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25th September 2013

Our Reference: UE.SU.01

Mr Lyndon Rowe
Chairman
Economic Regulation Authority, WA
P.O. Box 8469
PERTH BC WA 6849

BY EMAIL TO: publicsubmissions@erawa.com.au

Dear Mr Rowe,

Guidelines for the Rate of Return for Gas Transmission and Distribution Networks – Submission to Draft Rate of Return Guidelines

Please would you accept a submission by ESQUANT Statistical Consulting which has been prepared in relation to the ERA's draft rate of return guidelines for gas distribution and transmission networks. The submission comments on the analysis by the ERA of the cost of debt, using yield curves and the "joint-weighted DRP approach"[1].

If the ERA has further questions about this submission, then please do not hesitate to contact Jeremy Rothfield, Network Regulation and Compliance Manager, on (03) 8846 9854.

Yours sincerely,

Jeremy Rothfield
Network Regulation and Compliance Manager

[1] ERA (2013a), Explanatory Statement for the Draft Rate of Return Guidelines, Meeting the requirements of the National Gas Rules, Economic Regulation Authority, Western Australia, 6th August 2013; section 9.3.3, page 100.

ESQUANT
Statistical Consulting

Review of ERA (WA) Yield Curve Analysis

A REPORT FOR

UNITED ENERGY AND MULTINET GAS

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DEPARTMENT OF ECONOMETRICS AND BUSINESS STATISTICS

MONASH UNIVERSITY

September 26, 2013

Contents

1 Executive Summary

In section 9.3.3 of the Explanatory Statement for the Draft Rate of Return Guidelines, (ERA, 2013a), the ERA (WA) fitted the Nelson-Siegel model to the data that had been used in three recent regulatory decisions. The decisions were as follows :

- Final decision on WA Gas Networks Pty Ltd proposed revised access arrangement for the Mid-West and South-West Gas Distribution Systems, (ERA, 2011a). See, also (ERA, 2012a).
- Final Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline, (ERA, 2011b); and
- Final Decision on Proposed Revisions to the Access Arrangement for the Western Power Network, (ERA, 2012b).

Over the remainder of this report, the three decisions have, in the main, been abbreviated to WAGN, DBNGP, and WP.

Chapter 3: Nelson-Siegel Model

The ERA (WA) used the `YieldCurve` (Guirreri, 2013) package in R (R Core Team, 2013) to estimate the Nelson-Siegel model using the specification, suggested by Diebold and Li (2006),

$$y(\tau) = \beta_0 + \beta_1 \frac{1-\exp(-\lambda\tau)}{\lambda\tau} + \beta_2 \left(\frac{1-\exp(-\lambda\tau)}{\lambda\tau} - \exp(-\lambda\tau) \right).$$

In this specification $y(\tau)$ represents the Debt Risk Premium (DRP) at maturity τ, and β_0, β_1 and β_2 are the parameter estimates corresponding to the 'long-term', 'short-term', and 'medium-term' components respectively. Once the parameters are estimated, the average DRP at five years can be calculated.

The main purpose of the Nelson-Siegel analysis conducted by the ERA (WA) was to compare the result with the joint-weighted estimation method given by

$$\frac{\sum_i (\text{Maturity}_i) \times (\text{Issue Amount}_i) \times (\text{DRP}_i)}{\sum_i (\text{Maturity}_i) \times (\text{Issue Amount}_i)}$$

where:

Maturity_i	=	The remaining term to maturity of a particular bond (to be distinguished from the tenor at issuance).
Issue Amount_i	=	The size of the bond at issuance, measured in \$ million. For a plain vanilla, fixed coupon bond, the issue amount can be thought of as the bond's face value.
DRP_i	=	The debt risk premium attributable to the particular bond (bond 'i').

Chapter 4, A critique of the ERA (WA)s Yield Curve Analysis

The ERA (WA) sought to implement Nelson-Siegel yield curves, drawing upon the bond data that was reportedly used in three recent regulatory decisions. The ERA (WA) had applied a bond yield averaging approach, or a "joint weighted DRP approach" in those constituent decisions.

However, in two of the three cases, the analysis performed by the ERA (WA) for the purposes of its explanatory statement appears to have used different data from that provided and reported in the respective final decision documents. For WAGN, the data for four bonds was not used. For DBNGP, there are major differences between the data used and that given in the decision document.

A comparison of the results provided by the ERA (WA) in their explanatory statement (ERA, 2013a) and the results that we calculated using the `YieldCurve` package are given in the table below. Note that we have also computed standard errors and robust standard errors, using a bootstrap method.

Table 1: A comparison of values of the debt risk premium (DRP) at 5-years. Estimates of the debt risk premium provided by the ERA (WA), and the results of our own calculations based on the application of joint-weighted averaging and Nelson-Siegel curve fitting. Bootstrap standard errors (SE) are shown, together with robust standard errors (Robust SE).

			DRP (%)	SE (%)	Robust SE (%)
WA Gas Networks					
ERA (WA) reported results	Explanatory Statement (ERA, 2013a, Table 11)	Joint-Weighted	2.893		
		Nelson-Siegel	2.83		
ESQUANT/MONASH calculations	13 data points (ERA, 2011a, Table 17)	Joint-Weighted	2.894	0.200	0.157
		Nelson-Siegel	2.996	0.279	0.289
ESQUANT/MONASH calculations	17 data points (ERA, 2011a, Table 17)	Joint-Weighted	3.091	0.207	0.213
		Nelson-Siegel	2.857	0.254	0.245
Access arrangement for DBNGP					
ERA (WA) reported results	Explanatory Statement (ERA, 2013a, Table 11)	Joint-Weighted	3.196		
		Nelson-Siegel	3.34		
ESQUANT/MONASH calculations	Digitized Data (ERA, 2013a, Figure 11)	Nelson-Siegel	3.327	0.409	0.214
ESQUANT/MONASH calculations	Data from Decision (ERA, 2011b, Table 36)	Joint-Weighted	3.148	0.115	0.096
		Nelson-Siegel	3.277	1.360	0.292
Access arrangement for Western Power					
ERA (WA) reported results	Explanatory Statement (ERA, 2013a, Table 11)	Joint-Weighted	2.708		
		Nelson-Siegel	2.82		
ESQUANT/MONASH calculations	Digitized Data (ERA, 2013a, Figure 13)	Nelson-Siegel	2.815	0.160	0.134
ESQUANT/MONASH calculations	Data from Decision (ERA, 2012b, Table 167)	Joint-Weighted	2.719	0.113	0.118
		Nelson-Siegel	2.819	0.141	0.152

The data used by ESQUANT/MONASH has been taken from the respective final decision documents[1]. The data from the decisions was supplemented by information on bond issuance amounts, which was extracted from the Bloomberg data service by United Energy and Multinet Gas.

There are important differences between the results published by the ERA and those that we obtained. Consider for instance the analysis of the WAGN decision:

- In the explanatory statement, the ERA (WA) appears to have dropped the debt risk premium results from four bonds, thereby relying upon only 13 observations, as opposed to 17.
- We estimated Nelson-Siegel curves for 13 bonds, and for the full set of 17 bonds. The results are shown in Table 1 above. We also applied the ERA's approach to calculate a joint-weighted DRP.
- The ERA has reported that the DRP from the Nelson-Siegel method is 2.83% (see Table 1 above and Table 11 of the explanatory statement). However, this value is incorrect. The debt risk premium from the Nelson-Siegel approach, as applied to the WAGN data, is 2.996% if the observations from only 13 bonds are employed.

[1] Final decision on WA Gas Networks Pty Ltd proposed revised access arrangement for the Mid-West and South-West Gas Distribution Systems, (ERA, 2011a); see Table 15, page 80 and Table 17, page 88.

Final Decision on Proposed Revisions to the Access Arrangement for the Dampier to Bunbury Natural Gas Pipeline, (ERA, 2011b); see Table 35, page 146, and Table 36, page 148.

Final Decision on Proposed Revisions to the Access Arrangement for the Western Power Network, (ERA, 2012b); see Table 165, page 365, and Table 166, page 367.

- The estimate of the DRP derived using the joint-weighted method, as applied to 13 bonds, is 2.894%, with a relatively high standard error of 0.200%.

- The standard errors of the DRP estimates from the use of the Nelson-Siegel method are also comparatively high. For instance, when 13 bonds are used, the DRP estimate of 2.996% is associated with a bootstrap standard error of 0.279%. The quantum of the standard error should not, however, be interpreted as a possible failing of the Nelson-Siegel method (and, by implication, as an argument in favour of the joint-weighted DRP approach). The issue at stake is that the ERA (WA) has used very small bond samples when computing the DRP. The deficiencies inherent in the ERA's implementation of the Nelson-Siegel method are expounded upon further in later sections of this report.

- In other applications of the Nelson-Siegel method, we have found that DRP estimates can be generated with comparatively low standard errors. For instance, we recently used a large bond database compiled by the Competition Economists Group, (CEG) to calculate estimates of the DRP for a benchmark corporate bond with a 7-year tenor and a 10-year tenor. The reader is referred to Diamond, Brooks, and Young (2013b).

In the context of the final decision for the access arrangement for DBNGP (ERA, 2011b):

- The ERA appears to have used a different dataset for the analysis undertaken for the purpose of the explanatory statement, as compared to the bond data that was employed in the final decision for DBNGP.

- However, we have digitised the data from the hard copy of Figure 11 in the explanatory statement, and have applied the Nelson-Siegel method using the resulting observations. As shown in Table 1, the estimated DRP for a five-year tenor is 3.327%. If the Nelson-Siegel curve is applied to the observations from the DBNGP decision document, then the calculated DRP becomes 3.277%.

- We have also applied the ERA's method to calculate the joint-weighted DRP using bond data covering the debt risk premium, and remaining term to maturity, sourced from the final decision for DBNGP. Additional information showing the size of each bond issue was obtained from Bloomberg, and provided to us by United Energy and Multinet Gas. We calculated a joint-weighted DRP estimate of 3.148%, which is below the DRP figure of 3.196% that is reported in Table 11 of the explanatory statement.

- Accordingly, we were unable to precisely replicate the joint-weighted DRP result that was produced by the ERA (WA), although we followed the ERA's technique, in the way that it has been presented in the Western Power final decision, (ERA, 2012b, see Table 367, page 169).

From the perspective of the final decision for the access arrangement for Western Power (ERA, 2012b):

- The parameter estimates obtained from the application of the Nelson-Siegel method to the digitised data were similar to those reported in Table 11 of the explanatory statement. The estimate of the debt risk premium at five years, was, however, very similar to the result in the explanatory statement (2.840% as compared to 2.82%, see Table 1 above).

When comparing results from the joint-weighted DRP approach with those obtained from the estimation of Nelson-Siegel curves, the ERA (WA) has claimed that (ERA, 2013a, paragraph 532):

> "Estimates of the DRP can be higher (as in the case for WAGN), and lower (as in the case for DBNGP and Western Power). The difference of the estimates under both approaches varies within the range of 6 and 14 basis points".

The conclusion drawn by the ERA (WA) is erroneous. The previous discussion, when considered in conjunction with the results in Table 1 above, demonstrates that the joint weighted DRP method delivers consistently lower results for the DRP at 5-years. The ERA's method is downwardly biased, because of the phenomenon of Jensen's inequality (see section 8). Jensen's inequality applies because Nelson-Siegel curves are typically concave.

Chapter 5, Estimation of the Nelson-Siegel parameters

The usual approach for estimating the Nelson-Siegel parameters is to apply the method of nonlinear least squares, which, in contrast to linear least squares, requires an iterative solution. The difficulties associated with non-linear estimation are eased when applying the Nelson-Siegel approach because, given a particular value of λ, the Nelson-Siegel model is linear in the other parameters.

The `YieldCurve` package in R-software uses another method. A series of positive λ values are selected, and linear least squares is used to estimate the other parameters for each value of λ. An applicable constraint is that the corresponding parameter estimate for β_0 should be positive. The λ value with the smallest residual sum of squares is chosen as the best estimate, subject to the constraint being satisfied.

We disaggregated the Nelson-Siegel equation into three composite variables which can be described as short-term, medium term and long-term components. A degree of difficulty was encountered, however, when we attempted, to separate out the short, medium and long-term components. The problem arose because the data used by the ERA (WA) does not contain bonds with a remaining term to maturity of less than two years. The ERA's bond sample is, in effect, "truncated" at two years.

The inadequacies of the ERA's data meant that there was multi-collinearity between the composite variables which comprise the Nelson-Siegel model. There was some doubt, therefore, as to whether or not the parameter estimates had been identified properly and reliably.

Chapter 6, Profile Plots

The non-linear least squares facility in the R environment for statistical computing and graphics (R Core Team, 2013), which is also known as nls, was used for this part of the analysis. We note that in section 5, a constrained estimation was applied to the Nelson-Siegel curves, however for the empirical work undertaken in section 6, the constraints that λ and β_0 should both be positive were removed. β_0 can be regarded as the long-term parameter.

A plot of the λ value against the residual sum of squares of the associated linear regression is called a profile plot. The debt risk premium was used as the response variable, and profile plots were established for the three decisions, WAGN, DBNGP, and Western Power.

- For WAGN, the parameter estimates for λ and β_0 were insignificantly different from zero, thereby again demonstrating that the regression had been afflicted by multi-collinearity. The fitted model was on the boundary of the constraint region.

- For DBNGP, the parameter estimates for λ and β_0 were insignificantly different from zero, a phenomenon that is also symptomatic of multi-collinearity.

- For Western Power, the estimated value of λ was close to zero, while β_0 was weakly positive, with both parameter estimates only marginally significant.

In fact, in none of the three cases was the fitted curve better, in a statistical sense, than a constant DRP for all maturities. The F-tests that were applied to all three datasets did not reject the hypothesis that the debt risk premium was a constant for each and every value of the term to maturity.

These outcomes should not, in any way, be interpreted as a criticism of the Nelson-Siegel method. The main reason for the unsatisfactory outcomes in the three cases considered is that the ERA (WA) did not include bonds with maturities of less than two years. The estimated parameters of the Nelson-Siegel model therefore suffered from multi-collinearity. A further shortcoming of the ERA's approach was a failure to control for the different credit ratings of the bonds incorporated into the datasets. There was therefore greater variability in the observed data than would otherwise be the case for such small samples.

Chapter 7, Using the Total Cost of Debt as the Response Variable

When the total cost of debt (or the actual observed bond yield) was used as the response variable, instead of the debt risk premium, the results from the profile plots appeared to improve somewhat. The yield was estimated for a 5-year term to maturity, and the corresponding DRP could then be worked out. However, even with this approach, the only statistically significant model is that for Western Power. As is shown in section 7.3, the parameter estimate for β_0 is positive and statistically significant, while an F-test of the hypothesis that the bond yield is constant, across the range of maturities, is rejected at the 5% level of significance.

The estimation process would be improved via the inclusion of bonds with a remaining term to maturity of less than two years. A further necessary enhancement would be to control for different credit ratings in an appropriate way.

Chapter 8, Simulation Exercise to Compare Joint-weighted averaging to Yield Curve fitting

A simulation exercise was undertaken so as to investigate and compare the distribution of outcomes under the joint-weighted DRP approach and under the Nelson-Siegel method. In view of the findings in chapter 7, the simulations were conducted on the total cost of debt rather than on the debt risk premium, although the DRP was worked out subsequently. The dataset from the Western Power final decision was applied to the task, and was chosen because the unconstrained Nelson-Siegel curve based on the total cost of debt, as reported in section 7.3 was statistically significant. The unconstrained Nelson-Siegel curves obtained from the analysis of data from the WAGN and DBNGP decisions did not pass tests of statistical significance owing to problems with sample selection. The simulation conducted for Western Power was based on sample distributions using the observed data provided in the Western Power final decision and the fitted Nelson-Siegel model.

The simulation results demonstrate that the joint weighted averaging approach is downwardly biased for all sample sizes. The Nelson-Siegel approach and other curve-fitting approaches are unbiased but do not work particularly well for small sample sizes, when the maturities of bonds in the sample are limited to those over two years. The problem of small samples is highlighted by the larger standard errors that are obtained when the number of observations falls below 50.

Conclusions

In its deliberations on the application of Nelson-Siegel methods, the ERA (WA) has opined that (ERA, 2013a, paragraph 533, page 102):

> "Curve fitting is a complex issue and there are various different techniques which can be used. The Authority considers that the small benefit from this complex technique is not sufficient to outweigh the costs involved in carrying out the exercise."

We do not believe that the ERA (WA) has done sufficient analysis to justify such a conclusion being drawn. The limited work that the ERA (WA) has done on the implementation of the Nelson-Siegel method has serious shortcomings, and has served to highlight problems with the way in which the ERA (WA) selects its bond samples.

A more carefully constructed yield curve estimation exercise can produce estimates of the DRP that are well-founded and robust. For evidence, the reader is referred to Diamond, Brooks, and Young (2013b). We believe that there are considerable advantages in producing econometric estimates which properly capture the information that is inherent in bond yields and term to maturity.

Our analysis has shown that the joint-weighted averaging approach of the ERA (WA) is biased downwards and is not very precise. We have also found that eliminating short maturity bonds has a deleterious effect on the properties of the Nelson-Siegel parameter estimates. However, as the sample size increases the Nelson-Siegel estimates have far greater precision than the joint-weighted average estimates, and they are unbiased for all sample sizes.

If the available data is confined to the limited samples that the ERA (WA) has used in its recent decisions, then the Nelson-Siegel method, as applied to observations of the DRP, will produce results that are not statistically different from a constant DRP for all maturities. Improved models can be obtained by using Yield and not DRP as the response variable.

2 Terms of Reference - Review of Yield Curves and an assessment of methods used to determine the spot cost of debt

Background

The Economic Regulation Authority (Western Australia) is developing rate of return guidelines that will form the basis of the regulated rate of return to be applied in energy network decisions. In December 2012, the ERA (WA) published a consultation paper, which was said to be consistent with the National Gas Law (NGL) and the National Gas Rules (NGR). The ERA (WA) released its draft rate of return guidelines on 6th August 2013. In the new Rules, the AEMC has made fundamental changes to the way in which the allowance for the return of debt can be determined. Clause 87 (10) of the NGR provides that for each regulatory year of an access arrangement period, 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 sub-rules (a) and (b). 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, including methods which were not necessarily available for consideration under previous versions of the National Gas Rules.

The calculation of the spot cost of debt, or the 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, or access arrangement 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 (UEMG) are seeking a suitably qualified consultant to undertake specific analysis in relation to the current cost of debt, as measured over a representative 20 to 30 day averaging period.

Scope of work

The consultant is required to undertake a detailed review of the methods that have been applied by the ERA (WA) to determine the spot cost of debt. The methods that have been employed by the ERA (WA) include the calculation of an arithmetic mean of the debt risk premiums (DRPs) observed in a sample of bonds, and the derivation of "joint-weighted DRP estimates".

In the explanatory statement which accompanied the draft rate of return guidelines, the ERA (WA) has also presented the results from the application of Nelson-Siegel yield curve methods. (ERA (2013a), *Explanatory Statement for the Draft Rate of Return Guidelines, Meeting the requirements of the National Gas Rules*, Economic Regulation Authority (Western Australia), 6th August 2013; see section 9.3.3, Yield Curve Fitting, page 100.) 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 objectively assess the merits of the different approaches. In particular, the consultant should:

1. Assess the statistical properties of the cost of debt estimators that have been applied at different times by the ERA (WA).
2. Attempt to replicate the analysis already performed by the ERA (WA), and calculate standard errors.
3. Undertake a simulation analysis and apply other methods as appropriate.

The consultant should make use of the data that has been published by the ERA (WA) in various final decision documents. Relevant Decisions of the Australian Competition Tribunal should also be examined. United Energy and Multinet Gas will provide information sourced from the Bloomberg data service, if such information is required.

Timeframe

The consultant is to provide a draft report which discusses the results of the analysis by 12th September 2013. A final report addressing any ENA comments should be provided no later than 19th September 2013.

Reporting

Jeremy Rothfield will provide the primary interface for UEMG, for the duration of the engagement. The consultant will report on work progress on a regular basis. The consultant will make periodic presentations on analysis and advice when appropriate.

The consultant may also be called upon to present analysis and advice to the ENA Cost of Capital Subgroup.

Conflicts

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

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

3 Nelson-Siegel Model

The Nelson-Siegel model (Nelson and Siegel, 1987) can be written as

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

where m is the remaining term to maturity of the bond and $R(m)$ is the corresponding yield to maturity.

The ERA (WA) used the `YieldCurve` (Guirreri, 2013) package in R (R Core Team, 2013) to estimate the Nelson-Siegel model. That package uses the equivalent model specification, suggested by Diebold and Li (2006),

$$y_t(\tau) = \beta_{0t} + \beta_{1t}\frac{1-\exp(-\lambda\tau)}{\lambda\tau} + \beta_{2t}\left(\frac{1-\exp(-\lambda\tau)}{\lambda\tau} - \exp(-\lambda\tau)\right).$$

The equivalences between the two specifications are given below:

Nelson-Siegel	YieldCurve
$R(m)$	$y_t(\tau)$
β_0	β_{0t}
β_1	β_{1t}
β_2	β_{2t}
m	τ
τ	$\frac{1}{\lambda}$

Note that τ is used as a parameter in the Nelson and Siegel formulation but as the Maturity in the YieldCurve formulation. The subscript t allows the parameters to change over time but both the ERA (WA) and us have assumed the parameters are constant and hence the subscript has been dropped in the remaining part of this document.

The main purpose of the Nelson-Siegel analysis conducted by the ERA (WA) was to compare the result with the joint-weighted estimation method given by

$$\frac{\sum_i (\text{Maturity}_i) \times (\text{Issue Amount}_i) \times (\text{DRP}_i)}{\sum_i (\text{Maturity}_i) \times (\text{Issue Amount}_i)}$$

Any estimated value should be accompanied by a standard error, in order to assess the precision of the estimated quantity. In the following we have used bootstrap sampling in order to compare the estimates of the DRP based on the joint-weighted approach and the Nelson-Siegel curve fitting approach. In the bootstrap (see, for example, Efron and Tibshirani, 1993) a large number of replicate data sets are generated by sampling with replacement from the original data set. For each of the data sets, the statistic (in this case the joint-weighted DRP at 5 years maturity) is calculated, and the estimated standard error of the statistic is given by the standard deviation of the estimates.

Irrespective of the Nelson-Siegel model specification, it is also important to estimate the standard errors of the model parameters and fitted values. In most software packages this is automatically performed, based on theoretical considerations. One shortcoming of the `YieldCurve` package is that no standard errors are provided. For the Nelson-Siegel bootstrap we used *model based resampling* (see, for example, Venables and Ripley, 2002, p.164). The bootstrap datasets are created by $\hat{y}_i + e_i^*$, where $\hat{y}_i$ is the Nelson-Siegel fitted value for the ith observation and the e_i^* are sampled with replacement from the residuals given by $e_i = y_i - \hat{y}_i$ with $n = 100$ bootstrap samples. Again the standard error is estimated as the standard deviation of the calculated statistic over the bootstrap samples.

4 A critique of the ERA's Yield Curve Analysis

4.1 Introduction

In section 9.3.3 of the Explanatory Statement for the Draft rate of return guidelines (ERA, 2013a) the ERA (WA) fitted the Nelson-Siegel model to data used in three recent regulatory decisions. In this section, we try to reproduce the results given by the ERA (WA). We also undertake further analysis and fit the Nelson-Siegel approach using the `YieldCurve` package. We reproduce the results of the ERA (WA) and produce standard errors.

4.2 WAGN

The first regulatory decision was for the proposed revisions to the Western Australia Gas Network (ERA, 2011a). A plot of the Debt Risk Premiums against Years to Maturity is given in the left hand panel of Figure 1. The right hand panel of Figure 1 gives the plot for the data apparently analysed by the ERA (WA). Four bonds were not used, for reasons that are not clear to us The four bonds, identified by comparison with Figure 12 of the explanatory statement (ERA, 2013a), that have not been used[2]. are given in Table 2 with the information obtained from Table 17 of ERA (2011a).

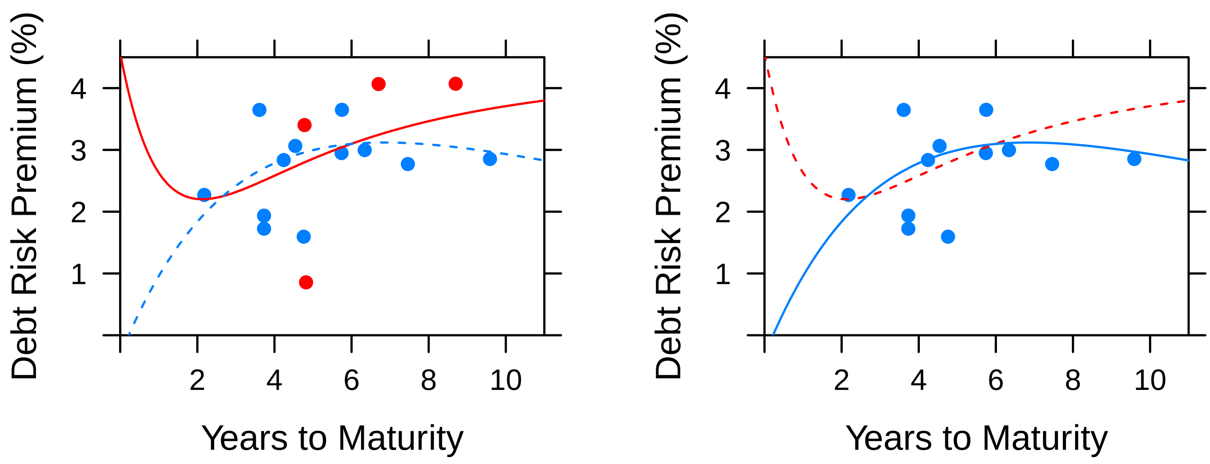

Figure 1: Scatter plots for WAGN Decision. The left panel shows the data given in Table 17 of the decision (ERA, 2011b), while the right panel shows the results when a more limited subset of the data has been used to fit the Nelson-Siegel curve.

Business	Bloomberg Ticker	Redemption Date	Maturity (years)	Yield (%)	RFR (%)	DRP (%)
Nexus Australia	EI204253	31/08/17	6.7	9.574	5.508	4.066
Nexus Australia	EI204261	31/08/19	8.7	9.648	5.577	4.071
Envestra Victoria Pty Ltd	EC866427	14/10/15	4.82	6.183	5.327	0.856
DBNGP Finance Co Pty	EI414656	29/09/15	4.78	8.725	5.323	3.402

Table 2: Bonds eliminated from the ERA (WA) WAGN yield curve analysis. RFR=Risk Free Rate, DRP=Debt Risk Premium.

Table 3 gives a comparison of the ERA (WA) Nelson-Siegel parameters and ours, both obtained using the `Nelson.Siegel` command in the `YieldCurve` package. We believe that there is a typographical error in the result given by the ERA (WA): the figure for $\hat{\lambda}$ should be 0.0227 not 0.2266.

[2]If the intention was to not use the data for BBB- bonds, then the data for Leighton Finance should have been removed, and the data for Envestra Victoria Pty. Ltd. should have been retained.

The application of the Nelson-Siegel approach to the dataset used by the ERA in the WAGN decision produces a debt risk premium of 3.00% and not 2.83% as has been reported incorrectly in Table 11 of the explanatory statement (ERA, 2013a).

	N	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\lambda}$	Nelson-Siegel DRP (%)
ERA (WA)	13	0.022	-0.347	10.913	0.2266	2.83
ESQUANT/MONASH	13	0.022	-0.347	10.913	0.0227	3.000
ESQUANT/MONASH	17	4.721	-0.151	-8.206	0.0686	2.86

Table 3: Comparison of ERA (WA) with our yield curve results for WAGN.

Table 4 gives a comparison of the DRPs at 5 years given by ERA (WA) in the explanatory statement and those calculated by us using the joint-weighted averaging approach and using Nelson-Siegel curve fitting. We have supplemented the estimates with standard errors based on bootstrap sampling.

	Source	Method	DRP (%)	SE (%)	Robust SE (%)
ERA (WA)	Explanatory Statement	Joint-Weighted	2.893		
	(ERA, 2013a, Table 11)	Nelson-Siegel	2.83		
ESQUANT/MONASH	13 data points	Joint-Weighted	2.894	0.2	0.157
	(ERA, 2011a, Table 17)	Nelson-Siegel	2.996	0.279	0.289
ESQUANT/MONASH	17 data points	Joint-Weighted	3.091	0.207	0.213
	(ERA, 2011a, Table 17)	Nelson-Siegel	2.857	0.254	0.245

Table 4: WA Gas Networks. Comparison of the DRPs at 5 years as between those given by ERA (WA) and our calculations, based on Joint-Weighted Averaging and Nelson-Siegel curve fitting, together with bootstrap standard errors.

The table shows that the standard errors for the joint-weighted average DRP are quite high, indicating the imprecision of the DRP estimate when $n = 13$ or $n = 17$. The Nelson-Siegel standard errors are higher still, since the method can break down with such a small number of samples. We have also computed robust standard errors based on the median absolute deviation (see, for example, Venables and Ripley, 2002, p.122.). The Nelson-Siegel results have slightly higher robust standard errors than the joint-weighted average estimators.

4.3 DBNGP

The second regulatory decision was for the proposed revisions to the access arrangement for the Dampier to Bunbury Natural Gas Pipeline. (ERA, 2011b). A plot of the Debt Risk Premiums against Years to Maturity, using digitized data[3] from Figure 11 of the explanatory statement, is given in the left hand panel of Figure 2. The right hand panel gives the data given in Table 36 of the decision (ERA, 2011). There is a mismatch between the two data sets. Table 5 gives the parameter estimates given in the explanatory statement and the estimated Debt Risk Premium at 5 years, compared to the corresponding quantities computed with the digitized data and the data from the decision. Although the estimated parameters are different using the digitized data, the two fitted curves are almost co-incident and hence the estimated debt risk premium is the same. Using the data from the actual decision document, however, gives a slightly different curve and reduced debt risk premium.

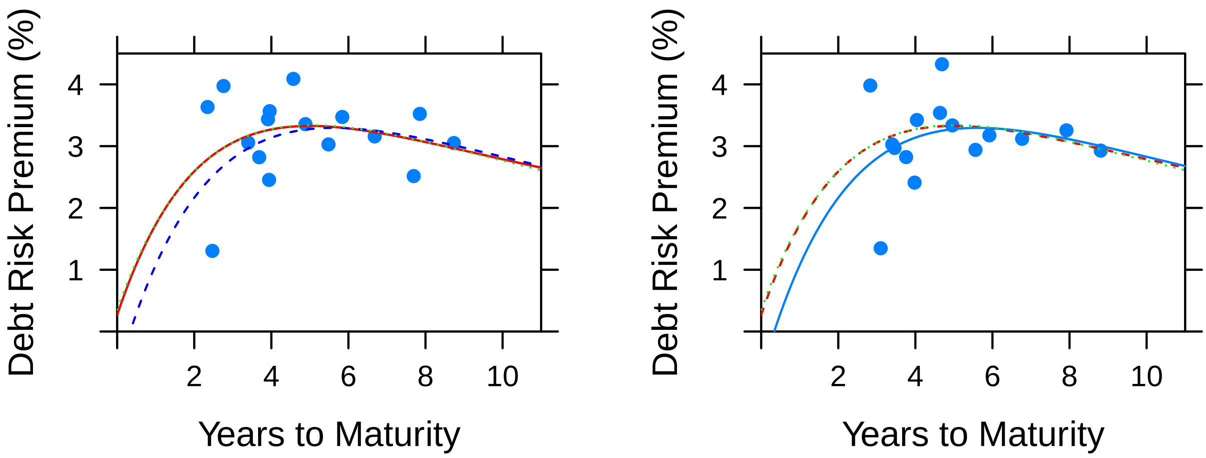

Figure 2: Scatter plots for DBNGP Decision. The left panel shows the data given in Figure 11 of the explanatory statement (ERA, 2013), while the right panel shows the data given in Table 36 of the decision (ERA, 2011).

		N	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\lambda}$	Nelson-Siegel DRP (%)
ERA (WA)	Explanatory Statement	16	0.0197	0.334	10.60	0.0285	3.34
ESQUANT/MONASH	Digitized Data from Figure 11 of (ERA, 2013)	16	0.504	-0.237	9.826	0.0308	3.33
ESQUANT/MONASH	Data from Decision	15	0.036	-0.724	12.023	0.0287	3.28

Table 5: Comparison of ERA (WA) with our yield curve results for DBNGP.

Table 6 gives a comparison of the calculated DRPs at 5 years given by ERA (WA) in the explanatory statement and those calculated by us using the joint-weighted averaging approach and using Nelson-Siegel curve fitting, together with bootstrap standard errors. We are unable to compute the DRP for the joint-weighted approach using the digitized data since the bond issue sizes are unknown. Again the Nelson-Siegel method breaks down giving large standard errors.

[3] The data in Figure 11 of the explanatory statement was digitized using the Java program Plot Digitizer (Humaltd, J.A. and Steinhorst, S.S., 2013), Version 2.63.

	Source	Method	DRP (%)	SE (%)	Robust SE (%)
ERA (WA)	Explanatory Statement	Joint-Weighted	3.196		
	(ERA, 2013a, Table 11)	Nelson-Siegel	3.34		
ESQUANT/MONASH	Digitized Data	Nelson-Siegel	3.327	0.409	0.214
	(ERA, 2013a, Figure 11)				
ESQUANT/MONASH	Data from Decision	Joint-Weighted	3.148	0.115	0.096
	(ERA, 2011b, Table 36)	Nelson-Siegel	3.277	1.360	0.292

Table 6: Access arrangement for DBNGP (WA). Comparison of the DRPs at 5 years as between those given by ERA (WA) and our calculations, based on Joint-Weighted Averaging and Nelson-Siegel curve fitting, together with bootstrap standard errors.

4.4 Western Power

The third regulatory decision was for the proposed revisions to the access arrangement for the Western Power Network (ERA, 2012b). A plot of the Debt Risk Premiums against Years to Maturity, using digitized data from Figure 13 of the explanatory statement, is given in the left hand panel of Figure 3. The right hand panel gives the data shown in Table 166 of the decision (ERA, 2012b). The two data sets match. Table 7 gives the parameter estimates given in the explanatory statement and the estimated Debt Risk Premium at 5 years, compared to the corresponding quantities computed with the digitized data and the data from the decision.

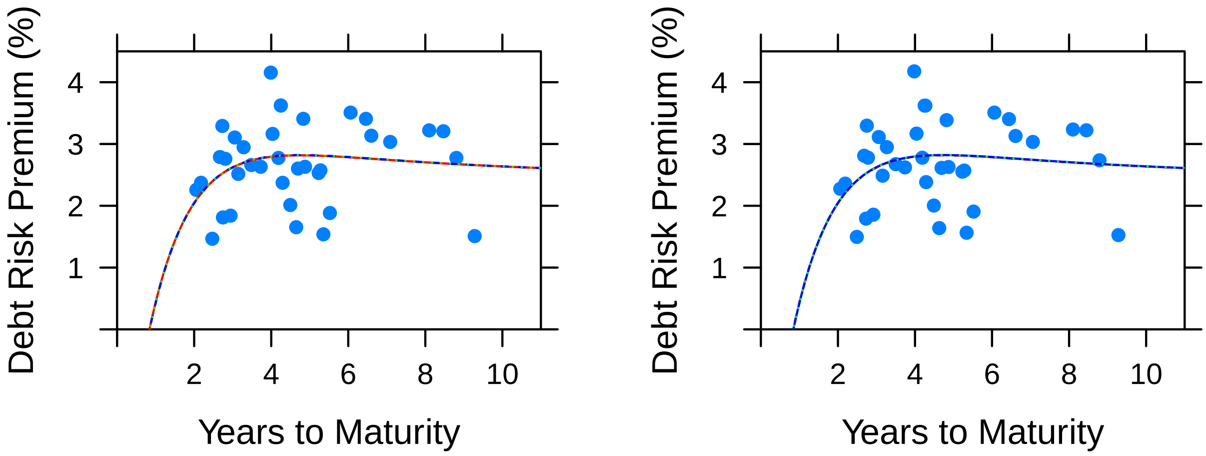

Figure 3: Scatter plots for Western Power Decision. The left panel shows the data given in Figure 13 of the explanatory statement (ERA, 2013a), while the right panel shows the data given in Table 166 of the decision (ERA, 2012b).

		N	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\lambda}$	Nelson-Siegel DRP (%)
ERA (WA)	Explanatory Statement	36	2.343	-6.115	8.707	0.0725	2.82
ESQUANT/MONASH	Digitized Data	36	2.344	-6.099	8.67	0.0727	2.81
ESQUANT/MONASH	Data from Decision	36	2.34	-6.119	8.725	0.0725	2.82

Table 7: Comparison of ERA (WA) with our yield curve results for Western Power.

Table 8 gives a comparison of the DRPs at 5 years given by ERA (WA) in the explanatory statement and those calculated by us using the joint-weighted averaging approach and using Nelson-Siegel curve fitting, together with bootstrap standard errors. The DRP given by the ERA (WA) using the joint-weighted average approach does not match the DRP we calculated using the data given in the decision. The standard errors are more comparable than for the other two decisions, reflecting the larger sample sizes. There is a bias between the joint-weighted approach and the Nelson-Siegel approach-and, as is explained later there is a actual negative bias with the joint-weighted approach.

	Source	Method	DRP (%)	SE (%)	Robust SE (%)
ERA (WA)	Explanatory Statement (ERA, 2013a, Table 11)	Joint-Weighted Nelson-Siegel	2.708 2.82		
ESQUANT/MONASH	Digitized Data (ERA, 2013a, Figure 13)	Nelson-Siegel	2.815	0.16	0.134
ESQUANT/MONASH	Data from Decision (ERA, 2012b, Table 167)	Joint-Weighted Nelson-Siegel	2.719 2.819	0.113 0.141	0.118 0.152

Table 8: Access arrangement for Western Power. Comparison of the DRPs at 5 years as between those given by ERA (WA) and our calculations, based on Joint-Weighted Averaging and Nelson-Siegel curve fitting, together with bootstrap standard errors.

5 Estimation of the Nelson-Siegel parameters

There are a number of ways of estimating the Nelson-Siegel parameters. In this section we review and compare the possible methods.

5.1 Nelson-Siegel approach

Nelson and Siegel (1987) suggested that non-linear least squares be used. In that method, the parameters are chosen so that

$$\sum(y-\hat{y})^2$$

is minimised, where $\hat{y}$ is the predicted value of the response variable (Yield or DRP in this case) which depends on the parameters in the model. The usual approach is to use Gauss-Newton methods. However, the Nelson-Siegel model is conditionally linear, that is given the value of τ, the model is linear in the other parameters i.e. the model can be expressed as

$$\text{Yield}(t) = \beta_0 + \beta_1 X_1 + \beta_2 X_2$$

where

$$X_1 = \frac{1-\exp(m/\tau)}{m/\tau}$$

and

$$X_2 = \frac{1-\exp(-m/\tau)}{m/\tau} - \exp(-m/\tau).$$

The method used by Nelson and Siegel (1987) is to take τ over a range of values, and for each value calculate the other parameters using multiple regression, and to choose the τ with the smallest residual sum of squares.

5.2 Diebold and Li Approach

Diebold and Li's (2006) formulation can be written as a function of three components, F_0, F_1 and F_2, termed the 'long-term', 'short-term', and 'medium-term' components with

$$y(\tau) = \beta_0 F_0 + \beta_1 F_1 + \beta_2 F_2$$

with

$$\begin{aligned}
F_0 &= 1 \\
F_1 &= \frac{1-\exp(-\lambda\tau)}{\lambda\tau} \\
F_2 &= \frac{1-\exp(1-\lambda\tau)}{\lambda\tau} - \exp(-\lambda\tau).
\end{aligned}$$

Recall that τ is the term to maturity under the Diebold and Li (2006) formulation. Diebold and Li (2006) fix λ at 0.0609 and then use linear least squares to estimate the parameters of the model. The figure 0.0609 is obtained as the maximum of the last factor in their equation when τ is 30 months, the term to maturity that is obtained by taking an average of the tenor of a two-year bond and of a three-year bond[4]

Figure 4 shows the composite variables F_0, F_1, and F_2 when the maximum of F_2 is at 2 years, 5 years, and 10 years, respectively.

Examination of the composite variables shows the problems with estimating the parameters when there is no data at less than two years maturity. When the maximum of the F_2 composite variable is at two years, the F_1 and F_2 composite varibles are very similar to each other. When the maximum of the F_2 composite variable is at 5 years, the F_2 composite variable is quite flat and therefore similar to the F_0 composite variable. Finally, when the maximum of the F_2 composite variable is at 10 years, the average of the F_1 and F_2 composite variables is quite flat. All three cases indicate that there will be multicollinearity problems when there is no data at less than two years maturity.

[4]Diebold and Li made a slight error here. The maximum at 30 months is in fact 0.0598.

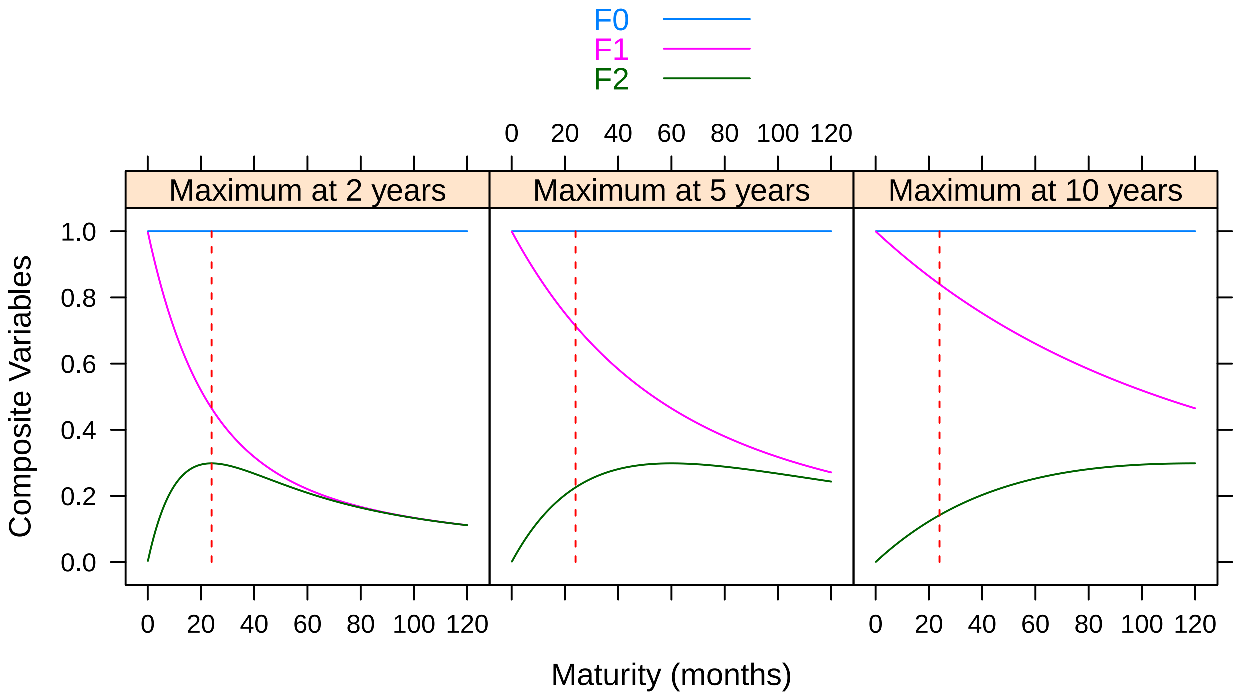

Figure 4: The three composite variables for the Diebold and Li parameterisation. The left panel shows the composite variables where the third composite variable is a maximum at a maturity of 2 years. The centre panel shows the composite variables where the third composite variable is a maximum at a maturity of 5 years. The right panel shows the composite variables when the third composite variable is a maximum at a maturity of 10 years.

5.3 Approach Used in YieldCurve package

The approach used in the `YieldCurve` package (Guierri, 2013) is a modification of the approach applied by Diebold and Li. Rather than use the λ value corresponding to the maximum of the last factor in the equation with a maturity of 30 months, they take a series of maturities from the smallest observed to the largest observed in steps of 0.5 months. For each of these maturities they maximise the last factor to give a corresponding value of λ and then use linear least squares to estimate the parameters in the model. Finally, they take the solution with the smallest residual sum of squares which satisfies the constraint that $\lambda > 0$ and $0 \leq \beta_0 \leq 20$.

A short coming of the `YieldCurve` package is that it is not equipped to generate standard errors. The package also does not produce comprehensive output information showing regression diagnostics, and therefore cannot provide signals about possible problems, such as multicollinearity.

6 Profile Plots

As indicated in section 5, one way to estimate the parameters of the model is to use various values of the λs and to compute the β parameters using linear least squares. A plot of λ against the residual sum of squares is called a profile plot. If there were no constraints on the model parameters, then the λ value corresponding to the minimum residual sum of squares would be the maximum likelihood estimate.

Profile plots have been calculated for the data given in each of the three decisions. We have ignored the constraint that $\lambda > 0$, and superimposed the corresponding estimate of β_0 so we can examine the constraint that $\beta_0 > 0$.

6.1 WAGN

The profile plot for WAGN is given in Figure 5. Based on the plot the optimal value of λ, ignoring the constraint, is negative. For small values of λ, the estimated value of β_0 is negative. The positive λ with smallest residual sum of squares and with a non-negative β_0 corresponds very closely to the $\hat{\lambda}$ value given in Table 2. i.e. $\hat{\lambda} = 0.0227$.

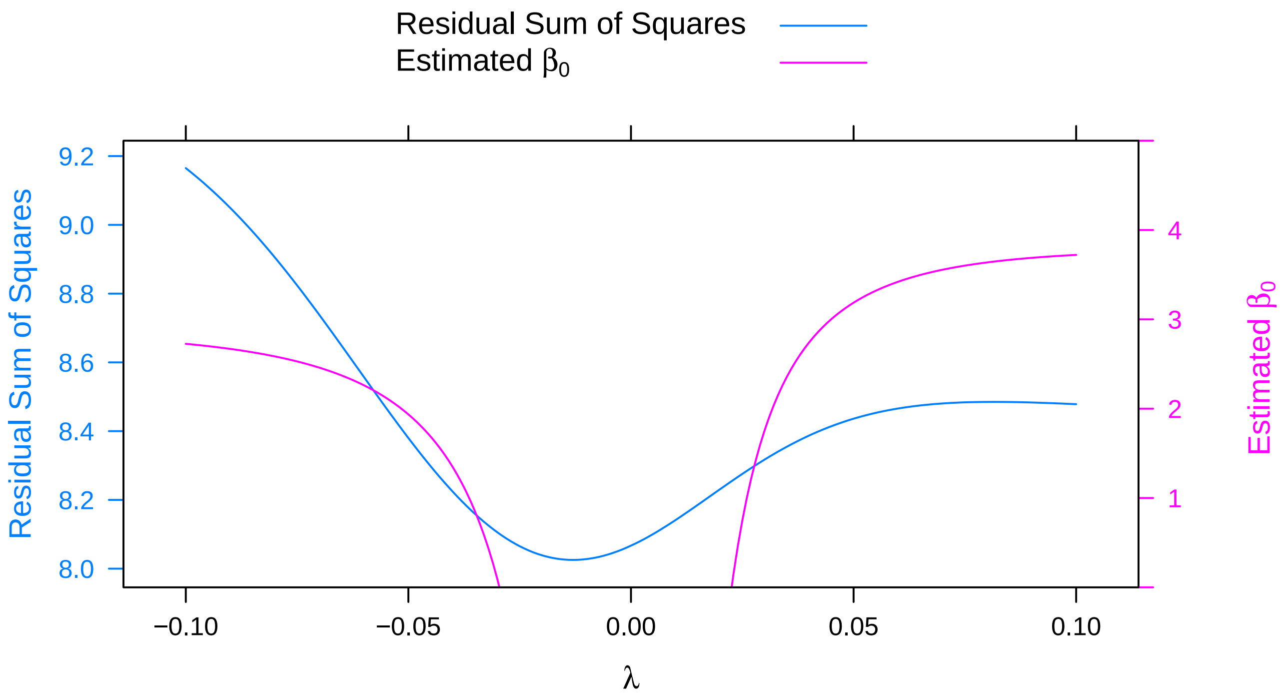

Figure 5: Residual Sum of Squares and Estimated β_0 for various values of λ: WAGN.

Table 9 gives the parameter estimates based on the 13 points used in the explanatory statement (ERA, 2013a), using non-linear least squares and ignoring the constraints. In this case all the parameters have large standard errors. An Analysis of Variance (ANOVA) is shown in Table 10. The ANOVA table compares the null hypothesis that the relationship between the DRP and Maturity is a constant value independent of Maturity versus the alternative hypothesis that the relationship is described by the Nelson-Siegel model. While the residual sum of squares decreases from 9.44 (Line 1 of Table 10, corresponding to the constant DRP model) to 8.03 (Line 2 of Table 10, corresponding to the Nelson-Siegel model) when going from the null to the alternative model, the small F value in the table of 0.53 and the corresponding high p value of 0.6746 shows that there is no statistical justification in going from the simpler to the more complicated model. The implications are that there is not sufficient data to define the Nelson-Siegel curve, due to the small amount of data and the absence of observations at less that two years maturity. Also, given that there is no statistical difference between the best-fitting Nelson-Siegel model, ignoring the constraints, and the constant DRP model, there also will not be any statistical difference between the Nelson-Siegel model with the constraints, found using the `YieldCurve` package, and the constant DRP model.

Figure 6 shows the fit of the model, ignoring the constraints, compared to the original fit, as well as the joint-weighted average DRP and the equally-weighted average DRP. Note that although we have not done so, it would be possible to fit the data using weighted non-linear least squares, if desired, using the same weights as for the joint-weighted average.

	Estimate	Std. Error	t value	Pr(>|t|)
lambda	-0.01	0.08	-0.16	0.87
beta0	-11.73	175.18	-0.07	0.95
beta1	12.84	172.03	0.07	0.94
beta2	7.09	116.64	0.06	0.95

Table 9: Parameter Estimates for non-linear least squares fit for WAGN (13 points) ignoring the constraints.

	Res.Df	Res.Sum Sq	Df	Sum Sq	F value	Pr(>F)
1	12	9.44				
2	9	8.03	3	1.41	0.53	0.6746

Table 10: ANOVA Table for WAGN (13 points) compared to a constant DRP model

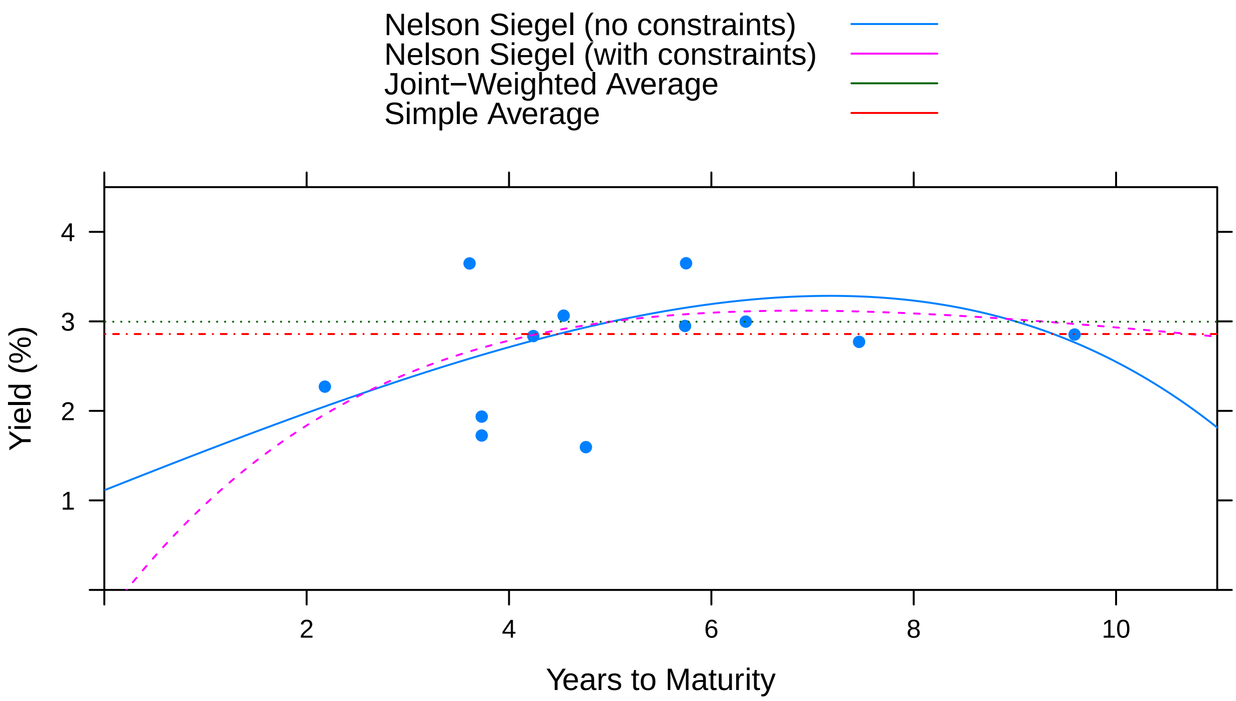

Figure 6: Fitted Debt Risk Premium Curve for WAGN, ignoring the constraints (blue) and with the constraints (magenta). The weighted average DRP (green) and the simple average DRP (red) are also given.

6.2 DBNGP

The profile plot for DBNGP is given in Figure 7. In this case the optimal value of λ is positive but the corresponding β_0 value is negative. The positive λ with smallest residual sum of squares and with a non-negative β_0 corresponds very closely to the $\hat{\lambda}$ value given in Table 3, i.e. $\hat{\lambda} = 0.0287$.

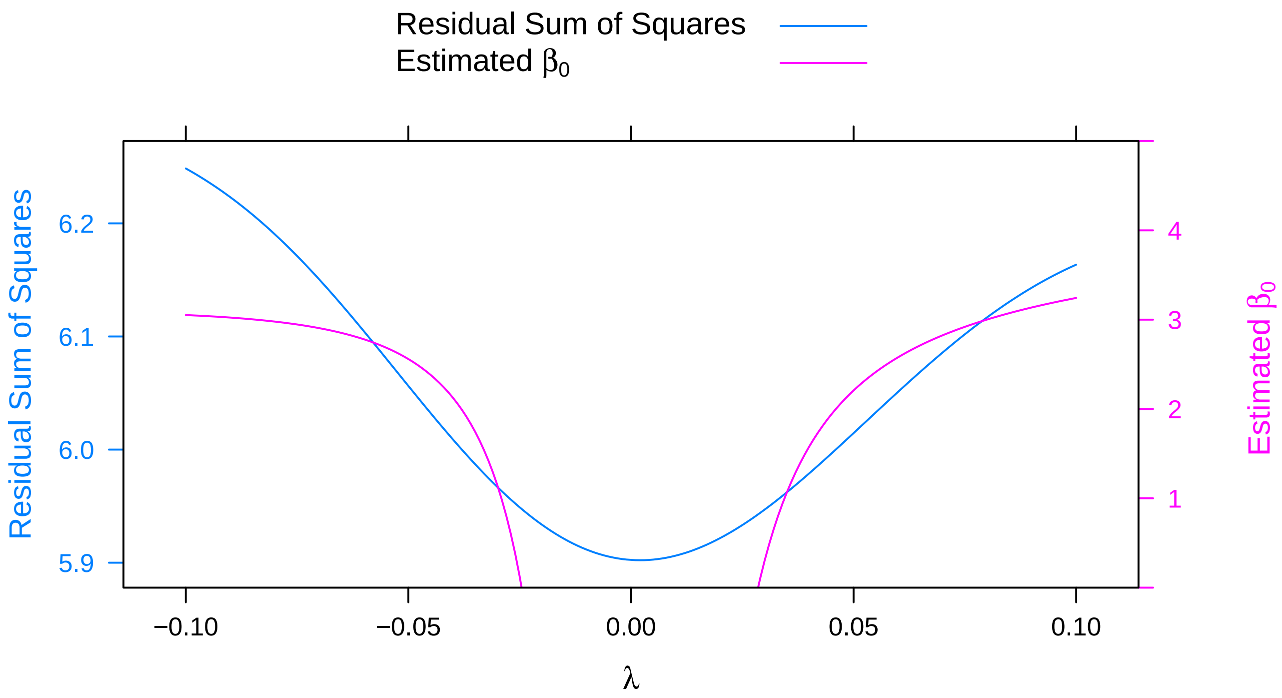

Figure 7: Residual Sum of Squares and Estimated β_0 for various values of λ: DBNGP.

Table 11 gives the parameter estimates for the data given in the decision, ignoring the constraints. In this case all the parameters have large standard errors, and as the Analysis of Variance shown in Table 12 indicates, there is no statistical difference between the fitted model and the model with a constant DRP. Figure 8 shows the fit of the model compared to the original fit.

	Estimate	Std. Error	t value	Pr(>|t|)
lambda	0.00	0.13	0.02	0.98
beta0	-353.45	36166.94	-0.01	0.99
beta1	354.64	36173.99	0.01	0.99
beta2	403.45	38381.97	0.01	0.99

Table 11: Parameter Estimates for the non-linear least squares fit for DBNGP ignoring the constraints.

	Res.Df	Res.Sum Sq	Df	Sum Sq	F value	Pr(>F)
1	14	6.37				
2	11	5.90	3	0.46	0.29	0.8333

Table 12: ANOVA Table for DBNGP compared to a constant DRP model.

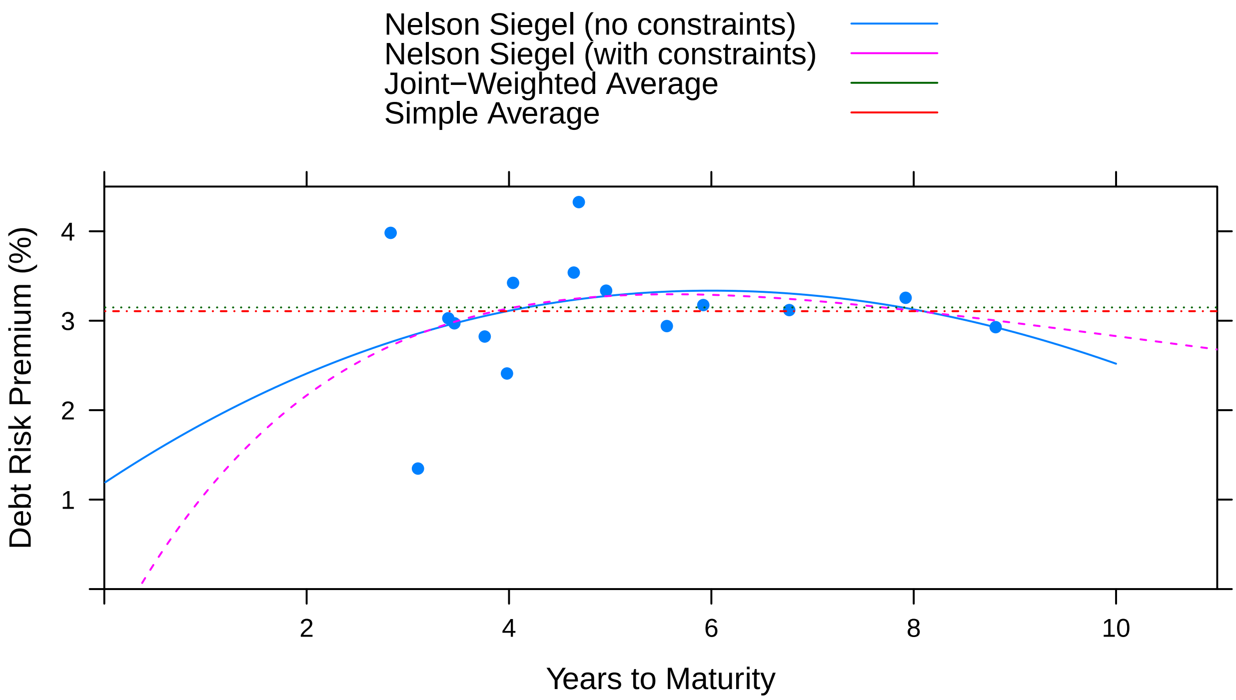

Figure 8: Fitted Debt Risk Premium Curve for DBNGP, ignoring the constraints (blue) and with the constraints (magenta). The weighted average DRP (green) and the simple average DRP (red) are also given.

6.3 Western Power

The profile plot for Western Power is given in Figure 6. In this case the optimal value of λ is negative and corresponds to a positive β_0 value. The positive λ with smallest residual sum of squares and with a non-negative β_0 corresponds very closely to the $\hat{\lambda}$ value given in Table 6, i.e. $\hat{\lambda} = 0.0295$.

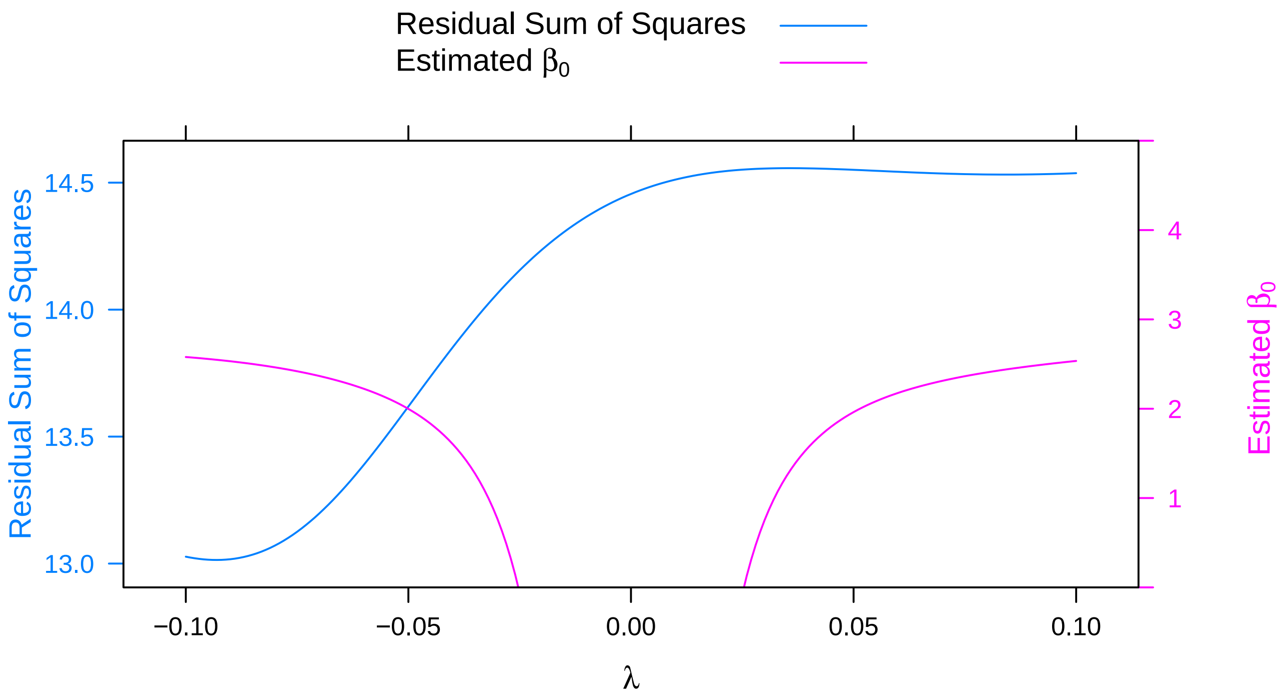

Figure 9: Residual Sum of Squares and Estimated β_0 for various values of λ: Western Power.

Table 13 gives the parameter estimates for the data given in the decision, ignoring the constraints. Although λ and β are statistically signifiant, the Analysis of Variance shown in Table 14 indicates that there is no statistical difference between the fitted model and the model with a constant DRP. Figure 10 shows the fit of the model compared to the original fit.

	Estimate	Std. Error	t value	Pr(>|t|)
lambda	-0.09	0.04	-2.62	0.01
beta0	2.55	0.23	11.27	0.00
beta1	0.01	0.02	0.31	0.76
beta2	0.00	0.00	0.28	0.78

Table 13: Parameter Estimates for the non-linear least squares fit for Western Power ignoring the constraints.

	Res.Df	Res.Sum Sq	Df	Sum Sq	F value	Pr(>F)
1	35	15.58				
2	32	13.01	3	2.56	2.10	0.1196

Table 14: ANOVA Table for Western Power compared to a constant DRP model

6.4 Solutions on the Boundary

The best parameters for all three Nelson-Siegel models based on the `YieldCurve` package lie close to a constraint boundary assuming there is a requirement that the limiting DRP for long maturities must be positive. It should be noted that this constraint may not be particularly relevant over the range of

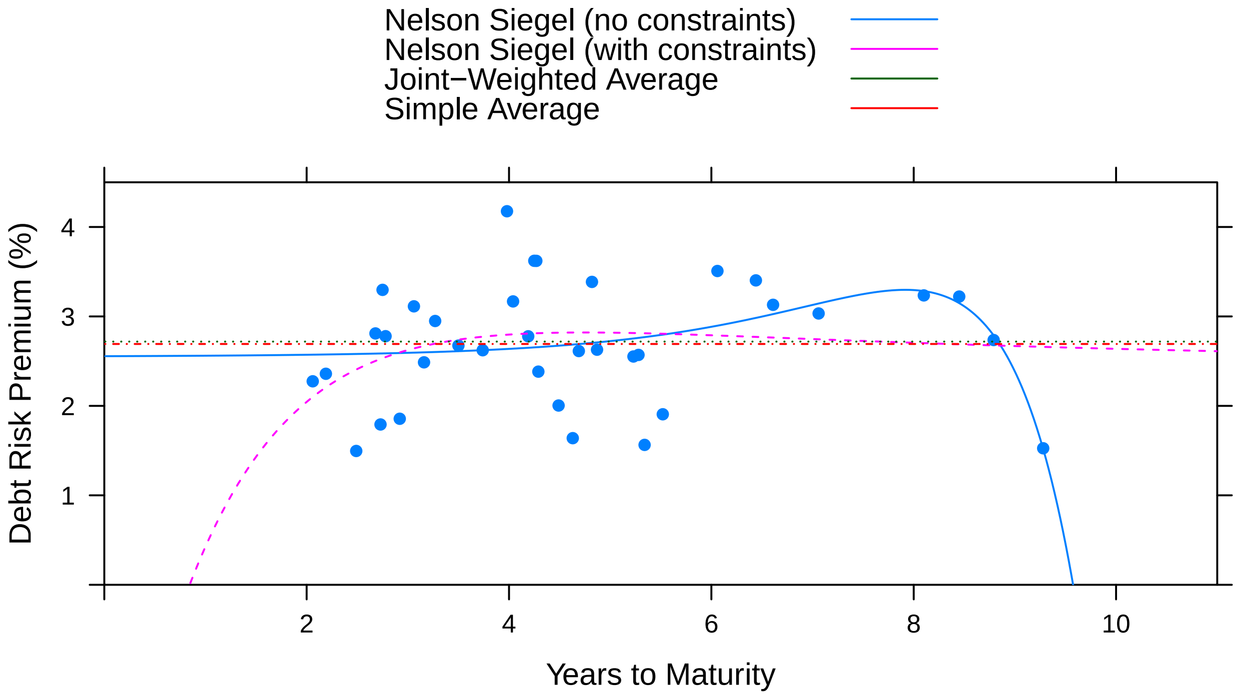

Figure 10: Fitted Debt Risk Premium Curve for Western Power, relaxing the assumptions.

the data and there may be solutions that fit the data more closely over the range of the data than the estimated model, but that do not satisfy the constraints outside the range of the data.

Another issue is that the calculation of standard errors from non-linear least squares programs assumes that the solutions are not on the boundaries. This is a major reason that we have had to resort to bootstrap calculations.

7 Using the Total Cost of debt as a response variable

The ERA (WA) have used the Debt Risk Premium as the response in the Nelson-Siegel model. In this section we use the Yield as the response, estimate the Yield at a maturity of 5 years and then subtract the Risk Free Rate at 5 years to determine a Debt Risk Premium at 5 years.

7.1 WAGN

The profile plot for WAGN is given in Figure 11. Based on the plot the optimal value of λ, ignoring the constraint, is negative. For small values of λ, the estimated value of β_0 is negative. The positive λ with smallest residual sum of squares and with a non-negative β_0 is smaller in magnitude than the $\hat{\lambda}$ value given in Table 3.

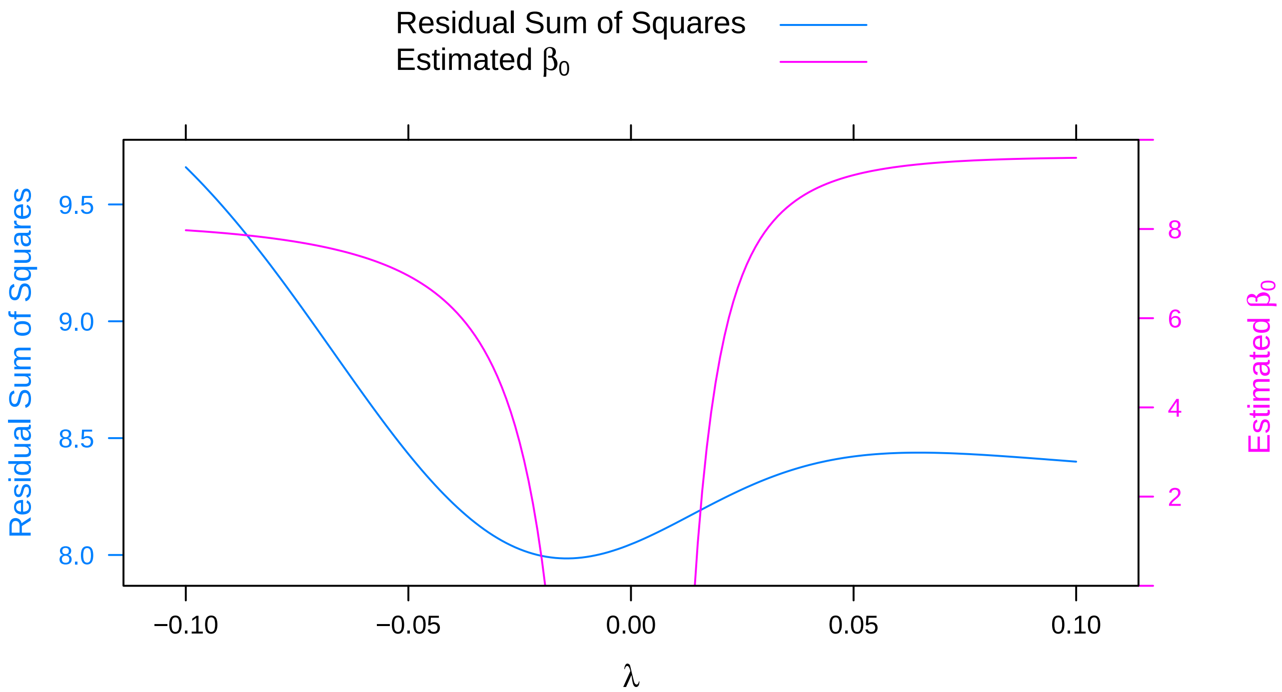

Figure 11: Residual Sum of Squares and Estimated β_0 for various values of λ: WAGN, using Yield as a response.

Table 15 gives the parameter estimates for the 13 points from the data given in the decision, using non-linear least squares, ignoring the constraints, and using Yield as the response. Again, all the parameters have large standard errors, and as the Analysis of Variance shown in Table 16 indicates, there is no statistical difference between the fitted model and the model with a constant Yield. Figure 12 shows the fit of the model compared to the fit using the YieldCurve package.

	Estimate	Std. Error	t value	Pr(>|t|)
lambda	-0.01	0.07	-0.21	0.84
beta0	-5.94	127.47	-0.05	0.96
beta1	12.02	124.42	0.10	0.93
beta2	6.14	79.35	0.08	0.94

Table 15: Parameter Estimates for non-linear least squares fit for WAGN (13 points) ignoring the constraints and using Yield as the response.

	Res.Df	Res.Sum Sq	Df	Sum Sq	F value	Pr(>F)
1	12	10.46				
2	9	7.99	3	2.47	0.93	0.4654

Table 16: ANOVA Table for WAGN (13 points) compared to a constant DRP model, using Yield as the response.

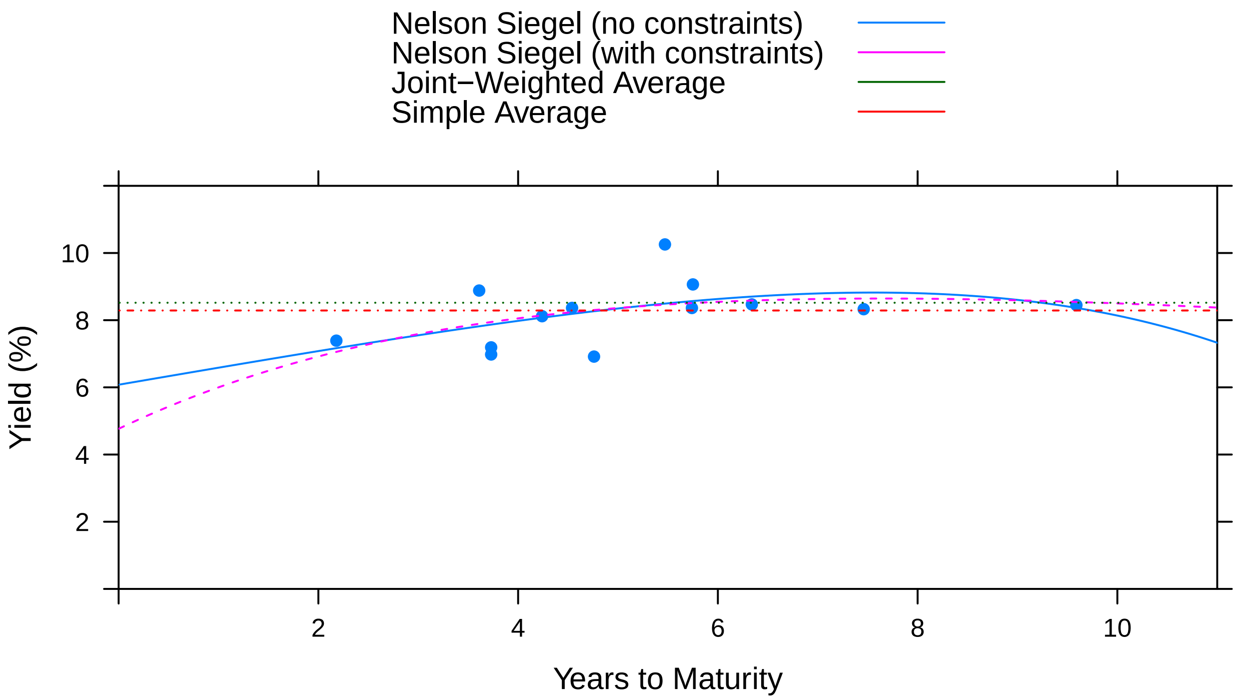

Figure 12: Fitted Yield Curve for WAGN, ignoring the constraints.

7.2 DBNGP

The profile plot for DBNGP is given in Figure 13. Based on the plot the optimal value of λ, ignoring the constraint, is positive but very small. For small values of λ, the estimated value of β_0 is negative. The positive λ with smallest residual sum of squares and with a non-negative β_0 is smaller in magnitude than the $\hat{\lambda}$ value given in Table 5.

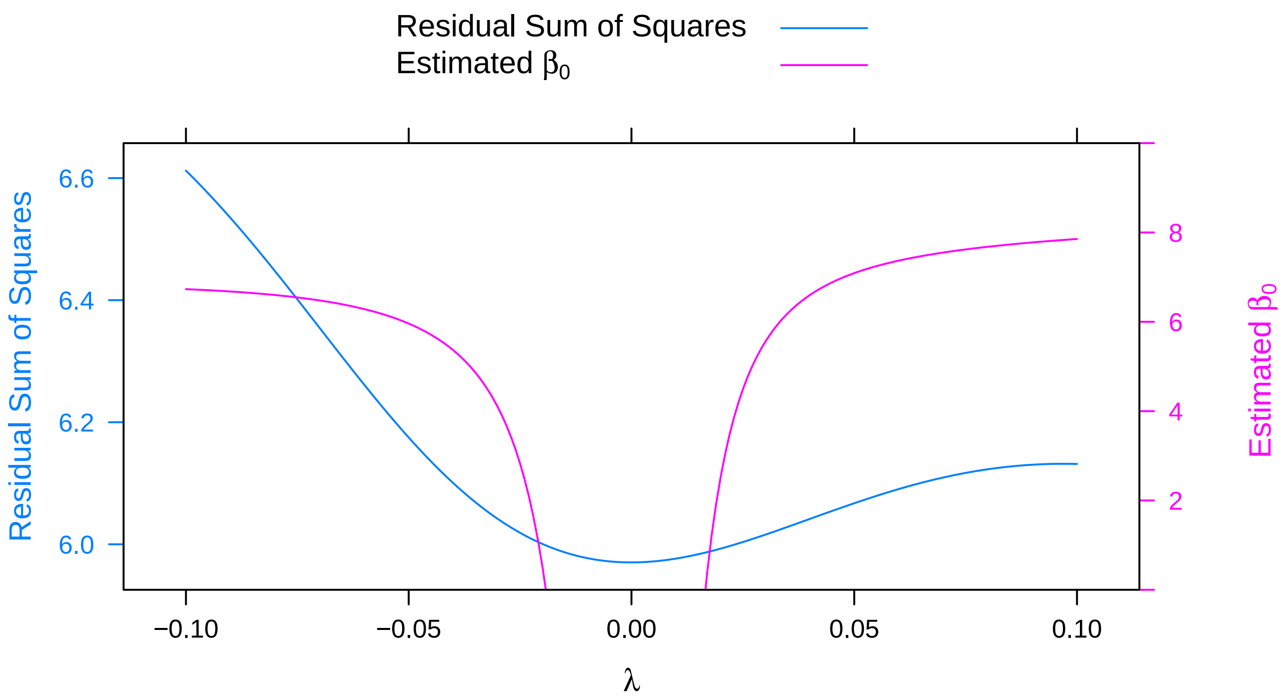

Figure 13: Residual Sum of Squares and Estimated β_0 for various values of λ: DBNGP, using Yield as a response.

Table 17 gives the parameter estimates for the data given in the decision, using non-linear least squares, ignoring the constraints, and using Yield as the response. Again, all the parameters have large standard errors, and as the Analysis of Variance shown in Table 18 indicates, there is no statistical difference between the fitted model and the model with a constant Yield. Figure 14 shows the fit of the model compared to the fit using the `YieldCurve` package.

	Estimate	Std. Error	t value	Pr(>|t|)
lambda	0.00	0.13	0.01	0.99
beta0	-907.42	146554.78	-0.01	0.99
beta1	911.93	146561.59	0.01	0.99
beta2	999.14	153066.81	0.01	0.99

Table 17: Parameter Estimates for non-linear least squares fit for DBNGP ignoring the constraints and using Yield as the response.

	Res.Df	Res.Sum Sq	Df	Sum Sq	F value	Pr(>F)
1	14	7.24				
2	11	5.97	3	1.27	0.78	0.5308

Table 18: ANOVA Table for DBNGP compared to a constant DRP model, using Yield as the response.

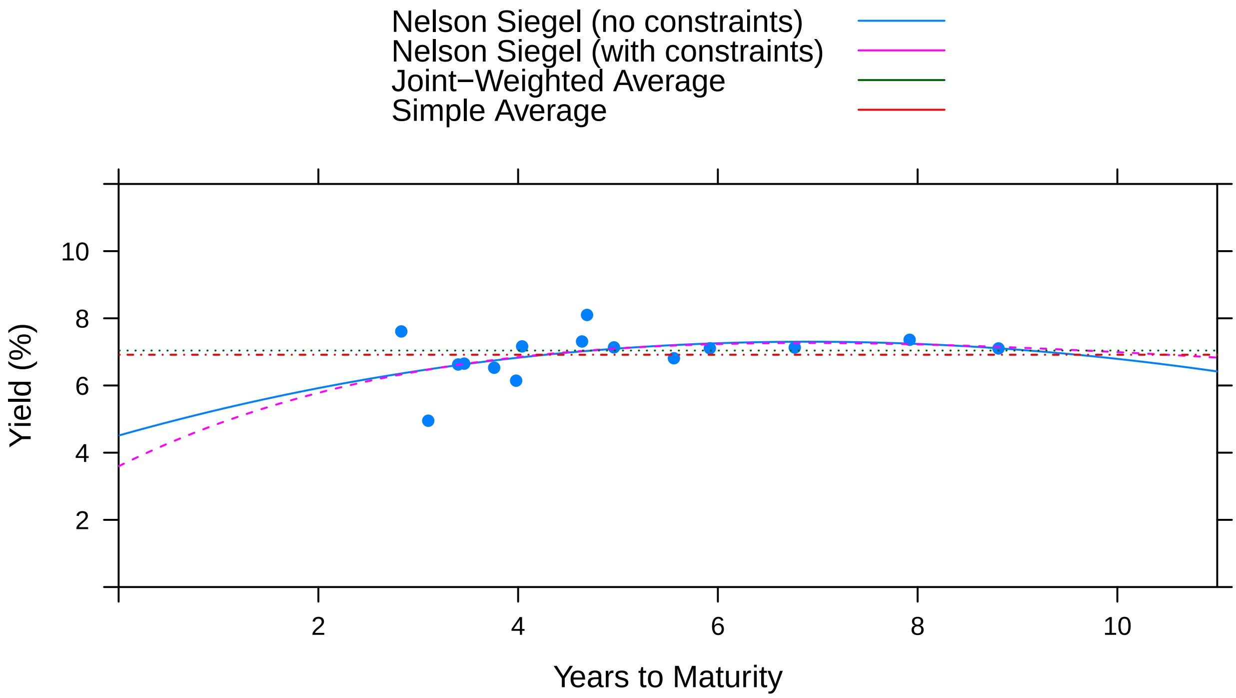

Figure 14: Fitted Yield Curve for DBNGP, ignoring the constraints.

7.3 Western Power

The profile plot for Western Power is given in Figure 15. Based on the plot the optimal value of λ, ignoring the constraint, is negative. For small values of λ, the estimated value of β_0 is negative. The positive λ with smallest residual sum of squares and with a non-negative β_0 is smaller in magnitude than the $\hat{\lambda}$ value given in Table 7.

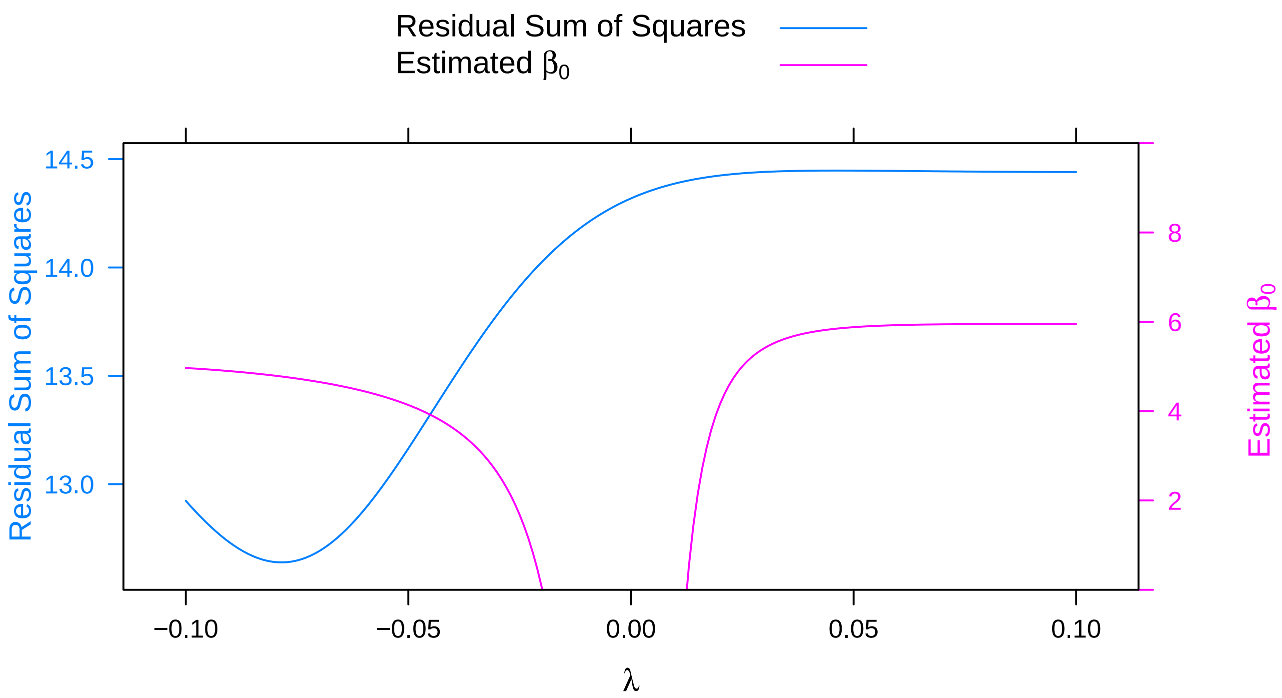

Figure 15: Residual Sum of Squares and Estimated β_0 for various values of λ: Western Power, using Yield as a response.

Table 19 gives the parameter estimates for the data given in the decision, using non-linear least squares, ignoring the constraints, and using Yield as the response. Now, both λ and β_0 are highly significant, and as the Analysis of Variance shown in Table 20 indicates, there is a statistical difference between the fitted model and the model with a constant Yield. Figure 16 shows the fit of the model compared to the fit using the `YieldCurve` package.

	Estimate	Std. Error	t value	Pr(>|t|)
lambda	-0.08	0.02	-3.57	0.00
beta0	4.78	0.32	14.95	0.00
beta1	0.04	0.07	0.54	0.59
beta2	0.01	0.01	0.47	0.64

Table 19: Parameter Estimates for non-linear least squares fit for Western Power ignoring the constraints and using Yield as the response.

	Res.Df	Res.Sum Sq	Df	Sum Sq	F value	Pr(>F)
1	35	17.39				
2	32	12.64	3	4.75	4.01	0.0157

Table 20: ANOVA Table for Western Power compared to a constant DRP model, using Yield as the response.

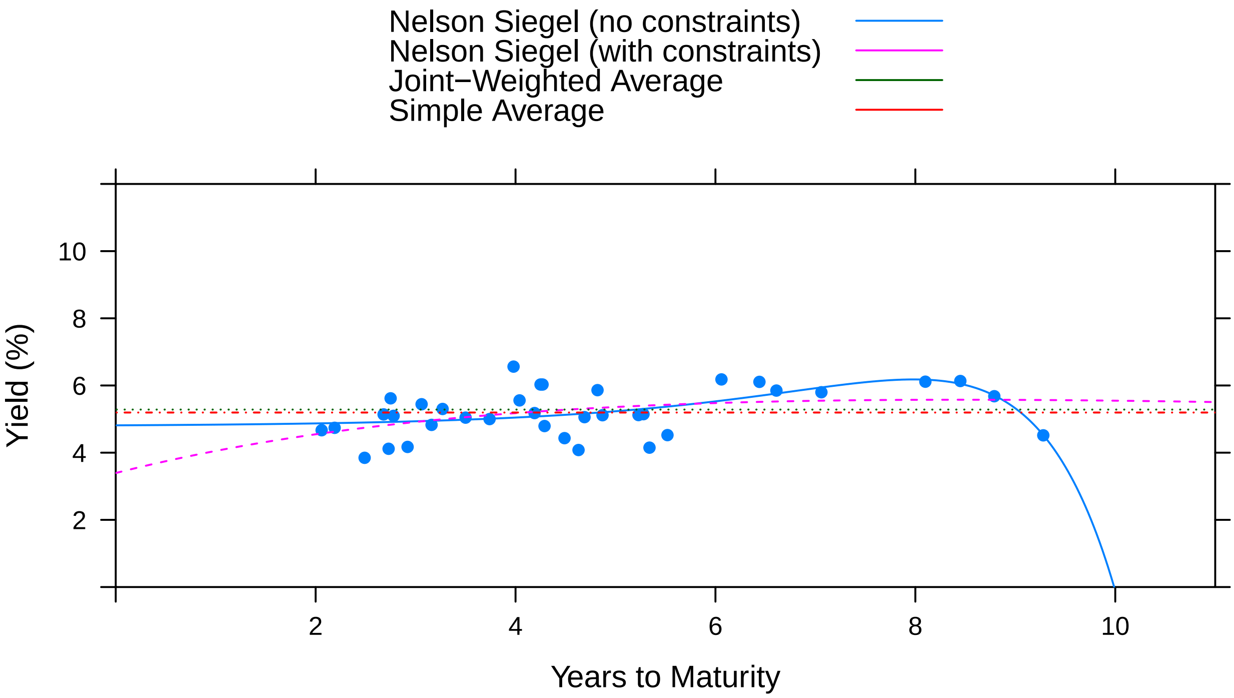

Figure 16: Fitted Yield Curve for Western Power, ignoring the constraints.

8 Simulation Exercise to Compare Averaging to Yield Curve Fitting

The ERA (WA) favours a joint-weighted bond yield approach to estimating the Debt Risk Premium at 5 years. According to the ERA, the application of the Nelson-Siegel model gives similar answers to the use of a joint-weighted DRP approach, and so there is no apparent advantage in using yield curves to estimate the debt risk premium.[5] This section reports on a simulation that compares the two methods.

In the simulation we have assumed that the correct DRP vs Maturity relationship is given by the fitted model for the Western Power bonds, given in Table 19. Note that the correct figure for the Debt Risk Premium at 5 years is 2.72%. We assumed that there were n bonds, with $n = 13, 25$ and from 50 to 300 in steps of 50. Maturities were assumed to follow a lognormal distribution[6] with mean on the log scale of 1.463 and standard deviation on the log scale of 0.397. Issue amounts were assumed to follow a lognormal distribution with mean on the log scale of 5.237 and standard deviation on the log scale of 0.534. The values for the mean and standard deviations for Maturities and Amounts were the sample values from the data given in the Western Power final decision. The assumed distributions are shown in Figure 17. We also assumed that the deviations of the DRP about the assumed relationship were distributed as a Normal distribution with mean 0% and standard deviation of 0.628%. The value 0.628% was the residual standard deviation from the fitted model. We assumed that Maturities and Amounts were uncorrelated. For each simulation we computed the DRP using the ERA (WA) joint-weighted bond approach, fitted the Nelson-Siegel model using the YieldCurve package and estimated the DRP at 5 years, and also fitted a smoothing spline using the `mgcv` package in R and estimated the DRP at 5 years. The steps of each simulation are given below:

1. Generate Maturities and corresponding Amounts for n bonds, using the random lognormal distribution generation in R.

2. For each of the bonds estimate the expected Yield according to the fitted equation in section 7.3.

3. For each of the bonds determine the "observed" Yield by adding random normal deviations using the random normal distribution generation in R.

4. For each bond, calculate the Debt Risk Premium, by subtracting the risk free rate for the corresponding Maturity, using a linear interpolation formula developed in R using the `approxfun` function, based on the maturities and risk free rates given in the Western Power final decision.

5. The joint-weighted DRP is calculated based on the Maturities, Amounts, and DRPs.

6. The Nelson-Siegel model is estimated using `nls` based on the "observed" Yields and generated Maturities. The average yield at 5 years is calculated and the DRP is calculated by subtracting the risk free rate at 5 years, based on the linear interpolation.

7. A smoothing spline model is estimated using the `gam` function in the `mgcv` package. Again the average yield at 5 years is calculated and the DRP is calculated by subtracting the risk free rate at 5 years, based on the linear interpolation.

We conducted 100 simulations for all three approaches. For each sample size we computed the median DRP at 5 years, so as to give typical behaviour, and a robust standard deviation of DRPs at 5 years. The results are given in Table 21.

The correct DRP is 2.717%. For the joint-weighted bond yield approach, the Table shows that there is a bias for all sample sizes. The effect has been noted previously in Hird (2012) and Diamond and Brooks (2013a), amongst others, and is related to Jensen's inequality (see, for example, Godunova, 2011):

$$f(\lambda_1 x_1 + \ldots + \lambda_n x_n) \leq \lambda_1 f(x_1) + \ldots + \lambda_n f(x_n)$$

[5] As has been shown in Chapter 4, the joint-weighted DRP approach delivers lower results for the DRP at 5-years across all three of the final decisions considered.

[6] A random variable, X follows a lognormal distribution when $\log(X)$ follows a Normal distribution. The parameters are the mean and standard deviation on the log scale which are estimated by the respective mean and standard deviation of the logged data.

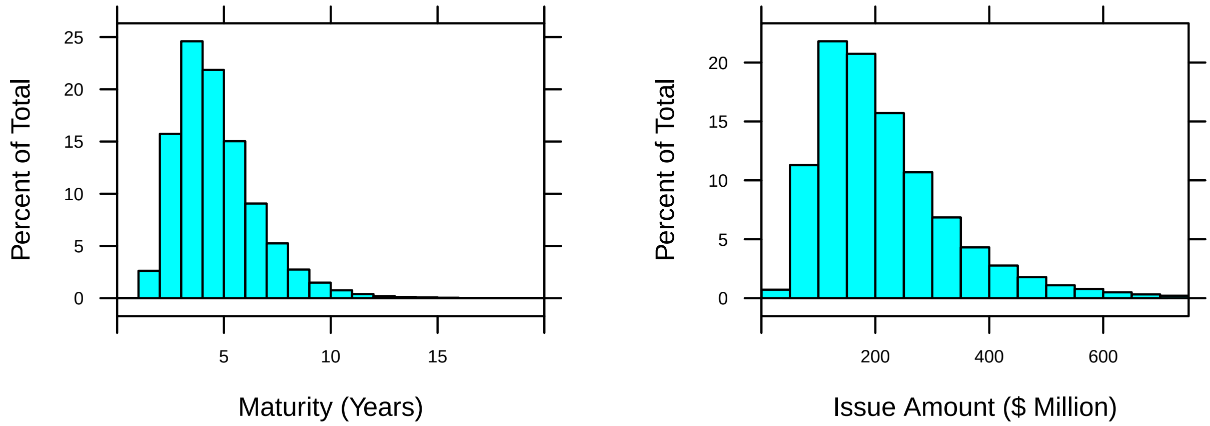

Figure 17: Histograms of 100,000 simulations from the assumed Maturity (left panel) and Amount distributions (right panel). The "Issue Amount" represents the bond issue (the amount being borrowed).

where f is a convex function on a set C in (the real numbers) R, $x_i \in C$, $\lambda \geq 0$, $i = 1, \ldots, n$ and

$$\lambda_1 + \ldots + \lambda_n = 1.$$

The equality holds if and only if $x_1 = \ldots = x_n$ or if f is linear.

Note that when f is concave, as it is for the fitted Nelson-Siegel function for two of the three decisions, then the sign is reversed and so

$$f(\lambda_1 x_1 + \ldots + \lambda_n x_n) \geq \lambda_1 f(x_1) + \ldots + \lambda_n f(x_n).$$

When the fitted DRP vs. maturity curve is concave, the weighted average DRP is less than the DRP at the weighted average term to maturity. For Western Power, the curve is relatively flat up to about 5 years and then concave for longer maturities.

The precision, as measured by the standard deviation, becomes better and better as the sample size increases. However, the bias is unaffected by the sample size.

For the Nelson-Siegel approach, once the sample size exceeds 50 there is no bias and the precision increases with sample size. The standard deviations are better than those obtained by the joint-weighted approach, and in addition they are estimating the correct value and not getting an increasingly acccurate estimate of the wrong quantity.

The smoothing spline results are similar to the Nelson-Siegel results but with slightly larger standard deviations.

Note that although we have assumed specific distributions for Amounts and Maturities, the implications of the results are expected to apply more generally, tin other words that the Joint-Weighted average approach is negatively biased and is not as good as the curve fitting approach when there is sufficient data to obtain useful standard errors.

We considered undertaking simulation analysis using the data from the WAGN and DBNGP regulatory decisions. However, our analysis in section 7 found that the unconstrained, fitted, total cost of debt curves for WAGN and DBNGP were statistically insignificant, and this was because of problems of sample size and sample selection. Therefore, we determined that we would not be able to use the Nelson-Siegel curves estimated from the WAGN and DBNGP datasets as valid counterfactuals.

	Joint-Weighted Average		Nelson-Siegel		Smoothing Spline	
	Median	Robust SD	Median	Robust SD	Median	Robust SD
n	(%)	(%)	(%)	(%)	(%)	(%)
13	2.678	0.341	2.799	0.288	2.723	0.292
25	2.645	0.287	2.736	0.192	2.747	0.221
50	2.638	0.183	2.754	0.15	2.745	0.188
100	2.615	0.135	2.727	0.084	2.718	0.149
150	2.636	0.113	2.736	0.055	2.719	0.11
200	2.614	0.09	2.714	0.053	2.711	0.101
250	2.645	0.089	2.717	0.051	2.721	0.085
300	2.62	0.078	2.706	0.039	2.741	0.101

Table 21: Results of Simulation Exercise comparing joint-weighted averaging to curve fitting using Nelson-Siegel and smoothing spline models.

9 Conclusions

In its deliberations on the application of Nelson-Siegel methods, the ERA (WA) has opined that (ERA, 2013a, paragraph 533, page 102):

> "Curve fitting is a complex issue and there are various different techniques which can be used. The Authority considers that the small benefit from this complex technique is not sufficient to outweigh the costs involved in carrying out the exercise."

We do not believe that the ERA (WA) has done sufficient analysis to justify such a conclusion being drawn. The limited work that the ERA (WA) has done on the implementation of the Nelson-Siegel method has serious shortcomings, and has served to highlight problems with the way in which the ERA (WA) selects its bond samples.

A more carefully constructed yield curve estimation exercise can produce estimates of the DRP that are well-founded and robust. For evidence, the reader is referred to Diamond, Brooks, and Young (2013b). We believe that there are considerable advantages in producing econometric estimates which properly capture the information that is inherent in bond yields and term to maturity.

Our analysis has shown that the joint-weighted averaging approach of the ERA (WA) is biased downwards and is not very precise. We have also found that eliminating short maturity bonds has a deleterious effect on the properties of the Nelson-Siegel parameter estimates. However, as the sample size increases the Nelson-Siegel estimates have far greater precision than the joint-weighted average estimates, and they are unbiased for all sample sizes.

If the available data is confined to the limited samples that the ERA (WA) has used in its recent decisions, then the Nelson-Siegel method, as applied to observations of the DRP, will produce results that are not statistically different from a constant DRP for all maturities. Improved models can be obtained by using Yield and not DRP as the response variable.

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A Dr Neil Diamond

Neil Diamond CV

Curriculum Vitae

Neil Diamond	March 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.

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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.

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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 Heath 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.

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M7. Diamond, N.T. and Hyndman, R.J. (2005). "The Monash Experience Questionnaire 2003: The Best and Worst, " prepared for CHEQ, Monash University.

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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.

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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.

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Professional Service

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

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.

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

Background

The Economic Regulation Authority (Western Australia) is developing rate of return guidelines that will form the basis of the regulated rate of return to be applied in energy network decisions. In December 2012, the ERA (WA) published a consultation paper, which was said to be consistent with the National Gas Law (NGL) and the National Gas Rules (NGR). The ERA (WA) released its draft rate of return guidelines on 6th August 2013.

In the new Rules, the AEMC has made fundamental changes to the way in which the allowance for the return of debt can be determined. Clause 87 (10) of the NGR provides that for each regulatory year of an access arrangement period, the allowance for the return of debt can be computed in one of three different ways:

a) 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.

b) 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

c) Some combination of the returns referred to in sub-rules (a) and (b). 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, including methods which were not necessarily available for consideration under previous versions of the National Gas Rules.

The calculation of the spot cost of debt, or the 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, or access arrangement 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 (UEMG) are seeking a suitably qualified consultant to undertake specific analysis in relation to the current cost of debt, as measured over a representative 20 to 30 day averaging period.

Scope of work

The consultant is required to undertake a detailed review of the methods that have been applied by the ERA (WA) to determine the spot cost of debt. The methods that have been employed by the ERA (WA) include the calculation of an arithmetic mean of the debt risk premiums (DRPs) observed in a sample of bonds, and the derivation of "joint-weighted DRP estimates".

In the explanatory statement which accompanied the draft rate of return guidelines, the ERA (WA) has also presented the results from the application of Nelson-Siegel yield curve methods[1]. 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 objectively assess the merits of the different approaches. In particular, the consultant should:

(1) Assess the statistical properties of the cost of debt estimators that have been applied at different times by the ERA (WA).

(2) Attempt to replicate the analysis already performed by the ERA (WA), and calculate standard errors.

(3) Undertake a simulation analysis and apply other methods as appropriate.

The consultant should make use of the data that has been published by the ERA (WA) in various final decision documents. Relevant Decisions of the Australian Competition Tribunal should also be examined. United Energy and Multinet Gas will provide information sourced from the Bloomberg data service, if such information is required.

Timeframe

The consultant is to provide a draft report which discusses the results of the analysis by 12th September 2013. A final report addressing any ENA comments should be provided by a date no later than 19th September 2013.

Reporting

Jeremy Rothfield will provide the primary interface for UEMG, for the duration of the engagement. The consultant will report on work progress on a regular basis. The consultant will make periodic presentations on analysis and advice when appropriate.

The consultant may also be called upon to present analysis and advice to the ENA Cost of Capital Subgroup.

Conflicts

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

[1] ERA (2013a), Explanatory Statement for the Draft Rate of Return Guidelines, Meeting the requirements of the National Gas Rules, Economic Regulation Authority (Western Australia), 6th August 2013; see section 9.3.3, Yield Curve Fitting, page 100.

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:

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