

## Appendix 6 DRP process for updating in Excel

### 1. Estimating DRP

1. This appendix sets out the operating procedure for updating debt risk premium (DRP) estimates using Excel (*Excel DRP process*).
2. In estimating the DRP, the ERA will solely rely on the R statistical process (*R DRP process*) detailed in the accompanying document. The estimation of the DRP through R is better implemented and maintained, and statistically more robust than Excel.
3. To provide stakeholders with accessibility options, the ERA also provides this *Excel DRP process*. However, the ERA will not rely on this Excel DRP process and the Excel DRP estimate will only provide an approximate DRP estimate.
4. As an Excel template is being provided that prepopulates formulas, at a high-level the information in this document can be divided into two categories:
  - Background information on the DRP process or template, which provides explanatory information on how the Excel spreadsheet was developed.
  - Information related to actionable steps for individuals estimating the DRP and undertaking the DRP process. These actionable steps are highlighted in grey and represent actions that will need to be undertaken to complete the DRP calculation.
5. Subscription, software and add-in requirements for the *Excel DRP process* include:
  - Bloomberg subscription
  - Excel 2013 or above
  - Bloomberg Excel Add-in; Excel Solver Add-in and Excel Analysis Tool Pack.

## 2. Framework for return on debt

6. The ERA has determined that the return on debt will be estimated as the sum of the:
  - risk free rate
  - spread of the bank bill swap rate over the risk free rate (BBSW spread)
  - DRP
  - debt raising and hedging costs.
7. The risk free rate, BBSW spread and the debt raising and hedging costs are estimated for the term of the regulatory period, that is, five years. These three components are estimated once every five years at the start of the regulatory period, so do not require annual updating.
8. The DRP is estimated using a 10-year trailing average consisting of a DRP for the current year and an annual DRP for each of the 9 prior years. The DRP estimate must be updated each year.
9. The DRP for each yearly update is based on:
  - a term to maturity of 10 years
  - the determined benchmark credit rating<sup>1</sup>
  - ERA's revised bond yield approach
  - a corresponding 10-year bank bill swap rate estimation.
10. The ERA's revised bond yield approach uses international bonds that have their country of risk identified by Bloomberg as Australia to estimate the cost of debt each year. The DRP represents the risk spread of the cost of debt estimated over the 10-year bank bill swap rate estimation in any given year.
11. The DRP estimates are based on a pre-determined averaging period. For illustrative purposes, this document uses 20 Sydney trading days<sup>2</sup> which is consistent with the Gas Rate of Return Guidelines.

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<sup>1</sup> For illustrative purposes, this document uses BBB+ credit rating which is consistent with the Gas Rate of Return Guidelines.

<sup>2</sup> With the trading days accounting for missed days due to the eastern states' public holidays.

### 3. High-level steps to estimate the DRP

12. The ERA's approach to estimating DRP is designed so that a stakeholder can replicate the calculation.
13. Once the settings and spreadsheet templates have been established in Bloomberg and Excel, the estimation process is deterministic.
14. The DRP estimation process consists of the following seven steps:
  1. Determining the Benchmark Sample
    - Identifying a sample of bonds based on the benchmark sample selection criteria.
  2. Collecting Data and Converting Yields to Australian Dollar Equivalents
    - Collecting data for the benchmark sample of bonds over the averaging period. This data represents a 'time series' of yields related to each bond.
    - Converting yields for bonds denominated in foreign currencies into Australian dollar (AUD).
  3. Averaging Yields over the Averaging Period
    - Calculating an average AUD equivalent bond yield for each bond across the averaging period.
    - Creating a static copy of AUD yield data, remaining term to maturity and AUD face values.
  4. Estimating Curves
    - Estimating yield curves based on Gaussian Kernel, Nelson Siegel and Nelson Siegel Svensson methods by using the average yield for each bond, the remaining term to maturity and the AUD face value.
  5. Estimating cost of debt
    - Cost of debt estimate is then the average of the three estimated yield curves at the 10-year tenor.
  6. Calculating the DRP
    - Calculating the DRP by subtracting the average of the 10-year AUD interest rate swap (IRS) rate from the 10-year cost of debt estimate.
  7. 10-year trailing average calculation
    - The DRP is estimated using a 10-year trailing average consisting of a DRP for the current year and a DRP for each of the 9 prior years and so the DRP estimate must be updated each year. Prior year DRP estimates are firm specific numbers previously approved in determination and tariff variations processes.

## 4. Excel template

15. An Excel template for DRP estimation entitled *DRP\_update\_template.xlsx* is available for the data acquisition and the *Excel DRP Process*. This Excel template is also used for data acquisition for *R DRP Process*.

16. The Excel template is comprised of following worksheets, defined in Table 1:

**Table 1: Worksheets in the Excel template for DRP estimation**

Worksheet Name	Description
Inputs	<ul style="list-style-type: none"> <li>Input cells for Bloomberg bond tickers, determination date, assumptions for converting yield into AUD equivalents etc.</li> <li>Formulas built in to retrieve corporate bond information from Bloomberg.</li> <li>This worksheet is only functional via access to the Bloomberg Application Programming Interface (API).</li> </ul>
Allowed trading days	<ul style="list-style-type: none"> <li>Input cells for nominated trading days of the averaging period.</li> <li>Retrieve 10-year Interest Rate Swap data from Bloomberg.</li> <li>This worksheet is only functional via access to the Bloomberg API.</li> </ul>
Individual trading date data downloader	<ul style="list-style-type: none"> <li>Formulas built in to retrieve yield data and to convert yield into AUD equivalents for each bond for each trading day.</li> <li>There is a worksheet established for each trading day. Available for maximum of 60 days.</li> <li>These worksheets are only functional via access to the Bloomberg API.</li> </ul>
AUD_Yield_Data_Live	<ul style="list-style-type: none"> <li>Summarise AUD equivalent yield for each nominated trading day, and calculate average yield for the averaging period.</li> <li>Summarise remaining term to maturity and AUD face values data for each bond.</li> <li>These worksheets are only functional via access to the Bloomberg API.</li> </ul>
AUD_Yield_Data_Static	<ul style="list-style-type: none"> <li>Copy and paste values from "AUD_Yield_Data_Live" worksheets.</li> <li>Contains all the data required for the 3 curve fitting techniques.</li> </ul>
GaussianKernel	<ul style="list-style-type: none"> <li>Calculates the target tenor yield using Gaussian Kernel method.</li> </ul>
NS_StartingValues	<ul style="list-style-type: none"> <li>Runs regression to calculate starting Beta values used in the Nelson Siegel method.</li> </ul>
NelsonSiegel	<ul style="list-style-type: none"> <li>Solves parameters required to calculate target tenor yield using Nelson Siegel method.</li> </ul>
NSS_StartingValues	<ul style="list-style-type: none"> <li>Runs regression to calculate starting Beta values used in the Nelson Siegel Svensson method.</li> </ul>
NelsonSiegelSvensson	<ul style="list-style-type: none"> <li>Solves parameters required to calculate target tenor yield using Nelson Siegel Svensson method.</li> </ul>

Worksheet Name	Description
NS Decay	<ul style="list-style-type: none"><li>• Calculate the starting <math>\lambda</math> value used in the Nelson Siegel method.</li></ul>
DRP output using Excel	<ul style="list-style-type: none"><li>• Summarises the outputs from other worksheets.</li><li>• Calculates final cost of debt by averaging the estimates produced by 3 methods.</li><li>• Calculates final DRP value.</li></ul>

## 5. DRP Process Step 1: Determining the benchmark sample

17. The benchmark sample of bonds should be identified as soon as practical, but 24 hours after the date identified as the final trading day in the averaging period.
- This time constraint allows the sample from Bloomberg to 'settle' to its final form.
  - An exception occurs when this 24 hour period overlaps a Western Australian non-trading day, in which case this process is carried out on the next Western Australian trading day.<sup>3</sup>
18. The first step in determining the benchmark sample of bonds is to identify the appropriate benchmark credit rating. For the Gas Rate of Return Guidelines the Standard & Poor's credit rating for the benchmark firm is BBB+.<sup>4</sup>
19. The Bloomberg search SRCH <GO> facility is used to conduct a search for bonds with a Standard & Poor's issue level rating that matches the benchmark credit rating, and other criteria set out in Table 2.<sup>5</sup>

**Table 2: Revised Bond Yield Approach Search Criteria – Bloomberg Search Structure**

Criteria	ERA's approach
Country of risk	Australia
S&P Rating	BBB+
Currency	Australian Dollar, United States Dollar, Euro Currency and British Pound
Maturity Date	>= 2 years from now
Maturity Type	Bullet or Callable or Puttable but not Perpetual
Security Type	Exclude Inflation Linked Note
Sector/Industry Group	Exclude 'Financials' (based on Bloomberg Industry Classification System Level 1 Sector Name)
Was Called	No

20. A screen shot of how this search would look on the Bloomberg SRCH<GO> function is presented in Figure 1.

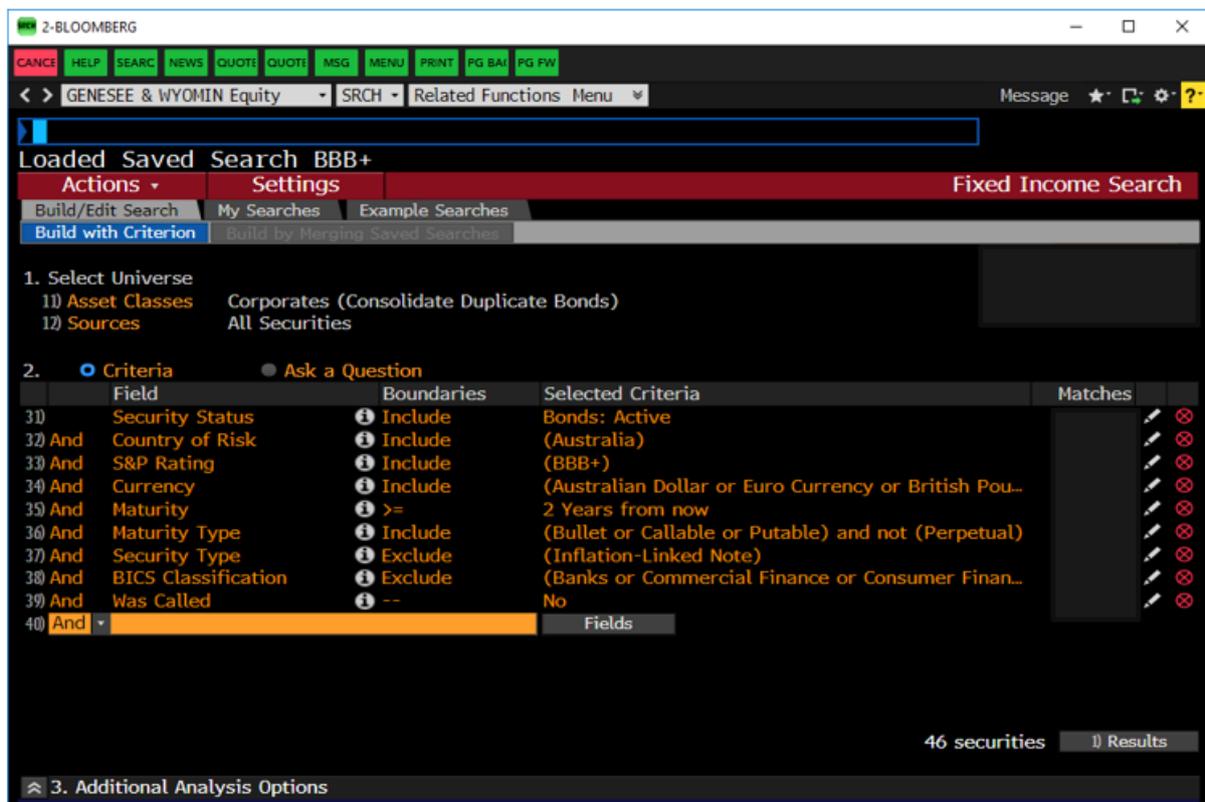
<sup>3</sup> Note that the revised bond yield approach is based on Eastern States trading days for consistency with Commonwealth Government Security data used in risk free rate and inflation calculations.

<sup>4</sup> ERA, Explanatory Statement for the 2018 Gas Rate of Return Guidelines

<sup>5</sup> <GO> is the Bloomberg equivalent of hitting the enter key after entering commands in the top left hand corner of the screen to the left of <HELP>. For example, type SRCH and then hit the <GO> key.

21. The security status defaults to 'active'. It is important to note that in the top left hand corner of this figure the 'Asset Classes' criteria has been enabled to consolidate duplicate bond issues. Ensure that *only* the 'Corporate' and 'Consolidate Duplicate Bonds' option is checked before clicking 'Update'.
22. The remaining criteria are entered into the Bloomberg SRCH function as shown in Figure 1 by typing the keywords into the 'Field' column and hitting <GO> after each of the criteria are entered.
23. The criteria in the Bloomberg search panel can be edited by clicking the pencil icon to the right of each criteria.<sup>6</sup>

**Figure 1 Bloomberg 'SRCH' Function Populated with Sample Selection Criteria**



Source: Bloomberg

24. Search criteria can be saved via "My Searches" button for future reference.
25. The results of this bond search are exported into Microsoft Excel. Click the 'Results' button and in the resulting screen click 'Actions' and then 'Export to Excel'.
26. The only information that is collected from the search result output into the Excel template at this stage is the eight digit 'Bloomberg ID' or 'ticker' for each bond.

<sup>6</sup> For the maturity date change the boundary condition to 'years from now' by selecting 'Y'.

27. Each ticker needs to be appended with “ Corp” so that formulas used in the next step can recognise them as a corporate bond. This can be carried out using the structure in Microsoft Excel below.<sup>7</sup>

**Table 3 Appending Bloomberg Bond Tickers for use in Pricing Formulas; Worksheet “Input”**

Attribute	Cell	Formula or entry
Pasted value of bond ticker	A11 down	XXXXXXXX
Bond ticker appended with “ Corp”	B11 down	=A11&" Corp" <sup>8</sup>

28. At the end of this step we have a list of all bond sample tickers with Corp down column B of worksheet “Input”. These tickers will then be used for data acquisition from Bloomberg into Excel.

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<sup>7</sup> It is recommended that formulas presented in these Excel structure tables are copied and pasted from an electronic copy of this document.

<sup>8</sup> If the downloaded Bloomberg ID already has “Corp” at the end, B11 should be amended to equal to A11, and then drag down the formula to cover all the bonds in the sample.

## 6. DRP Process Step 2: Collecting data and conversion of yields into AUD equivalents

29. Before data for each of the bonds are retrieved, some 'pricing source defaults' need to be set in the Bloomberg terminal, to ensure that data sources are consistent and of similar quality. These settings determine the information source from which the bond pricing is drawn.

30. Table 4 provides the 'pricing source defaults' for bonds issued in the relevant range of currencies.

**Table 4 Pricing Waterfall Set in Bloomberg for Retrieving Bond Price Data**

Currency of Issuance	1st Pricing Source	2nd Pricing Source
USD	BVAL	TRAC
EUR	BVAL	BGN
GBP	BVAL	BGN
AUD	BVAL	CBBT

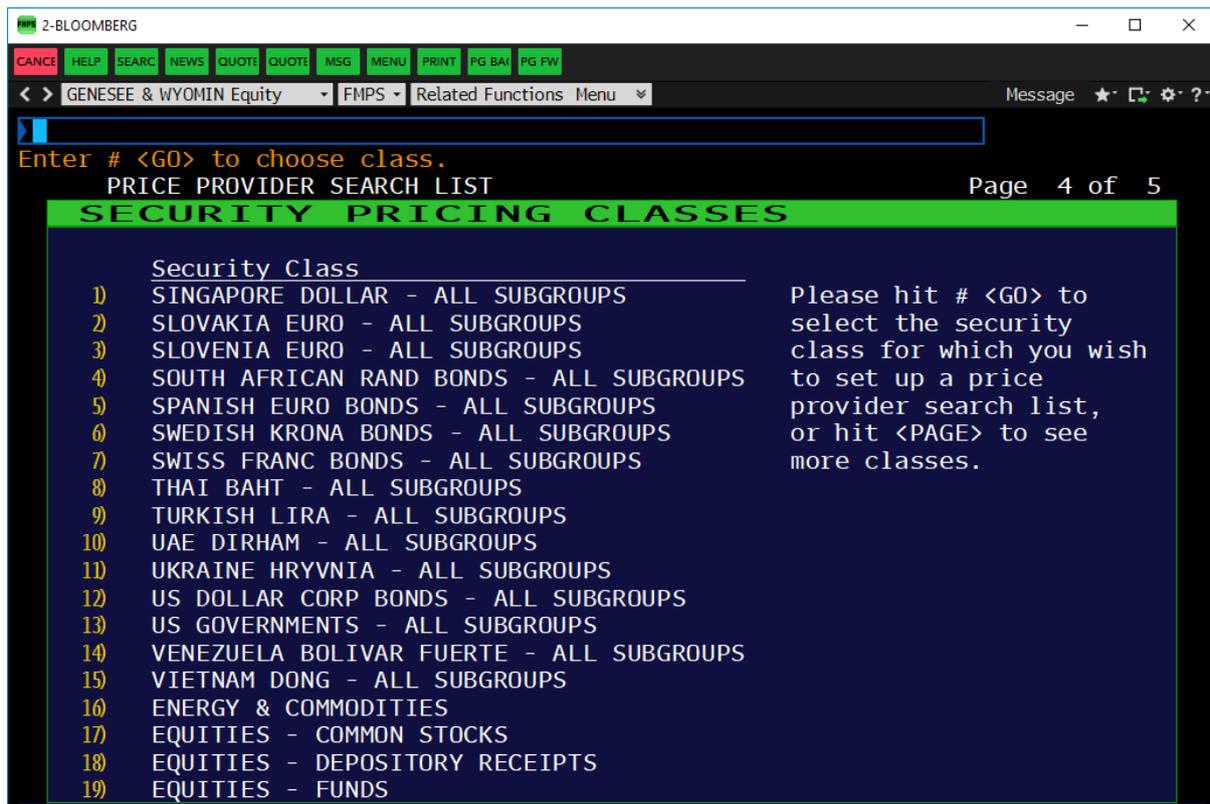
31. To set these as the default sources in the Bloomberg terminal for each currency use FMPS <GO> shown in Figure 2.<sup>9</sup>

32. Scroll down to reveal 'US Dollar Corporate Bonds – All Subgroups'. Select this option and in the resulting window select US Dollar Corporate Bonds – All Subgroups' again.

<sup>9</sup> The ERA considers the BVAL pricing source will find pricing data in most cases. If the first preference contains any observations of historical data FMPS ensures that all observations will rely on this one pricing source for consistency. Events such as US Federal public holidays can result in days within the averaging period where no prices will be returned from the first preference. In these rare cases the bond ticker is manually appended with "@PCS Corp" to hard code the preferred pricing source.

For example in Table 3 Appending Bloomberg Bond Tickers for use in Pricing Formulas; Worksheet "Input" Table 3 the ticker would be modified to "EXXXXXXXX@BGN Corp" as second preference for Euro denominated bonds. If no pricing is available from the second preference the observation is left blank.

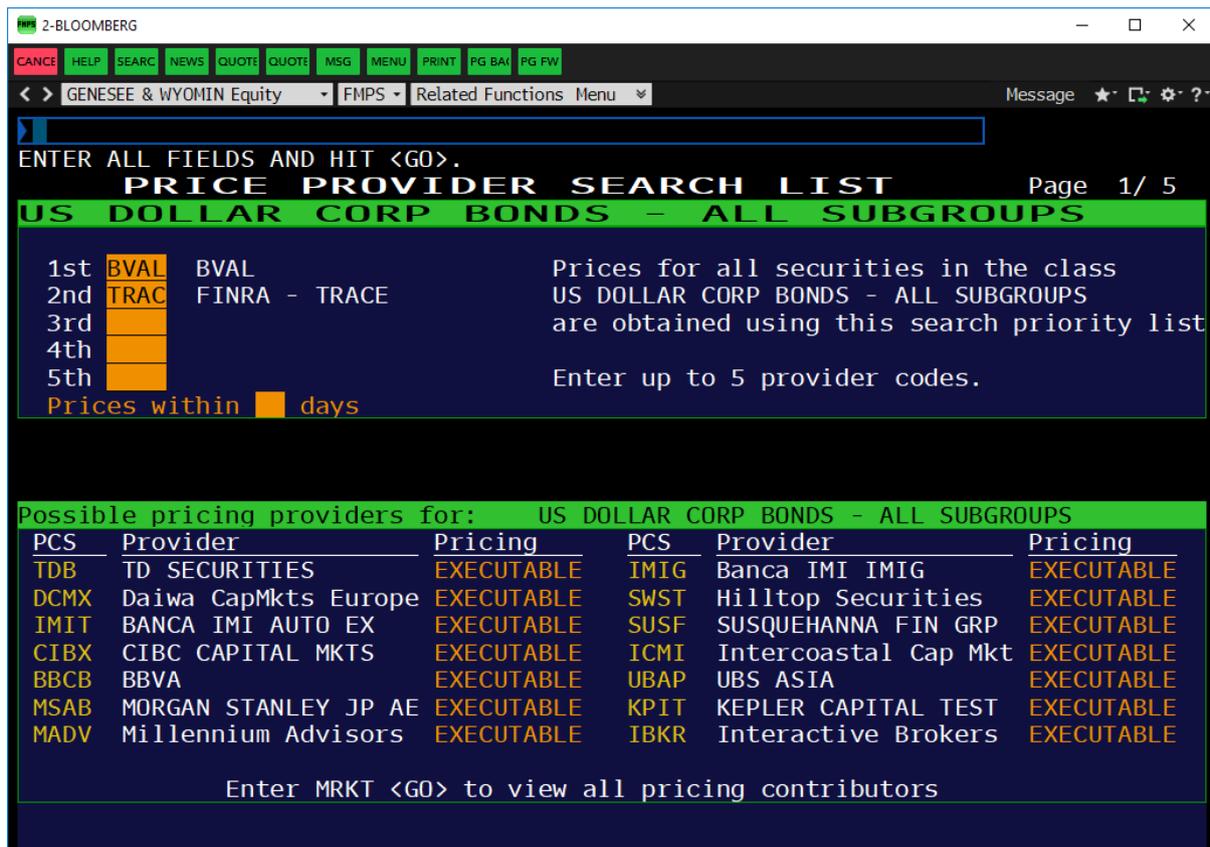
**Figure 2 Bloomberg Security Pricing Classes List**



Source: Bloomberg

33. Figure 3 shows where the pricing source settings in Table 4 should be entered in the pricing source window using the US dollar denominated bonds as an example.
34. In particular, the first pricing source should be entered to the right of '1st' and the second pricing source to the right of '2nd'.
35. Once this is complete select <GO> followed by 1 <GO> to save.

**Figure 3 Pricing Source Window Default Setting - US Dollar Corporate Bond Example**



Source: Bloomberg

36. Repeat the steps for the remaining currencies selecting:

- 'Euro Currency Bonds – All Subgroups' > 'Original EUR Issued Bonds and Other Redenominated Bonds' > 'Euro Currency Bonds – All Subgroups' for Euro denominated bonds.
- 'British Pound Bonds – All Subgroups' > 'British Pound Bonds – All Subgroups' for GBP denominated bonds.
- 'Australian Dollar Bonds – All Subgroups' > 'Australian Dollar Bonds – All Subgroups' for AUD denominated bonds.

37. Once the Bloomberg default price settings are established, the Excel spreadsheet that interfaces with Bloomberg through the Bloomberg API is ready to download bond data in the required format using Bloomberg formulas.

38. The 'tickers' identifying each bond in the sample selection step above are the key input into this spreadsheet. The bond tickers are appended with " Corp" so that they can be read by the "Bloomberg Data Point" (BDP) or "Bloomberg Data History" (BDH) function in Excel which then retrieves various attributes for each bond in question.<sup>10</sup>

<sup>10</sup> The space before " Corp" is intentional. BDP retrieves current values while BDH is used to retrieve historical data.

39. Data acquisition is performed using the provided template “DRP\_update\_template.xlsm”. This worksheet is only functional via access to the Bloomberg API.
40. Once the pricing source defaults have been set, some key attributes are exported into Excel including:
- Credit rating
  - ISIN
  - Issuer name
  - Industry
  - Country of Risk
  - Maturity date (MATURITY)
  - Currency (CRNCY)
  - Amount issued (AMT\_ISSUED)
  - Issue date (ISSUE\_DT)
  - Bond AUD Face Value
  - Bid price for the bond (px bid)
  - Ask price for the bond (px ask)
  - Asset swap spread bid (asset swap spd bid)
  - Asset swap spread ask (asset swap spd ask)
  - Australian dollar exchange rate with each bond’s native currency at date of issue (for example for the US/Australian dollar exchange rate; USDAUD Curncy).
41. The Bloomberg bond information retrieved in the “Input” worksheet do not vary with trading days.
42. Key inputs for “Input” worksheet are determination date at cell B2, and the Bloomberg IDs from cell A11 downward. Once these are entered, the “input” sheet will start populate data.
43. Formulas or entries for “input” sheet are summarised in Table 5.
44. All formulas from B11 to Q11 should be filled/copied down to retrieve the attributes for the entire cross section of bonds.

45. Once data acquisition is completed for the “Input” sheet, apply a filter to Row 10 of the “Input” worksheet and then sort “Residual Maturity” at column N from smallest to largest.<sup>11</sup>

**Table 5 Input parameters and formulas for data downloading – Worksheet “Input”**

Parameters	Cell	Formula or entry
Date of determination	B2	The date on which a DRP estimate is to be determined.
Credit rating	B3	Defines the allowed credit rating band. <sup>12</sup>
Number of trading days	B4	Number of trading days used in the determination. <sup>13</sup>
Target tenor	B5	10 years.
IRS Security	B6	ADSWAP10 CMPN Curncy <sup>14</sup>
Sigma (Gaussian kernel: years)	B7	1.5 <sup>15</sup>
Currency to convert to	D2	AUD
Payment frequency	E2	Q
Payment frequency for fixed leg of swap (leg 1)	G2	Semiannual
Payment frequency for floating leg of swap (leg 2)	G3	Quarterly
Deal type (fixed float)	H2	FXFL
Bloomberg Bond Tickers	A11 down	XXXXXXXX
Bond Ticker with “Corp”	B11 down	=IF(A11="", "", A11 & " Corp")
S&P Credit Rating	C11 down	=IF(A11="", "", BDP(B11, "RTG_SP"))
ISIN	D11 down	=IF(A11="", "", BDP(B11, "ID_ISIN"))
Issuer Name	E11 down	=BDP(B6, "LONG_COMP_NAME")
Industry	F11 down	=IF(A11="", "", BDP(B11, "BICS_LEVEL_1_SECTOR_NAME"))

<sup>11</sup> Click the drop down window in Cell N10 and select “sort from A to Z”.

<sup>12</sup> Not implemented, as controlled for in the stored Bloomberg SRCH request.

<sup>13</sup> This parameter is not really required, as it can be determined from the number of trading days on the 'Allowed trading days' sheet. Instead provides a consistency check that required data is present.

<sup>14</sup> The Bloomberg ticker of the security defining the swap rate adjustment of the cost of debt.

<sup>15</sup> The sigma parameter value for the Gaussian kernel estimation (in years). Sigma is nominally set at 1.5 years.

Parameters	Cell	Formula or entry
Country of Risk	G11 down	=IF(A11="", "", BDP(\$B11, "CNTRY_OF_RISK"))
Issue date	L11 down	=IF(A11="", "", BDP(\$B11, "ISSUE_DT"))
Maturity date	M11 down	=IF(A11="", "", BDP(\$B11, "MATURITY"))
Residual Maturity	N11 down	=IF(A11="", "", YEARFRAC(\$B\$2, M11))
Currency of bond issue	O11 down	=IF(A11="", "", BDP(\$B11, "CRNCY"))
Amount issued –currency of issuance (bond face value)	P11 down	=IF(A11="", "", BDP(B11, "AMT_ISSUED"))
Amount issued - Bond face value in AUD	I6 down	=IF(A11="", "", IF(O11="AUD", P11, P11*BDH(O11 & "AUD Curncy", "px_last", \$L11, \$L11)))

46. The “Allowed Trading days” worksheet is created for manually inputting nominated trading days of the averaging period and for retrieving 10-year Interest Rate Swap Rates from Bloomberg.

47. Generally averaging period is nominated by a regulated entity. However, there are situations where only the last day of the averaging period is nominated. The trading days must be Sydney trading days. If there is an Australian public holiday when AUD denominated bonds are not traded, it will not be used as a valid trading day for the averaging period.

**Table 6 Trading days input and 10-year AUD IRS Rate – Worksheet “Allowed trading days”**

Attribute	Cell	Formula or entry
Trading day date	A2 down	dd/mm/yyyy (Manual input)
AUD 10-year IRS rate <sup>16</sup>	B2 down	=IF(\$A2="", "", BDH(Inputs!\$B\$6, "PX_LAST", \$A2))
AUD 10-year IRS rate_Static	C2 down	Copy and paste values from cell B2 down

48. There is a worksheet identically created for each nominated trading day to pull daily price and AUD equivalent bond yield data across the bond sample using the formulas in Table 7 below.<sup>17</sup>

- The individual trading day worksheets retrieves data only if cell B1 of each worksheet is filled with a valid trading date, which is linked to trading day input of the “Allowed trading days” worksheet in Table 6.

<sup>16</sup> The ERA uses ADSWAP10 Curncy, PX\_LAST data from the Bloomberg terminal. This is the average of the bid and ask rate on the 10-year Australian Dollar interest rate swap rate (mid-rate).

<sup>17</sup> The DRP update template contains 60 worksheets named from “Day1” to “Day60, which is able to accommodate DRP estimation for a maximum of 60 trading days.

- For each trading day worksheet, all formulas B4 through to D4 in Table 7 **Error! Reference source not found.** should be filled downward in Excel to retrieve the attributes and the converted AUD yield to the end of the entire cross section of bonds.
- The data downloading process for individual trading day worksheet is more stable when the allowed trading date is entered one after another.
  - That is, enter a new trading date in column A of the “Allowed trading days” worksheet. Go to the relevant day worksheet and check that the data acquisition is complete.
  - Repeat the above process for each of the allowed trading days.
- Alternatively, it is possible to enter all allowed trading days in the “Allowed trading days” worksheet and then for all data to be acquired. However, please note that this will take some time and there is a chance that connectivity with Bloomberg will be lost.

49. Table 7 details the formulas used to convert bonds to Australian dollar equivalent yields. The tab utilises the YAS XCCY function that allows an asset swap of a bond to a fixed coupon equivalent in another currency.

**Table 7 Formula for pricing and converting to Hedged Australian Dollar Equivalent Yields– see Worksheet “Day1” as an example**

Attribute	Cell	Formula or entry
Trading Date	B1	Sourced from the corresponding cell in column A of the “Allowed trading days” worksheet.
Bid Price Label	B3	PX BID
Ask Price Label	C3	PX ASK
Bloomberg Bond Ticker	A4 down	=IF(\$B\$1="", "", IF(Inputs!A11="", "", Inputs!B11))
Bond bid price <sup>18</sup>	B4 down	=IF(A4="", "", BDH(A4, "px bid", \$B\$1, \$B\$1, "QuoteType", "P", "fill", "P"))
Bond ask price	C4 down	=IF(A4="", "", BDH(A4, "px ask", \$B\$1, \$B\$1, "QuoteType", "P", "fill", "P"))
Australian dollar equivalent yield	D4 down	=@IF(A4="", "", BDP(A4, "YAS_XCCY_FIXED_COUPON_EQUIVALENT", "YAS_BOND_PX", (\$B4+\$C4)/2, "YAS_XCCY_FOREIGN_CURRENCY", Inputs!\$D\$2, "SETTLE_DT", TEXT(\$B\$1, "YYYYMMDD"), "OAS_CURVE_DT", TEXT(\$B\$1, "YYYYMMDD")))

Source: ERA Research, Bloomberg

50. After the above step, all the required data for conducting the DRP calculation should have been downloaded from Bloomberg. The “Input” worksheet contains general bond

<sup>18</sup> ERA considers that the “fill” “P” option will not return values after the bond has matured, however, it will ensure a contiguous series whilst the bond is on issue.

information, residual maturity and AUD bond face value. The 20 individual trading day worksheets contain AUD equivalent bond yields for the cross section of bonds for each trading day.

## 6.1 Bloomberg connectivity

51. Once the download is complete, confirm by visual inspection any failed data requests across the different sheets.
52. The main weakness of the workflow is connectivity with the Bloomberg platform. Most of the time the Excel downloader will pull all data automatically. However, there can be instances where the connection to Bloomberg is temporarily lost or the internet may be lost, which may interrupt data acquisition.
53. This may mean that the sheets of the Excel downloader template will take significant time to complete their data requests. There is also a risk that all requested data is not downloaded due to connectivity issues.
54. Hence, it is critical that a complete download of the data is checked before running the DRP calculation process.
55. The data downloading process for individual trading day worksheet is more stable when the allowed trading date is entered one after another. That is, enter a new trading date in column A of the "Allowed trading days" worksheet. Go to the relevant day worksheet and check that the data acquisition is complete. Repeat the above process for each of the allowed trading days.
56. To help with the download process ensure that the Excel downloader template is stored on the local machine that holds a license for the Bloomberg terminal, rather than on a file share network not located on the local machine. The use of the local machine hard drive was found to result in faster downloads when tested in the development of the R DRP process.
57. If the Bloomberg automatic data requests are failing to complete try the following steps:
  - Recalculate the Excel worksheet that stops retrieving data using Calculation Options button found on the FORMULAS tab.
  - Close and re-open the Excel workbook and allow the data to be automatically downloaded again.
  - If the above two options are not working, restart connection with Bloomberg terminal.

## 7. DRP Process Step 3: Averaging yields over the averaging period

58. The 20-day averaging period is based on eastern states trading days with the last day of the averaging period being on the DRP determination date.
59. A table of AUD equivalent bond yields is established for each bond with observations for every day across the averaging period.
60. To build up this time series, the AUD equivalent yield in column D of each trading day worksheet will be linked to "AUD\_Yield\_Data\_Live" worksheet. To include all the data required for calculation processes in R and Excel, remaining term to maturity and bond AUD face value data are also pulled from the "input" worksheet to the "AUD\_Yield\_Data\_Live" worksheet as shown in Table 8.
61. Once all the data is retrieved in "AUD\_Yield\_Data\_Live" worksheet, copy and paste all the values into "AUD\_Yield\_Data\_Static" worksheet which has exactly the same format and structure as the live worksheet.
  - This is because Bloomberg formulas automatically retrieve data when the Excel workbook is opened each time, which is time consuming and may lead to unstable modelling issues.
  - A static copy of the data will provide data stability for the subsequent R or Excel DRP calculation process.
62. The data download must be completed in the live worksheet before the data can be pasted to the worksheet. If there is "Requesting Data" displayed in the cell, it means the data is still downloading.

**Table 8 AUD equivalent yield data over averaging period – Worksheet “AUD\_Yield\_Data\_Live”**

Attribute	Cell	Formula or entry
Trading Days	D1:BK1	Each trading day date in the averaging period. Sourced from Cell B1 of each individual trading day worksheet.
Bond Ticker	A2 down	EXXXXXXXX sourced from cell A11 down of “Input” worksheet.
Remaining Term to Maturity	B2 down	Sourced from cell N11 down of “Input” worksheet.
AUD Bond Face value	C2 down	Sourced from cell Q11 down of “Input” worksheet.
Australian dollar equivalent yields for each trading day	D2 down :BK2 down	Sourced from Cell D4 down of each individual trading day worksheet.
Averaging Yield over the average period	BL2 down	=AVERAGE(D:BK)

63. Once data is pasted into the static worksheet, some data cleaning may be required. If there is “#N/A” or “#DIV/0” displayed in the cell, it indicates there is no data available for this bond on the trading day. If the trading day is valid, the cell should be amended to a blank cell. If the bond has blank data for over 50 per cent of the trading days, this bond would be manually removed from the bond sample for the subsequent calculation process.
64. After the data cleaning, the average AUD equivalent yield for the averaging period is calculated at cell BL2 down of the “AUD\_Yield\_Data\_Static” worksheet.
65. At the end of this step, “AUD\_Yield\_Data\_Static” worksheet is established with values only. It will be used as the only data interface for the subsequent R and Excel DRP calculation process.

## 8. DRP Process Step 4: Apply curve fitting techniques

66. To improve the validity of the yield estimates, three estimation techniques are used to fit curves as part of the automatic formula to estimate the 10-year cost of debt used in the calculation of the annually updated DRP. These are:
- the Gaussian Kernel Method
  - the Nelson-Siegel (NS) Method
  - the Nelson-Siegel-Svensson (NSS) Method.

### *Gaussian Kernel Method*

67. Overall, the Gaussian Kernel Method may be classified with spline methods as a smoothed, non-parametric regression method. The method equates to a Nadaraya-Watson kernel regression,<sup>19</sup> weighted by bond face value and has existed in the literature since at least 2001.<sup>20</sup>
68. The Gaussian Kernel Method is consistent with the approach used by the Reserve Bank of Australia as published in 'New Measures of Australian Corporate Credit Spreads'.<sup>21</sup>
69. The formulas in column A to K in the "GaussianKernel" worksheet must be dragged down to include all the bonds in the sample. The Gaussian Kernel method then is automated in Excel via clicking the "Calculate Gaussian Kernel" button on the top right corner of the "DRP output using Excel" worksheet.<sup>22</sup>

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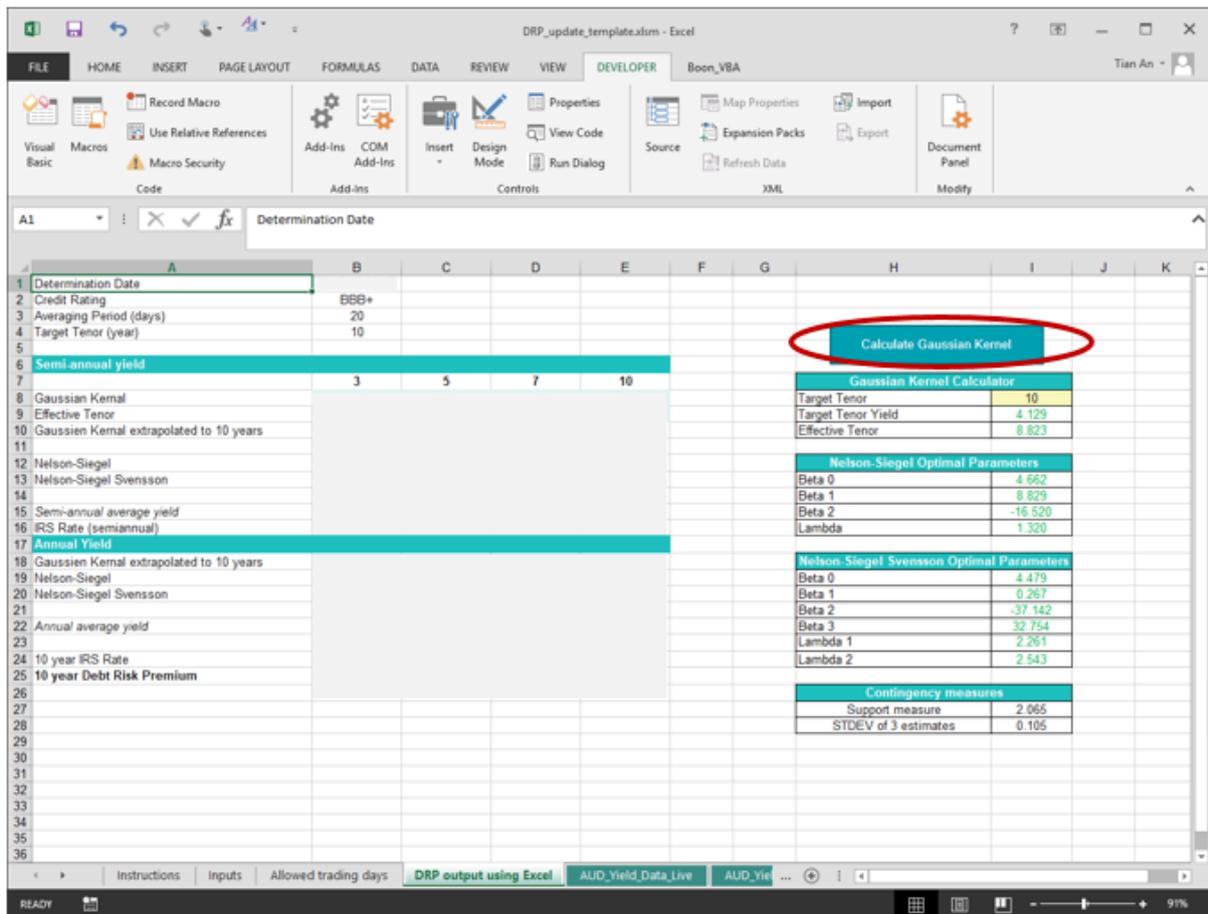
<sup>19</sup> Bowman, and Azzalini, *Applied Smoothing Techniques for Data Analysis: the Kernel Approach with S-Plus Illustrations*, Oxford University Press, Oxford, 1997.

<sup>20</sup> Linton, Mammon, Nielson and Tanggard, 'Yield curve estimation by kernel smoothing methods', *Journal of Econometrics*, 105, 2001, pp. 185-223.

<sup>21</sup> Reserve Bank of Australia, 'New Measures of Australian Corporate Credit Spreads', Bulletin, December Quarter 2013.

<sup>22</sup> A short macro is assigned to the button for copying and pasting values from the Gaussian Kernel results.

**Figure 4 Nelson Siegel Output Worksheet and Automated Button**



- 70. The Excel formulae that replicate the Gaussian Kernel Method are provided in Table 9.
- 71. Note that the inputs required for each bond in the benchmark sample are: remaining term to maturity; bond face value in Australian dollars; and Australian dollar equivalent yield. These are the outputs reported in cells W2, X2 and V2 in Table 8 respectively.

**Table 9 Gaussian Kernel Point Estimation Methodology – Worksheet “GaussianKernel”**

Attribute	Cell	Formula or entry
Remaining term to maturity	B2 down	Sourced from cell B2 down of “AUD_Yield_Data_Static” worksheet
Amount issued – Australian dollars (bond face value)	C2 down	Sourced from cell C2 down of “AUD_Yield_Data_Static” worksheet
Australian dollar equivalent yield (average of 20 days)	D2 down	Sourced from cell BL2 down of “AUD_Yield_Data_Static” worksheet
Target tenor	N2	Input target tenor sourced from Cell I8 of “DRP output using Excel” worksheet
Smoothing parameter (sigma)	N3	1.5
Actual sigma	N4	=STDEV(B:B)

Attribute	Cell	Formula or entry
Sigma squared	N5	=N3^2
mean	N6	=AVERAGE(B:B)
pi	N7	=PI()
Square root of 2 x pi	N8	=SQRT(2*N7)
Smoothing parameter x Square root of 2 x pi	N9	=N3*N8
Absolute deviation from target tenor	E2 down	=ABS(B2-\$N\$2)
Squared deviation from target tenor	F2 down	=(B2-\$N\$2)^2
Gaussian kernel	G2 down	=(EXP(-F2/(2*\$N\$5)))/\$N\$9
Joint Weighting	H2 down	=G2*C2
Sum of Joint Weighting	Last cell column H	=SUM(H2:H\$Second last row)
Weight	I2 down	=H2/(H\$Last row)
Weighted yield	J2 down	=I2*D2
Weighted maturity	K2 down	=I2*B2
Sum weighted maturity (effective term to maturity)	Last cell column K	=SUM(K2:K\$Second last row)
Target tenor yield	N11	=SUM(J:J)

72. The target tenor yield may be deduced analytically for the Gaussian Kernel Method, without recourse to optimisation of a function of model fit. Hence, the target tenor yield reported in cell N11 is rapidly calculated for any target tenor input into cell N2.
73. The target tenor yields are calculated for 3, 5, 7 and 10 year terms. The associated effective term to maturity in the last cell of column K is also recorded for each tenor. A linear extrapolation out to an effective tenor of 10 years using effective tenor of 7 years is performed using the following formula.

$$y(10) = y[et(7)] + \left[ \frac{y[et(10)] - y[et(7)]}{et(10) - et(7)} \right] \times [10 - et(7)]$$

where:

- $y(10)$  is the semi-annual yield extrapolated out to 10 years  
 $y[et(\tau)]$  is target tenor yield output from the Gaussian Kernel Method  
 $et(\tau)$  is the effective tenor output from the Gaussian Kernel Method.

74. The Excel worksheet for calculating the target tenor yields is provided at Table 10.

**Table 10 Linear Interpolation and Extrapolation of Gaussian Kernel Estimates – Worksheet “DRP output using Excel”**

Attribute	Cell	Formula or entry
Tenor	D7:E7	Values 7 and 10
7-year target tenor yield (semi-annual basis)	D7	From cell N11 in “GaussianKernel” worksheet.
10-year target tenor yield (semi-annual basis)	E7	From cell N11 in “GaussianKernel” worksheet.
7-year effective tenor	D8	Last row of column K in “GaussianKernel” worksheet.
10-year effective tenor	E8	Last row of column K in “GaussianKernel” worksheet.
Extrapolated 10-year yield (semi-annual basis)	E10	=D8+((E8-D8)/(E9-D9))*(10-D9)
Extrapolated 10-year yield annualised	E18	=((1+E10/200)^2-1)*100

75. The value for E18 in Table 10 is the Gaussian Kernel cost of debt extrapolated to a tenor of 10 years. This will be used to inform the DRP in later steps.

### *The Nelson Siegel method*

76. The NS estimator of the yield curve, given a tenor  $\tau$ , consists of three parametric components:<sup>23</sup>

$$Y_{\tau} = \beta_0 + \beta_1 \frac{1 - e^{-\lambda_1 \tau}}{\lambda_1 \tau} + \beta_2 \left( \frac{1 - e^{-\lambda_1 \tau}}{\lambda_1 \tau} - e^{-\lambda_1 \tau} \right)$$

where

$\beta_0$  is the constant long-run yield level

$\beta_1$  is the weighting for the short-end shift, defined as a downward or upward shift that then decays

$\beta_2$  is the weighting for the medium-term ‘hump’ ( $\beta_2 > 0$ ) or ‘trough’ ( $\beta_2 < 0$ )

$\lambda_1$  is the decay factor.

77. The decay factor  $\lambda$  determines the rate of decay of both the short-end shift and the hump/trough. The factor loadings  $\beta_1$  and  $\beta_2$  determine the magnitude of the shift or hump/trough, respectively.

78. The NS method is a manual process in Excel, which uses the Excel Solver.

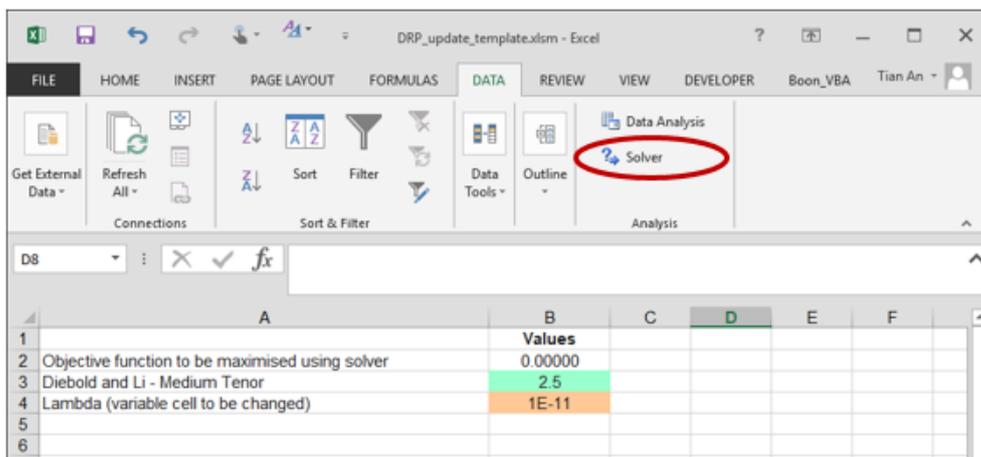
<sup>23</sup> Nelson, and Siegel, ‘Parsimonious modelling of yield curves’, *Journal of business*, 60, 1987, pp. 473-489.

79. The NS method requires a regression to be run to obtain starting values of  $\beta_0$ ,  $\beta_1$ , and  $\beta_2$ ; which are subsequently applied to the Excel Solver to solve the parameters required for calculating cost of debt at 10-years target tenor.
80. The first step in the NS method involves the estimation of the starting value for the decay factor ( $\lambda$ ) that provides the tenor at which the medium-term factor ( $\beta_2$ ) reaches its maximum influence. Diebold and Li (2006) propose that 30 months (2.5 years) is commonly used as a medium-term tenor.<sup>24</sup> Setting  $\tau$  to 2.5 and substituting it into the weighting factor attached to  $\beta_2$  in the NS specification gives:

$$\text{Max} \left[ \frac{1 - e^{-2.5\lambda}}{2.5\lambda} - e^{-2.5\lambda} \right]$$

81. The Excel worksheet and Excel Solver settings that are used to determine the value of  $\lambda$  that maximises  $\beta_2$  are provided at Table 11. The Excel Solver Add-in and Data analysis tool pack must be enabled for the following steps. Solver can be accessed via “Data” tab as shown in the Figure below.

**Figure 5 Accessing the Excel Solver**



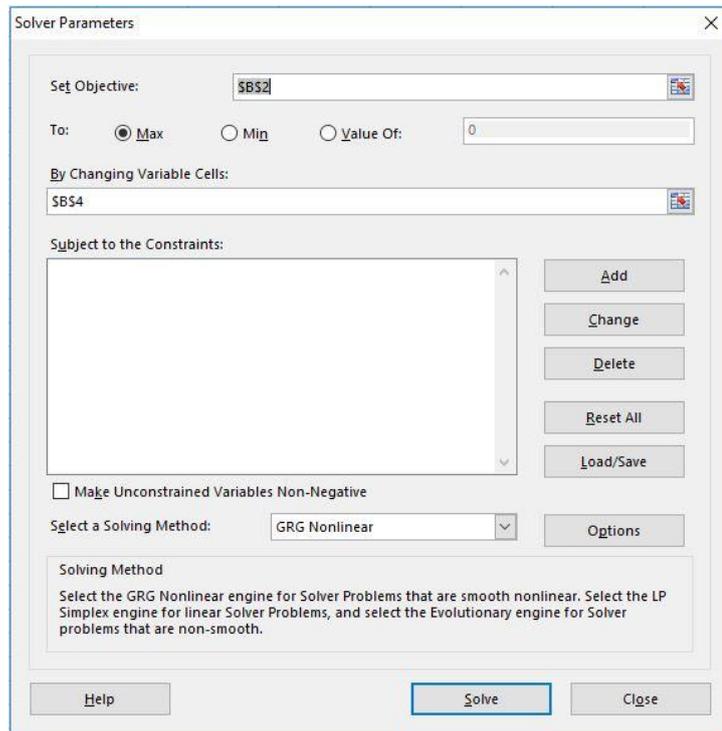
**Table 11 Nelson Siegel Decay Factor Estimation – Worksheet “NS Decay”**

Attribute	Cell	Formula or entry
$\beta_{2t}$ weighting factor	B2	$=(((1-\text{EXP}(-\$B\$4*B3))/(\$B\$4*B3))-\text{EXP}(-\$B\$4*B3))$
Tenor (maturity) $\tau$	B3	2.5
Decay factor $\lambda$ (Starting value used)	B4	0.000000000000001 (that is 1E-14)

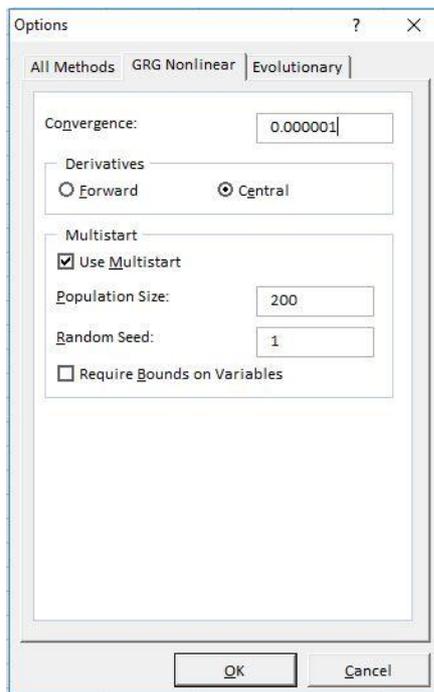
82. The Solver setting for NS decay are shown in Figure 6 and Figure 7 respectively. Note that a GRG non-linear solver is applied to find the maximum point (or peak) on a non-linear function, hence the selection of ‘GRG Nonlinear’ and ‘Max’.

<sup>24</sup> Diebold and Li, ‘Forecasting the term structure of government bond yields’, *Journal of Econometrics*, vol.130, no.2, pp. 337-364.

**Figure 6 Nelson Siegel Decay Factor Estimation – Microsoft Excel Solver Settings**



**Figure 7 Microsoft Excel GRG Nonlinear Solver Settings**



83. The convergence of 0.000001 is considered precise enough such that the solver will stop when the solution in the last iterations change by this amount.<sup>25</sup> ‘

<sup>25</sup> Diebold and Li (2006) published their decay method to 4 decimal places.

84. Multistart' option in Figure 7 is selected for global optimisation using multiple starting points. The number of different starting points is based on the 'Population size' field. Setting the 'Random seed' to 'one' ensures that the random selection process is always based on the same seed each time the solver is used. The central difference derivative method is selected for the greatest accuracy. In this case the problem is unconstrained and so no bounds are required on variables.
85. Enter 0.00000000000001 as starting value in Cell B4 of "NS Decay" worksheet, and click solve button in Figure 6. This estimation process yields a value for Lambda of 0.71731 which is already entered into the worksheet and will be used for every calculation as a starting value in the final fitting of NS yield curve.
86. Starting values are still required for  $\beta_0, \beta_1, \beta_2$ . These are obtained by:
- Substituting the calculated decay factor value ( $\lambda$ ) as a constant into factor loading formulas shown Table 12.

**Table 12: Beta parameters and Factor Loading formula for Nelson Siegel method**

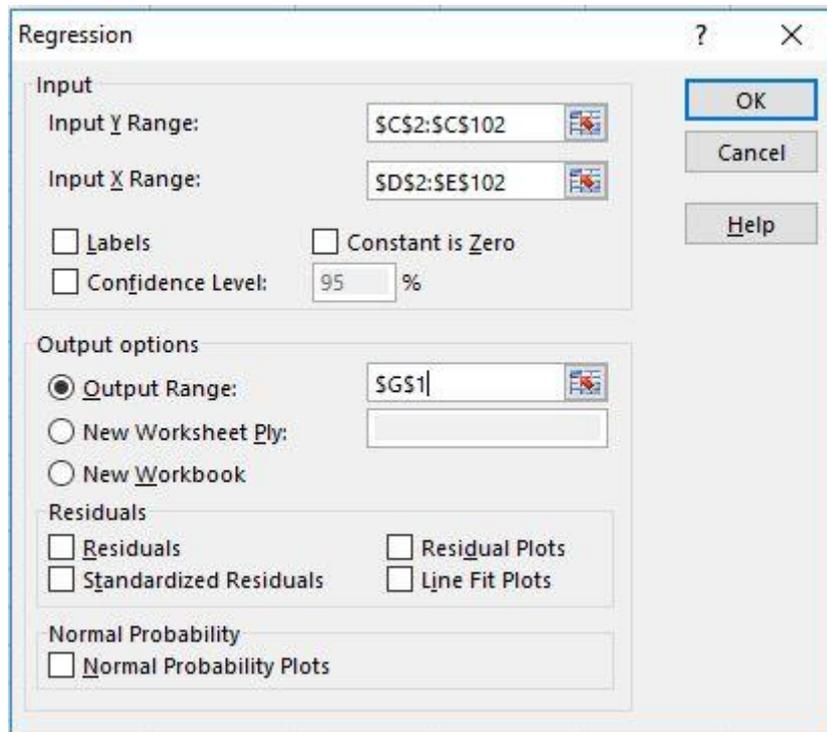
Factor	Factor Loading
$\beta_1$	$\left[ \frac{1 - e^{-\lambda\tau}}{\lambda\tau} \right]$
$\beta_2$	$\left[ \frac{1 - e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau} \right]$

- Setting these terms as a function of each bond's remaining term to maturity as shown for cell W2 in Table 8, which will provide a  $\beta_1$  weight and  $\beta_2$  weight for every bond in the sample. The column formulas in the "NS\_StartingValues" worksheet must be dragged down to include all the bonds in the sample.
  - Performing Ordinary Least Squares (OLS) regression using the Excel Data Analysis tools' 'Regression' function. The Excel structure for setting out the data to which the OLS regression is applied is shown in Table 13.
87. The Excel worksheet and regression settings are provided at Table 13 and Figure 8 respectively.
88. In the regression window, the Y and X input ranges will need to be entered to reflect the sample of bonds. The Y input values are the Australian dollar yield equivalents output for each bond as shown in cell V2 in Table 8. The X input values are the entire series of  $\beta_1$  and  $\beta_2$  weights associated with each of the bonds. Note that the 'Constant is zero' box shown in Figure 8 should be left unchecked so that an intercept term is included in the regression which will serve as a starting value for  $\beta_0$ .

**Table 13 Nelson Siegel Starting Value Regression – Worksheet “NS\_StartingValues”**

Attribute	Cell	Formula or entry
Decay factor $\lambda$	A2	Copy and paste the solved value from cell B4 in “NS_Decay” worksheet
Remaining Maturity	B2 down	Linked to cell B2 down in “AUD_Yield_Data_Static”
Australian dollar equivalent yield	C2 down	Linked to cell BL2 down in “AUD_Yield_Data_Static”
$\beta_1$ factor loading	D2 down	$=((1-EXP(-\$A\$2*B2))/(\$A\$2*B2))$
$\beta_2$ factor loading	E2 down	$=(((1-EXP(-\$A\$2*B2))/(\$A\$2*B2))-EXP(-\$A\$2*B2))$

**Figure 8 Nelson Siegel Starting Value Regression – Microsoft Excel Regression Settings**



89. The intercept, X Variable 1 and X Variable 2 that appear under the coefficients in the Excel regression output table are copied and pasted respectively as the starting value estimates for  $\beta_0, \beta_1, \beta_2$  in the NSI curve fitting process while the value in cell A2 in Table 13 is used as the starting value for  $\lambda$ .

90. The Excel worksheet that replicates the NS curve fitting process is provided at Table 14.<sup>26</sup>

<sup>26</sup> A key limitation for GRG non-linear solving method in Excel is its dependence on the initial conditions. Even with “Multistart” option selected, the solver can still possibly stop at the local optimum value nearest to the

**Table 14 Nelson Siegel Curve Fitting Methodology – Worksheet “NelsonSiegel”**

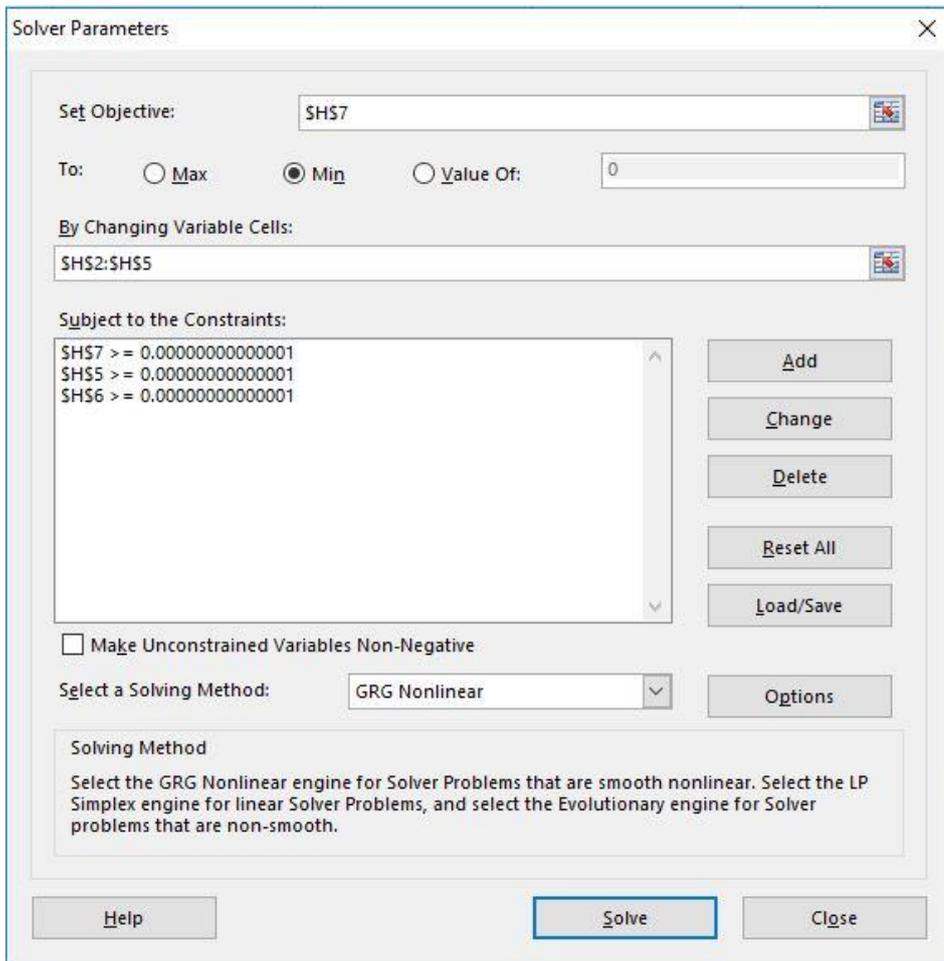
Attribute	Cell	Formula or entry
Bond Ticker	A2 down	Sourced from cell A2 down in “AYD_Yield_Data_Static” worksheet
Remaining Term to Maturity	B2 down	Sourced from cell B2 down in “AYD_Yield_Data_Static” worksheet
Australian dollar equivalent yield (20 days average)	C2 down	Sourced from cell BL2 down in “AYD_Yield_Data_Static” worksheet
Nelson Siegel	D2 down	=\$H\$2+\$H\$3*((1-EXP(-\$H\$5*B2))/(\$H\$5*B2))+\$H\$4*(((1-EXP(-\$H\$5*B2))/(\$H\$5*B2))-EXP(-\$H\$5*B2))
Squared Residual	E2 down	=(C2-D2)^2
$\beta_0$	H2	Starting value for $\beta_0$ calculated above
$\beta_1$	H3	Starting value for $\beta_1$ calculated above
$\beta_2$	H4	Starting value for $\beta_2$ calculated above
$\lambda$	H5	Starting value for $\lambda$ calculated above
$\beta_0 + \beta_1$	I6	=H3+H2
Sum of Squared Residuals	H7	=SUM(E:E)

91. Click the “Solve” button in Figure 9 to solve for NS parameters. This process will minimise the sum of squared residual at cell H5 by solving  $\beta_0, \beta_1, \beta_2$  and  $\lambda$  values in the cells H2 through to cell H5 in Table 14.
92. The Excel Solver settings (including constraints) that are required for the excise are provided in Figure 9. The associated GRG Nonlinear solver settings are provided at Figure 7.

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initial conditions, giving the solution may or may not be optimised globally. This is also the reason for Excel being utilised for checking purpose only in ERA’s DRP estimation.

**Figure 9 Nelson Siegel Parameter Constraints - Excel Solver Settings**



93. The final solutions for  $\beta_0, \beta_1, \beta_2$  and  $\lambda$  in cells H2 to H5 in Table 14 are entered back into the NS functional form to obtain tenor yields for 3, 5, 7 and 10 year terms in the “DRP output using Excel” worksheet.
94. The Excel formula that calculates the semi-annual yields at each tenor is provided at Table 15. The additional Excel calculations that are required to annualise the output values for B12, C12, D12 and E12 in Table 15 (below) so that it represents an effective annual interest rate at each tenor is provided in Table 16 (below).

**Table 15 Nelson Siegel Yield Estimation Methodology – Worksheet “DRP output using Excel”**

Attribute	Cell	Formula or entry
Tenor	B7:E7	Values 3, 5, 7 and 10.
$\beta_0$	I13	Sourced from $\beta_0$ solved result in cells H2 of “NelsonSiegel” worksheet
$\beta_1$	I14	Sourced from $\beta_1$ solved result in cells H3 of “NelsonSiegel” worksheet
$\beta_2$	I15	Sourced from $\beta_2$ solved result in cells H4 of “NelsonSiegel” worksheet
$\lambda$	I16	Sourced from $\lambda$ solved result in cells H5 of “NelsonSiegel” worksheet
3 year AUD yield (semi-annual basis)	B12	= $\$I13+\$I14*((1-EXP(-\$I16*B7))/(\$I16*B7))+\$I15*(((1-EXP(-\$I16*B7))/(\$I16*B7))-EXP(-\$I16*B7))$
5 year AUD yield (semi-annual basis)	C12	= $\$I13+\$I14*((1-EXP(-\$I16*C7))/(\$I16*C7))+\$I15*(((1-EXP(-\$I16*C7))/(\$I16*C7))-EXP(-\$I16*C7))$
7 year AUD yield (semi-annual basis)	D12	= $\$I13+\$I14*((1-EXP(-\$I16*D7))/(\$I16*D7))+\$I15*(((1-EXP(-\$I16*D7))/(\$I16*D7))-EXP(-\$I16*D7))$
10 year AUD yield (semi-annual basis)	E12	= $\$I13+\$I14*((1-EXP(-\$I16*E7))/(\$I16*E7))+\$I15*(((1-EXP(-\$I16*E7))/(\$I16*E7))-EXP(-\$I16*E7))$

**Table 16 Annualising Semi-Annual Bond Yields – Worksheet “DRP output using Excel”**

Attribute	Cell	Formula or entry
3 year AUD yield (annual basis)	B19	= $((1+B12/200)^2-1)*100$
5 year AUD yield (annual basis)	C19	= $((1+C12/200)^2-1)*100$
7 year AUD yield (annual basis)	D19	= $((1+D12/200)^2-1)*100$
10 year AUD yield (annual basis)	E19	= $((1+E12/200)^2-1)*100$

95. The value for E19 in Table 16 is the NS 10-year cost of debt estimate. This will be used to inform the DRP in later steps.

## The Nelson Siegel Svensson Methodology

96. The NSS estimator extends the NS estimator by adding a further hump/trough factor to the equation:<sup>27</sup>

$$y(\tau) = \beta_0 + \beta_1 \left[ \frac{1 - e^{-\tau/\lambda_1}}{\tau/\lambda_1} \right] + \beta_2 \left[ \frac{1 - e^{-\tau/\lambda_1}}{\tau/\lambda_1} - e^{-\tau/\lambda_1} \right] + \beta_3 \left[ \frac{1 - e^{-\tau/\lambda_2}}{\tau/\lambda_2} - e^{-\tau/\lambda_2} \right]$$

where

$y(\tau)$  is the yield at time  $t$  for maturity  $\tau$

$\beta_0, \beta_1, \beta_2, \beta_3, \lambda_1, \lambda_2$  are the parameters of the model to be estimated from the data.

97. The NSS method estimates the parameters from the observed yields and maturities of bonds. The factor loading parameterised by  $\beta_3$  and  $\lambda_2$  provides a more flexible yield curve than the NS method by allowing for an additional hump/trough structure to be included in the model. A yield curve is produced by substituting these estimates into the above equation and plotting the resulting estimated yield  $y(\tau)$  by varying the maturity  $\tau$ .  $y(\tau)$  has the interpretation of being the estimated yield for a benchmark bond with a maturity for a given credit rating.
98. The ERA applies 1.25 and 4 as the starting values for  $\lambda_1$  and  $\lambda_2$  each time to solve NSS parameters. These starting values are the mid-points of box-constraints for  $\lambda_1$  and  $\lambda_2$  defined by Gilli, Große and Schumann<sup>28</sup>.
99. The NSS method is a manual process in Excel. The process requires a regression to be run to obtain starting values for  $\beta_0, \beta_1, \beta_2$  and  $\beta_3$ . These starting values are then used by the Excel Solver to solve the parameters required for calculating cost of debt at 10-year target tenor.

100. Starting values are still required for  $\beta_1, \beta_2, \beta_3$ . These are obtained by:

- Substituting the decay factor values  $\lambda_1, \lambda_2$  as a constant into factor loading formulas shown Table 17.

**Table 17: Beta parameters and Factor Loading formula for NSS method**

Factor	Factor Loading
$\beta_1$	$\left[ \frac{1 - e^{-\tau/\lambda_1}}{\tau/\lambda_1} \right]$
$\beta_2$	$\left[ \frac{1 - e^{-\tau/\lambda_1}}{\tau/\lambda_1} - e^{-\tau/\lambda_1} \right]$
$\beta_3$	$\left[ \frac{1 - e^{-\tau/\lambda_2}}{\tau/\lambda_2} - e^{-\tau/\lambda_2} \right]$

<sup>27</sup> Svensson, L.E.O., *Estimating and interpreting forward interest rates: Sweden 1992-1994*, National Bureau of Economic Research, Working Paper No. 4871, Cambridge MA, 1994.

<sup>28</sup> Gilli, Große and Schumann (2010), *Calibrating Nelson-Siegel-Svensson Model*, Page 13

- Setting these terms as a function of each bond's remaining term to maturity. This will result in a  $\beta_1$  weight,  $\beta_2$  weight and  $\beta_3$  weight for every bond in the sample. The formulas in the column in the "NSS\_StartingValues" worksheet must be dragged down to include all the bonds in the sample.
- The Ordinary Least Squares (OLS) regression is carried out using the Excel Data Analysis tools' 'Regression' function. The Excel structure for setting out the data to which the OLS regression is applied is shown in Table 18.

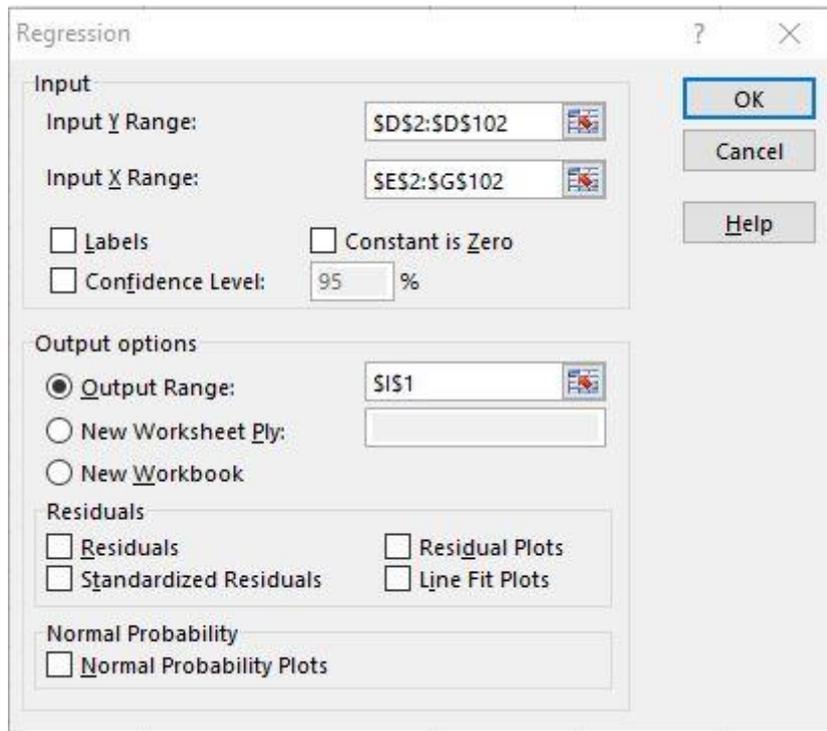
**Table 18 NSS Starting Value Regression – Worksheet "NSS\_StartingValues"**

Attribute	Cell	Formula or entry
Decay factor $\lambda_1$	A2	1.25 <sup>29</sup>
Decay factor $\lambda_2$	B2	4
Remaining Maturity	C2 down	Sourced from cell B2 down in "AYD_Yield_Data_Static" worksheet
Australian dollar equivalent yield	D2 down	Sourced from cell BL2 down in "AYD_Yield_Data_Static" worksheet
$\beta_1$ factor loading	E2 down	=((1-EXP(-C2/\$A\$2))/(C2/\$A\$2))
$\beta_2$ factor loading	F2 down	=((((1-EXP(-C2/\$A\$2))/(C2/\$A\$2))-(EXP(-C2/\$A\$2))))
$\beta_3$ factor loading	G2 down	=((((1-EXP(-C2/\$B\$2))/(C2/\$B\$2))-(EXP(-C2/\$B\$2))))

101. The Excel worksheet and regression settings are provided at Table 18 and Figure 10 respectively.
102. In the regression window, the Y and X input ranges will need to be entered to reflect the sample of bonds. The Y input values are the Australian dollar yield equivalents output for each bond as shown in cell V2 in Table 8. The X input values are the entire series of  $\beta_1, \beta_2, \beta_3$  weight factors associated with each of the bonds.
103. Note that the 'Constant is zero' box shown in Figure 10 should be left unchecked so that an intercept term is included in the regression which will serve as a starting value for  $\beta_0$ .

<sup>29</sup> 1.25 and 4 are the mid-points of box-constraints for  $\lambda_1$  and  $\lambda_2$  defined by Gilli, Große and Schumann (2010).

**Figure 10 NSS Starting Value Regression – Microsoft Excel Regression Settings**



104. The intercept, X Variable 1, X Variable 2 and X Variable 3 that appear under the coefficients in the Excel regression output table are copied and pasted respectively as the starting value estimates for  $\beta_0, \beta_1, \beta_2, \beta_3$  in the NSS curve fitting process. While the values in cell A2 and B2 in Table 18 are used as the starting values for  $\lambda_1, \lambda_2$ .
105. The Excel worksheet that replicates the NSS curve fitting process is provided at Table 19.

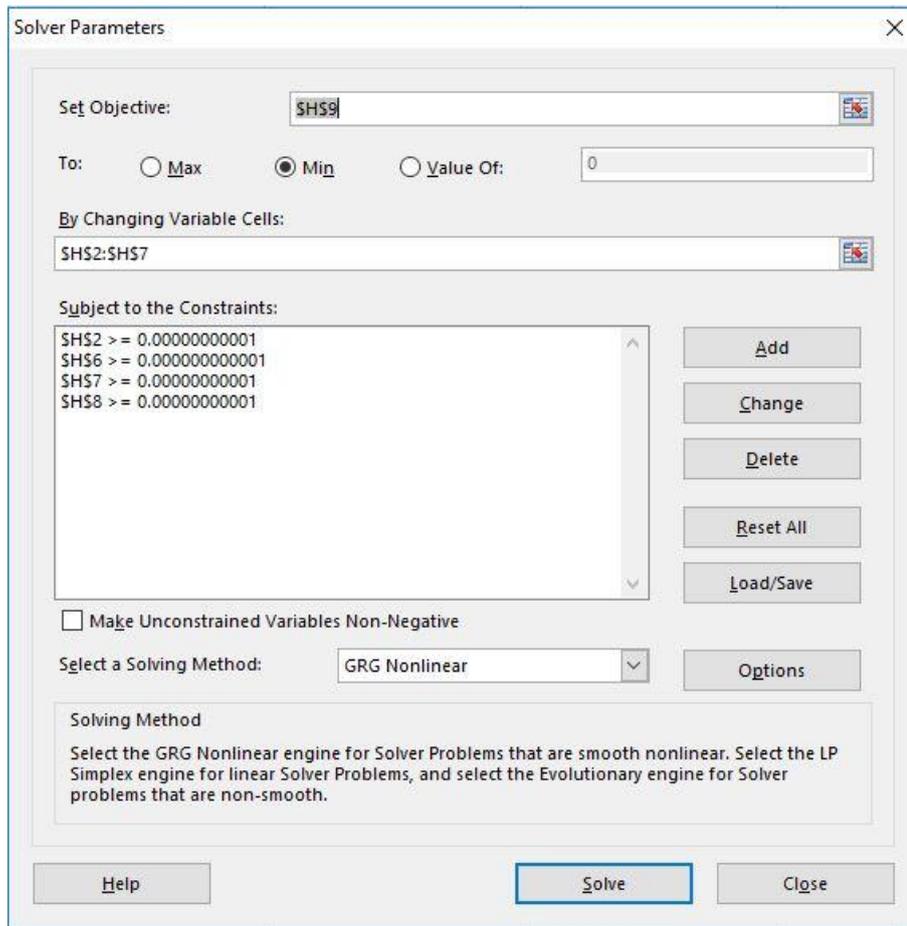
**Table 19 NSS Yield Curve Estimation Methodology – Worksheet “NelsonSiegelSvensson”**

Attribute	Cell	Formula or entry
Bond Ticker	A2 down	Sourced from cell A2 down in “AYD_Yield_Data_Static” worksheet
Remaining Term to Maturity	B2 down	Sourced from cell B2 down in “AYD_Yield_Data_Static” worksheet
Australian dollar equivalent yield	C2 down	Sourced from cell BL2 down in “AYD_Yield_Data_Static” worksheet
Nelson Siegel Svensson	D2 down	= $\$H\$2+\$H\$3*((1-EXP(-B2/\$H\$6))/\$H\$6)+\$H\$4*(((1-EXP(-B2/\$H\$6))/\$H\$6))-EXP(-B2/\$H\$6))+\$H\$5*(((1-EXP(-B2/\$H\$7))/\$H\$7))-EXP(-B2/\$H\$7))$
Squared Residual	E2 down	=(D2-C2)^2
$\beta_0$	H2	Starting value for $\beta_0$ calculated above
$\beta_1$	H3	Starting value for $\beta_1$ calculated above
$\beta_2$	H4	Starting value for $\beta_2$ calculated above
$\beta_3$	H5	Starting value for $\beta_3$ calculated above
$\lambda_1$	H6	1.25 <sup>30</sup>
$\lambda_2$	H7	4
$\beta_0 + \beta_1$	H8	=H3+H2
Sum of Squared Residuals	H9	=SUM(E:E)

106. Click the “Solve” button in Figure 11 to solve for NS parameters. This process will minimise the sum of squared residual at cell H5 by solving  $\beta_0, \beta_1, \beta_2$  and  $\lambda$  values in the cells H2 through to cell H5 in Table 14.
107. The Excel Solver settings (including constraints) that are required for the excise are provided in Figure 11.

<sup>30</sup> 1.25 and 4 are the mid-points of box-constraints for  $\lambda_1$  and  $\lambda_2$  defined by Gilli, Große and Schumann (2010).

**Figure 11 NSS Parameter Constraints – Microsoft Excel Solver Settings**



108. The associated GRG Nonlinear solver settings are provided at Figure 7.
109. The final solutions for  $\beta_0, \beta_1, \beta_2, \beta_3, \lambda_1, \lambda_2$  outputs in cells H2 to H7 are automatically linked back into the NSS functional form to obtain tenor yields for 3, 5, 7 and 10-year terms in “DRP output using Excel” worksheet.
110. The formula that calculates semi-annual yields at each tenor are provided at Table 20. To convert the output to the effective annual interest rate, the output values for B13, C13, D13 and E13 in Table 20 are converted through the formula provided in Table 21.

**Table 20 Nelson Siegel Svensson Yield Estimation Methodology – Worksheet “DRP output using Excel”**

Attribute	Cell	Formula or entry
Tenor	B7:E7	Values 3, 5, 7 and 10.
$\beta_0$	I19	Sourced from cells H2 of “NelsonSiegelSvensson” worksheet
$\beta_1$	I20	Sourced from cells H3 of “NelsonSiegelSvensson” worksheet
$\beta_2$	I21	Sourced from cells H4 of “NelsonSiegelSvensson” worksheet
$\beta_3$	I22	Sourced from cells H5 of “NelsonSiegelSvensson” worksheet
$\lambda_1$	I23	Sourced from cells H6 of “NelsonSiegelSvensson” worksheet
$\lambda_2$	I24	Sourced from cells H7 of “NelsonSiegelSvensson” worksheet
3 year AUD yield (semi-annual basis)	B13	= $\$19+\$120*((1-EXP(-B7/\$123))/(B7/\$123))+\$121*(((1-EXP(-B7/\$123))/(B7/\$123))-(EXP(-B7/\$123)))+\$122*(((1-EXP(-B7/\$124))/(B7/\$124))-(EXP(-B7/\$124)))$
5 year AUD yield (semi-annual basis)	C13	= $\$19+\$120*((1-EXP(-C7/\$123))/(C7/\$123))+\$121*(((1-EXP(-C7/\$123))/(C7/\$123))-(EXP(-C7/\$123)))+\$122*(((1-EXP(-C7/\$124))/(C7/\$124))-(EXP(-C7/\$124)))$
7 year AUD yield (semi-annual basis)	D13	= $\$19+\$120*((1-EXP(-D7/\$123))/(D7/\$123))+\$121*(((1-EXP(-D7/\$123))/(D7/\$123))-(EXP(-D7/\$123)))+\$122*(((1-EXP(-D7/\$124))/(D7/\$124))-(EXP(-D7/\$124)))$
10 year AUD yield (semi-annual basis)	E13	= $\$19+\$120*((1-EXP(-E7/\$123))/(E7/\$123))+\$121*(((1-EXP(-E7/\$123))/(E7/\$123))-(EXP(-E7/\$123)))+\$122*(((1-EXP(-E7/\$124))/(E7/\$124))-(EXP(-E7/\$124)))$

**Table 21 Annualising Semi-Annual Bond Yields - Worksheet “DRP output using Excel”**

Attribute	Cell	Formula or entry
3 year AUD yield (annual basis)	B20	= $((1+B13/200)^2-1)*100$
5 year AUD yield (annual basis)	C20	= $((1+C13/200)^2-1)*100$
7 year AUD yield (annual basis)	D20	= $((1+D13/200)^2-1)*100$
10 year AUD yield (annual basis)	E20	= $((1+E13/200)^2-1)*100$

111. The value at E20 in Table 21 is the NSS 10-year cost of debt estimate. This will be used to inform the DRP in later steps.

## 9. DRP Process Step 5: Estimating the cost of debt

- 112. The annualised 10-year cost of debt estimate from each of the three methods provided above is averaged to arrive at the final estimate of the 10-year cost of debt.
- 113. This step is performed automatically in Excel.
- 114. The outputs of the semi-annual and annual 10-year cost of debt estimates from the three methods are provided in the “DRP output using Excel” worksheet.
- 115. The final 10-year cost debt is the simple average of cell E18 in Table 10, E19 in Table 16 and E20 in Table 21.

**Table 22: Estimating 10 year Cost of Debt – Worksheet “DRP output using Excel”**

Attribute	Cell	Formula or entry
Gaussian Kernal annualised yield	E18	As illustrated in Table 10
Nelson Siegel annualised yield	E19	As illustrated in Table 16
Nelson Siegel Svensson annualised yield	E20	As illustrated in Table 21
Annualised 10 year Cost of Debt	E22	=AVERAGE(E18:E20)

- 116. This averaged 10-year cost of debt is then subtracted by 10-year Interest Rate Swap Rate to derive the final 10-year DRP estimate.

## 10. DRP Process Step 6: Estimating annual DRP

117. 10-year DRP is the difference between 10-year cost of debt and 10-year IRS rate.
118. This step is performed automatically in Excel.
119. The 10 year IRS rate is downloaded in “Allowed trading days” worksheet with formulas provided at Table 23 below.

**Table 23 10 year AUD IRS Rate downloading – Worksheet “Allowed trading days”**

Attribute	Cell	Formula or entry
Trading day date	A2 down	dd/mm/yyyy
AUD 10 year IRS rate <sup>31</sup>	B2 down	=BDH("ADSWAP10 Curncy","PX_LAST",A2)
AUD 10 year IRS rate (paste values)	C2 down	Copy and paste values from cell B2 down

120. The averaging semi-annual 10-year IRS rate for the averaging period is calculated in the “DRP output using Excel”. This semi-annual rate is then annualised for DRP calculation.

121. The 10-year DRP estimate is calculated in the “DRP output using Excel” worksheet cell E25 by subtracting the IRS Rate from the final estimate of 10-year cost of debt.

**Table 24: Estimating 10-year DRP – Worksheet “DRP output using Excel”**

Attribute	Cell	Formula or entry
Annualised 10 year cost of debt	E22	As illustrated in Table 22
Semi-annual 10 year AUD IRS	E16	=AVERAGE('Allowed trading days'!C2:C21)
Annualised 10 year AUD IRS	E24	=((1+E16/200)^2-1)*100
10 year Debt Risk Premium	E25	=E22-E24

<sup>31</sup> ERA uses ADSWAP10 Curncy, PX\_LAST data from the Bloomberg terminal. This is the average of the bid and ask rate on the 10 year Australian Dollar interest rate swap rate (mid-rate).

## 11. DRP Process Step 7: Trailing average DRP estimate

122. The estimate of the DRP for each year will be a simple trailing average.
123. The trailing average estimate of the DRP will average the most recent 10 years of annual DRP estimates.
124. Annually updating the resulting 10-year trailing average will involve adding in the most recent estimate of the DRP and dropping the estimate from 10 years ago. The weights for a simple hybrid trailing average DRP estimate will be 10 per cent each.
125. The automatic formula for the equally weighted trailing average of the DRP to apply in any regulatory year as shown below:

$$TA\ DRP_0 = \frac{\sum_{t=0}^{-9} DRP_t}{10}$$

where

$TA\ DRP_0$  is the equally weighted trailing average of the DRP to apply in the following year as the annual update of the estimate used in the current year  $t=0$

$DRP_t$  is the DRP estimated for each of the 10 regulatory years  $t = 0, -1, -2, \dots, -9$ .

126. All years are in the same year convention as year 0. For example, if year 0 is the calendar year 2018,  $t = -9$  must be the calendar year 2009.
127. Historic numbers for each of the DRP estimates over the 10 year period will be specific to the approved DRP's of a particular entity. The historic number will remain unchanged for the trailing average period.
128. The DRP process in R and Excel is used to calculate the annual updated DRP estimate. The trailing average calculation is separate from this process.

## 12. Contingency events

The ERA will apply the following contingencies outlined in Table 25.

**Table 25 Contingency approaches to data related issues**

Event	Changes to Approach
<p><b>Contingency A – Bond Size</b></p>	
<p>This contingency is triggered when:</p> <ul style="list-style-type: none"> <li>the total number of bonds in the sample is less than 15 across the term structure; and/or</li> <li>the sample is less than 10 bonds between the maturities of five and 15 years.</li> </ul>	<p>In the event that minimum bond sample requirements are not met, the ERA will use the AER’s method to calculate the cost of debt using RBA, Bloomberg and Thompson Reuters’ data sources.</p> <p>Under this contingency, the 10-year BBB+ cost of debt estimate will be calculated by the sum of:</p> <ul style="list-style-type: none"> <li>1/3 of the broad A-rated estimate</li> <li>2/3 of the broad BBB-rated estimate.</li> </ul> <p>The debt risk premium will then be calculated by removing the risk free rate.</p>
<p><b>Contingency B – Estimation divergence</b></p>	
<p>The three curve estimation techniques diverge to a large extent.</p> <p>Contingency is triggered when the standard deviation of the three yield estimates (Gaussian Kernel, NS and NSS) is equal to or greater than 100 basis points.</p> <p>The standard deviation is calculated at cell I28 of “DRP output using Excel” worksheet in the DRP_update_template.xlsm.</p>	<p>In the event that estimation techniques diverge to a significant degree, the ERA will use the AER’s method to calculate the cost of debt using RBA, Bloomberg and Thompson Reuters’ data sources.</p> <p>Under this contingency, the 10-year BBB+ cost of debt estimate will be calculated by the sum of:</p> <ul style="list-style-type: none"> <li>1/3 of the broad A-rated estimate</li> <li>2/3 of the broad BBB-rated estimate.</li> </ul> <p>The debt risk premium will then be calculated by removing the risk free rate.</p>
<p><b>Contingency C – Bloomberg data unavailable</b></p>	
<p>Bloomberg stops producing bond data and bond data becomes unavailable.</p>	<p>In the event that Bloomberg data is unavailable, the ERA will use the AER’s method to calculate the cost of debt using RBA and Thompson Reuters’ data sources. If RBA data is not available, the ERA will rely on Thompson Reuters’ data.</p> <p>Under this contingency, the 10-year BBB+ cost of debt estimate will be calculated by the sum of:</p> <ul style="list-style-type: none"> <li>1/3 of the broad A-rated estimate</li> <li>2/3 of the broad BBB-rated estimate.</li> </ul> <p>The debt risk premium will then be calculated by removing the risk free rate.</p>

129. The daily yield estimates over the return on debt averaging period for year  $n$  must be calculated as an average of each curve provider's daily yield estimates as follows:

$$Yield_n^i = \frac{\left(\frac{1}{3}BVALA_n^i + \frac{2}{3}BVALB_n^i\right) + \left(\frac{1}{3}RBAA_n^i + \frac{2}{3}RBAB_n^i\right) + \left(\frac{1}{3}TRA_n^i + \frac{2}{3}TRB_n^i\right)}{Curves_n^i}$$

Where:

$Yield_n^i$  is the daily yield estimate for day  $i$  within the averaging period for year  $n$

$BVALA_n^i$  is the effective annual yield for the Bloomberg broad A-rated curve for day  $i$  within the averaging period in year  $n$

$BVALB_n^i$  is the effective annual yield for the Bloomberg broad B-rated curve for day  $i$  within the averaging period in year  $n$

$RBAA_n^i$  is the effective annual yield for the RBA broad A-rated curve for day  $i$  within the averaging period in year  $n$

$RBAB_n^i$  is the effective annual yield for the RBA broad BBB-rated curve for day  $i$  within the averaging period in year  $n$

$TRA_n^i$  is the effective annual yield for the Thomson Reuters broad -rated curve for day  $i$  within the averaging period in year  $n$

$TRB_n^i$  is the effective annual yield for the Thomson Reuters broad B-rated curve for day  $i$  within the averaging period in year  $n$

$Curves_n^i$  is the number of curve providers used for day  $i$  within the averaging period in year  $n$ .

130. The published Bloomberg, RBA and Thomson Reuters 10-year semi-annual yield estimates, must be converted to effective annual yields using formula below:

$$Yield_{annual} = \left( \left( 1 + \frac{Yield_{semi-annual}}{2} \right)^2 - 1 \right) * 100$$

Where:

$Yield_{annual}$  is the daily 10-year yield estimate converted into an effective annual rate

$Yield_{semi-annual}$  is the 10 year-year daily yields from each curve providers.

131. If the effective tenor of the bond is less than the 10-year target tenor, the following formula allows the yield data to be extrapolated to 10 years<sup>32</sup>:

$$Yield_{semi-annual} = Yield_{later} + \left[ \frac{Yield_{later} - Yield_{earlier}}{Term_{later} - Term_{earlier}} \right] \times [10 - Term_{later}]$$

Where:

$Yield_{semi-annual}$  is the 10-year extrapolated rate

$Yield_{later}$  is the un-extrapolated yield for the longest published term

$Yield_{earlier}$  is the yield for the second longest published term

$Term_{later}$  is the effective term for  $Yield_{later}$

$Term_{earlier}$  is the effective term for  $Yield_{earlier}$ .

132. Where daily interpolation is necessary, the following interpolation formula will be used:

$$Y_i = Y_{month\ start} + \left( \frac{Y_{month\ end} - Y_{month\ start}}{Date_{month\ end} - Date_{month\ start}} \right) \times (Date_{estimation} - Date_{month\ start})$$

Where:

$Y_i$  is the interpolated yield for day  $i$

$Y_{month\ start}$  is the yield published for the end date of previous month

$Y_{month\ end}$  is the yield published for the end date of current month

$Date_{month\ start}$  is the end date of previous month

$Date_{estimation}$  is the date required to be estimated

$Date_{month\ end}$  is the end date of the current month.

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<sup>32</sup> The RBA currently publishes 10-year broad A-rated and broad BBB-rated yield estimates that have an effective term of less than 10 years and so extrapolation is currently required to extend their term to exactly 10 years.