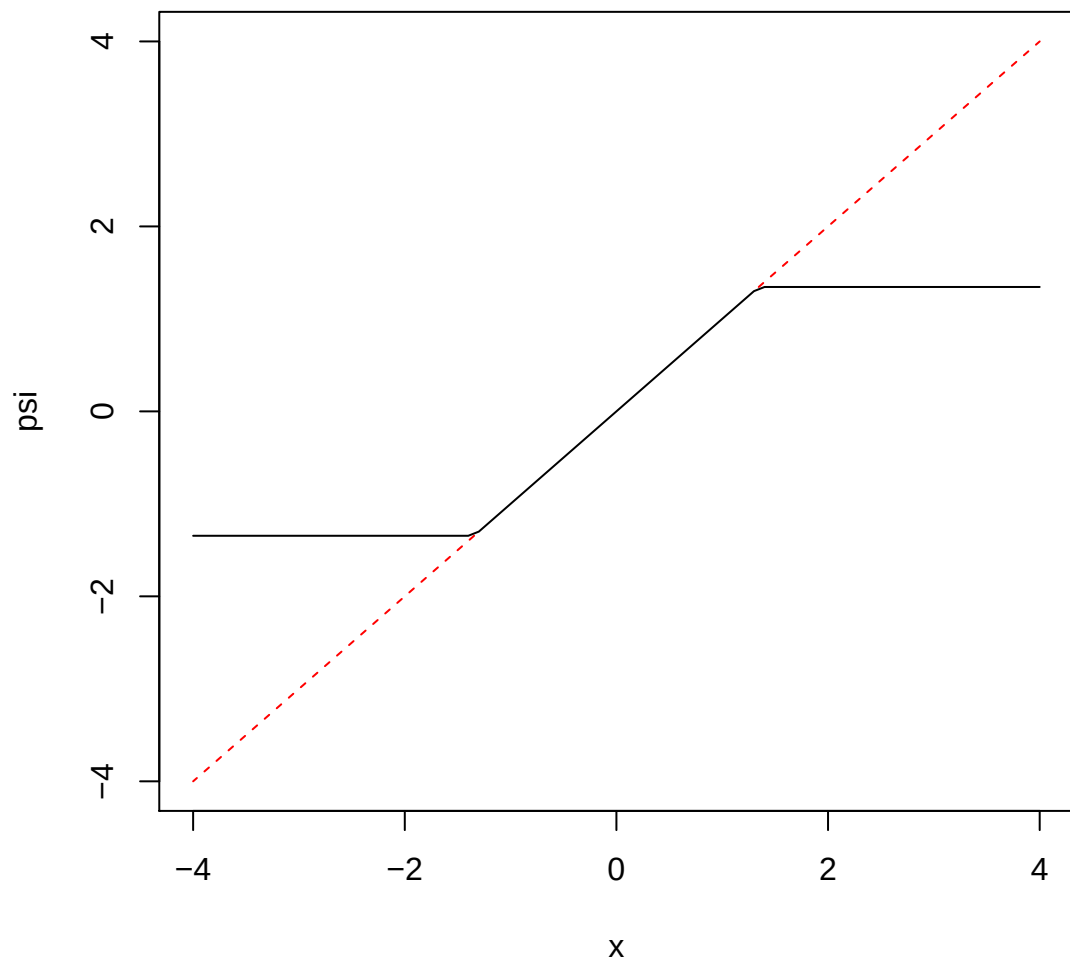


Figure 1: ψ function for Robust regression (solid) and for Normal regression (dotted).

Date	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$
21/11/11	3.56	11.36	-5.78	-4.26
22/11/11	2.96	10.89	-5.28	-4.52
23/11/11	2.67	10.62	-5.01	-4.76
24/11/11	2.49	10.39	-4.78	-4.57
25/11/11	2.46	10.41	-4.86	-4.69
28/11/11	2.62	10.47	-5.03	-4.04
29/11/11	2.90	10.73	-5.24	-3.86
30/11/11	3.10	10.78	-5.30	-3.66
01/12/11	3.45	11.06	-5.57	-3.44
02/12/11	3.77	11.26	-5.72	-3.47
05/12/11	3.81	11.27	-5.70	-3.53
06/12/11	3.31	11.14	-5.59	-4.30
07/12/11	2.59	10.90	-5.19	-5.52
08/12/11	2.56	10.90	-5.23	-5.67
09/12/11	2.47	10.66	-5.02	-5.47
12/12/11	2.51	10.90	-5.23	-5.54
13/12/11	2.43	10.71	-5.09	-5.48
14/12/11	2.45	10.80	-5.14	-5.86
15/12/11	2.59	10.66	-5.06	-5.54
16/12/11	2.67	10.76	-5.18	-5.51

Table 1: Estimated parameters of Nelson-Siegel model for Australian issued AUD bonds: nls fit.

3 Estimation

3.1 Australian issued AUD bonds

The Nelson-Siegel formula was fitted to the 15 Australian issued AUD bonds rated BBB+ only using the `nls` function in R for each of the 20 days from 21/11/11 to 16/12/11, excluding weekends. The estimated parameters for each day are given in Table 1.

For each day, the set of residuals and fitted values from the model were computed. Figure 2 shows a normal probability plot of the average residual per bond over the 20 days, and Figure 3 shows a plot of the average residual per bond over the 20 days versus the average predicted value per bond over the 20 days. The normal probability plot is reasonably straight and there does not appear to be a pattern in the residuals versus fitted values plot, indicating there is no evidence of problems with the model.

A set of similar fits, but using robust non-linear regression, was performed using the `nlsrob` function in R. The estimated parameters for each day are given in Table 2. Note that days 7, 8, 10 and 11 had to be removed in order to get the robust fits.

Figure 4 gives a comparison of the estimated average yield at 10 years for both the non-linear least squares fit and the robust non-linear fit. The estimated average yield at 10 years from the report is also shown. The estimated average yield at 10 years given in the report differs slightly from the estimated average yield based on the `nls` fit in R. There are two reasons for this:

1. There are differences in the way that the parameters are estimated in Excel and R. The effects of these are relatively minor.
2. In the report, the estimated yield was based on the average estimated yield over the 20 days. However, given the autocorrelated nature of the estimated yields shown in Figure 4, we estimated the mean estimated yield by fitting an AR(1) model where

$$y_t = \mu + \rho y_{t-1} + u_t$$

Date	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$
21/11/11	6.206	12.444	-6.898	-2.671
22/11/11	4.705	11.618	-6.091	-3.054
23/11/11	4.053	11.199	-5.703	-3.302
24/11/11	4.058	10.967	-5.497	-2.767
25/11/11	4.268	11.137	-5.729	-2.777
28/11/11	5.817	11.347	-6.007	-1.004
29/11/11				
30/11/11				
01/12/11	7.955	12.270	-6.838	-0.041
02/12/11				
05/12/11				
06/12/11	6.841	12.556	-7.061	-2.239
07/12/11	3.664	11.449	-5.880	-4.272
08/12/11	3.705	11.499	-5.977	-4.336
09/12/11	3.380	11.102	-5.606	-4.232
12/12/11	3.799	11.529	-6.041	-3.966
13/12/11	3.773	11.360	-5.930	-3.810
14/12/11	3.548	11.377	-5.897	-4.441
15/12/11	3.813	11.311	-5.862	-4.322
16/12/11	3.873	11.390	-5.947	-4.261

Table 2: Estimated parameters of Nelson-Siegel model for Australian issued AUD bonds: robust fit.

where

$$\begin{aligned}
y_t &= \text{Estimated Average yield at 10 years at Day } t \\
y_{t-1} &= \text{Estimated Average yield at 10 years at Day } t - 1 \\
\mu &= \text{Average yield at 10 years to be estimated} \\
u_t &= \text{Independent random errors}
\end{aligned}$$

The advantage of fitting the AR(1) model is that a slightly more efficient estimate of the Average yield is obtained, but also, and more importantly, a standard error for the estimate can be obtained.

We have assumed that the process is stationary, and therefore that the sampled 20 days represent typical behaviour of the bond yields. It is not possible to confirm this, although clear instabilities would have been discernable. The results are dependent on the length and representativeness of the sample period chosen.

We also investigated whether estimating the standard error based on the delta method⁵ would give similar results. However, we found that the day to day variation was much larger than the variation based on the delta method and that the variation based on the delta method was relatively constant for a particular maturity, and hence the modelling based on the AR(1) model was the best way to estimate the average and obtain a standard error.

The robust estimate of the Average yield at 10 years is slightly less than both the non-robust estimates.

A comparison of the estimated fair-value curve given in the report and that using `nls` in R and also using the robust fit is given in Figure 5. The confidence intervals for the fitted curves for the estimated

⁵For each day, estimates of the parameters and associated variance-covariance matrix are given by `nls` and robust version. The yield at 10 years is a non-linear function of the parameters, say g . The delta method approximates the variance of a function of the parameters by $V(g(b)) \approx g'V(b)$ where b are the estimated parameters, g' is derivative of g with respect to b , and $V(b)$ is the variance-covariance matrix of b .

average yields for each day at maturities from 0.1 to 15 years in steps of 0.1 were calculated by fitting the AR(1) model to the daily estimates and determining the standard error of the average yield. The confidence intervals are quite narrow.

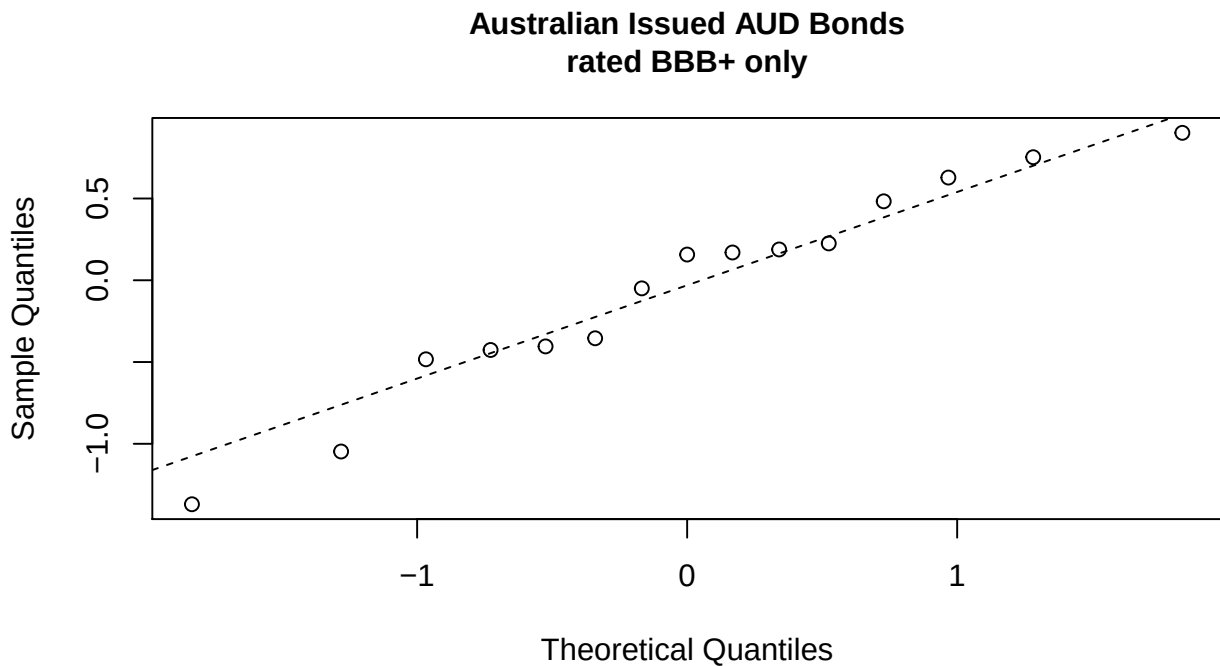


Figure 2: QQ Plot of average residuals for Australian issued AUD bonds labelled BBB+ only.

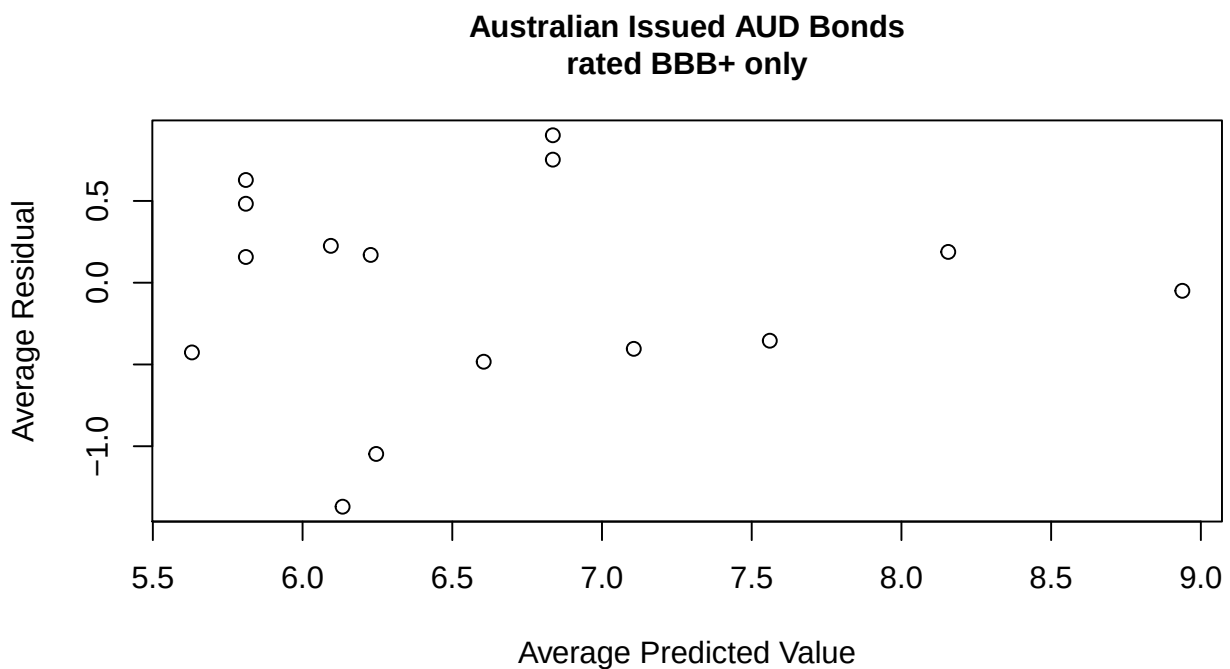


Figure 3: Plot of average residuals versus average fitted values for Australian issued AUD bonds labelled BBB+ only.

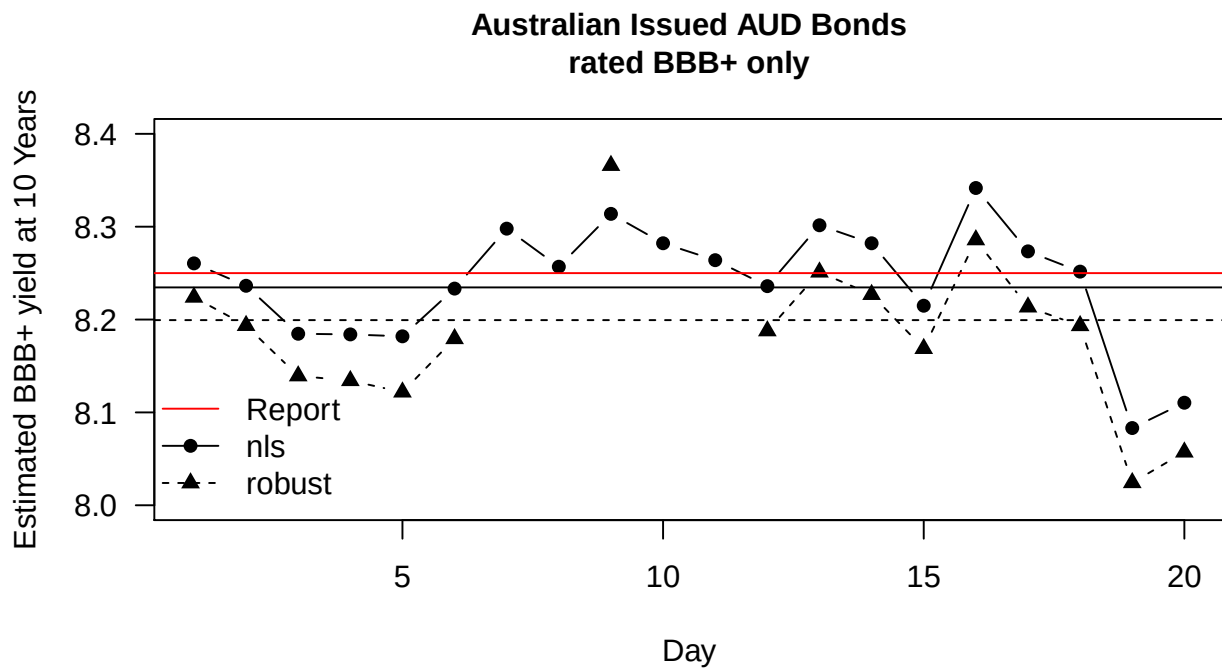


Figure 4: Plot of daily estimated average yield at 10 years for Australian issued AUD bonds labelled BBB+ only.

Figure 5: Yield to Maturity curves for Australian issued AUD bonds labelled BBB+ only with 95% pointwise confidence intervals. The curves given in the report are shown in red.

Date	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$
21/11/11	1.20	9.36	-3.14	-6.61
22/11/11	1.13	9.17	-2.91	-6.57
23/11/11	1.11	9.14	-2.89	-6.65
24/11/11	1.10	9.14	-2.86	-6.74
25/11/11	1.09	9.20	-2.94	-6.91
28/11/11	1.08	9.21	-3.01	-6.77
29/11/11	1.08	9.26	-2.95	-6.96
30/11/11	1.12	9.39	-3.05	-7.26
01/12/11	1.13	9.40	-3.08	-7.17
02/12/11	1.14	9.39	-3.01	-7.16
05/12/11	1.15	9.32	-2.95	-7.02
06/12/11	1.14	9.34	-2.97	-7.23
07/12/11	1.14	9.31	-2.87	-7.42
08/12/11	1.15	9.31	-2.91	-7.43
09/12/11	1.15	9.42	-3.02	-7.67
12/12/11	1.13	9.41	-2.94	-7.73
13/12/11	1.12	9.34	-2.94	-7.57
14/12/11	1.12	9.21	-2.85	-7.29
15/12/11	1.18	9.14	-3.01	-6.61
16/12/11	1.17	9.06	-2.89	-6.63

Table 3: Estimated parameters of Nelson-Siegel model for Australian issued bonds: nls fit.

3.2 Australian issued bonds rated BBB+ only

A similar process was adopted for the 42 Australian issued bonds rated BBB+ only. Table 3 and Table 4 give the parameter estimates for the nls and robust fits, respectively.

Figure 6 gives the Normal probability plot of the average residuals, while Figure 7 gives the plot of the average residual versus the average fitted value. Both plots are affected by an outlier.

Removing the outlier, the re-estimated parameters are given in Table 5 and Table 6.

The Normal probability plot, shown in Figure 8, and the plot of average residuals versus average fitted values, shown in Figure 9, for the nls fit are much more satisfactory.

Figure 10 shows a comparison of the estimated average yield at 10 years while Figure 11 shows a comparison of the estimated fair-value curve in the report and that using nls in R and also using the robust fit, both with and without the outlier. While there is only a minor difference between the estimated average yield at 10 years given in the report and that computed from R, the values using either robust regression or deleting the outlier are almost 20 basis points less. The pointwise 95% confidence intervals for the average yield are quite narrow with a slight increase in width for higher maturities.

Date	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$
21/11/11	1.18	9.03	-2.97	-5.65
22/11/11	1.11	8.82	-2.73	-5.55
23/11/11	1.08	8.77	-2.70	-5.57
24/11/11	1.06	8.76	-2.65	-5.65
25/11/11	1.05	8.81	-2.72	-5.85
28/11/11	1.04	8.81	-2.79	-5.69
29/11/11	1.04	8.86	-2.71	-5.97
30/11/11	1.08	8.98	-2.79	-6.25
01/12/11	1.09	9.01	-2.80	-6.28
02/12/11	1.10	8.98	-2.74	-6.18
05/12/11	1.10	8.91	-2.67	-6.05
06/12/11	1.10	8.94	-2.71	-6.25
07/12/11	1.10	8.91	-2.61	-6.45
08/12/11	1.11	8.91	-2.68	-6.39
09/12/11	1.11	9.01	-2.78	-6.62
12/12/11	1.09	9.02	-2.70	-6.74
13/12/11	1.09	8.94	-2.71	-6.52
14/12/11	1.08	8.80	-2.64	-6.11
15/12/11	1.14	8.74	-2.78	-5.56
16/12/11	1.14	8.66	-2.68	-5.50

Table 4: Estimated parameters of Nelson-Siegel model for Australian issued bonds: robust fit.

Date	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$
21/11/11	1.16	8.95	-2.85	-5.73
22/11/11	1.08	8.75	-2.61	-5.68
23/11/11	1.05	8.71	-2.57	-5.75
24/11/11	1.04	8.70	-2.53	-5.82
25/11/11	1.03	8.75	-2.59	-6.01
28/11/11	1.02	8.75	-2.66	-5.85
29/11/11	1.02	8.79	-2.60	-6.00
30/11/11	1.06	8.90	-2.68	-6.25
01/12/11	1.07	8.92	-2.72	-6.15
02/12/11	1.09	8.90	-2.65	-6.12
05/12/11	1.09	8.83	-2.58	-5.96
06/12/11	1.08	8.86	-2.62	-6.21
07/12/11	1.08	8.83	-2.52	-6.37
08/12/11	1.10	8.84	-2.57	-6.40
09/12/11	1.10	8.95	-2.68	-6.65
12/12/11	1.08	8.94	-2.61	-6.72
13/12/11	1.07	8.88	-2.60	-6.57
14/12/11	1.07	8.75	-2.51	-6.28
15/12/11	1.12	8.66	-2.66	-5.60
16/12/11	1.12	8.59	-2.56	-5.60

Table 5: Estimated parameters of Nelson-Siegel model for Australian issued bonds: nls fit, removing outlier.

Date	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$
21/11/11	1.17	8.94	-2.90	-5.47
22/11/11	1.10	8.74	-2.67	-5.38
23/11/11	1.07	8.69	-2.64	-5.41
24/11/11	1.05	8.68	-2.59	-5.50
25/11/11	1.04	8.74	-2.66	-5.71
28/11/11	1.03	8.74	-2.73	-5.56
29/11/11	1.03	8.78	-2.64	-5.80
30/11/11	1.07	8.90	-2.72	-6.10
01/12/11	1.08	8.92	-2.73	-6.08
02/12/11	1.09	8.89	-2.67	-6.04
05/12/11	1.09	8.82	-2.59	-5.89
06/12/11	1.09	8.85	-2.65	-6.07
07/12/11	1.09	8.83	-2.54	-6.26
08/12/11	1.10	8.83	-2.62	-6.20
09/12/11	1.10	8.93	-2.72	-6.44
12/12/11	1.08	8.93	-2.65	-6.54
13/12/11	1.07	8.86	-2.66	-6.32
14/12/11	1.07	8.71	-2.59	-5.92
15/12/11	1.13	8.65	-2.71	-5.35
16/12/11	1.13	8.57	-2.64	-5.24

Table 6: Estimated parameters of Nelson-Siegel model for Australian issued bonds: robust fit, removing outlier.

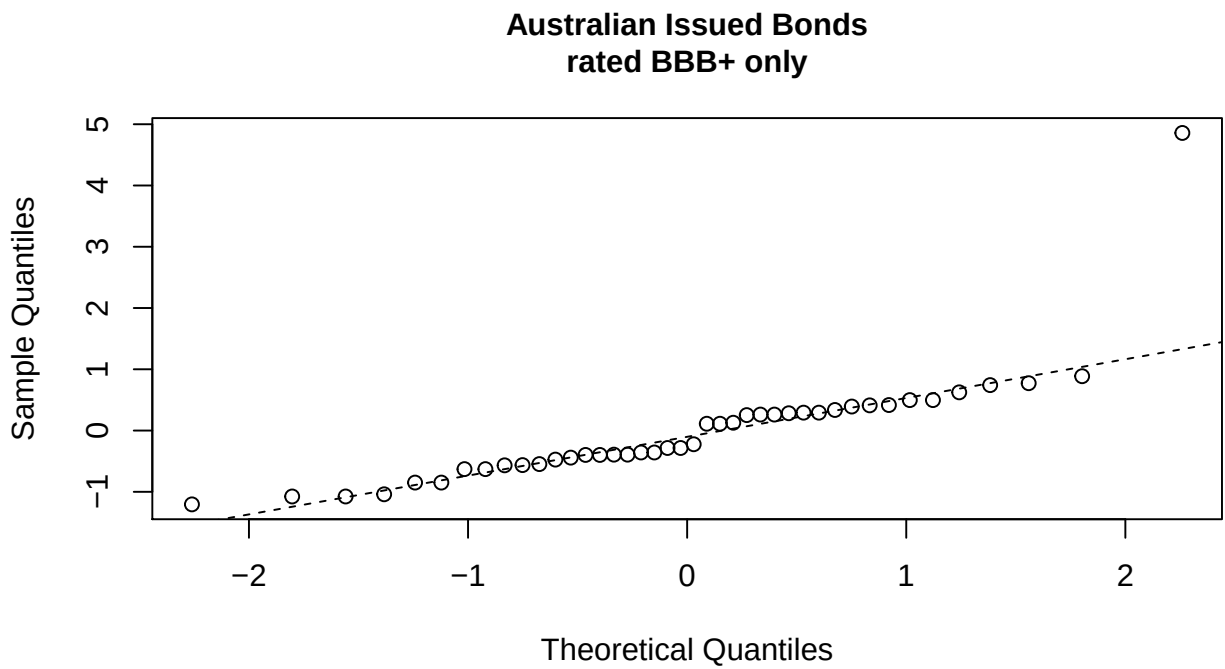


Figure 6: QQ Plot of average residuals for Australian issued bonds labelled BBB+ only.

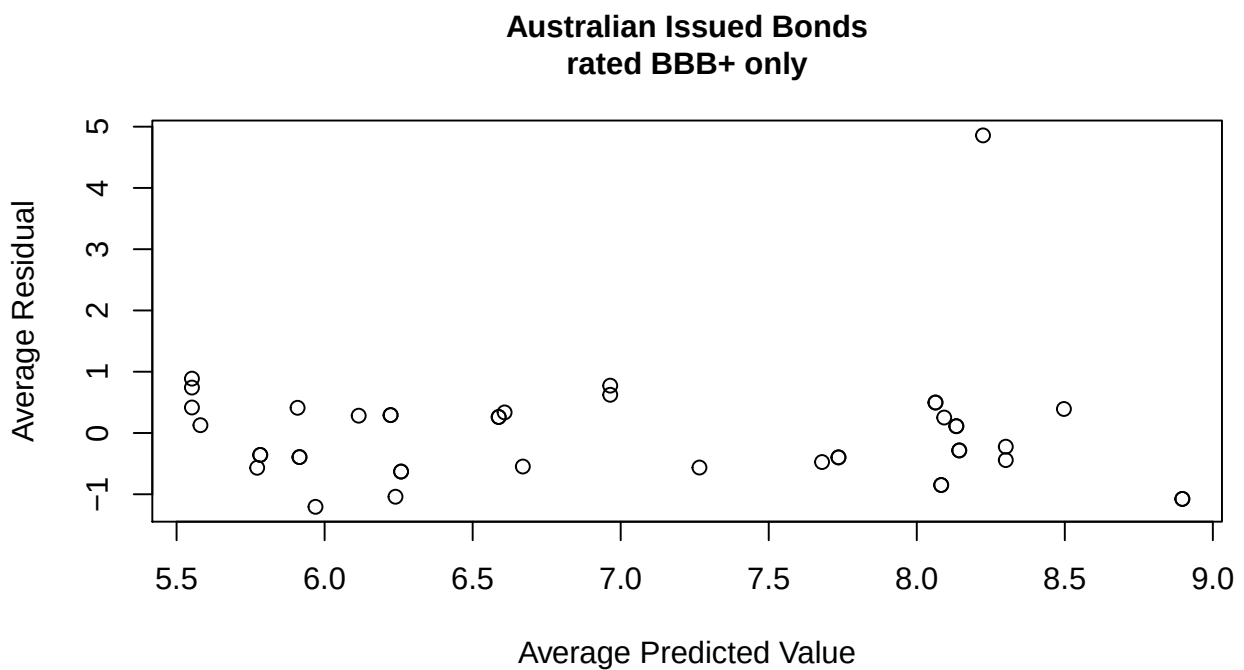


Figure 7: Plot of average residuals versus average fitted values for Australian issued bonds labelled BBB+ only.

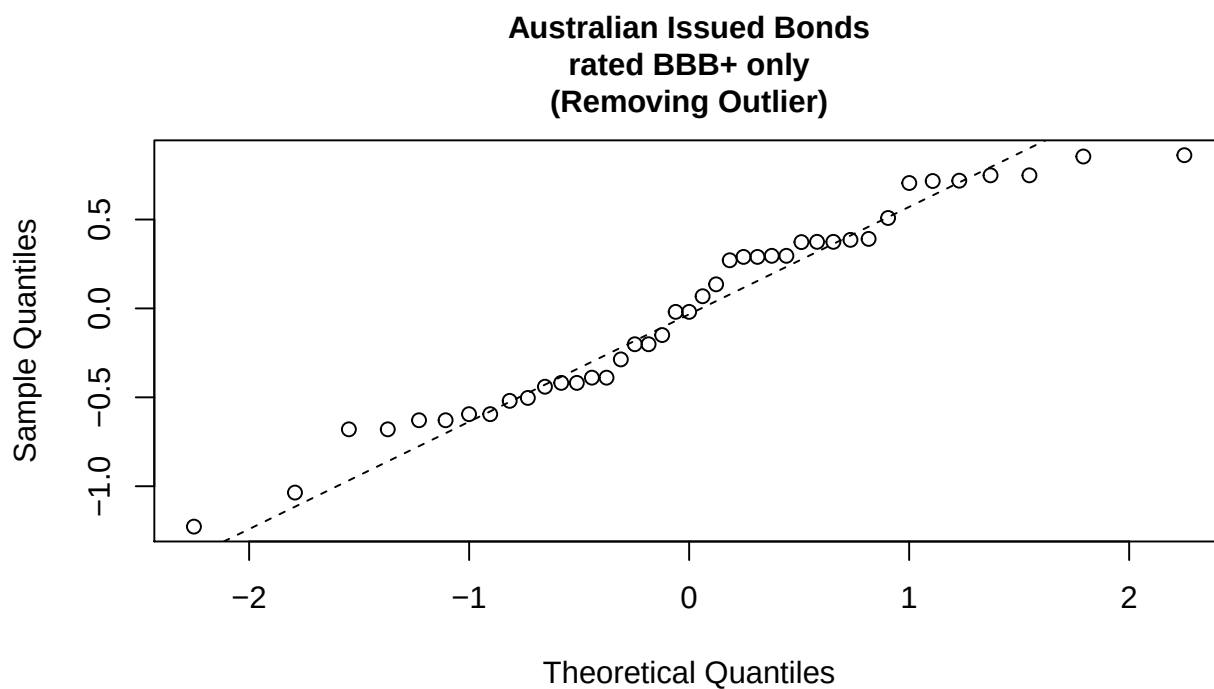


Figure 8: QQ Plot of average residuals for Australian issued bonds labelled BBB+ only (removing outlier).

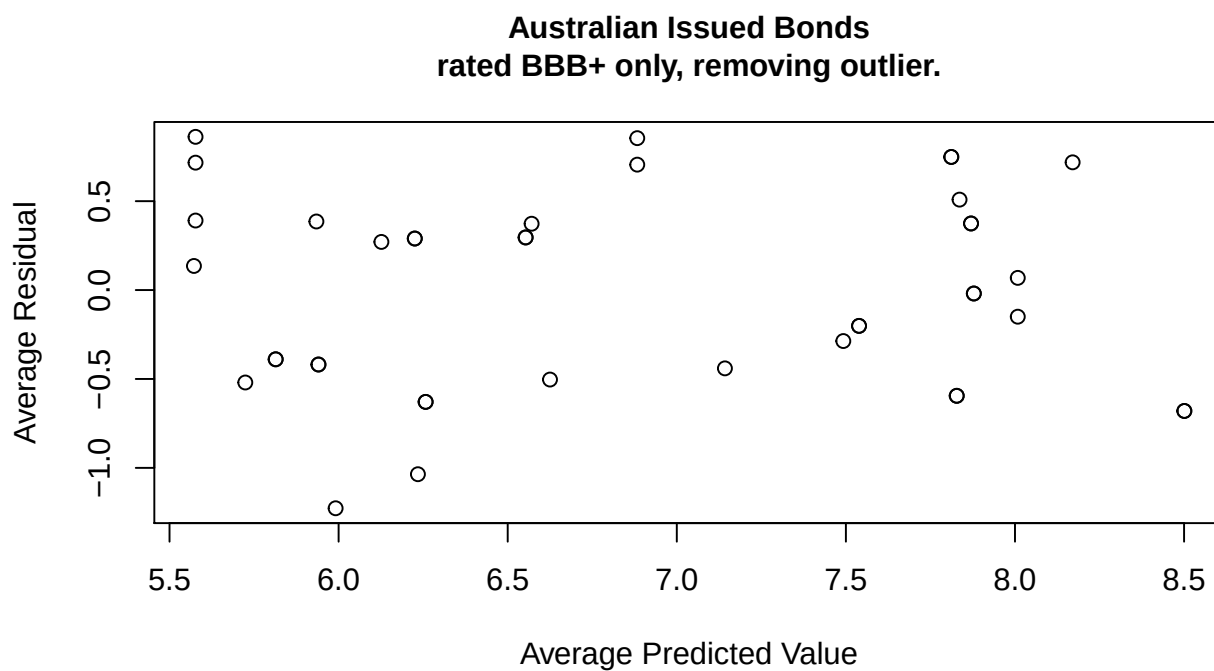


Figure 9: Plot of average residuals versus average fitted values for Australian issued bonds labelled BBB+ only (removing outlier).

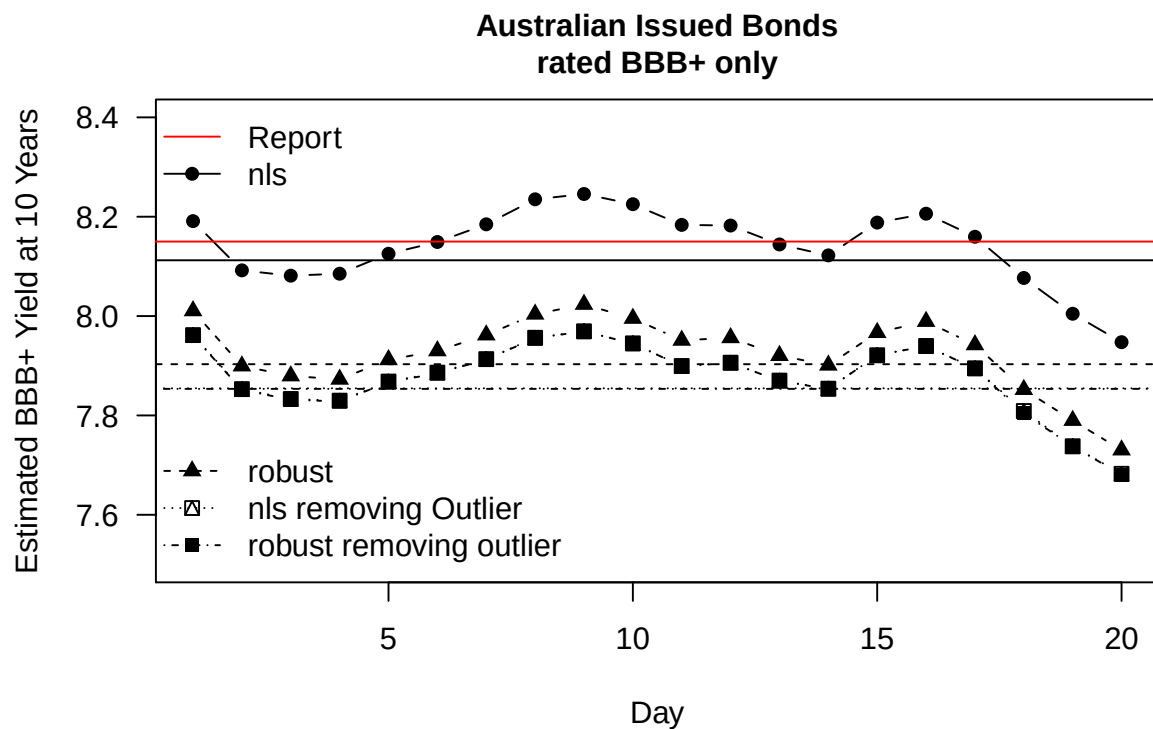


Figure 10: Plot of daily estimated average yield at 10 years for Australian issued bonds labelled BBB+ only.

3.2.1 Demonstration of the need for Fair Value Curves

Figure 12 shows the result of a simulation exercise that demonstrates that the AER's approach of averaging the yields of a number of bonds is biased and that there is a need to use the Fair Value Curve. This analysis complements and supports that given in the report in paragraphs 176 to 181.

In the simulation exercise we sampled 9 bonds with maturities uniformly distributed between 7.5 and 12.5 years. For each bond we took the average yield based on the fitted curve deleting the outlier. We performed 10,000 simulations and for each simulation calculated the average yield of the 9 bonds. Figure 12 shows the histogram of the averages, with an overall grand average of 7.74, which is clearly below the yield on the curve at 10 years which is 7.85.

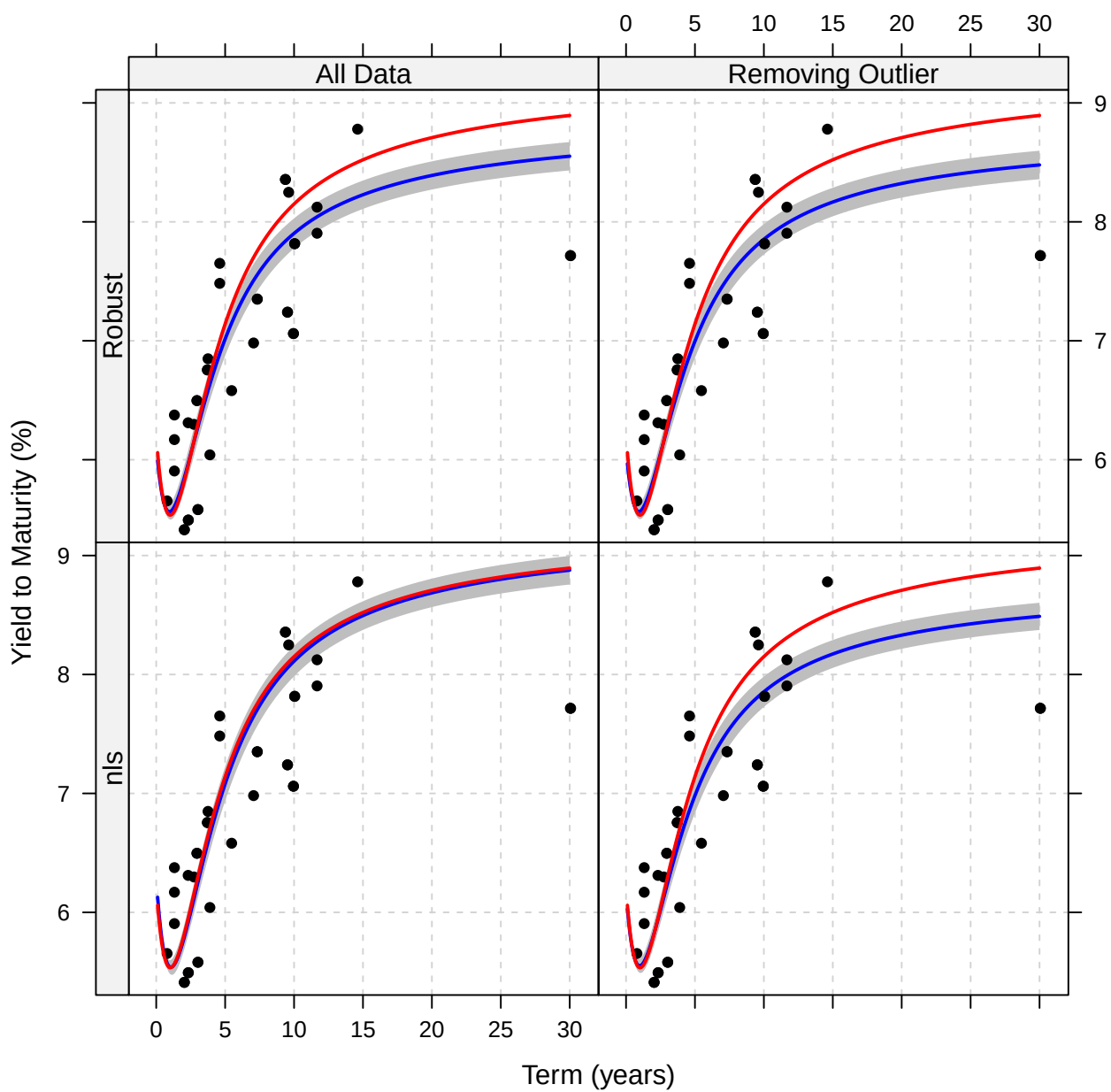


Figure 11: Yield to Maturity curves for Australian issued bonds labelled BBB+ only with 95% point-wise confidence intervals. The curves given in the report are shown in red.

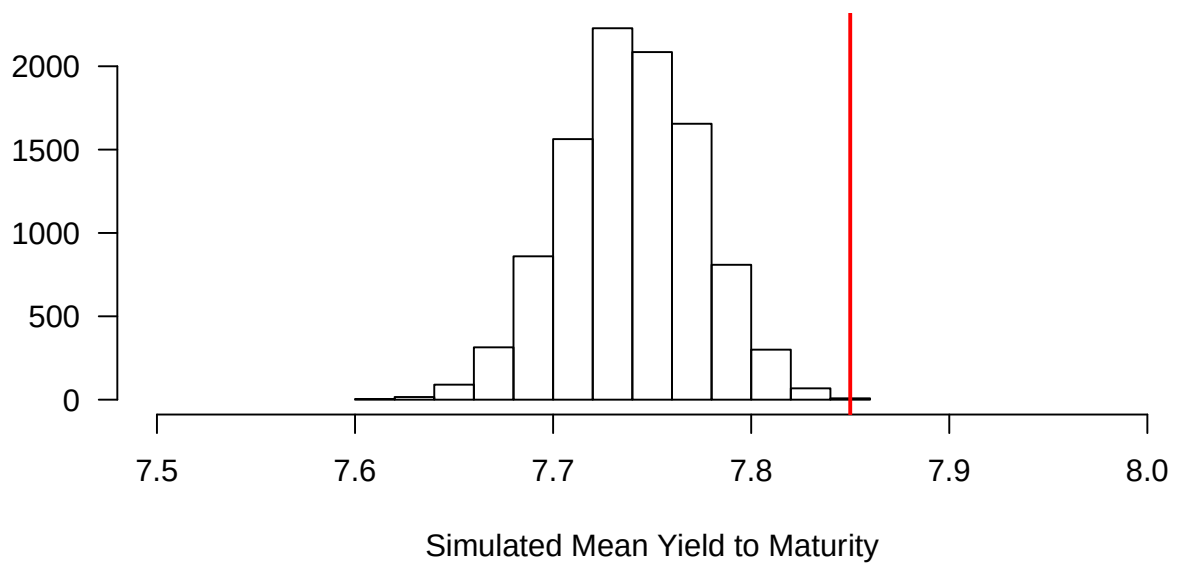


Figure 12: Results of Simulation Exercise to illustrate the bias of simple averaging.

Date	$\hat{\beta}_0$	$\hat{\beta}_1^{A-}$	$\hat{\beta}_1^{BBB+}$	$\hat{\beta}_1^{BBB}$	$\hat{\beta}_2$	$\hat{\beta}_3$
21/11/11	1.236	7.752	8.724	8.773	-1.919	-5.644
22/11/11	1.194	7.684	8.648	8.686	-1.821	-5.694
23/11/11	1.165	7.547	8.520	8.570	-1.688	-5.730
24/11/11	1.151	7.525	8.500	8.565	-1.705	-5.660
25/11/11	1.268	7.650	8.594	8.633	-2.043	-5.255
28/11/11	1.382	7.701	8.655	8.695	-2.375	-4.458
29/11/11	1.415	7.797	8.758	8.800	-2.485	-4.321
30/11/11	1.445	7.777	8.714	8.746	-2.414	-4.202
01/12/11	1.313	7.801	8.738	8.770	-2.151	-4.829
02/12/11	1.326	7.743	8.692	8.721	-2.082	-4.703
05/12/11	1.321	7.712	8.666	8.700	-2.011	-4.748
06/12/11	1.369	7.804	8.744	8.781	-2.126	-5.144
07/12/11	1.370	7.891	8.785	8.785	-2.153	-5.136
08/12/11	1.364	7.877	8.785	8.785	-2.154	-5.303
09/12/11	1.301	7.784	8.669	8.669	-1.973	-5.441
12/12/11	1.283	7.874	8.789	8.789	-2.054	-5.530
13/12/11	1.270	7.790	8.693	8.693	-2.011	-5.461
14/12/11	1.276	7.790	8.707	8.707	-1.953	-5.683
15/12/11	1.317	7.654	8.553	8.553	-1.897	-5.429
16/12/11	1.307	7.690	8.596	8.596	-1.905	-5.503

Table 7: Estimated parameters of Nelson-Siegel model for Australian issued AUD bonds rated BBB to A-: nls fit.

3.3 Australian issued AUD rated BBB to A-

The same process was followed using the 81 Australian issued AUD bonds rated BBB to A-. Table 7 and Table 8 give the estimated parameters for the nls fit and robust fit, respectively.

Figure 13 provides the normal probability plot and Figure 14 plots the average residual versus the average fitted value. While no outliers were present in the normal probability plot, the low early values and high latter values are suggestive of fat tails in the distribution.

Figure 15 shows the comparison of the estimated average yield at 10 years while Figure 16 shows a comparison of the yield to maturity curve in the report and that using nls in R and also using the robust fit. There is virtually no difference between the estimated average yields at 10 years between the report and that estimated by R. The presence of a fat tailed distribution would suggest that the robust regression estimation is more realistic. However, the results of the robust regression are almost 10 basis points higher. The confidence intervals for the average yields are quite narrow although the width is slightly higher for the robust fits.

Date	$\hat{\beta}_0$	$\hat{\beta}_1^{A-}$	$\hat{\beta}_1^{BBB+}$	$\hat{\beta}_1^{BBB}$	$\hat{\beta}_2$	$\hat{\beta}_3$
21/11/11	1.185	7.854	8.825	8.825	-2.041	-5.940
22/11/11	1.140	7.771	8.738	8.738	-1.937	-5.991
23/11/11	1.117	7.652	8.622	8.622	-1.809	-6.046
24/11/11	1.094	7.639	8.595	8.595	-1.804	-6.010
25/11/11	1.304	7.851	8.776	8.776	-2.396	-5.357
28/11/11	1.549	8.047	8.970	8.970	-2.928	-4.434
29/11/11	1.600	8.147	9.071	9.071	-3.055	-4.221
30/11/11	1.721	8.210	9.105	9.105	-3.090	-4.106
01/12/11	1.579	8.188	9.098	9.098	-2.897	-4.485
02/12/11	1.715	8.236	9.156	9.156	-2.977	-4.275
05/12/11	1.603	8.115	9.042	9.042	-2.773	-4.422
06/12/11	1.720	8.313	9.219	9.219	-3.027	-4.801
07/12/11	1.696	8.311	9.208	9.208	-3.016	-4.704
08/12/11	1.634	8.249	9.165	9.165	-2.945	-4.928
09/12/11	1.426	8.000	8.894	8.894	-2.546	-5.179
12/12/11	1.420	8.095	9.027	9.027	-2.655	-5.213
13/12/11	1.403	8.002	8.917	8.917	-2.609	-5.125
14/12/11	1.389	7.990	8.927	8.927	-2.518	-5.409
15/12/11	1.497	7.923	8.833	8.833	-2.559	-5.115
16/12/11	1.460	7.920	8.840	8.840	-2.498	-5.208

Table 8: Estimated parameters of Nelson-Siegel model for Australian issued AUD bonds rated BBB to A-: robust fit.

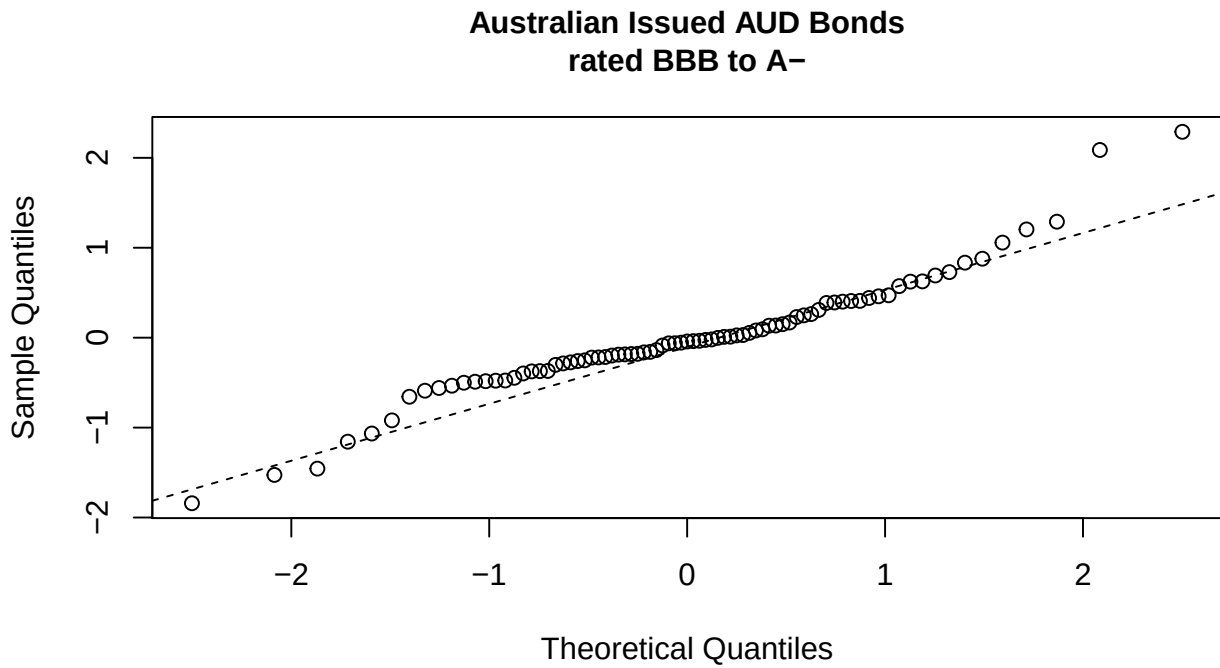


Figure 13: QQ Plot of average residuals for Australian issued Australian dollar bonds rated BBB to A-.

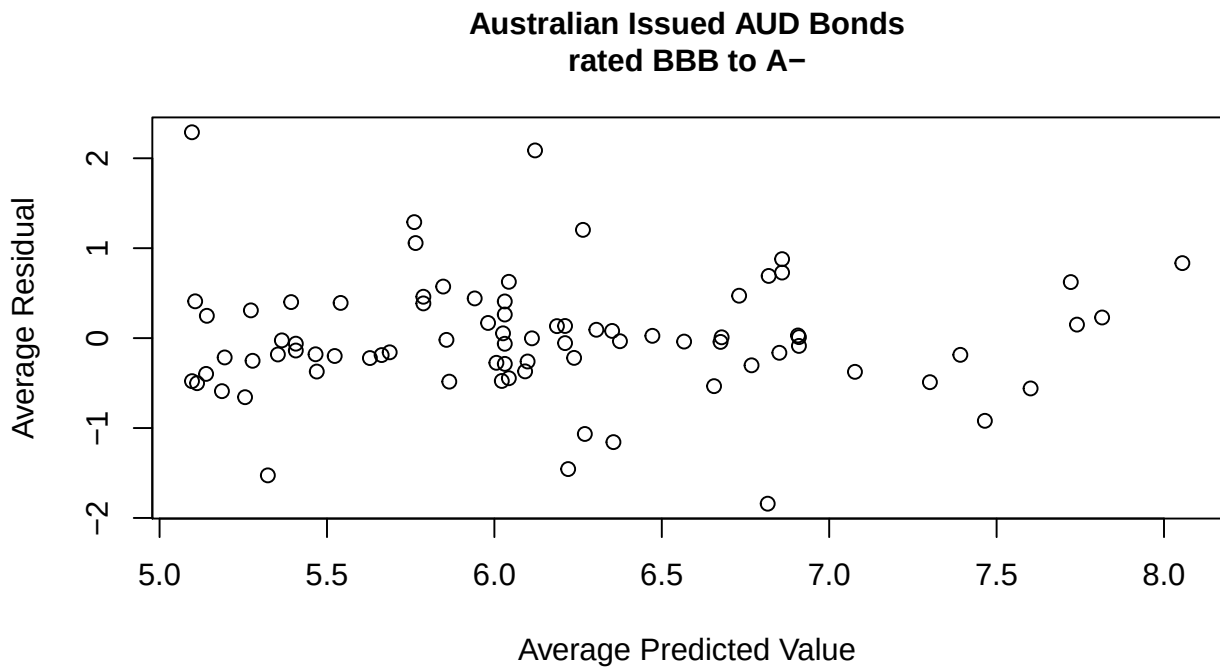


Figure 14: Plot of average residuals versus average fitted values for Australian issued Australian dollar bonds rated BBB to A-.

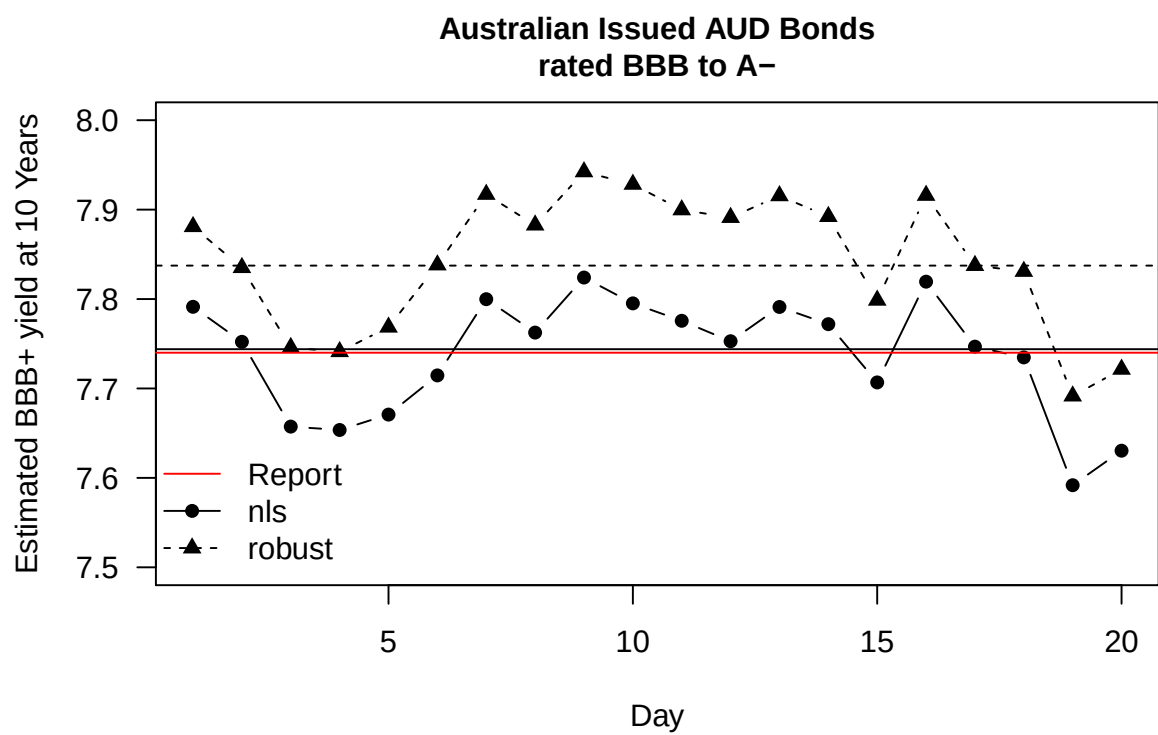


Figure 15: Plot of daily estimated average yield at 10 years for Australian issued AUD bonds rated BBB to A-.

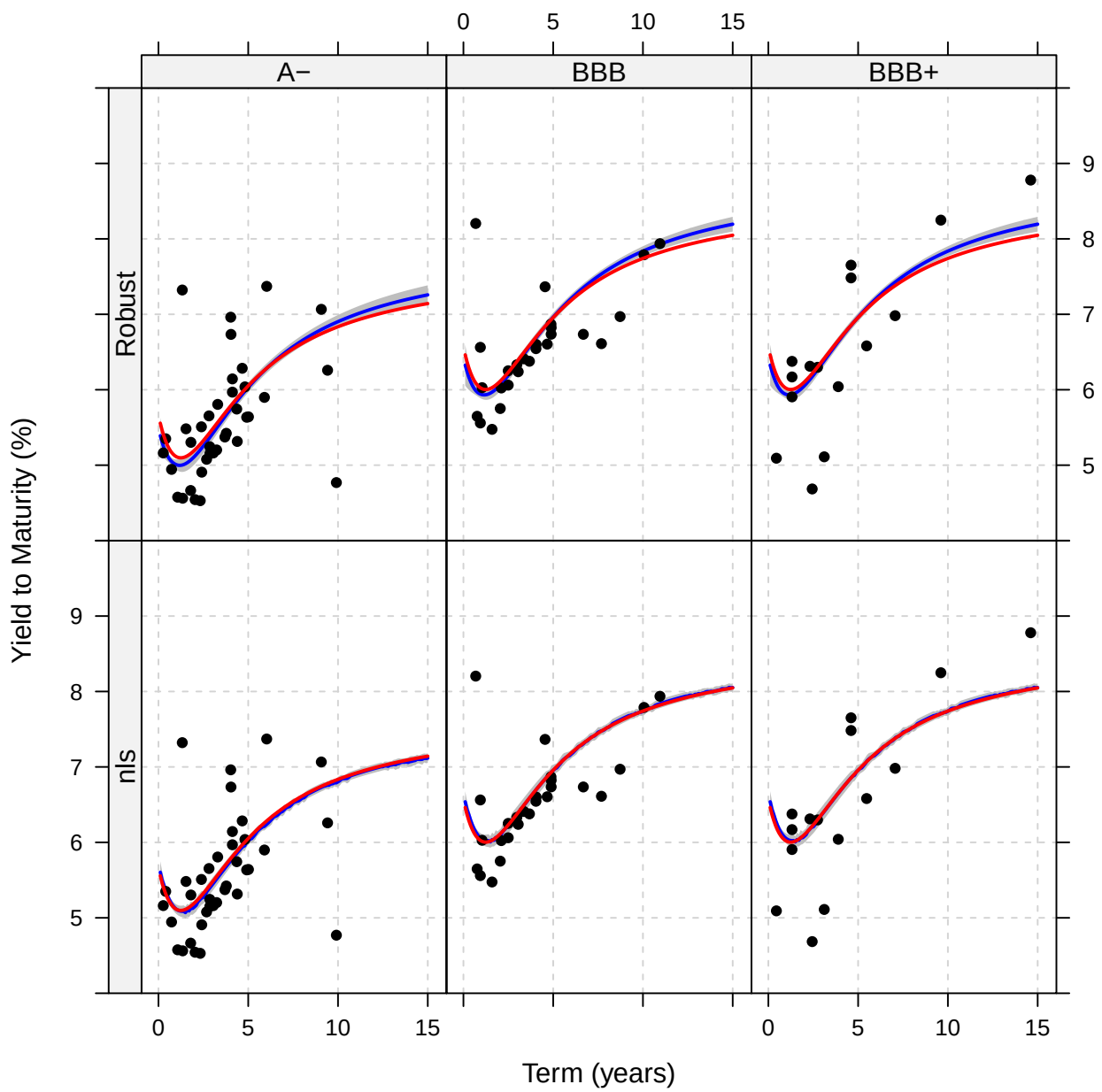


Figure 16: Yield to Maturity curves for Australian issued AUD bonds rated BBB to A- with 95% point-wise confidence intervals. The curves given in the report are shown in red.

Date	$\hat{\beta}_0$	$\hat{\beta}_1^{A-}$	$\hat{\beta}_1^{BBB+}$	$\hat{\beta}_1^{BBB}$	$\hat{\beta}_2$	$\hat{\beta}_3$
21/11/11	1.021	8.032	9.050	9.602	-1.892	1.018
22/11/11	1.004	7.966	8.951	9.544	-1.794	0.985
23/11/11	1.000	7.977	8.952	9.546	-1.765	0.976
24/11/11	0.992	8.012	8.963	9.572	-1.802	0.951
25/11/11	1.006	8.102	9.031	9.664	-1.956	0.929
28/11/11	1.026	8.110	9.047	9.692	-2.222	0.937
29/11/11	1.040	8.165	9.098	9.743	-2.297	0.933
30/11/11	1.069	8.267	9.193	9.851	-2.363	0.927
01/12/11	1.032	8.253	9.175	9.836	-2.112	0.923
02/12/11	1.025	8.160	9.101	9.741	-1.997	0.941
05/12/11	1.026	8.144	9.075	9.728	-1.955	0.931
06/12/11	1.043	8.216	9.137	9.793	-2.015	0.921
07/12/11	1.037	8.166	9.068	9.767	-2.011	0.902
08/12/11	1.037	8.093	9.020	9.699	-1.923	0.927
09/12/11	1.045	8.234	9.151	9.838	-2.023	0.917
12/12/11	1.035	8.181	9.106	9.827	-1.930	0.925
13/12/11	1.024	8.131	9.057	9.752	-1.859	0.927
14/12/11	1.010	8.030	8.950	9.676	-1.730	0.919
15/12/11	1.008	8.011	8.910	9.664	-1.718	0.899
16/12/11	1.002	7.951	8.823	9.616	-1.655	0.873

Table 9: Estimated parameters of Nelson-Siegel model for Australian issued bonds rated BBB to A-: nls fit.

3.4 Australian issued bonds rated BBB to A-

Using the 224 Australian issued bonds rated BBB to A-, again the same process was followed. The estimated parameters for the nls fir and robust fit are given in Table 9 and Table 10, respectively.

The normal probability plot is given in Figure 17, and the average residual versus the average fitted value is given in Figure 18. Both plots are affected by two outliers.

Removing the outliers, the estimated parameters are given in Table 11 and Table 12, respectively.

The results are more satisfactory, as can be seen in Figure 19 and Figure 20. Figure 21 shows a comparison of the estimated average yield at 10 years with and without the outliers removed while Figure 22 shows the corresponding fair value cureves. The report and the results from R (without removing the outliers) are similar. The robust regression results (with and without the outliers) and the R result with the outliers removed are all similar, and about 20 basis points lower than the report and the unadjusted R result. The presence of a fat tailed distribution would suggest that the robust regression estimation is more realistic.

The 95% confidence intervals for the average yield for A-, BBB+, and BBB bonds with both nls and robust fits including all the data and removing the outliers are quite narrow.

Date	$\hat{\beta}_0$	$\hat{\beta}_1^{A-}$	$\hat{\beta}_1^{BBB+}$	$\hat{\beta}_1^{BBB}$	$\hat{\beta}_2$	$\hat{\beta}_3$
21/11/11	0.986	7.806	8.801	9.196	-1.720	0.995
22/11/11	0.964	7.729	8.688	9.135	-1.616	0.959
23/11/11	0.954	7.701	8.659	9.087	-1.564	0.958
24/11/11	0.947	7.712	8.645	9.064	-1.574	0.933
25/11/11	0.974	7.826	8.730	9.165	-1.765	0.904
28/11/11	0.995	7.818	8.730	9.174	-2.038	0.912
29/11/11	1.006	7.858	8.771	9.249	-2.108	0.913
30/11/11	1.049	7.979	8.872	9.367	-2.191	0.894
01/12/11	1.005	7.982	8.868	9.386	-1.970	0.886
02/12/11	0.995	7.901	8.801	9.317	-1.878	0.901
05/12/11	0.996	7.879	8.767	9.288	-1.819	0.888
06/12/11	1.021	7.939	8.827	9.311	-1.901	0.888
07/12/11	1.014	7.899	8.765	9.305	-1.863	0.866
08/12/11	1.013	7.835	8.724	9.238	-1.784	0.889
09/12/11	1.028	7.964	8.847	9.341	-1.878	0.884
12/12/11	1.010	7.927	8.830	9.352	-1.816	0.903
13/12/11	0.999	7.849	8.752	9.249	-1.753	0.904
14/12/11	0.981	7.741	8.642	9.137	-1.613	0.901
15/12/11	0.977	7.727	8.602	9.127	-1.596	0.875
16/12/11	0.966	7.666	8.516	9.084	-1.519	0.850

Table 10: Estimated parameters of Nelson-Siegel model for Australian issued bonds rated BBB to A-: robust fit.

Date	$\hat{\beta}_0$	$\hat{\beta}_1^{A-}$	$\hat{\beta}_1^{BBB+}$	$\hat{\beta}_1^{BBB}$	$\hat{\beta}_2$	$\hat{\beta}_3$
21/11/11	0.994	7.868	8.791	9.368	-1.746	0.924
22/11/11	0.975	7.798	8.686	9.303	-1.645	0.887
23/11/11	0.970	7.800	8.675	9.290	-1.609	0.874
24/11/11	0.961	7.829	8.676	9.303	-1.639	0.847
25/11/11	0.976	7.915	8.739	9.389	-1.797	0.825
28/11/11	0.996	7.919	8.749	9.411	-2.065	0.830
29/11/11	1.010	7.970	8.793	9.460	-2.139	0.823
30/11/11	1.041	8.068	8.881	9.565	-2.202	0.813
01/12/11	1.002	8.058	8.867	9.556	-1.953	0.809
02/12/11	0.994	7.964	8.790	9.462	-1.841	0.826
05/12/11	0.995	7.946	8.760	9.445	-1.797	0.814
06/12/11	1.014	8.019	8.828	9.510	-1.858	0.809
07/12/11	1.007	7.970	8.761	9.485	-1.854	0.792
08/12/11	1.008	7.901	8.719	9.425	-1.770	0.818
09/12/11	1.017	8.040	8.848	9.559	-1.868	0.808
12/12/11	1.006	7.989	8.805	9.551	-1.775	0.816
13/12/11	0.996	7.941	8.760	9.480	-1.708	0.819
14/12/11	0.980	7.840	8.651	9.405	-1.580	0.810
15/12/11	0.978	7.823	8.614	9.394	-1.566	0.791
16/12/11	0.971	7.766	8.531	9.351	-1.505	0.765

Table 11: Estimated parameters of Nelson-Siegel model for Australian issued bonds rated BBB to A-: nls fit removing outliers.

Date	$\hat{\beta}_0$	$\hat{\beta}_1^{A-}$	$\hat{\beta}_1^{BBB+}$	$\hat{\beta}_1^{BBB}$	$\hat{\beta}_2$	$\hat{\beta}_3$
21/11/11	0.976	7.748	8.727	9.097	-1.669	0.979
22/11/11	0.954	7.673	8.615	9.040	-1.567	0.942
23/11/11	0.942	7.627	8.577	8.953	-1.499	0.950
24/11/11	0.937	7.661	8.575	8.973	-1.527	0.914
25/11/11	0.963	7.764	8.652	9.055	-1.714	0.888
28/11/11	0.986	7.761	8.656	9.077	-1.993	0.895
29/11/11	0.997	7.806	8.700	9.160	-2.065	0.894
30/11/11	1.041	7.924	8.798	9.275	-2.146	0.875
01/12/11	0.995	7.923	8.792	9.289	-1.924	0.869
02/12/11	0.986	7.851	8.731	9.237	-1.836	0.880
05/12/11	0.987	7.825	8.694	9.202	-1.778	0.869
06/12/11	1.012	7.881	8.752	9.213	-1.856	0.871
07/12/11	1.004	7.842	8.689	9.211	-1.816	0.848
08/12/11	1.004	7.774	8.648	9.136	-1.740	0.873
09/12/11	1.020	7.897	8.767	9.225	-1.831	0.870
12/12/11	1.000	7.867	8.753	9.250	-1.770	0.887
13/12/11	0.987	7.785	8.675	9.136	-1.703	0.890
14/12/11	0.969	7.681	8.567	9.031	-1.561	0.886
15/12/11	0.965	7.661	8.525	9.007	-1.539	0.863
16/12/11	0.951	7.599	8.438	8.961	-1.459	0.839

Table 12: Estimated parameters of Nelson-Siegel model for Australian issued bonds rated BBB to A-: robust fit removing outliers.

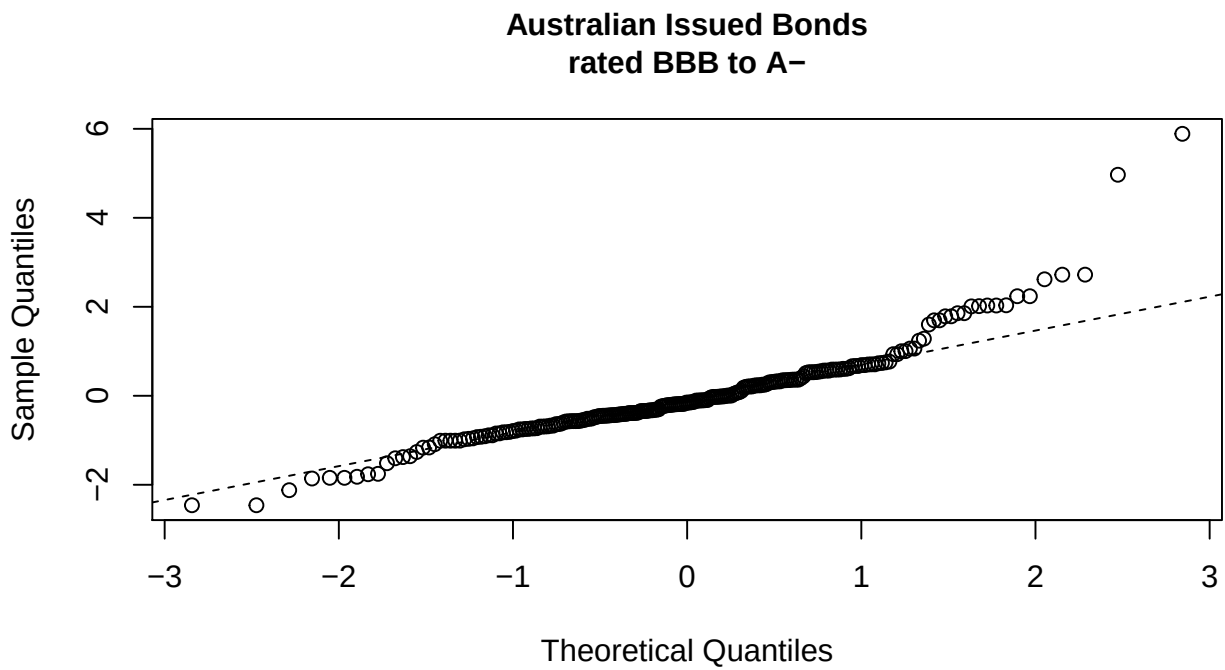


Figure 17: QQ Plot of average residuals for Australian issued bonds rated BBB to A-.

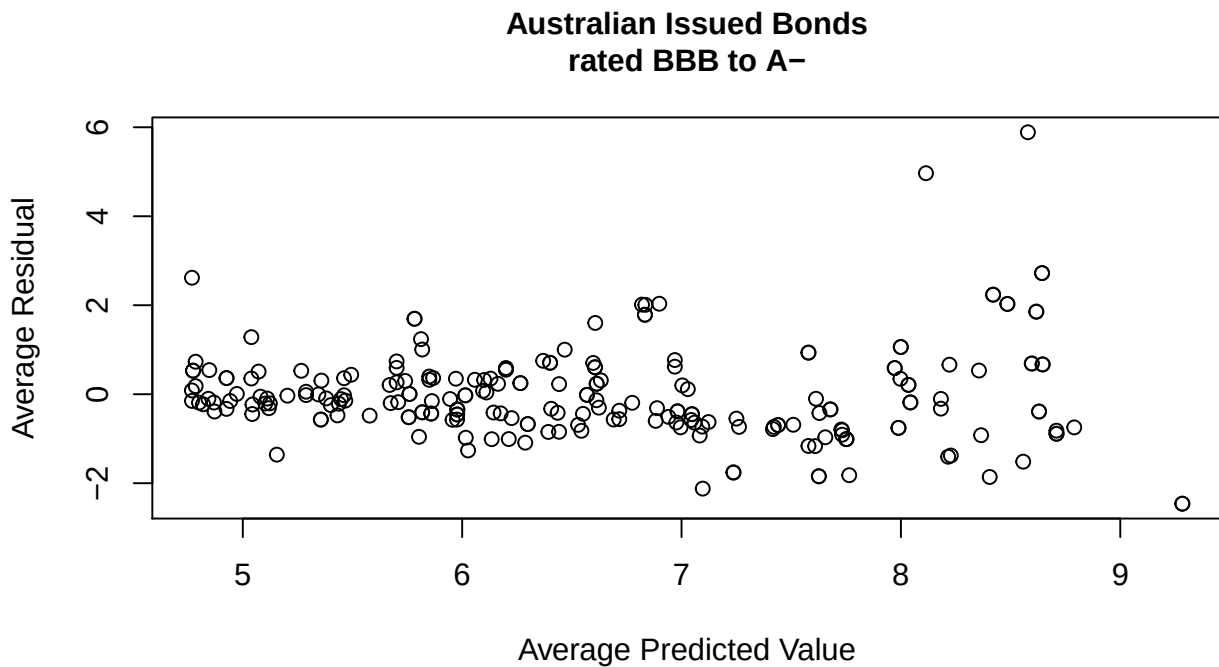


Figure 18: Plot of average residuals versus average fitted values for Australian issued bonds rated BBB to A-.

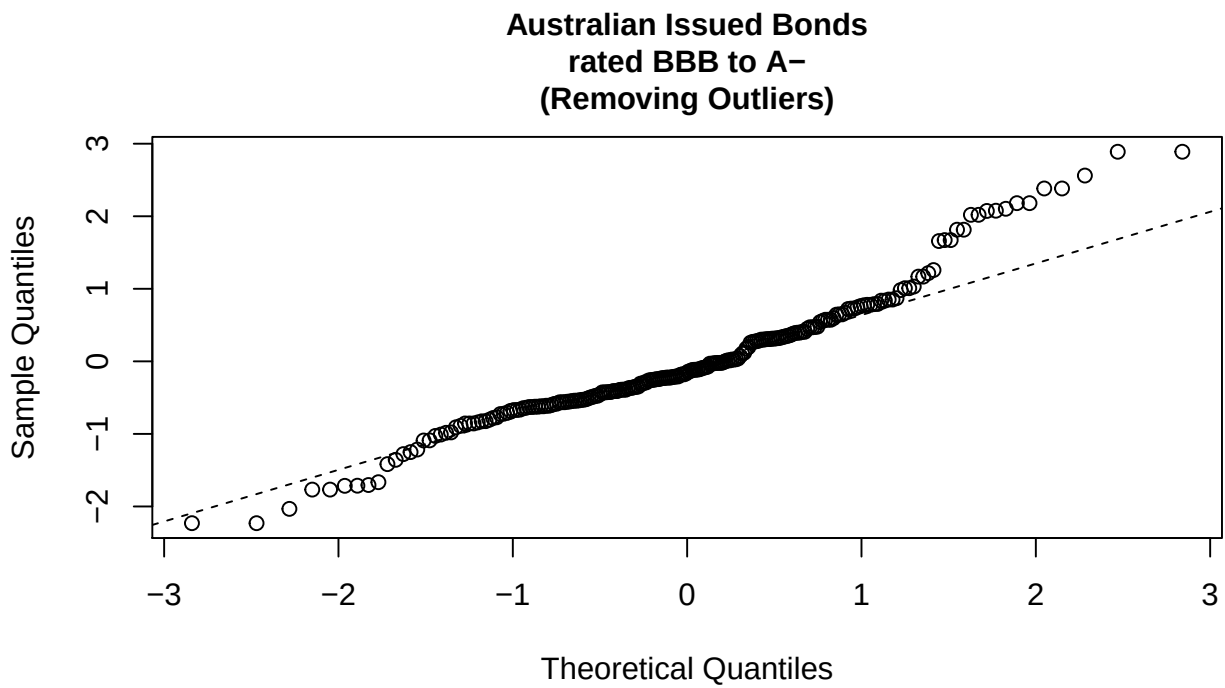


Figure 19: QQ Plot of average residuals for Australian issued bonds rated BBB to A-, removing outliers.

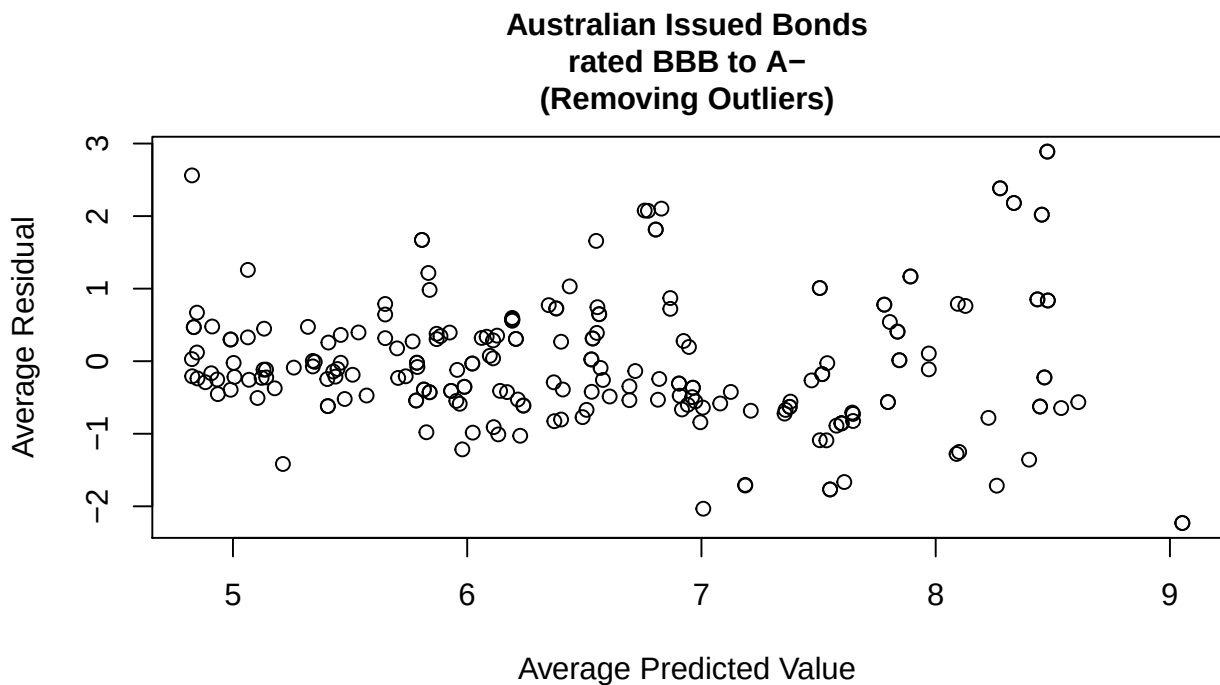


Figure 20: Plot of average residuals versus average fitted values for Australian issued bonds rated BBB to A-, removing outliers.

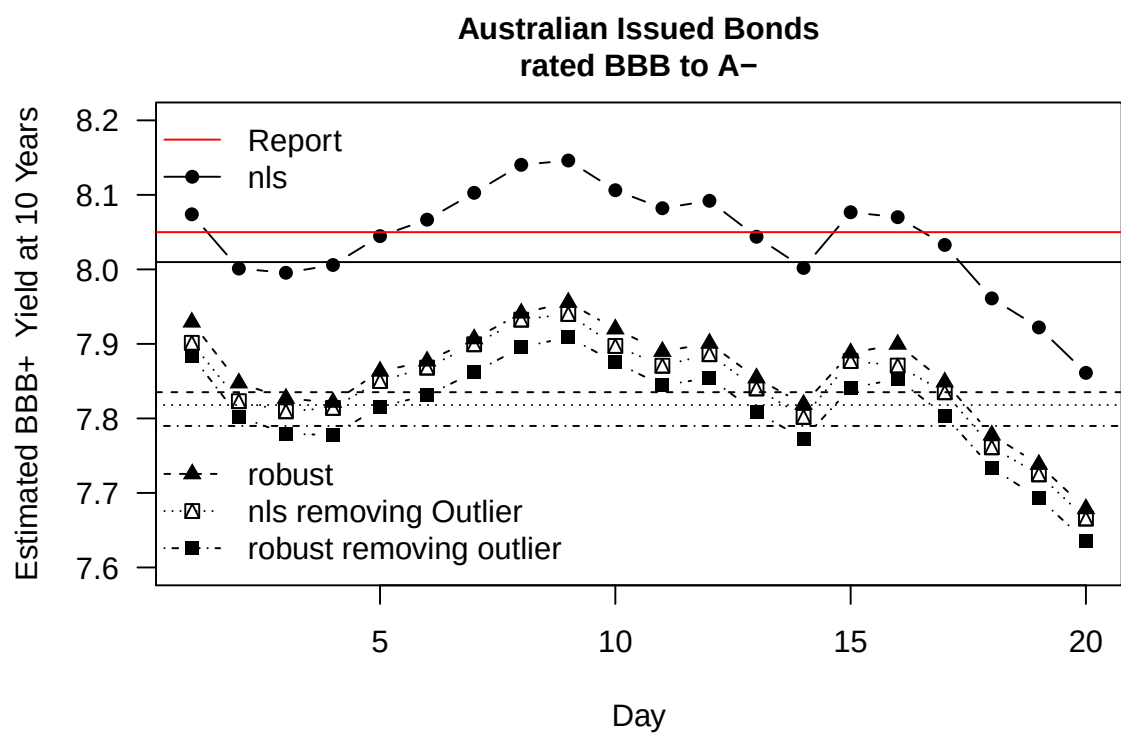


Figure 21: Plot of daily estimated average yield at 10 years for Australian issued bonds rated BBB to A-.

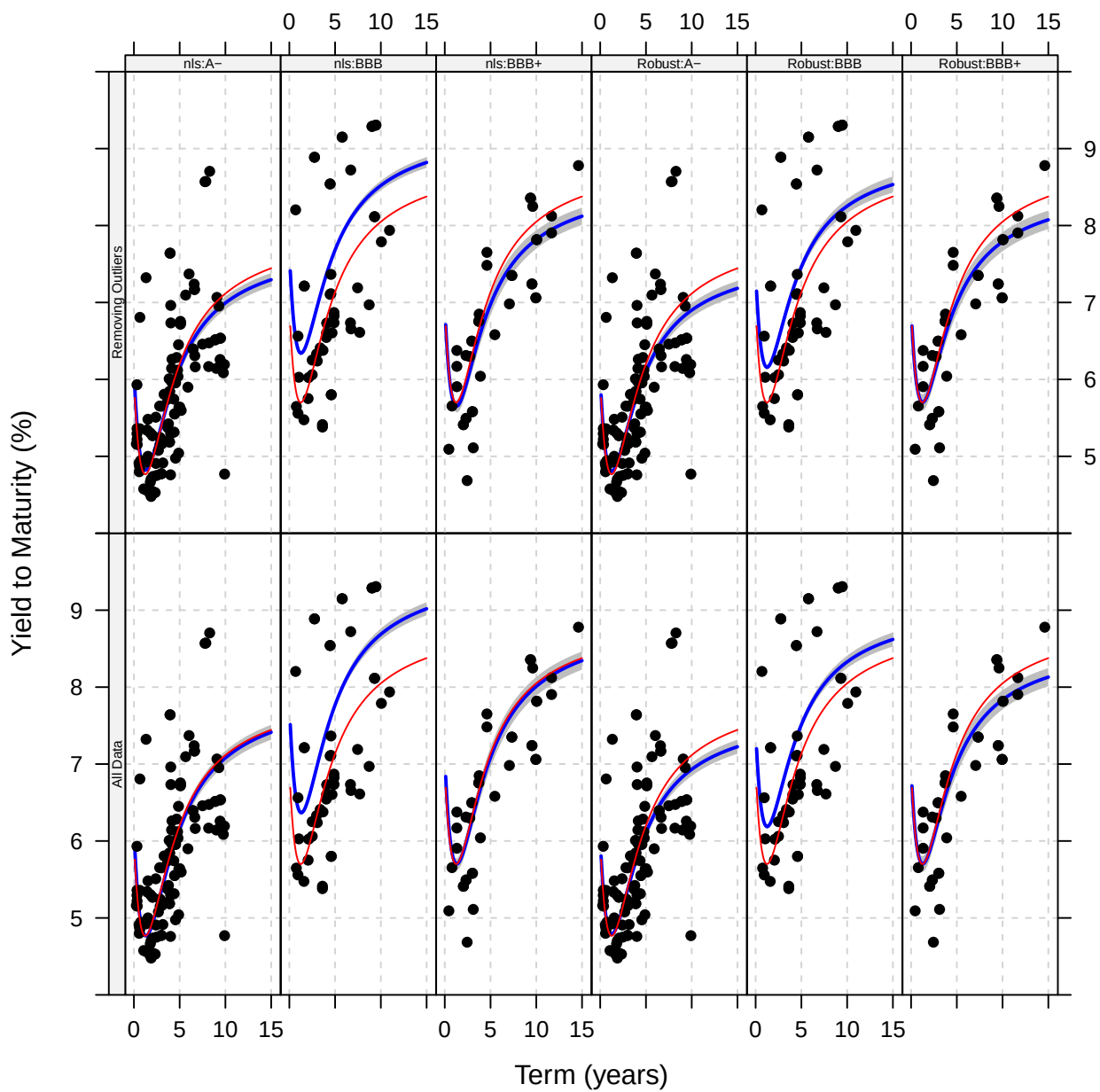


Figure 22: Yield to Maturity curves for Australian issued bonds rated BBB to A- with 95% pointwise confidence intervals. The curves given in the report are shown in red.

Date	$\hat{\beta}_0$	$\hat{\beta}_1^A$	$\hat{\beta}_1^{A-}$	$\hat{\beta}_1^{BBB+}$	$\hat{\beta}_1^{BBB}$	$\hat{\beta}_1^{BBB-}$	$\hat{\beta}_2$	$\hat{\beta}_3$
21/11/11	1.174	7.662	7.662	8.542	8.542	9.238	-1.825	-5.092
22/11/11	1.131	7.589	7.589	8.460	8.460	9.165	-1.728	-5.128
23/11/11	1.104	7.466	7.466	8.340	8.340	9.036	-1.601	-5.162
24/11/11	1.083	7.465	7.465	8.327	8.327	9.032	-1.613	-5.129
25/11/11	1.238	7.598	7.598	8.443	8.443	9.170	-2.007	-4.680
28/11/11	1.382	7.682	7.682	8.535	8.535	9.279	-2.354	-3.927
29/11/11	1.427	7.789	7.789	8.648	8.648	9.389	-2.476	-3.784
30/11/11	1.470	7.763	7.763	8.603	8.603	9.356	-2.427	-3.614
01/12/11	1.316	7.753	7.753	8.601	8.601	9.329	-2.196	-4.111
02/12/11	1.362	7.719	7.719	8.574	8.574	9.294	-2.170	-3.928
05/12/11	1.335	7.674	7.674	8.536	8.536	9.258	-2.077	-4.000
06/12/11	1.411	7.784	7.784	8.633	8.633	9.357	-2.229	-4.350
07/12/11	1.404	7.823	7.823	8.627	8.665	9.405	-2.248	-4.334
08/12/11	1.400	7.813	7.813	8.621	8.667	9.400	-2.242	-4.505
09/12/11	1.284	7.682	7.682	8.481	8.515	9.262	-2.008	-4.716
12/12/11	1.273	7.776	7.776	8.598	8.636	9.365	-2.092	-4.777
13/12/11	1.235	7.677	7.677	8.489	8.524	9.258	-2.007	-4.775
14/12/11	1.269	7.689	7.689	8.495	8.554	9.267	-1.990	-4.897
15/12/11	1.304	7.560	7.560	8.357	8.404	9.134	-1.919	-4.714
16/12/11	1.316	7.606	7.606	8.397	8.458	9.189	-1.965	-4.703

Table 13: Estimated parameters of Nelson-Siegel model for Australian issued AUD bonds rated BBB- to A: nls fit.

3.5 Australian issued AUD bonds rated BBB- to A

The same process was again applied to the 111 Australian issued AUD bonds rated BBB to A. The estimated parameters for the nls fit is given in Table 13, while the estimated parameters for the robust fit is given in Table 14.

The normal probability plot for the nls fit is given in Figure 23, and the average residual versus the average fitted value is given in Figure 24. Neither plot shows evidence of outliers, however Figure 23 suggests that the distribution may have fat tails.

Figure 25 shows a comparison of the estimated average yield at 10 years. The average yield from the report and using R are almost identical, however, the average yield from the robust regression is almost 20 basis points higher.

The presence of a fat tailed distribution in Figure 23 would suggest that the robust regression estimation is more realistic.

Figure 26 shows a comparison of the yield to maturity curves and 95% confidence intervals for the average yield for A, A-, BBB+, BBB, and BBB- bonds with both nls and robust fits. The confidence intervals are quite narrow but wider for the robust fits.

Date	$\hat{\beta}_0$	$\hat{\beta}_1^A$	$\hat{\beta}_1^{A-}$	$\hat{\beta}_1^{BBB+}$	$\hat{\beta}_1^{BBB}$	$\hat{\beta}_1^{BBB-}$	$\hat{\beta}_2$	$\hat{\beta}_3$
21/11/11	1.260	7.848	7.848	8.794	9.516	9.516	-2.133	-5.473
22/11/11	1.207	7.762	7.762	8.694	9.430	9.430	-2.027	-5.504
23/11/11	1.190	7.651	7.651	8.588	9.312	9.312	-1.913	-5.543
24/11/11	1.139	7.623	7.623	8.540	9.278	9.278	-1.854	-5.594
25/11/11	1.395	7.899	7.899	8.787	9.556	9.556	-2.475	-5.062
28/11/11	1.839	8.284	8.284	9.165	9.945	9.945	-3.206	-4.163
29/11/11	2.275	8.722	8.722	9.595	10.386	10.386	-3.724	-3.847
30/11/11	2.454	8.801	8.801	9.652	10.469	10.469	-3.771	-3.751
01/12/11								
02/12/11								
05/12/11								
06/12/11								
07/12/11								
08/12/11	2.325	8.856	8.856	9.735	10.536	10.536	-3.746	-4.477
09/12/11	1.509	8.017	8.017	8.889	9.694	9.694	-2.618	-4.881
12/12/11	1.507	8.107	8.107	9.011	9.791	9.791	-2.716	-4.868
13/12/11	1.461	7.987	7.987	8.874	9.655	9.655	-2.626	-4.815
14/12/11	1.488	8.003	8.003	8.908	9.679	9.679	-2.597	-5.007
15/12/11	1.594	7.956	7.956	8.836	9.618	9.618	-2.632	-4.829
16/12/11	1.540	7.927	7.927	8.817	9.607	9.607	-2.548	-4.897

Table 14: Estimated parameters of Nelson-Siegel model for Australian issued AUD bonds rated BBB- to A: robust fit.

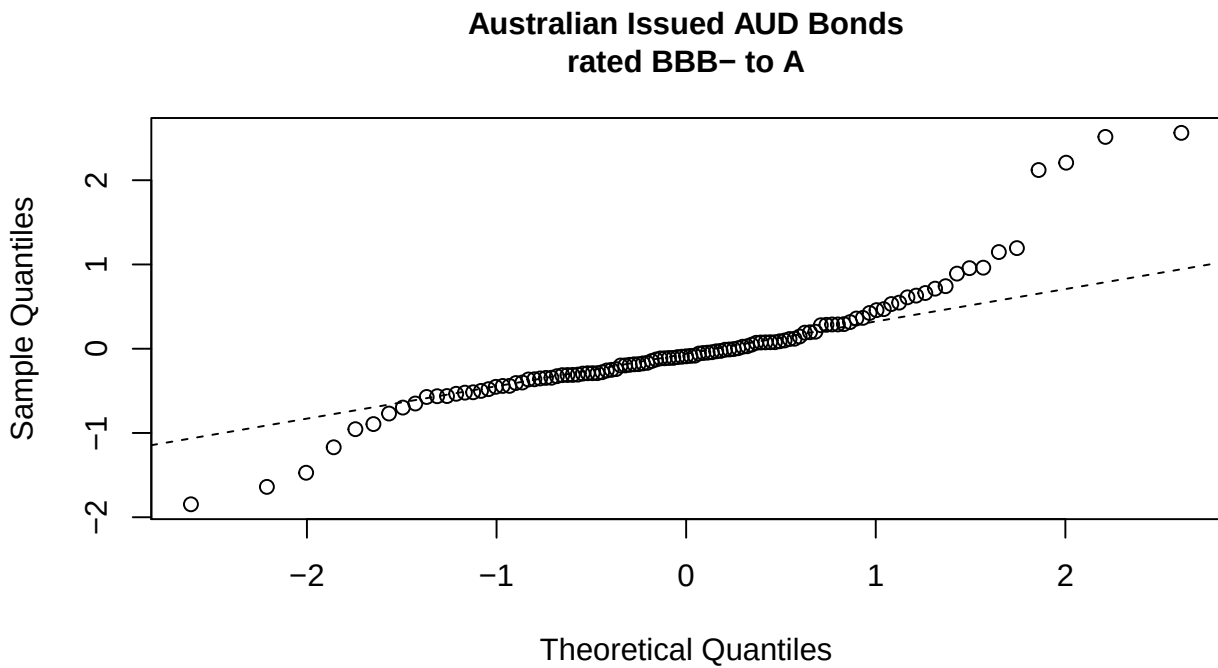


Figure 23: QQ Plot of average residuals for Australian issued AUD bonds rated BBB- to A

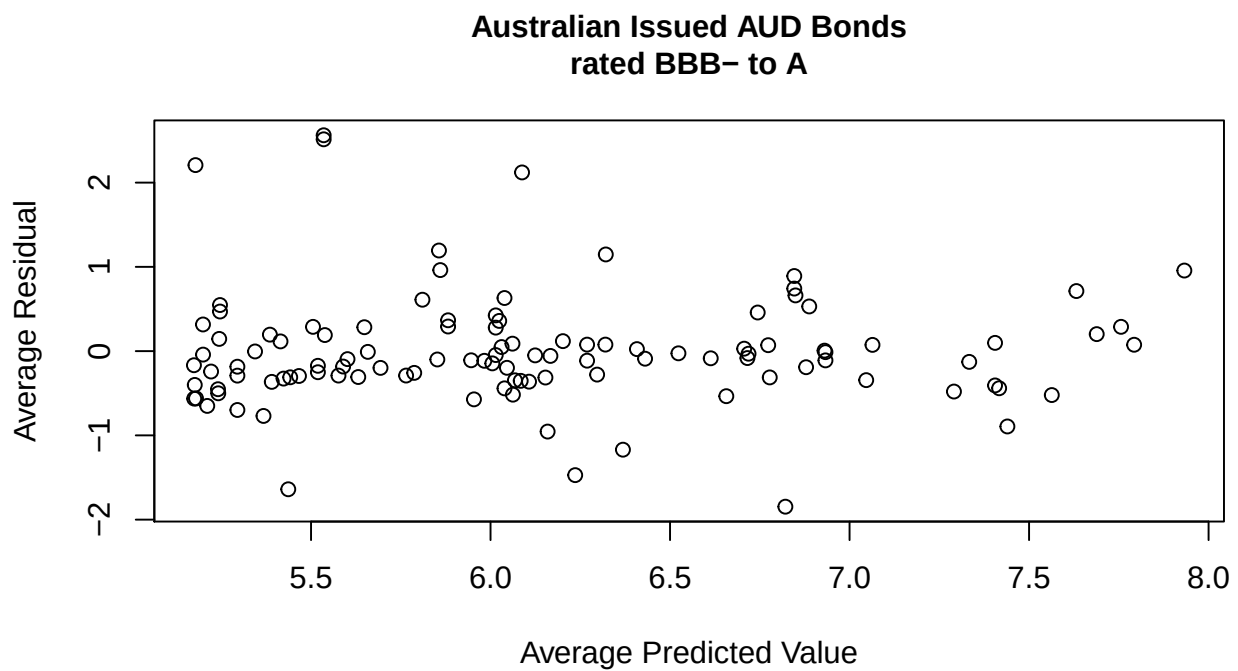


Figure 24: Plot of average residuals versus average fitted values for Australian issued AUD bonds rated BBB- to A.

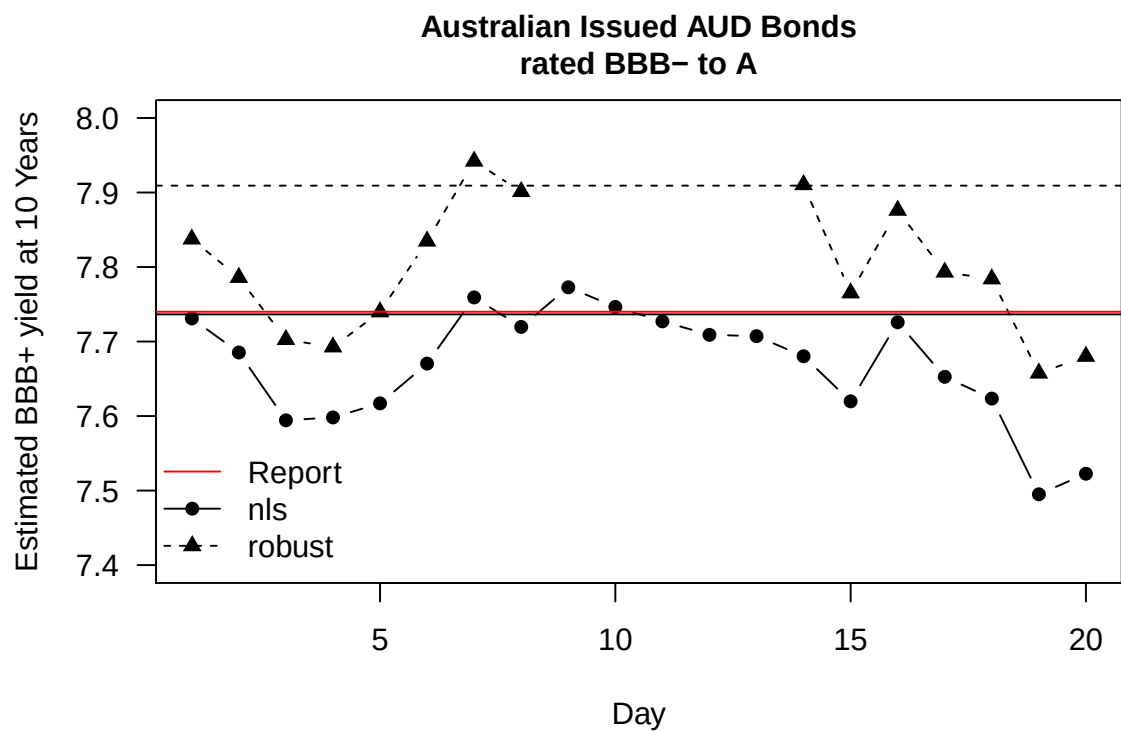


Figure 25: Plot of daily estimated average yield at 10 years for Australian issued AUD bonds rated BBB- to A.

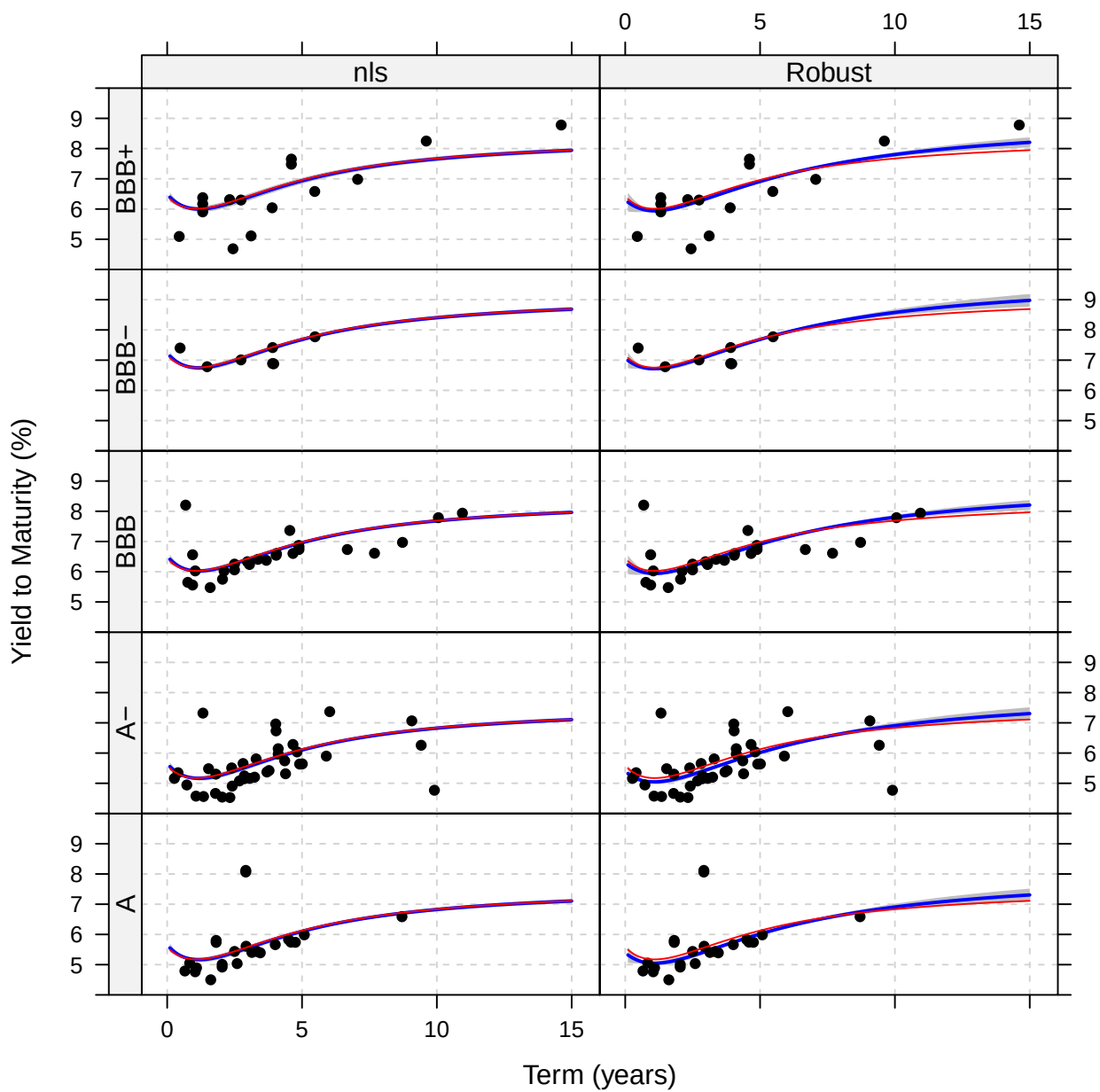


Figure 26: Yield to Maturity curves for Australian issued AUD bonds rated BBB- to A with 95% point-wise confidence intervals. The curves given in the report are given in red.

Date	$\hat{\beta}_0$	$\hat{\beta}_1^A$	$\hat{\beta}_1^{A-}$	$\hat{\beta}_1^{BBB+}$	$\hat{\beta}_1^{BBB}$	$\hat{\beta}_1^{BBB-}$	$\hat{\beta}_2$	$\hat{\beta}_3$
21/11/11	1.076	8.023	8.023	8.964	9.509	9.509	-1.965	-6.859
22/11/11	1.054	7.958	7.958	8.862	9.447	9.447	-1.867	-6.863
23/11/11	1.039	7.954	7.954	8.849	9.446	9.446	-1.830	-6.984
24/11/11	1.029	7.990	7.990	8.862	9.471	9.471	-1.863	-7.042
25/11/11	1.056	8.102	8.102	8.953	9.572	9.572	-2.028	-7.097
28/11/11	1.072	8.108	8.108	8.962	9.587	9.587	-2.244	-6.640
29/11/11	1.085	8.161	8.161	9.006	9.631	9.631	-2.313	-6.561
30/11/11	1.115	8.256	8.256	9.099	9.742	9.742	-2.381	-6.761
01/12/11	1.078	8.235	8.235	9.084	9.735	9.735	-2.155	-7.103
02/12/11	1.067	8.142	8.142	9.008	9.635	9.635	-2.014	-6.999
05/12/11	1.068	8.135	8.135	8.991	9.613	9.613	-1.959	-7.085
06/12/11	1.083	8.203	8.203	9.056	9.682	9.682	-2.018	-7.390
07/12/11	1.074	8.136	8.136	8.970	9.639	9.639	-1.985	-7.228
08/12/11	1.066	8.046	8.046	8.905	9.560	9.560	-1.880	-7.230
09/12/11	1.080	8.202	8.202	9.051	9.720	9.720	-2.000	-7.603
12/12/11	1.067	8.131	8.131	8.995	9.702	9.702	-1.906	-7.386
13/12/11	1.052	8.075	8.075	8.942	9.632	9.632	-1.850	-7.423
14/12/11	1.035	7.979	7.979	8.837	9.556	9.556	-1.708	-7.377
15/12/11	1.034	7.969	7.969	8.810	9.557	9.557	-1.694	-7.468
16/12/11	1.029	7.904	7.904	8.717	9.501	9.501	-1.634	-7.295

Table 15: Estimated parameters of Nelson-Siegel model for Australian issued bonds rated BBB- to A: nls fit.

3.6 Australian issued bonds rated BBB- to A

As before, the same process was applied using all of the 299 Australian issued bonds rated BBB- to A. The estimated parameters are given in Table 15 for the nls fit and in Table 16 for the robust fit.

The normal probability plot for the nls fit is given in Figure 27, and the average residual versus the average fitted value is given in Figure 28. Both plots are affected by two outliers.

The estimated parameters, removing the outliers, are given in Table 17 for the nls fit and in Table 18 for the robust fit.

Removing the outliers provided more satisfactory results, as can be seen in Figure 29 and Figure 30. Figure 29 suggests that the distribution may have fat tails.

Figure 31 shows a comparison of the estimated average yield at 10 years with and without the outliers removed. The report and the result from R (without removing the outliers) are a little different. The unadjusted R estimate is about 10 basis points higher than in the report. The unadjusted robust regression results and the R result with the outliers removed are similar, and about 20 basis points lower than the the unadjusted R result, and about 10 basis points lower than the report result. The robust regression result with the outlier removed is around an extra 5 basis points lower still.

Figure 32 shows the 95% confidence intervals for the yield to maturity curve for A, A-, BBB+, BBB, and BBB- bonds for maturities of 0.1 to 15 years in steps of 0.1 with both nls and robust fits both for all data and removing the outliers. The confidence intervals are quite narrow but wider for A and BBB+ bonds and for longer maturities.

Date	$\hat{\beta}_0$	$\hat{\beta}_1^A$	$\hat{\beta}_1^{A-}$	$\hat{\beta}_1^{BBB+}$	$\hat{\beta}_1^{BBB}$	$\hat{\beta}_1^{BBB-}$	$\hat{\beta}_2$	$\hat{\beta}_3$
21/11/11	1.044	7.837	7.837	8.799	9.237	9.237	-1.750	-6.809
22/11/11	1.026	7.776	7.776	8.694	9.186	9.186	-1.668	-6.789
23/11/11	1.002	7.742	7.742	8.664	9.155	9.155	-1.605	-6.873
24/11/11	0.995	7.779	7.779	8.667	9.177	9.177	-1.628	-6.921
25/11/11	1.032	7.894	7.894	8.762	9.252	9.252	-1.806	-6.955
28/11/11	1.040	7.883	7.883	8.747	9.255	9.255	-2.012	-6.446
29/11/11	1.053	7.920	7.920	8.775	9.306	9.306	-2.101	-6.304
30/11/11	1.098	8.027	8.027	8.867	9.422	9.422	-2.189	-6.449
01/12/11	1.048	8.007	8.007	8.849	9.422	9.422	-1.959	-6.828
02/12/11	1.039	7.924	7.924	8.777	9.337	9.337	-1.868	-6.666
05/12/11	1.045	7.908	7.908	8.749	9.286	9.286	-1.820	-6.663
06/12/11	1.067	7.973	7.973	8.817	9.337	9.337	-1.896	-6.916
07/12/11	1.054	7.906	7.906	8.733	9.294	9.294	-1.832	-6.800
08/12/11	1.038	7.817	7.817	8.672	9.217	9.217	-1.712	-6.840
09/12/11	1.060	7.977	7.977	8.822	9.373	9.373	-1.832	-7.217
12/12/11	1.033	7.903	7.903	8.779	9.353	9.353	-1.736	-7.105
13/12/11	1.023	7.837	7.837	8.713	9.286	9.286	-1.704	-7.010
14/12/11	1.008	7.740	7.740	8.610	9.199	9.199	-1.575	-6.941
15/12/11	1.009	7.738	7.738	8.589	9.196	9.196	-1.558	-7.049
16/12/11	0.998	7.672	7.672	8.494	9.142	9.142	-1.487	-6.897

Table 16: Estimated parameters of Nelson-Siegel model for Australian issued bonds rated BBB- to A: robust fit.

Date	$\hat{\beta}_0$	$\hat{\beta}_1^A$	$\hat{\beta}_1^{A-}$	$\hat{\beta}_1^{BBB+}$	$\hat{\beta}_1^{BBB}$	$\hat{\beta}_1^{BBB-}$	$\hat{\beta}_2$	$\hat{\beta}_3$
21/11/11	1.044	7.874	7.874	8.722	9.303	9.336	-1.821	-6.518
22/11/11	1.020	7.806	7.806	8.614	9.236	9.273	-1.720	-6.514
23/11/11	1.004	7.796	7.796	8.592	9.210	9.301	-1.679	-6.615
24/11/11	0.993	7.826	7.826	8.596	9.227	9.311	-1.705	-6.660
25/11/11	1.020	7.933	7.933	8.681	9.335	9.361	-1.867	-6.703
28/11/11	1.035	7.936	7.936	8.685	9.351	9.358	-2.085	-6.237
29/11/11	1.047	7.985	7.985	8.722	9.393	9.398	-2.152	-6.151
30/11/11	1.080	8.078	8.078	8.808	9.496	9.524	-2.220	-6.334
01/12/11	1.042	8.059	8.059	8.797	9.490	9.534	-1.991	-6.692
02/12/11	1.030	7.966	7.966	8.719	9.395	9.422	-1.849	-6.588
05/12/11	1.029	7.957	7.957	8.698	9.375	9.375	-1.790	-6.669
06/12/11	1.047	8.025	8.025	8.767	9.444	9.444	-1.850	-6.973
07/12/11	1.037	7.961	7.961	8.686	9.404	9.404	-1.819	-6.818
08/12/11	1.028	7.875	7.875	8.626	9.331	9.331	-1.717	-6.829
09/12/11	1.045	8.029	8.029	8.771	9.487	9.490	-1.837	-7.196
12/12/11	1.030	7.960	7.960	8.717	9.468	9.488	-1.744	-6.986
13/12/11	1.018	7.909	7.909	8.668	9.393	9.453	-1.694	-7.021
14/12/11	0.999	7.813	7.813	8.563	9.321	9.371	-1.550	-6.983
15/12/11	0.998	7.803	7.803	8.538	9.321	9.374	-1.535	-7.076
16/12/11	0.992	7.741	7.741	8.447	9.272	9.311	-1.476	-6.911

Table 17: Estimated parameters of Nelson-Siegel model for Australian issued bonds rated BBB- to A: nls fit, removing outliers.

Date	$\hat{\beta}_0$	$\hat{\beta}_1^A$	$\hat{\beta}_1^{A-}$	$\hat{\beta}_1^{BBB+}$	$\hat{\beta}_1^{BBB}$	$\hat{\beta}_1^{BBB-}$	$\hat{\beta}_2$	$\hat{\beta}_3$
21/11/11	1.033	7.793	7.793	8.737	9.178	9.178	-1.706	-6.720
22/11/11	1.015	7.731	7.731	8.630	9.123	9.123	-1.624	-6.696
23/11/11	0.991	7.699	7.699	8.606	9.096	9.096	-1.562	-6.789
24/11/11	0.984	7.735	7.735	8.607	9.116	9.116	-1.582	-6.837
25/11/11	1.019	7.850	7.850	8.700	9.194	9.194	-1.759	-6.871
28/11/11	1.029	7.839	7.839	8.687	9.191	9.191	-1.968	-6.359
29/11/11	1.044	7.881	7.881	8.719	9.249	9.249	-2.064	-6.218
30/11/11	1.089	7.985	7.985	8.808	9.361	9.361	-2.152	-6.351
01/12/11	1.039	7.964	7.964	8.787	9.361	9.361	-1.923	-6.728
02/12/11	1.030	7.883	7.883	8.716	9.278	9.278	-1.830	-6.571
05/12/11	1.036	7.868	7.868	8.690	9.227	9.227	-1.783	-6.570
06/12/11	1.058	7.931	7.931	8.758	9.277	9.277	-1.858	-6.822
07/12/11	1.044	7.867	7.867	8.674	9.238	9.238	-1.795	-6.712
08/12/11	1.029	7.774	7.774	8.612	9.156	9.156	-1.677	-6.738
09/12/11	1.052	7.933	7.933	8.763	9.309	9.309	-1.795	-7.115
12/12/11	1.024	7.866	7.866	8.722	9.300	9.300	-1.698	-7.024
13/12/11	1.014	7.797	7.797	8.656	9.228	9.228	-1.668	-6.918
14/12/11	0.998	7.700	7.700	8.553	9.141	9.141	-1.537	-6.853
15/12/11	0.999	7.699	7.699	8.532	9.141	9.141	-1.519	-6.965
16/12/11	0.989	7.630	7.630	8.435	9.082	9.082	-1.451	-6.799

Table 18: Estimated parameters of Nelson-Siegel model for Australian issued bonds rated BBB- to A: robust fit, removing outliers.

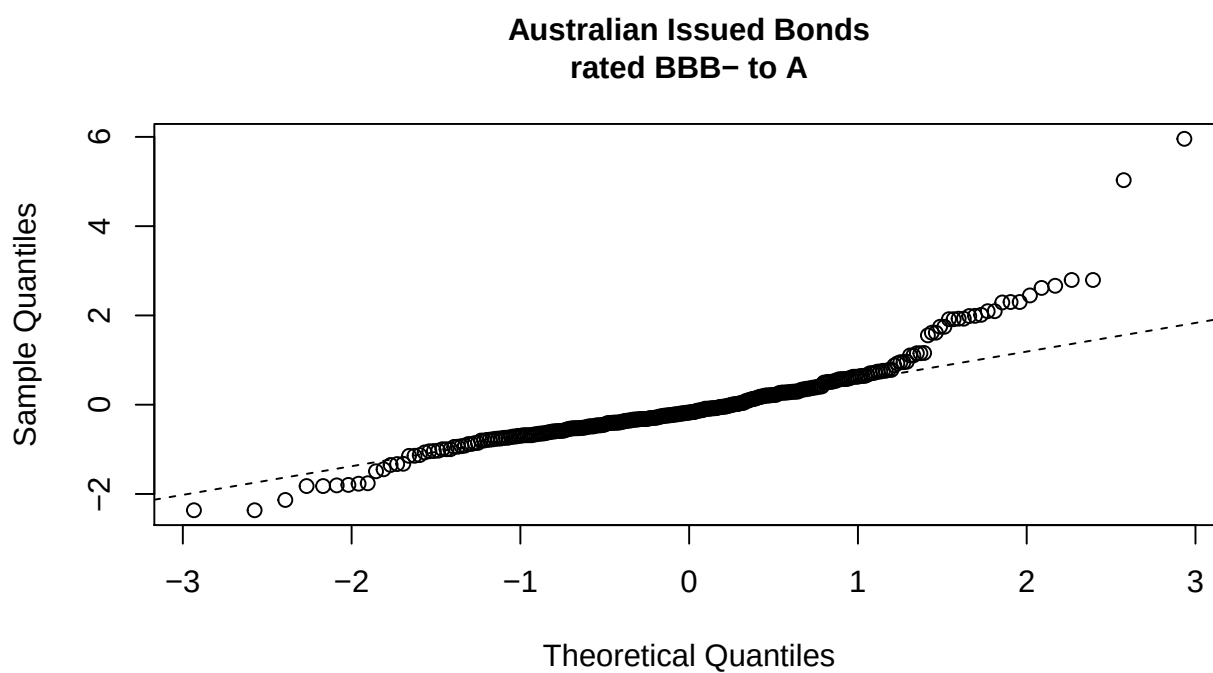


Figure 27: QQ Plot of average residuals for Australian issued bonds rated BBB- to A

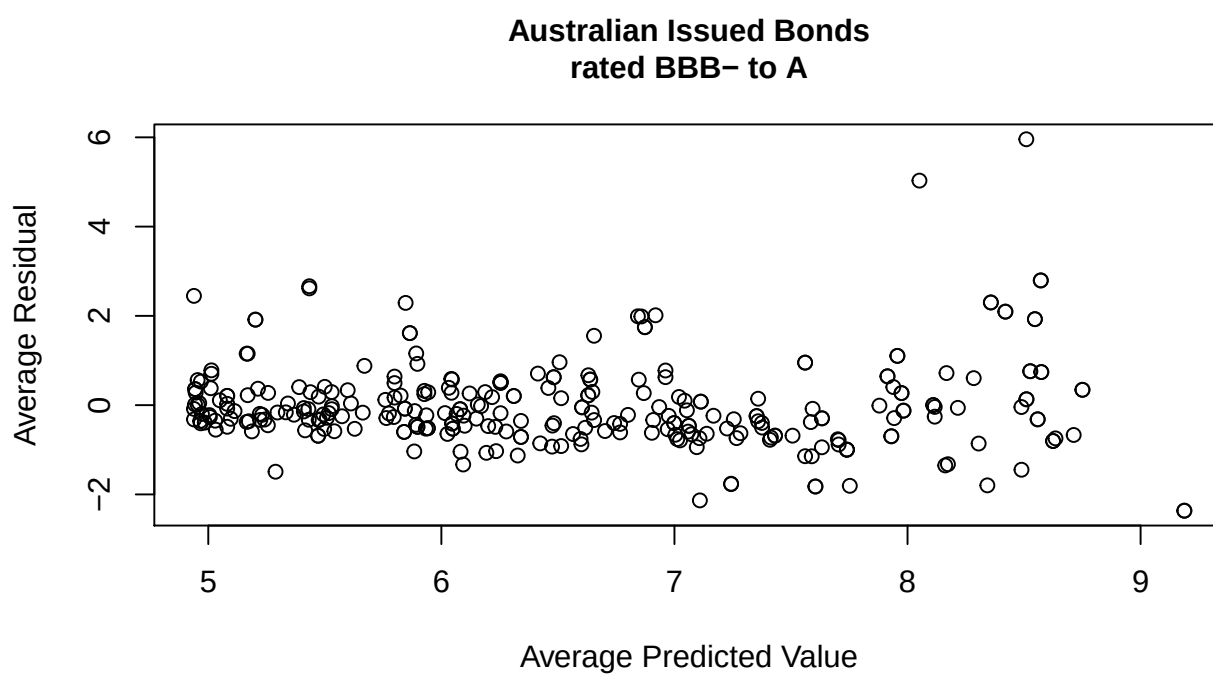


Figure 28: Plot of average residuals versus average fitted values for Australian issued bonds rated BBB- to A.

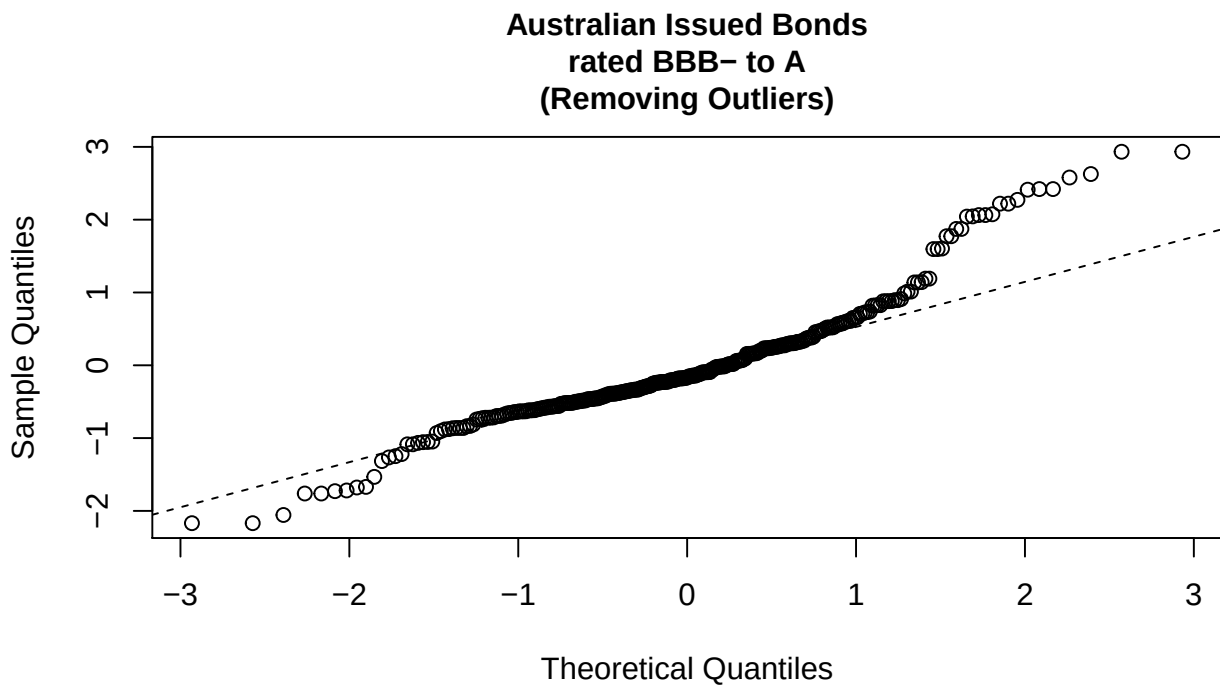


Figure 29: QQ Plot of average residuals for Australian issued bonds rated BBB- to A, removing outliers.

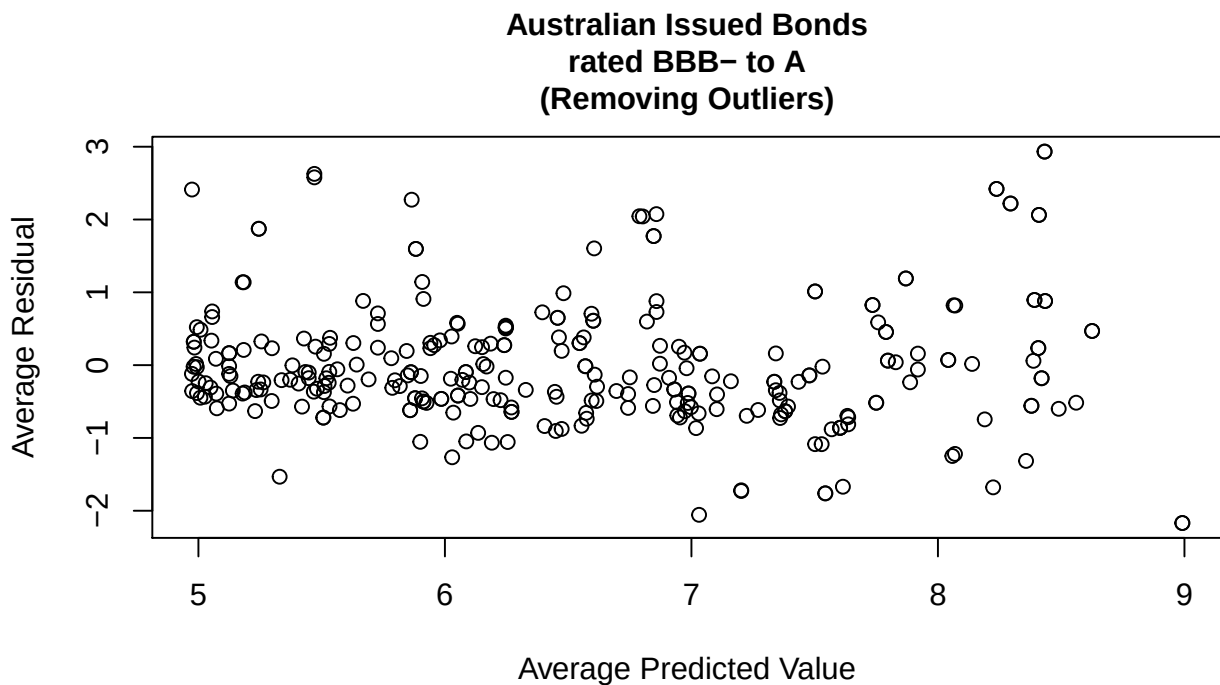


Figure 30: Plot of average residuals versus average fitted values for Australian issued bonds rated BBB- to A, removing outliers.

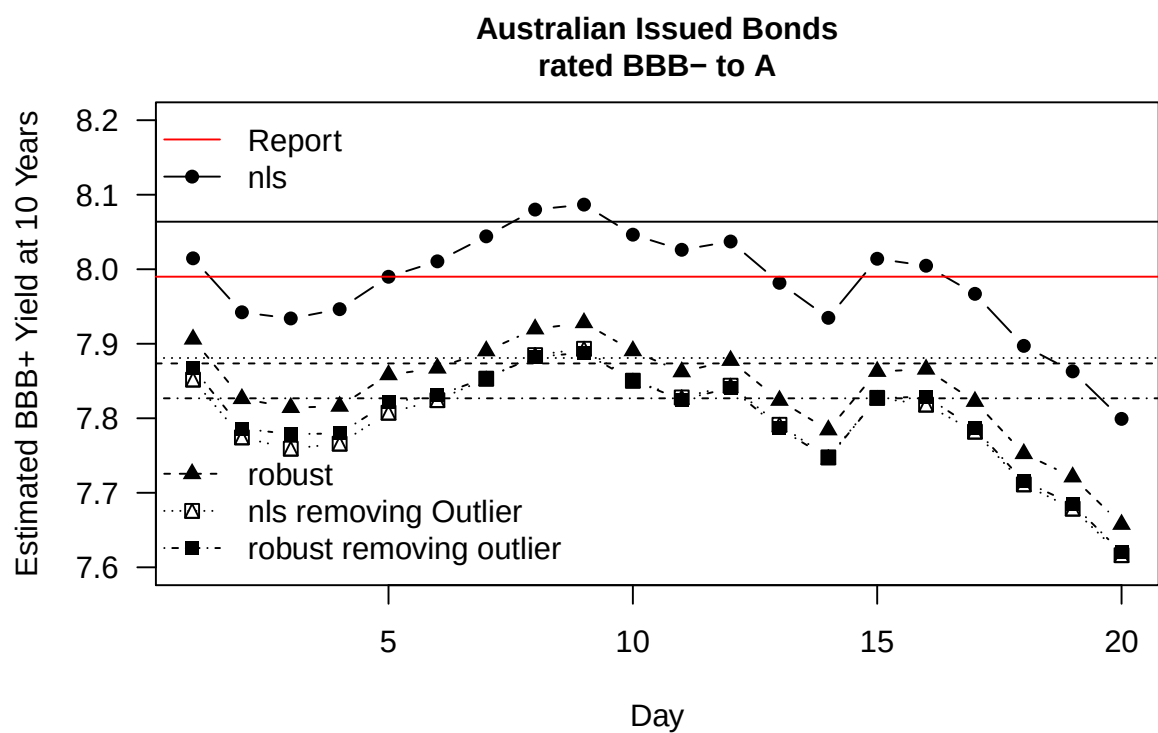


Figure 31: Plot of daily estimated average yield at 10 years for Australian issued AUD bonds rated BBB- to A.

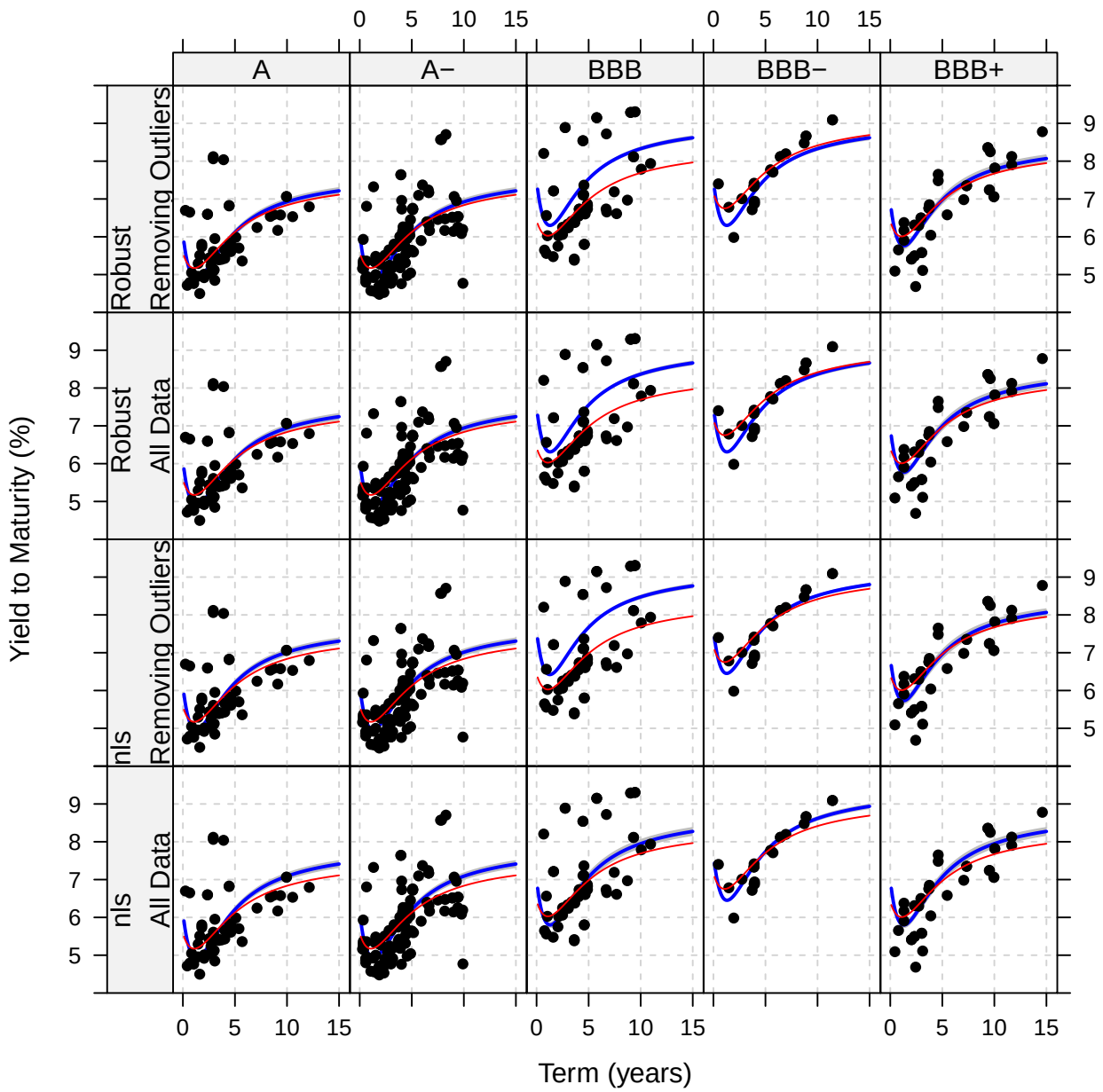


Figure 32: Yield to Maturity curves for Australian issued bonds rated BBB- to A with 95% pointwise confidence intervals. The curves given in the report are given in red.

3.7 Summary of Estimation Results

A summary of the results is given in Table 19.

Sample/Bond Category	<i>n</i>	BBB+ Yield at 10 Years % (Std.Error)		
		Report	R	Robust
Australian issued AUD bonds rated BBB+ only	15	8.25	8.24 (0.024)	8.20 (0.036)
Australian issued bonds rated BBB+ only	42	8.15	8.11 (0.065)	7.9 (0.064)
Removing outlier	41		7.85 (0.065)	7.85 (0.065)
Australian issued AUD bonds rated BBB to A-	81	7.74	7.74 (0.03)	7.84 (0.033)
Australian issued bonds rated BBB to A-	224	8.05	8.01 (0.062)	7.84 (0.062)
Removing outliers	222		7.82 (0.061)	7.79 (0.063)
Australian issued AUD bonds rated BBB- to A	111	7.67	7.66 (0.039)	7.8 (0.037)
Australian issued bonds rated BBB- to A	299	7.99	7.95 (0.062)	7.81 (0.062)
Removing Outliers	297		7.77 (0.061)	7.78 (0.061)

Table 19: Comparison of yields at 10 years between values given in the report and those based on R.

4 Application of zero coupon Nelson-Siegel yield curves to estimate par yield curves

In section 5.1.2 of the report the spot curve was estimated. This is more complex than estimating the yield to maturity curve. The discount rate for a bond of credit rating rank is given by

$$r(t, \text{rank}) = \beta_{1, \text{rank}} + (\beta_2 + \beta_3) \frac{1 - \exp(-t/\beta_0)}{t/\beta_0} - \beta_3 \exp(-t/\beta_0)$$

where t is the time to the bond's next payment which is discounted at rate $r(t, \text{rank})$. The parameters are estimated by minimising the weighted sum of pricing errors

$$\sum_{i=1}^N [w_i (P_i^A - \hat{P}_i)]^2$$

where

$$\begin{aligned} w_i &= \frac{1/d_i}{\sum_{k=1}^N 1/d_k} \text{ where } d_i = \text{Macaulay duration of bond } i \\ N &= \text{Number of bonds in the sample} \\ P_i^A &= \text{the actual 'dirty' price of bond } i \\ \hat{P}_i &= \text{fitted price of bond } i \text{ given by } \hat{P}_i = \sum_t C_{it} \exp[-t \times r(t, \text{rank})] \end{aligned}$$

where C_{it} is a cash flow on bond i promised to be paid t years from now.

It should be emphasised that the weights, w_i , in the report are inside the square brackets in the equation above and hence are squared. Essentially the parameters are estimated by minimising the quantity

$$\sum_{i=1}^N [u_i (P_i^A - \hat{P}_i)^2]$$

where

$$u_i = w_i^2 = \frac{(1/d_i)^2}{(\sum_{k=1}^N (1/d_k))^2},$$

giving more weight to bonds with shorter durations. The u_i correspond to the more traditional weights in "weighted least squares". Examination of the literature shows that such a weighting has been used by a number of authors. For example, Ioannidis (2003) says

I estimate the Nelson and Siegel ... I choose to minimise the distance between squared price errors weighted by the inverse of the duration of the issue squared. This weight function best adjusts for the differential importance of small price changes at different maturities on estimates of the yield curve. An error in price of three-month treasury bill would not have the same impact as the error in the price of a fifteen year bond. If we assume an equal weight, the pricing of long term issues would be less accurate than the pricing of short term maturity issues due to increasing duration. Similar weighting schemes are adopted by Vasicek and Fong (1982) and Bliss (1997).

The parameters were estimated using the `optim` command in R, with the BFGS optimisation method. Once the parameters are estimated, the par yield, the coupon rate C that causes the bond price to equal its par value, can be calculated. Assuming annual coupon payments for bond maturity T , the equation is

$$100 = C \exp[-r_t] + C \exp[-2r_t] + \dots + (100 + C) \exp[-Tr_T].$$

In the report Solver was used to solve for C but the following equation can be used:

$$C = \frac{100(1 - \exp[-Tr_T])}{\sum_{t=1}^T \exp[-tr_t]}$$

Years	Report	R
11	8.50	8.55
10	8.40	8.45
9	8.26	8.33
8	8.14	8.19
7	7.98	8.03
6	7.78	7.84
5	7.56	7.63
4	7.30	7.38
3	6.99	7.1
2	6.61	6.79
1	6.17	6.44

Table 20: Comparison of Par Yields given in the report and those calculated using R for Australian issued AUD BBB+ bonds.

Years	A-		BBB+		BBB	
	Report	R	Report	R	Report	R
11	7.93	7.98	8.30	8.33	8.30	8.33
10	7.81	7.86	8.19	8.22	8.19	8.22
9	7.67	7.72	8.05	8.07	8.05	8.07
8	7.50	7.54	7.88	7.9	7.88	7.9
7	7.29	7.33	7.67	7.68	7.67	7.68
6	7.04	7.07	7.42	7.43	7.42	7.43
5	6.74	6.76	7.12	7.12	7.12	7.12
4	6.39	6.4	6.77	6.76	6.77	6.76
3	6.01	6.03	6.39	6.4	6.39	6.4
2	5.67	5.76	6.05	6.12	6.05	6.12
1	5.59	5.84	5.97	6.2	5.97	6.2

Table 21: Comparison of Par Yields given in the report and those calculated using R for A-, BBB+, and BBB bonds, based on an analysis of Australian issued AUD bonds rated BBB to A-.

Table 20 gives a comparison of the results given in the report and those that we have calculated for bond maturities of 1 to 11 years, for BBB+ bonds, based on an analysis of the 15 Australian issued AUD bonds rated BBB+ only. For longer maturities, we get slightly higher par yields, but slightly lower par yields for shorter maturities.

Table 21 gives a comparison of the results given in the report and those that we have calculated for bond maturities of 1 to 11 years, for A-, BBB+, and BBB bonds, based on an analysis of the 81 Australian issued AUD bonds rated BBB to A-. There is very little substantive difference except for maturities of one and two years.

Table 22 gives a comparison of the results given in the report and those that we have calculated for bond maturities of 1 to 11 years, for A-, BBB+, and BBB bonds, based on an analysis of the 111 Australian issued AUD bonds rated BBB- to A. Again, there is very little substantive difference except for maturities of one and two years.

	A-		BBB+		BBB	
Years	Report	R	Report	R	Report	R
11	7.91	7.96	8.26	8.28	8.26	8.28
10	7.75	7.81	8.10	8.13	8.10	8.13
9	7.58	7.64	7.93	7.96	7.93	7.96
8	7.40	7.45	7.75	7.77	7.75	7.77
7	7.20	7.24	7.55	7.56	7.55	7.56
6	7.01	7.01	7.33	7.33	7.33	7.33
5	6.72	6.76	7.08	7.09	7.08	7.09
4	6.49	6.5	6.82	6.83	6.82	6.83
3	6.19	6.23	6.54	6.56	6.54	6.56
2	5.89	5.97	6.24	6.3	6.24	6.3
1	5.57	5.75	5.92	6.07	5.92	6.07

Table 22: Comparison of Par Yields given in the report and those calculated using R for A-, BBB+, and BBB bonds, based on an analysis of Australian issued AUD bonds rated BBB- to A.

5 References

- Bliss, R.R. (1997). "Testing Term Structure Estimation Methods," *Advances in Futures and Options Research*, **9** 197-231.
- Fox, J. (2008). *Applied Regression Analysis and Generalized Linear Models*, 2nd. Ed., Sage, Thousand Oaks, CA.
- Hird, T. (2012). "Estimating the regulatory debt risk premium for Victorian gas businesses," Competitive Economics Group.
- Ioannidis, M. (2003). "A Comparison of Yield Curve Estimation Techniques Using UK Data," *Journal of Banking and Finance*, **27** 1-26.
- Nelson, C.R. and Siegel, A.F. (1987). "Parsimonious Modeling of Yield Curves," *The Journal of Business*, **60** 473-489.
- R Core Team (2012). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL <http://www.R-project.org/>.
- Rousseeuw, P., Croux, C., Todorov, V., Ruckstuhl, A., Salibian-Barrera, M, Verbeke, T., Koller, M., and Martin Maechler, M. (2012). robustbase: Basic Robust Statistics. R package version 0.9-4. URL <http://CRAN.R-project.org/package=robustbase>
- Vasicek, O.A. and Fong, H.G. (1982). "Term Structure Modeling Using Exponential Splines," *The Journal of Finance*, **37** 339-348.
- Venables, W.N. and Ripley, B.D. (2008). *Modern Applied Statistics with S*, 4th. Ed. Springer.

A Dr Neil Diamond

Neil Diamond CV

Curriculum Vitae

Neil Diamond

January 2013

Full Name:	Neil Thomas Diamond
Date of Birth:	2/2/1956
Academic Qualifications:	B.Sc (Hons) (Monash), Ph.D. (Melbourne), A.Stat

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 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

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).

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.

Journal Articles

1. Diamond, N.T., (1991). "Two visits to Wisconsin," *Quality Australia*, **7**, 30-31.
2. Diamond, N.T., (1991). "The use of a class of foldover designs as search designs," *Austral. J. Statist*, **33**, 159-166.
3. Diamond, N.T., (1995). "Some properties of a foldover design," *Austral. J. Statist*, **37**, 345-352.
4. Watson, D.E.R., Hallett, R.F., and Diamond, N.T., (1995). "Promoting a collegial approach in a multidisciplinary environment for a total quality improvement process in higher education, " *Assessment & Evaluation in Higher Education*, **20**, 77-88.
5. Van Matre, J. and Diamond, N.T., (1996). "Team work and design of experiments," *Quality Engineering*, **9**, 343-348.
6. Diamond, N.T., (1999). "Overlap probabilities and delay detonators," *Teaching Statistics*, **21**, 52-53. Also published in "Getting the Best from Teaching Statistics", one of the best 50 articles from volumes 15 to 21 of *Teaching Statistics*.
7. Cerone, P. and Diamond, N.T., (2000). "On summing permutations and some statistical properties," *The International Journal of Mathematical Education in Science and Technology*, **32**, 477-485.
8. Behera, J.M., Diamond, N.T., Bhuta, C.J. and Thorpe, G.R., (2000). "The impact of job assignment rules for straddle carriers on the throughput of container terminal detectors," *Journal of Advanced Transportation*, **34**, 415-454.
9. Sahama, T. and Diamond, N.T., (2001). "Sample size considerations and augmentation of computer experiments," *The Journal of Statistical Computation and Simulation*, **68**, 307-319.
10. Paul, W. and Diamond, N.T., (2001). "Designing a monitoring program for environmental regulation: Part 1-The operating characteristic curve," *Water: Journal of Australian Water Association*, October 2001, 50-54.
11. Sztendur, E.M. and Diamond, N.T., (2002). "Extension to confidence region calculations for the path of steepest ascent," *Journal of Quality Technology*, **34**, 288-295.
12. Paul, W. and Diamond, N.T., (2002). "Designing a monitoring program for environmental regulation: Part 2-Melbourne Water case study," *Water: Journal of Australian Water Association*, February 2002, 33-36.
13. Steart, D.C., Greenwood, D.R., Boon, P.I. and Diamond, N.T., (2002) "Transport of leaf litter in upland streams of Eucalyptus and Nothofagus forests in South Eastern Australia," *Archiv Für Hydrobiologie*, **156**, 43-61.
14. Peachey, T. C., Diamond, N. T., Abramson, D. A., Sudholt, W., Michailova, A., and Amirrazi, S. (2008). "Fractional factorial design for parameter sweep experiments using Nimrod/E," *Sci. Program.*, **16**(2-3), 217-230.

- 15 Sahama, T.R. and Diamond, N.T. (2009) "Computer Experiment-A case study for modelling and simulation of Manufacturing Systems," *Australian Journal of Mechanical Engineering*, **7**(1), 1–8.
- 16 Booth, R., Brookes, R., and Diamond, N. (2012) "The declining player share of AFL clubs and league revenue 2001-2009: Where has the money gone?," *Labour and Industry* 22:4, 433–446.
- 17 Booth, R., Brookes, R., and Diamond, N. (2012) "Theory and Evidence on Player Salaries and Revenues in the AFL 2001-2009," Accepted for publication in *Economics and Labour Relations Review*.
- 18 Chambers, J.D., Bethwaite, B., Diamond, N.T., Peachey, T.C., Ambramson, D., Petrou, S., and Thomas, E.A. (2012) "Parametric computation predicts a multiplicative interaction between synaptic strength parameters controls properties of gamma oscillations," *Frontiers in Computational Neuroscience* Volume 6, Article 53 doi:10.3389/fncom.2012.00053.

Refereed Conference Papers

1. Behera, J., Diamond, N.T., Bhuta, C. and Thorpe, G., (1999). "Simulation: a decision support tool for improving the efficiency of the operation of road vehicles in container terminals," 9th ASIM Dedicated Conference, Berlin, February 2000, 75-86.
2. Jutrisa, I., Diamond, N.T. and Cerone. P., (1999). "Frame size effects on throughput and return traffic in reliable satellite broadcast transmission, " 16th International Teletraffic Congress, Edinburgh, Scotland.
3. Diamond, N.T. and Sztendur, E.M. (2002). "The use of consulting problems in introductory statistics classes", *Proceedings of the 6th International Conference on the Teaching of Statistics*.
4. Summitt, R.A., Cerone. P., and Diamond, N.T. (2002). "Simulation Reliability Estimation from Early Failure Data, *Proceedings of the Fourth International Conference on Modelling and Simulation*, 368-390.
5. Summitt, R.A., Cerone. P., and Diamond, N.T. (2002). "Simulation Reliability Estimation from Early Failure Data II, *Proceedings of the Fourth International Conference on Modelling and Simulation*, 391-396.
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.

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.

VU6. Diamond, N.T (1998). "Statistical Analysis of BOD and SS compliance rates and license limits at ETP and WTP," prepared for Melbourne Water.

VU7. Diamond, N.T (1998). "Fate of pollutants at WTP-method for determining safety margins," prepared for Egis consulting group.

VU8. Bromley, M. and Diamond, N.T (2002). "The manufacture of Laboratory coreboard using various chip furnishes," prepared for Orica adhesives and resins.

Monash University

M1. Hyndman, R.J, Diamond, N.T. and de Silva, A. (2004). "A review of the methodology for identifying potential risky agents," prepared for the Australian Tax Office.

M2. Diamond, N.T. and Hyndman, R.J. (2005). "Sample Size for Maternal and Child Health Service Evaluation," prepared for the Department of Human Services.

M3. Diamond, N.T. (2005). "Analysis of Customer Satisfaction Survey 2005," prepared for JD Macdonald.

- M4. Diamond, N.T. (2005). "Analysis of 2005 Orientation Survey," prepared for Monash Orientation.
- M5. Diamond, N.T. (2005). "Analysis of Before and After and Sequential Monadic Concept Consumer Surveys," prepared for IMI-Research.
- M6. Diamond, N.T. and Hyndman, R.J. (2005). "The Monash Experience Questionnaire 2003: First Year Students," prepared for CHEQ, Monash University.
- M7. Diamond, N.T. and Hyndman, R.J. (2005). "The Monash Experience Questionnaire 2003: The Best and Worst, " prepared for CHEQ, Monash University.
- M8. Diamond, N.T. and Hyndman, R.J. (2005). "The Monash Experience Questionnaire 2003: The Best and Worst for First Year Students," prepared for CHEQ, Monash University.
- M9. Diamond, N.T. (2005). "Technical Document for DUKC Uncertainty Study," prepared for Port of Melbourne Corporation.
- M10. Diamond, N.T. (2005). "DUKC Uncertainty Study-Summary of Results," prepared for Port of Melbourne Corporation.
- M11. Diamond, N.T. (2005). "Number of Ship trials for DUKC Uncertainty Study," prepared for Port of Melbourne Corporation.
- M12. Diamond, N.T. (2005). "Threshold Criteria for Touch Bottom Probabilities," prepared for Port of Melbourne Corporation.
- M13. Diamond, N.T. and Hyndman, R.J. (2006). "The Monash Experience Questionnaire 2005: The Best and Worst," prepared for CHEQ, Monash University.
- M14. Diamond, N.T. and Hyndman, R.J. (2006). "The Monash Experience Questionnaire 2005: The Best and Worst for First Year Students," prepared for CHEQ, Monash University.
- M15. Diamond, N.T. and Hyndman, R.J. (2006). "The Monash Experience Questionnaire 2005: A Statistical Analysis," prepared for CHEQ, Monash University.
- M16. Diamond, N.T. and Hyndman, R.J. (2006). "The Monash Experience Questionnaire 2005: 2005 vs. Pre-2005 Students," prepared for CHEQ, Monash University.
- M17. Diamond, N.T. (2006). "Agreement of 110/116 and 111/117 items by Consultant Physicians," prepared for the Australian College of Consultant Physicians.

- M18. Diamond, N.T. (2006). "Analysis of Statistical Issues regarding Cornish v Municipal Electoral Tribunal," prepared for Agricola, Wunderlich & Associates.
- M19. Diamond, N.T. (2006). "Analysis of Parks Victoria Staff Allocation," prepared for Parks Victoria.
- M20. Diamond, N.T. and Hyndman, R.J. (2006). "Summary of Results of IPL Sales Forecasting Improvement Project," prepared for Incitec Pivot.
- M21. Sztendur, E.M. and Diamond, N.T. (2007) "A model for student retention at Monash University", prepared for University retention committee.
- M22. Sztendur, E.M. and Diamond, N.T. (2007) "An extension to a model for student retention at Monash University", prepared for University review of coursework committee.
- M23. Sztendur, E.M. and Diamond, N.T. (2007) "A model for student academic performance at Monash University", prepared for University review of coursework committee.
- M24. Diamond, N.T. (2007). "Analysis of IB student 1st year results at Monash University 2003-2005", prepared for VTAC.
- M25. Diamond, N.T. (2008). "Effect of smoking bans on numbers of clients utilising problem gambling counselling and problem gambling financial counselling", prepared for Department of Justice
- M26. Diamond, N.T. (2008). "Development of Indices Based Approach for Forecasting Gambling Expenditure at a Local Government Area Level", prepared for Department of Justice
- M27. Diamond, N.T. (2008). "Orientation 2007- Analysis of Quantitative results", prepared for University Orientation committee.
- M28. Diamond, N.T. (2008). "Orientation 2007- Analysis of Qualitative results, prepared for University Orientation committee.
- M29. Diamond, N.T. (2008). "Analysis of Clients presenting to Problem Gambling Counselling Services-2002/03 to 2005/06", prepared for the Department of Justice.
- M30. Diamond, N.T. (2008). "Analysis of Clients presenting to Problem Gambling Financial Counselling Services-2001/02 to 2005/06", prepared for the Department of Justice.
- M31. Diamond, N.T. (2008). "Analysis of Clients presenting to Problem Gambling Counselling and Problem Gambling Financial Counselling Services-2006/07", prepared for the Department of Justice.

- M32. Diamond, N.T. (2008). “The effect of changes to Electronic Gaming Machine numbers on gambling expenditure”, prepared for the Department of Justice.
- M33. Diamond, N.T. (2009). “Adjustment of Mark Distributions”, prepared for the Faculty of Law.
- M34. Diamond, N.T. (2009). “Summary of Results for Dyno Nobel Sales Forecasting Improvement Project,” prepared for Incitec Pivot.
- M35. Diamond, N. and Brooks, R. (2010). “Determining the value of imputation credits: Multicollinearity and Reproducibility Issues”, prepared for the Victorian Electricity Distributors.
- M36. Booth, R., Diamond, N., and Brooks, R. (2010). “Financial Analysis of Revenues and Expenditures of the AFL and of the AFL Clubs”, prepared for the Australian Football League Players’ Association.
- M37. Diamond, N. and Brooks, R. (2010). “Determining the value of imputation credits: Sample Selection, and Standard Errors”, prepared for the Victorian Electricity Distributors.
- M38. Diamond, N. and Brooks, R. (2010). “Determining the value of imputation credits: Joint Confidence Region and Other Multicollinearity Issues”, prepared for the Victorian Electricity Distributors.
- M39. Diamond, N. and Brooks, R. (2010). “Reconstructing the Beggs and Skeels Data Set”, prepared for the Victorian Electricity Distributors.
- M40. Diamond, N. and Brooks, R. (2010). “Response to AER Final Decision”, prepared for the Victorian Electricity Distributors.
- M41. Diamond, N. and Sztendur, E. (2011). “The Student Barometer 2010. Faculty Results”, prepared for Victoria University (6 reports).
- M42. Diamond, N. and Sztendur, E. (2011). “The Student Barometer 2010. Campus Results”, prepared for Victoria University.
- M43. Diamond, N. and Sztendur, E. (2011). “The Student Barometer 2010. Qualitative analysis of comments”, prepared for Victoria University (17 reports).
- M44. Diamond, N. and Brooks, R. (2011). “Review of SFG 2011 Dividend Drop-off Study”, prepared for the South Australian Electricity Distributors.

R Packages (Extensions to R Programming Environment)

- R1. Diamond, N.T. (2010), VizCompX, <http://cran.r-project.org/web/packages/VizCompX>

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*

B Professor Robert Brooks

Robert Brooks is a professor in the Department of Econometrics and Business Statistics and Deputy Dean, Education in the Faculty of Business and Economics.

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.

Publications

Books

Brooks, R.D., Morley, C.L., Kam, B., Stewart, M., Diggle, J., Gangemi, M., 2003, *Benefits of Road Investment to Assist Tourism*, Austroads Incorporated, Sydney NSW Australia.

Brooks, R.D., Fausten, D.K., 1998, *Macroeconomics in the Open Economy*, Longman, Melbourne Vic Australia.

Book Chapters

Iqbal, J., Brooks, R., Galagedera, D., 2011, Testing the lower partial moment asset-pricing models in emerging markets, in *Financial Econometrics Modeling: Market Microstructure, Factor Models and Financial Risk Measures*, eds Greg N Gregoriou and Razvan Pascual, Palgrave Macmillan, Basingstoke UK, pp. 154-175.

Booth, D., Brooks, R., 2011, Violence in the Australian Football League: Good or bad?, in *Violence and Aggression in Sporting Contests: Economics, History and Policy*, eds R Todd Jewell, Springer Science+Business Media, New York NY USA, pp. 133-151.

Lim, K., Brooks, R.D., 2010, Are emerging stock markets less efficient? A survey of empirical literature, in *Emerging Markets: Performance, Analysis and Innovation*, eds Greg N Gregoriou, CRC Press, Boca Raton FL USA, pp. 21-38.

Iqbal, J., Brooks, R.D., Galagedera, D.U.A., 2010, Asset pricing with higher-order co-moments and alternative factor models: The case of an emerging market, in *Emerging Markets: Performance, Analysis and Innovation*, eds Greg N Gregoriou, CRC Press, Boca Raton FL USA, pp. 509-531.

Woodward, G., Brooks, R.D., 2010, The market timing ability of Australian superannuation funds: Nonlinearities and smooth transition models, in *The Risk Modeling Evaluation Handbook: Rethinking Financial Risk Management Methodologies in the Global Capital Markets*, eds Greg N Gregoriou, Christian Hoppe and Carsten S Wehn, McGraw-Hill, USA, pp. 59-73.

Bissoondoyal-Bheenick, E., Brooks, R.D., 2010, Volatility asymmetry and leverage: Some U.S. evidence, in *The Risk Modeling Evaluation Handbook: Rethinking Financial Risk Management*

Methodologies in the Global Capital Markets, eds Greg N Gregoriou, Christian Hoppe and Carsten S Wehn, McGraw-Hill, USA, pp. 115-123.

Dimovski, W., Brooks, R.D., 2007, Differences in underpricing returns between REIT IPOs and industrial company IPOs, in *Advances in Quantitative Analysis of Finance and Accounting - Volume 5*, eds Cheng-Few Lee, World Scientific, Singapore, pp. 215-225.

Brooks, R.D., Faff, R., Fry, T.R.L., Gunn, L.D., 2005, Censoring and its impact on beta risk estimation, in *Advances in Investment Analysis and Portfolio Management (New Issue) Volume 1*, eds Cheng F. Lee and Alice C. Lee, Center for Pacific Basin Business, Economics, and Finance Research, New Jersey, pp. 111-136.

Brooks, R.D., Merlot, E.S., 2005, Changing candidature approval processes: a review of the RMIT business panel review of candidature process, in *Supervising postgraduate research: contexts and processes, theories and practices*, eds Pam Green, RMIT University Press, Melbourne Vic Australia, pp. 178-201.

Boucher, C., Brooks, R.D., 2005, Changing times, changing research, changing degrees: supervising and managing the first PhD by project undertaken in a business faculty, in *Supervising postgraduate research: contexts and processes, theories and practices*, eds Pam Green, RMIT University Press, Melbourne Vic Australia, pp. 73-88.

Brooks, R.D., Faff, R.W., Fry, T.R.L., Maldonado-Rey, D., 2004, Alternative beta risk estimators in emerging markets: the Latin American case, in *Latin American Financial Markets: Developments in Financial Innovations*, eds H Arbelaez, R Click, Elsevier Ltd, Oxford UK, pp. 329-344.

Brooks, R.D., Sayers, R., 2002, Trends in printed matter exports, in *The International Publishing Services Market: Emerging Markets for Books, from Creator to Consumer*, eds Bill Cope and Christopher Ziguas, Common Ground, Altona Vic Australia, pp. 27-38.

Faff, R., Brooks, R.D., Tan, P.F., 2001, A test of a new dynamic CAPM, in *Advances in Investment Analysis and Portfolio Management Volume 8*, eds Cheng Few Lee, Elsevier Science, Oxford, pp. 133-159.

Journal Articles

Treepongkaruna, S., Brooks, R.D., Gray, S., 2012, Do trading hours affect volatility links in the foreign exchange market?, *Australian Journal of Management [P]*, vol 37, issue 1, Sage Publications Ltd, London UK, pp. 7-27.

Chan, K., Treepongkaruna, S., Brooks, R., Gray, S., 2011, Asset market linkages: Evidence from financial, commodity and real estate assets, *Journal of Banking and Finance [P]*, vol 35, issue 6, Elsevier BV, Amsterdam Netherlands, pp. 1415-1426.

Brooks, R., 2011, CO2 emissions and economic growth: Structural breaks and market reforms in the case of China, *The International Journal of Climate Change: Impacts and Responses [E]*, vol 2, issue 3, Common Ground Publishing, Altona Vic Australia, pp. 25-36.

Luo, W., Brooks, R., Silvapulle, P., 2011, Effects of the open policy on the dependence between the Chinese 'A' stock market and other equity markets: An industry sector perspective, *Journal of International Financial Markets, Institutions and Money [P]*, vol 21, issue 1, Elsevier BV, Amsterdam Netherlands, pp. 49-74.

Bissoondoyal-Bheenick, E., Brooks, R., Hum, X., Treepongkaruna, S., 2011, Sovereign rating changes and realized volatility in Asian foreign exchange markets during the Asian crisis, *Applied Financial Economics [P]*, vol 21, issue 13, Routledge, Abingdon UK, pp. 997-1003.

Masters, T., Russell, R., Brooks, R., 2011, The demand for creative arts in regional Victoria, Australia, *Applied Economics [P]*, vol 43, issue 5, Routledge, Abingdon UK, pp. 619-629.

Lim, K., Brooks, R., 2011, The evolution of stock market efficiency over time: A survey of the empirical literature, *Journal Of Economic Surveys [P]*, vol 25, issue 1, Wiley-Blackwell Publishing Ltd, Oxford UK, pp. 69-108.

Guo, H., Brooks, R., Fung, H., 2011, Underpricing of Chinese initial public offerings, *The Chinese Economy [P]*, vol 44, issue 5, M E Sharpe Inc, Armonk NY USA, pp. 72-85.

Dimovski, W., Philavanh, S., Brooks, R., 2011, Underwriter reputation and underpricing: Evidence from the Australian IPO market, *Review of Quantitative Finance and Accounting [P]*, vol 37, issue 4, Springer, Secaucus NJ USA, pp. 409-426.

Brooks, R., Di Iorio, A., Faff, R., Fry, T., Joymungul, Y., 2010, Asymmetry and time variation in exchange rate exposure: An investigation of Australian stocks returns, *International Journal of Commerce and Management [P]*, vol 20, issue 4, Emerald Group Publishing Ltd, UK, pp. 276-295.

Guo, H., Brooks, R.D., Shami, R.G., 2010, Detecting hot and cold cycles using a Markov regime switching model-Evidence from the Chinese A-share IPO market, *International Review of Economics and Finance [P]*, vol 19, issue 2, Elsevier BV, North-Holland, Netherlands, pp. 196-210.

Bissoondoyal-Bheenick, E., Brooks, R.D., 2010, Does volume help in predicting stock returns? An analysis of the Australian market, *Research in International Business and Finance [P]*, vol 24, issue 2, JAI Press Inc, USA, pp. 146-157.

Iqbal, J., Brooks, R.D., Galagedera, D.U.A., 2010, Multivariate tests of asset pricing: Simulation evidence from an emerging market, *Applied Financial Economics [P]*, vol 20, issue 5, Routledge, UK, pp. 381-395.

Iqbal, J., Brooks, R.D., Galagedera, D.U.A., 2010, Testing conditional asset pricing models: An emerging market perspective, *Journal of International Money and Finance [P]*, vol 29, issue 5, Pergamon, UK, pp. 897-918.

Suntah, N., Brooks, R., 2010, The stock exchange of Mauritius: A study of segmentation versus integration at the regional and global level, *African Journal of Accounting, Economics, Finance and Banking Research [P]*, vol 6, issue 6, Global Business Investments and Publications LLC, USA, pp. 32-41.

Nguyen, H., Dimovski, W., Brooks, R., 2010, Underpricing, risk management, hot issue and crowding out effects: Evidence from the Australian resources sector initial public offerings, *Review of Pacific Basin Financial Markets and Policies [P]*, vol 13, issue 3, World Scientific Publishing Co Pte Ltd, Singapore, pp. 333-361.

Hill, P., Brooks, R.D., Faff, R., 2010, Variations in sovereign credit quality assessments across rating agencies, *Journal of Banking and Finance [P]*, vol 34, issue 6, Elsevier BV, North-Holland, Netherlands, pp. 1327-1343.

Zhang, X., Brooks, R.D., King, M.L., 2009, A Bayesian approach to bandwidth selection for multivariate kernel regression with an application to state-price density estimation, *Journal of Econometrics [P]*, vol 153, issue 1, Elsevier BV, North-Holland, Netherlands, pp. 21-32.

Brooks, R.D., Fry, T.R.L., Dimovski, W., Mihajilo, S., 2009, A duration analysis of the time from prospectus to listing for Australian initial public offerings, *Applied Financial Economics [P]*, vol 19, issue 3, Routledge, United Kingdom, pp. 183-190.

- Lim, K., Brooks, R.D., 2009, Are Chinese stock markets efficient? Further evidence from a battery of nonlinearity tests, *Applied Financial Economics [P]*, vol 19, issue 2, Routledge, United Kingdom, pp. 147-155.
- Brooks, R.D., Faff, R., Mulino, D., Scheelings, R., 2009, Deal or no deal, that is the question: The impact of increasing stakes and framing effects on decision-making under risk, *International Review of Finance [P]*, vol 9, issue 1-2, Wiley-Blackwell Publishing Asia, Richmond Vic Australia, pp. 27-50.
- Woodward, G., Brooks, R.D., 2009, Do realized betas exhibit up/down market tendencies?, *International Review of Economics and Finance [P]*, vol 18, issue 3, Elsevier BV, North-Holland, The Netherlands, pp. 511-519.
- Mulino, D., Scheelings, R., Brooks, R.D., Faff, R., 2009, Does risk aversion vary with decision-frame? An empirical test using recent game show data, *Review of Behavioral Finance [P]*, vol 1, issue 1-2, John Wiley & Sons Ltd, UK, pp. 44-61.
- Guo, H., Brooks, R.D., 2009, Duration of IPOs between offering and listing: Cox proportional hazard models-Evidence for Chinese A-share IPOs, *International Review of Financial Analysis [P]*, vol 18, issue 5, Elsevier BV, North-Holland, Netherlands, pp. 239-249.
- Brooks, R.D., Harris, E.M., Joymungul, Y., 2009, Market depth in an illiquid market: Applying the VNET concept to Victorian water markets, *Applied Economics Letters [P]*, vol 16, issue 13, Routledge, UK, pp. 1361-1364.
- Nandha, M.S., Brooks, R.D., 2009, Oil prices and transport sector returns: An international analysis, *Review of Quantitative Finance and Accounting [P]*, vol 33, issue 4, Springer New York LLC, United States, pp. 393-409.
- Lim, K., Brooks, R.D., 2009, On the validity of conventional statistical tests given evidence of nonsynchronous trading and nonlinear dynamics in returns generating process: A further note, *Applied Economics Letters [P]*, vol 16, issue 6, Routledge, United Kingdom, pp. 649-652.
- Lim, K., Brooks, R.D., 2009, Price limits and stock market efficiency: Evidence from rolling bicomrelation test statistic, *Chaos, Solitons and Fractals [P]*, vol 40, issue 3, Pergamon, United Kingdom, pp. 1271-1276.
- Brooks, R.D., Di Iorio, A., Faff, R., Wang, Y., 2009, Testing the integration of the US and Chinese stock markets in a Fama-French framework, *Journal of economic integration [P]*, vol 24, issue 3, Sejong University, Center for International Economics, Republic of Korea, pp. 435-454.
- Lim, K., Brooks, R.D., 2009, Why do emerging stock markets experience more persistent price deviations from a random walk over time? A country-level analysis, *Macroeconomic Dynamics [P]*, issue S1, Cambridge University Press, UK, pp. 1-39.
- Brooks, R.D., Naylor, S., 2008, An ordered probit model of Morningstar individual stock ratings, *Applied Financial Economics Letters*, vol 4, issue 5, Routledge, UK, pp. 341-345.
- Russell, R., Atchison, M., Brooks, R.D., 2008, Business plan competitions in tertiary institutions: Encouraging entrepreneurship education, *Journal of Higher Education Policy and Management*, vol 30, issue 2, Routledge, UK, pp. 123-138.
- Jugurnath, B., Stewart, M., Brooks, R.D., 2008, Dividend taxation and corporate investment: A comparative study between the classical system and imputation system of dividend taxation in the United States and Australia, *Review of Quantitative Finance and Accounting*, vol 31, issue 2, Springer New York LLC, USA, pp. 209-224.

- Brooks, R.D., Harris, E.M., 2008, Efficiency gains from water markets: Empirical analysis of Watermove in Australia, *Agricultural Water Management*, vol 95, issue 4, Elsevier BV, Netherlands, pp. 391-399.
- Brooks, R.D., Maharaj, E.A., Pellegrini, B., 2008, Estimation and analysis of the Hurst exponent for Australian stocks using wavelet analysis, *Applied Financial Economics Letters*, vol 4, issue 1, Routledge, UK, pp. 41-44.
- Lim, K.P., Brooks, R.D., Kim, J., 2008, Financial crisis and stock market efficiency: Empirical evidence from Asian countries, *International Review of Financial Analysis*, vol 17, issue 3, Elsevier BV, North-Holland, The Netherlands, pp. 571-591.
- Lim, K., Brooks, R.D., Hinich, M.J., 2008, Nonlinear serial dependence and the weak-form efficiency of Asian emerging stock markets, *Journal of International Financial Markets, Institutions and Money*, vol 18, issue 5, Elsevier BV, North-Holland, Netherlands, pp. 527-544.
- Galagedera, D.U.A., Maharaj, E.A., Brooks, R.D., 2008, Relationship between downside risk and return: New evidence through a multiscaling approach, *Applied Financial Economics*, vol 18, issue 20, Routledge, UK, pp. 1623-1633.
- Vaz, J.J., Ariff, M., Brooks, R.D., 2008, The effect of interest rate changes on bank stock returns, *Investment Management and Financial Innovations*, vol 5, issue 4, Dilovi Perspektyvy, Ukraine, pp. 221-236.
- Fry, T.R.L., Mihajilo, S., Russell, R., Brooks, R.D., 2008, The factors influencing saving in a matched savings program: Goals, knowledge of payment instruments, and other behavior, *Journal of Family and Economic Issues*, vol 29, issue 2, Springer New York LLC, USA, pp. 234-250.
- Kutsuna, K., Dimovski, W., Brooks, R.D., 2008, The pricing and underwriting costs of Japanese REIT IPOs, *Journal of Property Research*, vol 25, issue 3, Routledge, United Kingdom, pp. 221-239.
- Dimovski, W., Brooks, R.D., 2008, The underpricing of gold mining initial public offerings, *Research in International Business and Finance*, vol 22, issue 1, JAI Press Inc, USA, pp. 1-16.
- Guo, H., Brooks, R.D., 2008, Underpricing of Chinese A-share IPOs and short-run underperformance under the approval system from 2001 to 2005, *International Review of Financial Analysis*, vol 17, issue 5, Elsevier BV, North-Holland, Netherlands, pp. 984-997.
- Sokulsky, D.L., Brooks, R.D., Davidson, S., 2008, Untangling demand curves from information effects: Evidence from Australian index adjustments, *Applied Financial Economics*, vol 18, issue 8, Routledge, UK, pp. 605-616.
- Loh, J.Y.C., Brooks, R.D., 2008, Valuing biotechnology companies: Does classification by technology type help?, *Journal of Commercial Biotechnology*, vol 14, issue 2, Palgrave Macmillan Ltd, UK, pp. 118-127.
- Iqbal, J., Brooks, R.D., 2007, A test of CAPM on the Karachi Stock Exchange, *International Journal of Business*, vol 12, issue 4, Premier Publishing Inc, USA, pp. 429-444.
- Iqbal, J., Brooks, R.D., 2007, Alternative beta risk estimators and asset pricing tests in emerging markets: The case of Pakistan, *Journal of Multinational Financial Management*, vol 17, issue 1, Elsevier BV, North-Holland, Netherlands, pp. 75-93.
- Jugurnath, B., Stewart, M., Brooks, R.D., 2007, Asia/Pacific Regional Trade Agreements: An empirical study, *Journal of Asian Economics*, vol 18, issue 6, Elsevier, Netherlands, pp. 974-987.

- Brooks, R.D., Zhang, X., Bissoondoyal-Bheenick, E., 2007, Country risk and the estimation of asset return distributions, *Quantitative Finance*, vol 7, issue 3, Routledge, UK, pp. 261-265.
- Dimovski, W., Brooks, R.D., 2007, Factors influencing the direct costs of property trust IPOs, *Pacific Rim Property Research Journal*, vol 13, issue 1, Pacific Rim Real Estate Society, Australia, pp. 2-15.
- Galagedera, D.U.A., Brooks, R.D., 2007, Is co-skewness a better measure of risk in the downside than downside beta?. Evidence in emerging market data, *Journal of Multinational Financial Management*, vol 17, issue 3, Elsevier BV, North-Holland, Netherlands, pp. 214-230.
- Brooks, R.D., 2007, Power ARCH modelling of the volatility of emerging equity markets, *Emerging Markets Review*, vol 8, issue 2, Elsevier BV, North-Holland, Netherlands, pp. 124-133.
- Dimovski, W., Brooks, R.D., van Eekelen, A., 2007, The costs of raising equity capital for closed-end fund IPOs, *Applied Economics Letters*, vol 3, issue 5, Routledge, UK, pp. 295-299.
- Diggle, J., Brooks, R.D., 2007, The target cash rate and its impact on investment asset returns in Australia, *Applied Financial Economics*, vol 17, issue 8, Routledge, UK, pp. 615-633.
- Brooks, R.D., Byrne, J., 2006, A citation analysis of ARC Discovery and Linkage grant investigators in economics and finance, *Applied Economics Letters*, vol 13, issue 3, Routledge, UK, pp. 141-146.
- Jens, P., Brooks, R.D., Nicoletti, G., Russell, R., 2006, Capital raising by Australian biotechnology IPOs: underpricing, money left and proceeds raised, *Accounting Research Journal*, vol 19, issue 1, RMIT, Department of Economics and Finance, Melbourne Vic Australia, pp. 31-45.
- Bissoondoyal-Bheenick, E., Brooks, R.D., Yip, A.Y.N., 2006, Determinants of sovereign ratings: A comparison of case-based reasoning and ordered probit approaches, *Global Finance Journal*, vol 17, issue 1, Elsevier BV, North-Holland, The Netherlands, pp. 136-154.
- Dimovski, W., Brooks, R.D., 2006, Factors influencing money left on the table by property trust IPO issuers, *Journal of Property Research*, vol 23, issue 3, Routledge, UK, pp. 269-280.
- Berman, G., Brooks, R.D., Murphy, J., 2006, Funding the non-profit welfare sector: Explaining changing funding sources 1960-1999, *Economic Papers*, vol 25, issue 1, Economic Society of Australia, St. Ives NSW Australia, pp. 83-99.
- Dimovski, W., Brooks, R.D., 2006, Intangible assets and the underpricing of industrial company initial public offerings, *The International Journal of Knowledge, Culture & Change Management*, vol 6, issue 4, Common Ground, Altona Vic Australia, pp. 67-73.
- Jens, P., Brooks, R.D., Nicoletti, G., Russell, R., 2006, Media coverage and biotechnology IPOs: some Australian evidence, *Journal of Commercial Biotechnology*, vol 13, issue 1, Palgrave Macmillan Ltd, UK, pp. 43-47.
- Diggle, J., Brooks, R.D., 2006, Risk-return tradeoffs from investing in the Australian cash management industry, *Applied Financial Economics Letters*, vol 2, issue 3, Routledge, UK, pp. 147-150.
- Dimovski, W., Brooks, R.D., 2006, The gender composition of boards after an IPO, *Corporate Governance*, vol 6, issue 1, Emerald Group Publishing Ltd, UK, pp. 11-17.
- Brooks, R.D., Shoung, L.C., 2006, The impact of capital controls on Malaysian banking industry betas, *Applied Financial Economics Letters*, vol 2, issue 4, Routledge, UK, pp. 247-249.
- Russell, R., Brooks, R.D., Nair, A., Fredline, L., 2006, The initial impacts of a matched savings program: the Saver Plus program, *Economic Papers*, vol 25, issue 1, The Economic Society of Australia, St. Ives NSW Australia, pp. 32-40.

- Dimovski, W., Brooks, R.D., 2006, The pricing of property trust IPOs in Australia, *Journal of Real Estate Finance and Economics*, vol 32, issue 2, Springer New York LLC, USA, pp. 185-199.
- Loh, J.Y.C., Brooks, R.D., 2006, Valuing biotechnology companies using the price earnings ratio, *Journal of Commercial Biotechnology*, vol 12, issue 4, Palgrave Macmillan Ltd, UK, pp. 254-260.
- Faff, R.W., Brooks, R.D., Kee, H., 2005, A simple test of the 'risk class hypothesis', *Journal for Studies in Economics and Econometrics*, vol 29, issue 1, Universiteit Stellenbosch, Bureau for Economic Research, South Africa, pp. 83-96.
- Brooks, R.D., Faff, R.W., Fry, T.R.L., Bissoondoyal-Bheenick, E., 2005, Alternative beta risk estimators in cases of extreme thin trading: Canadian evidence, *Applied Financial Economics*, vol 15, issue 18, Routledge, UK, pp. 1251-1258.
- Dimovski, W., Brooks, R.D., 2005, Dividend forecasts and dividend payments of initial public offerings - when zero means zero and no comment most likely also means zero, *Applied Financial Economics Letters*, vol 1, issue 3, Routledge, UK, pp. 139-141.
- Dimovski, W., Brooks, R.D., 2005, Putting their money where their mouth is: the importance of shareholder directors post listing, *Accounting Research Journal*, vol 18, issue 1, Queensland University of Technology, Australia, pp. 34-39.
- Brooks, R.D., 2005, Ranking economics research output by Econbase downloads: a comparison to publication based measures, *Applied Financial Economics Letters*, vol 1, issue 2, Routledge, UK, pp. 75-78.
- Diggle, J., Brooks, R.D., 2005, The changing nature of world return correlations, *Asia Pacific Journal of Economics and Business*, vol 9, issue 1, Curtin University of Technology, School of Economics and Finance, Australia, pp. 40-47.
- Dimovski, W., Brooks, R.D., 2005, The gender composition of boards of property trust IPOs in Australia from 1994 to 2004, *Pacific Rim Property Research Journal*, vol 11, issue 2, Pacific Rim Real Estate Society, Australia, pp. 200-210.
- Treloar, K.M., Brooks, R.D., 2005, The relative size of the venture capital market in Australia, *The International Journal of Knowledge, Culture and Change Management*, vol 5, issue 1, Common Ground, Altona Vic Australia, pp. 47-50.
- Brooks, R.D., Faff, R.W., Sokulsky, D.L., 2005, The stock market impact of German reunification: international evidence, *Applied Financial Economics*, vol 15, issue 1, Routledge, UK, pp. 31-42.
- Maldonado-Rey, D., Brooks, R.D., 2004, ARC linkage projects and research-intensive organizations: Are research-intensive organizations likely to participate?, *Economic Papers*, vol 23, issue 2, Economic Society of Australia, St Ives NSW Australia, pp. 175-188.
- Brooks, R.D., Faff, R., Fry, T.R.L., Newton, E., 2004, Censoring and its impact on multivariate testing of the capital asset pricing model, *Applied Financial Economics*, vol 14, Routledge, UK, pp. 413-420.
- Ragunathan, V., Faff, R., Brooks, R.D., 2004, Correlations, integration and Hansen-Jagannathan bounds, *Applied Financial Economics*, vol 14, Routledge, UK, pp. 1167-1180.
- Diggle, J., Brooks, R.D., Stewart, M., 2004, Credit wrapping and local infrastructure investment, *Sustaining Regions*, vol 4, issue 2, Australian and New Zealand Regional Science Association Inc, Wollongong NSW Australia, pp. 39-46.

- Brooks, R.D., Davidson, S., Gangemi, M., 2004, Determinants of R & D in Australia, *International Journal of Knowledge, Culture and Change Management*, vol 4, Common Ground, Altona Vic Australia, pp. 1803-1818.
- Dimovski, W., Brooks, R.D., 2004, Do you really want to ask an underwriter how much money you should leave on the table?, *Journal of International Financial Markets, Institutions and Money*, vol 14, issue 3, Elsevier BV, North-Holland, Netherlands, pp. 267-280.
- Brooks, R.D., Davidson, S., 2004, How much R & D should Australia undertake?, *Economic Papers*, vol 23, issue 2, Economic Society of Australia, St Ives NSW Australia, pp. 165-174.
- Dimovski, W., Brooks, R.D., 2004, Initial public offerings in Australia 1994 to 1999, Recent evidence of underpricing and underperformance, *Review of Quantitative Finance and Accounting*, vol 22, issue 3, Springer, USA, pp. 179-198.
- Jones, S., Brooks, R.D., Maldonado-Rey, D., Russell, R., 2004, Researching innovation in the knowledge economy: Developing a multi-disciplinary, multi-methodology research process, *The International Journal of Knowledge, Culture and Change Management*, vol 4, Common Ground, Altona Vic Australia, pp. 935-941.
- Dimovski, W., Brooks, R.D., 2004, Stakeholders representation on the boards of Australian initial public offerings, *Applied Financial Economics*, vol 14, issue 17, Routledge, Abingdon UK, pp. 1233-1238.
- Holian, R., Brooks, R.D., 2004, The Australian National Statement on Ethical Conduct in Research: Application and implementation for 'insider' applied research in business, *Action Research International*, vol Paper 7, Southern Cross Institute of Action Research, Lismore NSW Australia, pp. 1-20.
- Dimovski, W., Brooks, R.D., 2004, The importance of intangible assets in initial public offerings, *The International Journal of Knowledge, Culture and Change Management*, vol 4, Common Ground, Altona Vic Australia, pp. 1505-1509.
- Brooks, R.D., Faff, R., Hillier, D., Hillier, J., 2004, The national market impact of sovereign rating changes, *Journal of Banking & Finance*, vol 28, issue 1, Elsevier, The Netherlands, pp. 233-250.
- Brooks, R.D., Davidson, S., Jackson, M., 2004, The price of discrimination: An economic analysis of the Human Rights and Equal Opportunity Commission rulings 1985-2000, *Economic Papers*, vol 23, issue 3, Economic Society of Australia, St Ives NSW Australia, pp. 244-256.
- Brooks, R.D., Faff, R., Fry, T.R.L., Newton, E., 2004, The selectivity corrected market model and heteroscedasticity in stock returns: Volume versus GARCH revisited, *Accounting Research Journal*, vol 17, issue 2, RMIT, Department of Economics and Finance, Melbourne Vic Australia, pp. 192-201.
- Keane, P., Brooks, R.D., Green, P., 2003, Developing a knowledge base for postal organisations, *International Journal of Knowledge, Culture and Change Management*, vol 3, Common Ground, Altona Vic Australia, pp. 23-34.
- Brooks, R.D., Faff, R.W., Hillier, D., Hillier, J., 2003, Do stock markets react to the re-rating of sovereign risk?, *JASSA*, vol 4, issue 4, Securities Institute of Australia, Australia, pp. 2-8.
- Brooks, R.D., 2003, Econbase downloads and the ranking of Australian university economics research: A comparative study, *Economic Papers*, vol 22, issue 2, Economic Society of Australia, St Ives NSW Australia, pp. 21-29.
- Dimovski, W., Brooks, R.D., 2003, Financial characteristics of Australian initial public offerings from 1994 to 1999, *Applied Economics*, vol 35, issue 14, Routledge, Abingdon UK, pp. 1599-1607.

Lai, E., Brooks, R.D., Faff, R.W., 2003, Mean Reversion of Skewness: International Evidence, *International Journal of Finance*, vol 15, issue 2, International Journal of Finance, USA, pp. 2619-2627.

Brooks, R.D., Stewart, M., Gangemi, M., 2003, Measuring the economic impact of knowledge-based institutions on national and local economies, *The International Journal of Knowledge, Culture and Change Management*, vol 3, Common Ground, Altona Vic Australia, pp. 521-550.

Brooks, R.D., Dimovski, W., 2003, New economy stocks and Australian industry IPO returns in the late 1990s, *International Journal of Knowledge, Culture and Change Management*, vol 3, Common Ground, Altona Vic Australia, pp. 1-4.

Lai, E., Brooks, R.D., Faff, R.W., 2003, Persistence and predictability of skewness in country equity market returns, *Journal of Quantitative Economics*, vol 1, issue 1, The Indian Economic Society, India, pp. 36-51.

Sokulsky, D.L., Brooks, R.D., Davidson, S., 2003, Price effects of changes to size sub-indexes on the Australian Stock Exchange: An event study, *Accounting, Accountability & Performance*, vol 9, issue 2, Griffith University, Department of Accounting, Finance & Economics, Gold Coast Qld Australia, pp. 67-88.

Dimovski, W., Brooks, R.D., 2003, Promise more, leave less: The importance of dividend forecasts in initial public offerings, *International Journal of Knowledge, Culture and Change Management*, vol 3, Common Ground, Altona Vic Australia, pp. 5-9.

Brooks, R.D., Ragunathan, V., 2003, Returns and volatility on the Chinese stock markets, *Applied Financial Economics*, vol 13, issue 10, Routledge, Abingdon UK, pp. 747-752.

Brooks, R.D., Davidson, S., Faff, R.W., 2003, Sudden changes in property rights: the case of Australian native title, *Journal of Economic Behaviour & Organization*, vol 52, Elsevier, The Netherlands, pp. 427-442. [View Publication](#)

McKenzie, M.D., Brooks, R.D., 2003, The role of information in Hong Kong individual stock futures trading, *Applied Financial Economics*, vol 13, issue 2, Routledge, Abingdon UK, pp. 123-131.

Sokulsky, D.L., Brooks, R.D., Davidson, S., 2003, Time varying volatility and beta patterns of sub-indices on the Australian Stock Exchange, *Accounting Research Journal*, vol 16, issue 2, Royal Melbourne Institute of Technology, Department of Economics and Finance, Melbourne Vic Australia, pp. 117-132.

Brooks, R.D., Faff, R.W., Sokulsky, D., 2002, An ordered response model of test cricket performance, *Applied Economics*, vol 18, issue 4, Routledge, UK, pp. 2353-2365.

Brooks, R.D., Davidson, S., 2002, Investigating the "bounce-back" hypothesis after the Asian crisis, *Economic Papers*, vol 21, issue 2, Economic Society of Australia, St Ives NSW Australia, pp. 71-85.

Faff, R.W., Brooks, R.D., Kee, H., 2002, New evidence on the impact of financial leverage on beta risk: a time-series approach, *The North American Journal of Economics and Finance*, vol 13, Elsevier Science Ltd, UK, pp. 1-20.

Brooks, R.D., Faff, R., McKenzie, M., 2002, Time-varying country risk: an assessment of alternative modelling techniques, *The European Journal of Finance*, vol 8, issue 3, Routledge, UK, pp. 249-274. [View Publication](#)

Bollen, B., Brooks, R.D., Faff, R.W., 2001, An Empirical Examination of the Required Number of Leading and Lagged Terms in Estimating the Dimson Beta: An Updated Analysis, *Accounting*,

Accountability and Performance, vol 7, issue 1, Griffith University, Gold Coast Qld Australia, pp. 23-30.

Brooks, R.D., Faff, R., Josev, T., 2001, An empirical investigation of the cross-industry variation in mean reversion of Australian stock betas, *Pacific Accounting Review*, vol 13, issue 2, Emerald Group Publishing Ltd, Bradford UK, pp. 1-16.

Brooks, R.D., Fausten, D., Silvapulle, P., 2001, Causality in international capital movements: The income mobility of Australian investment abroad, *Accounting Research Journal*, vol 14, issue 1, Queensland Institute of Technology, Brisbane Australia, pp. 58-64.

Brooks, R.D., Faff, R.W., Fry, T.R.L., 2001, GARCH modelling of individual stock data: The impact of censoring, firm size and trading volume, *Journal of International Financial Markets, Institutions and Money*, vol 11, Elsevier, Holland, pp. 215-222.

Thomas, S., Brooks, R.D., 2001, GARCH-based hedge ratios for Australian share price index futures: Does asymmetry matter?, *Accounting, Accountability & Performance*, vol 7, issue 2, Griffith University, Department of Accounting, Finance & Economics, Gold Coast Qld Australia, pp. 61-76.

McKenzie, M.D., Mitchell, H., Brooks, R.D., Faff, R., 2001, Power ARCH modelling of commodity futures data on the London Metal Exchange, *The European Journal of Finance*, vol 7, issue 1, Routledge, Abingdon UK, pp. 22-38.

Josev, T., Brooks, R.D., Faff, R., 2001, Testing a two-factor APT model on Australian industry equity portfolio: The effect of intervaling, *Applied Financial Economics*, vol 11, issue 2, Routledge, Abingdon UK, pp. 157-163.

Brooks, R.D., Silvapulle, P., 2001, Testing for linear and nonlinear Granger causality between the Australian current account and trade weighted index, *Journal of Quantitative Economics*, vol 17, issue 1, The Indian Econometric Society, India, pp. 102-116.

Brooks, R.D., Faff, R., McKenzie, M., Mitchell, H., 2000, A multi-country study of power ARCH models and national stock market returns, *Journal of International Money and Finance*, vol 19, issue 3, Pergamon, UK, pp. 377-397. [View Publication](#)

Brooks, R.D., Fry, T.R., Harris, M.N., 1997, The size and power properties of combining choice set partition tests for the IIA property in the Logit model, *Journal of Quantitative Economics*, vol 13, Indian Econometric Society, Delhi, pp. 45-61.

Conference Proceedings

Russell, R., Brooks, R.D., Nair, A., 2006, Evaluating a financial literacy program: the case of the Australian MoneyMinded program, *Proceedings of the Financial Literacy, Banking & Identity Conference*, 25 October 2006 to 26 October 2006, RMIT University, <http://mams.rmit.edu.au/ushkbbuvz3wfz.pdf>, pp. 1-11. [View Publication](#)

Galagedera, D.U.A., Brooks, R.D., 2006, Is co-skewness a better measure of risk in the downside than downside beta? Evidence in emerging market data, *Far Eastern Meeting of the Econometric Society (FEMES)*, 9 July 2006 to 12 July 2006, Far Eastern Meeting of the Econometric Society (FEMES), Beijing China, pp. 1-43.

Iqbal, J., Brooks, R.D., 2006, Multivariate tests of asset pricing in an emerging market, *Proceedings of ESAM 2006: Australasian Meeting of the Econometric Society*, 04 July 2006 to 07 July 2006, The Econometric Society, <http://esam06.anu.edu.au>, pp. 1-29.

Brooks, R.D., 2006, Power ARCH modelling of the volatility of emerging equity markets, *Quantitative Methods in Finance (QMF)*, 13 December 2006 to 16 December 2006, Quantitative Finance Research Centre, School of Finance and Economics, UTS, Sydney NSW Australia, pp. 1-26.

Dimovski, W., Brooks, R.D., 2006, Stakeholder and gender characteristics of mining and energy IPO boards of directors, *Enhancing Corporate Accountability: Prospects and Challenges: Proceedings of the Conference*, 08 February 2006 to 09 February 2006, Department of Business Law and Taxation & School of Business and Economics, Monash University, Gippsland Vic Australia, pp. 103-113.

Fry, T.R.L., Mihajilo, S., Russell, R., Brooks, R.D., 2006, The factors influencing saving in a matched savings program: The case of the Australian Saver Plus program, *Academy of Financial Services 20th Annual Meeting*, 11 October 2006 to 12 October 2006, Academy of Financial Services, Salt Lake City UT USA, pp. 1-22.

Other

Russell, R., Brooks, R.D., Nair, A., 2006, *Evaluation of the Youth Financial Literacy Trial Program*, RMIT University, Melbourne Vic Australia, pp. 1-26.

Russell, R., Brooks, R.D., Gangemi, M., 2006, *MoneyMinded evaluation 2006: Report 1*, RMIT University, Melbourne Vic Australia, pp. 1-12.

Russell, R., Mihajilo, S., Nair, A., Brooks, R.D., 2006, *Saver Plus - encouraging savings and increasing financial capabilities among low-income families*, ANZ Banking Corporation, <http://www.anz.com/aus/about/saver/Evaluation.asp>, pp. 1-87.

Russell, R., Brooks, R.D., Nair, A., 2006, *SaverPlus - improving financial literacy and establishing long-term saving habits*, ANZ Banking Corporation, <http://www.anz.com/aus/about/saver/Evaluation.asp>, pp. 1-12.

Russell, R., Brooks, R.D., Nair, A., 2005, *Evaluation of MoneyMinded: an adult financial education program*, ANZ Banking Corporation, <http://www.anz.com/aus/values/moneyminded/evaluation.asp>, pp. 1-48.

Russell, R., Brooks, R.D., Nair, A., Fredline, L., 2005, *Saver Plus: Improving financial literacy through encouraging savings*, ANZ Banking Corporation, <http://www.anz.com/aus/about/saver/Evaluation.asp>, pp. 1-86.

C Lachlan Macquarie

LACHLAN MACQUARIE

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EDUCATION

M. Phil. in Econometrics (in progress)

Monash University

Clayton, Victoria, Australia

Thesis entitled: "Bayesian Estimation of the Multinomial Probit Model", entering the final stage toward completion.

Wrote computer code for a Monte Carlo Markov Chain to implement the model, which estimates product purchase probabilities, and enables the user to estimate and forecast almost any marketing variable of interest.

Bachelor of Economics (Honours)

Monash University

1992

Clayton, Victoria, Australia

Majored in Econometrics and received First Class Honours.

Awarded the 1992 Australian Bureau of Statistics Award for Economic Statistics.

RESEARCH

Publications

"The Kuznets U-Curve Hypothesis: Some Panel Data Evidence", with L. Mátyás and L. Kónya, *Applied Economics Letters*, Vol. 5, No. 11, 1998.

"A Comparison of Alternative Estimators for Binary Panel Probit Models", with M. Harris and A. Siouclis, *Monash University Working Paper*, 1998.

"A Comparison of Some Introductory and Undergraduate Econometric Textbooks", with M. Harris, *Journal of Economic Surveys*, Vol. 9, No. 3, 1995.

EXPERIENCE

Consultant

Monash University

July 2009-Present

Melbourne, Victoria

I have been employed as part of the Monash Statistical Service as a part-time consultant. I have been involved in external consultancy projects for the Department of Justice and Victoria University. I am also involved in internal University consulting with students and staff from other Departments. I provide advice and expertise to people with non-statistical backgrounds who need help with statistical problems they encounter in their theses or publications.

Assistant Lecturer

Monash University

Mar 2003-Present

Clayton, Victoria

I am presently co-coordinator for the main second year econometrics course at Caulfield campus. I am responsible for writing the exam and assignments, all grading and all tutorial material for this course. This course provides students with a theoretical and applied foundation of econometrics, and is the feeder subject into further econometrics study. I have also been the sole course coordinator for the first year statistics course Monash provided for Open Universities Australia. I was also responsible for lecturing and acting as a student liaison for two econometrics courses provided to the Department of Treasury in Canberra. My teaching duties also involve teaching students how to use statistical computer packages, such as SPSS, E-Views and Excel.

Consultant
Starcom MediaVest

July-Dec 2009
Melbourne, Victoria

I was engaged as a part-time consultant at Starcom MediaVest analysing the effectiveness of media campaigns for clients. This involved the creation of a dataset encompassing both direct and indirect media spending and the use of a Seemingly Unrelated Regression model. Media impact was analyzed using Adstock variables for several different products by state, age group and customer type. This work involved the extensive use of Stata and culminated in the creation of a scenario forecasting tool for the client's use.

Research Assistant
Monash University

Mar 2008-Present
Clayton, Victoria

I am presently employed at the Centre for Health Economics as a part-time research assistant on various projects concerning obesity. We are using discrete choice models to model potentially varying boundaries for Body Mass Index classifications. I am responsible for data gathering and verification, adapting existing Gauss code to estimate the models according to various theoretical specifications, and collating and reporting results.

Assistant Vice President
State Street Corporation, Investment Manager Solutions

Mar 2001-Dec 2002
Newport Beach, California, USA

I worked as a Business Analyst in the Business Solutions group, developing both new processes and enhancements to existing workflows. I consulted with members of the various teams involved to design a more efficient and scalable process. I managed the procedural implementation and the co-ordination of the technological resources required to implement these strategies, ultimately reporting to senior management. I was also actively involved in defining an enterprise strategy with high-level management to determine how the firm could efficiently cope with more clients.

Senior Portfolio Associate
Pacific Investment Management Company
USA

Nov 1998-Feb 2001
Newport Beach, California,

I worked very closely with portfolio managers who are responsible for managing approximately \$20bn (US) against global bond indices. I researched and allocated block trades across individual accounts, matching our investment strategy with client guidelines. Due to swift market movements, accuracy and timeliness were paramount, for both the client's interest and for the liability of the firm. I created flexible and adaptable ad-hoc reports for both portfolio and account managers, which could be made available extremely quickly. I was responsible for running daily position and risk reports, and suggested the appropriate action needed to rectify any account variances from our strategy. Additionally, this involved ensuring that new accounts matched our investment strategy from inception. I was accountable for the integrity of index data in the system, against which each account was managed, and from which our performance was calculated. I trained new portfolio associates, and led them as a portfolio manager support. I worked with account managers, keeping them informed of strategy changes, researching client questions and requests, and preparing risk and performance reports for clients.

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 evidence¹, and to assist experts to understand in general terms what the Court expects of them. Additionally, it is hoped that the guidelines will assist individual expert witnesses to avoid the criticism that is sometimes made (whether rightly or wrongly) that expert witnesses lack objectivity, or have coloured their evidence in favour of the party calling them.

Guidelines

1. General Duty to the Court²

- 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.

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].

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

2. The Form of the Expert's Report³

- 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) above⁴; 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 Court⁵.
- 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 reports⁶.

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

United Energy Distribution Pty Limited
ABN 70 064 651 029

Multinet Gas Distribution Partnership
ABN 53 634 214 009



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TERMS OF REFERENCE – REVIEW OF FAIR VALUE CURVES AND AN ASSESSMENT OF METHODS USED TO DETERMINE THE SPOT COST OF DEBT

Background

On 30th August 2013, the Australian Energy Regulator (AER) published its draft rate of return guideline that will form the basis of the regulated rate of return to be applied in energy network decisions made from 2014 onwards. Previously the AER published an Issues Paper on 18th December 2012 and a Consultation Paper on 10th May 2013.

Under the new Rules, promulgated by the Australian Energy Market Commission, (AEMC), in December 2012, fundamental changes have been made to the way in which the allowance for the return of debt can be determined. Clause 6.5.2(j) of the National Electricity Rules (NER) provides that, at each determination, the allowance for the return of debt can be computed in one of three different ways:

- (1) The return that would be required by debt investors in a benchmark efficient entity if it raised debt at the time or shortly before the making of the distribution determination for the regulatory control period.
- (2) The average return that would have been required by debt investors in a benchmark efficient entity if it raised debt over an historical period prior to the commencement of a regulatory year in the regulatory control period; or
- (3) Some combination of the returns referred to in subparagraphs (1) and (2). Implicit in these considerations is that the regulatory framework should encourage efficient financing practices that the former approach did not explicitly consider.

Implicit in these considerations is that the regulatory framework should encourage efficient financing practices that the previous approach did not explicitly consider.

The calculation of the spot cost of debt, or the market cost of debt at a particular point in time remains an essential component of all three of the aforementioned approaches. Option one, which is known as the rate-on-the-day approach, uses an estimate of the cost of debt that is determined over a limited number of days in advance of the commencement of a new regulatory period. Option two calculates a form of historical average cost of debt, using historic information on spot rates. Under option three, the base cost of debt may be estimated separately from the debt risk premium.

United Energy and Multinet Gas are seeking a suitably qualified consultant to undertake specific analysis in relation to the current cost of debt, as measured over a recent 20 to 30 day averaging period. The purpose of the current exercise is to investigate whether yield curves can be used to derive robust estimates of the cost of debt for a benchmark corporate bond with a ten-year tenor.

The consultant will be supplied with:

- A spread sheet database containing information about the characteristics of bonds used in the empirical analysis. The attributes covered will include credit ratings, maturity dates, and yields. Data covering plain vanilla bonds will, in the main, be provided, although there may also be results for callable bonds and other types of bonds. Both domestic and foreign currency bonds will be supplied, although the yields on the latter will have been swapped into Australian dollar yields.
- A report from CEG which contains empirical estimates of yield curves. Please refer to: *Estimating the debt risk premium* (Incorporating CEG notice of errata, 22nd August 2013), prepared for the Energy Networks Association by the Competition Economists Group, August 2013. The report discusses yield curves that have been estimated according to the methods of Nelson and Siegel (1987)¹. The report also contains an assessment of the performance of the Bloomberg fair value curve for BBB+ corporate debt.
- Regression results will have been reported in a spread sheet workbook. Program code may be supplied if it is available.

Scope of work

The consultant is required to undertake a detailed review of the yield curves that have been estimated by CEG, with a view to assessing the merits of the overall approach. The yield curves are a tool for working out the benchmark cost of debt corresponding to a particular term to maturity. The Nelson-Siegel model is non-linear in the parameters and is therefore more complicated to fit than a normal regression model.

The consultant should assess the case for using yield curves by comparison with the method of direct averaging of observed bond yields. The direct averaging technique takes a simple arithmetic average of bond yields, and has been applied by the AER and the Economic Regulation Authority (Western Australia).

The consultant should also develop yield curves for zero coupon bonds, and par yield curves. A zero coupon bond is a fixed income investment that provides only one payment at maturity. Bonds which trade at par are those for which the calculated yield is equal to the coupon rate. Par yield curves provide a theoretically correct specification for the term structure of the cost of debt.

Preliminary review of CEG methods

- (1) Investigate the equations which have been estimated by CEG and seek to reproduce the reported results using a suitable software package. Categorise the results from yield-to-maturity curves separately from the results for par value yield curves. Assess how the estimated equations vary according to the bond samples used.

¹ Nelson, C.R. and Siegel, A.F. (1987). "Parsimonious Modeling of Yield Curves," The Journal of Business, 60, pages 473-489.

- (2) Examine and report on the accuracy and correctness of the results from the estimated equations. Check whether outliers are present, and review the regression diagnostics. Note the standard errors and report on the precision of the parameter estimates.
- (3) Assess whether the estimates of the cost of debt that have been presented by CEG are justifiable in the context of the estimated yield curves.

Refinements to the analysis – for both types of yield curve

- (4) Investigate the case for the use of alternative estimation methods, such as robust regression techniques, for the daily regressions. Compare the results from different estimation methods.
- (5) Examine the day-to-day drift of the parameter estimates over the nominated days of the averaging period. Suggest an alternative method for combining the daily results for the estimated benchmark 10-year corporate bond yield.
- (6) Examine the validity of restrictions that may be imposed upon the Nelson-Siegel curves. The types of restriction are likely to include different intercept terms for bonds in different credit rating bands.
- (7) The empirical methods that are applied to derive par value yield curves are more advanced. Firstly, a zero coupon yield curve is estimated. Secondly, a further non-linear equation has to be solved in order to determine par value yields. Diagnostic tests are needed for the overall model, and these should be developed by the consultant. The consultant should also investigate the impact of the weighting scheme based on Macaulay duration².
- (8) Evaluate the results for the cost of debt that have been determined as par value yields. Comment on the methods that have been applied.

Comparison of results from yield curves with those obtained using the methods applied separately by the AER and the Economic Regulation Authority (WA).

- (9) Critically assess the statistical properties of the cost of debt estimators developed separately by the AER and the ERA (WA). Consider the use of an overall measure of usefulness such as mean squared error (which is equal to the sum of the variance and the bias squared).
- (10) Undertake a simulation analysis and apply other methods as appropriate.

Timeframe

The consultant is to provide a draft report which discusses the results of the analysis by Monday 23rd September 2013. A final report should be provided by no later than Monday 7th October.

² CEG (2012), Estimating the regulatory debt risk premium for Victorian gas businesses, a report prepared by Dr Tom Hird for APA Group, Envestra, Multinet Gas, and SP AusNet, Competition Economists Group, March 2012; page 31. A standard measure of risk is the Macaulay duration which computes the average maturity of a bond using the present values of its cash flows as weights.

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.

The consultant is likely to be called upon to present analysis and advice to the cost of capital sub-group of the Energy Networks Association (ENA).

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:

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