Appendix 1 DRP process for updating in R

1.   Estimating DRP

1.   This appendix sets out the operating procedure for updating debt risk premium (DRP) estimates within the R statistical computing environment (*R DRP process*).

2.   In estimating the DRP, the ERA will solely rely on the R statistical process detailed in this 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 an accompanying Excel DRP process (*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

- information related to actionable steps for the purposes of estimating the DRP (for ease of reference this information is highlighted).

5.   Subscription, software and add-in requirements for the *R DRP process* include:

- Bloomberg Anywhere Subscription.

- Excel 2013 or above.

- Bloomberg Excel Add-in; Excel Solver Add-in and Analysis Tool Pack.

- RStudio - an integrated development environment (IDE) that supports the running of R code. Ideally use R version 3.5.1 for running the code provided for DRP estimation exercise.[1]

- R packages: NMOF, readxl, sm, YieldCurve, lubridate, openxlsx, Rblpapi.[2] [3]

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[1] Available at: https://www.rstudio.com/

[2] R packages are inbuilt into the RStudio software and therefore do not need to be separately sourced. These packages, however, will need to be individually installed before running the provided code. Detailed step are provided in this process document.

[3] The Rblapi package provides R with access to Bloomberg data via the Bloomberg C++ API, given an API license.

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[4]

   - 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 purpose, this document uses 20 Sydney trading days[5] which is consistent with Gas Rate of Return Guidelines.

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[4] For illustrative purposes, this document uses BBB+ credit rating which is consistent with the Gas Rate of Return Guidelines.

[5] 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 process to estimate DRP, and accompanying tools, is designed so that stakeholders can replicate the calculation.   Once the settings and spreadsheet templates have been established in Bloomberg, Excel and R, the estimation process is deterministic.

13.   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.

      – As R has limitations in acquiring certain specialist Bloomberg data, R will pull data from the "AUD_Yield_Data_Static" Excel worksheet.

   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.   The use of R

14.   The key advantage of an R workflow (*R DRP process*) over an Excel workflow (*Excel DRP process*) is that automation of the workflow is better implemented and maintained, and statistically more robust.

15.   R has access to some 13,000+ statistical packages, among which several apply to yield curve estimation. Importantly, R has access to numerous optimisation methods. This allows for a better solution of the parameter estimation problem to be implemented for both the Nelson-Siegel (NS) and Nelson-Siegel-Svensson (NSS) models, in terms of accuracy, consistency and speed.

16.   The main drawback of an R DRP process is that the Bloomberg API allows for standardised data requests only.

- Hence, once appropriate SRCH parameters are defined and stored on the Bloomberg terminal then the results of the SRCH may be regenerated with each call to the SRCH from R. Similarly, data history queries will readily pull data requested of the Bloomberg servers into the R environment.

- However, the specialist functions of BSTRUCTURE, BPRICE and BVIEW are used by the ERA to convert asset swaps into hedged AUD equivalent yields. This API functionality is only available through Excel, and not R, at this point in time.

17.   Hence, the *R DRP Process* requires a data 'pull' component from Excel as an input into the estimation of the cost of debt.

18.   This data 'pull' component has been facilitated by an Excel template that has capacity for a sample of up to 300 bonds to be averaged across up to 60 trading days.

- This Excel 'downloader' template may be readily extended in terms of capacity without further alteration of the R code base.

19.   Once data is downloaded in the Excel downloader template then the R process *drp_bloomberg_automation.R* may be run from within the R statistical environment (RStudio is recommended as an integrated development environment).

20.   The *R DRP Process* reports the results of the estimation in a separate Excel output file.

21.   Overall, the *R DRP Process* implements and replicates the *Excel DRP Process*, altering only how the DRP estimation is performed.

5. Excel template

22. An Excel template for DRP estimation entitled *DRP_update_template.xlsm* is available for the data acquisition and the *Excel DRP Process*. This Excel template is also used for data acquisition for *R DRP Process*.

23. 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	• Input cells for Bloomberg bond tickers, determination date, assumptions for converting yield into AUD equivalents etc. • Formulas built in to retrieve corporate bond information from Bloomberg. • This worksheet is only functional via access to the Bloomberg Application Programming Interface (API).
Allowed trading days	• Input cells for nominated trading days of the averaging period. • Retrieve 10-year Interest Rate Swap data from Bloomberg. • This worksheet is only functional via access to the Bloomberg API.
Individual trading date data downloader	• Formulas built in to retrieve yield data and to convert yield into AUD equivalents for each bond for each trading day. • There is a worksheet established for each trading day. Available for maximum of 60 days. • These worksheets are only functional via access to the Bloomberg API.
AUD_Yield_Data_Live	• Summarise AUD equivalent yield for each nominated trading day, and calculate average yield for the averaging period. • Summarise remaining term to maturity and AUD face values data for each bond. • These worksheets are only functional via access to the Bloomberg API.
AUD_Yield_Data_Static	• Copy and paste values from "AUD_Yield_Data_Live" worksheets. • Contains all the data required for the 3 curve fitting techniques.
GaussianKernel	• Calculates the target tenor yield using Gaussian Kernel method.
NS_StartingValues	• Runs regression to calculate starting Beta values used in the Nelson Siegel method.
NelsonSiegel	• Solves parameters required to calculate target tenor yield using Nelson Siegel method.
NSS_StartingValues	• Runs regression to calculate starting Beta values used in the Nelson Siegel Svensson method.
NelsonSiegelSvensson	• Solves parameters required to calculate target tenor yield using Nelson Siegel Svensson method.

Worksheet Name	Description
10_year_IRS_Rate	• Pulls 10-year AUD IRS data from Bloomberg. • Calculates annualised 10-year IRS rate.
NS Decay	• Calculate the starting λ value used in the Nelson Siegel method.
DRP output using Excel	• Summarises the outputs from other worksheets. • Calculates final cost of debt by averaging the estimates produced by 3 methods. • Calculates final DRP value.

6. DRP Process Step 1: Determining the benchmark sample

24. 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.[6]

25. 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+.[7]

26. 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.[8]

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

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

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[6]   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.

[7]   ERA, Explanatory Statement for the 2018 Gas Rate of Return Guidelines

[8]   <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.

28. 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'.

29. 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.

30. The criteria in the Bloomberg search panel can be edited by clicking the pencil icon to the right of each criteria. [9]

Figure 1   Bloomberg 'SRCH' Function Populated with Sample Selection Criteria
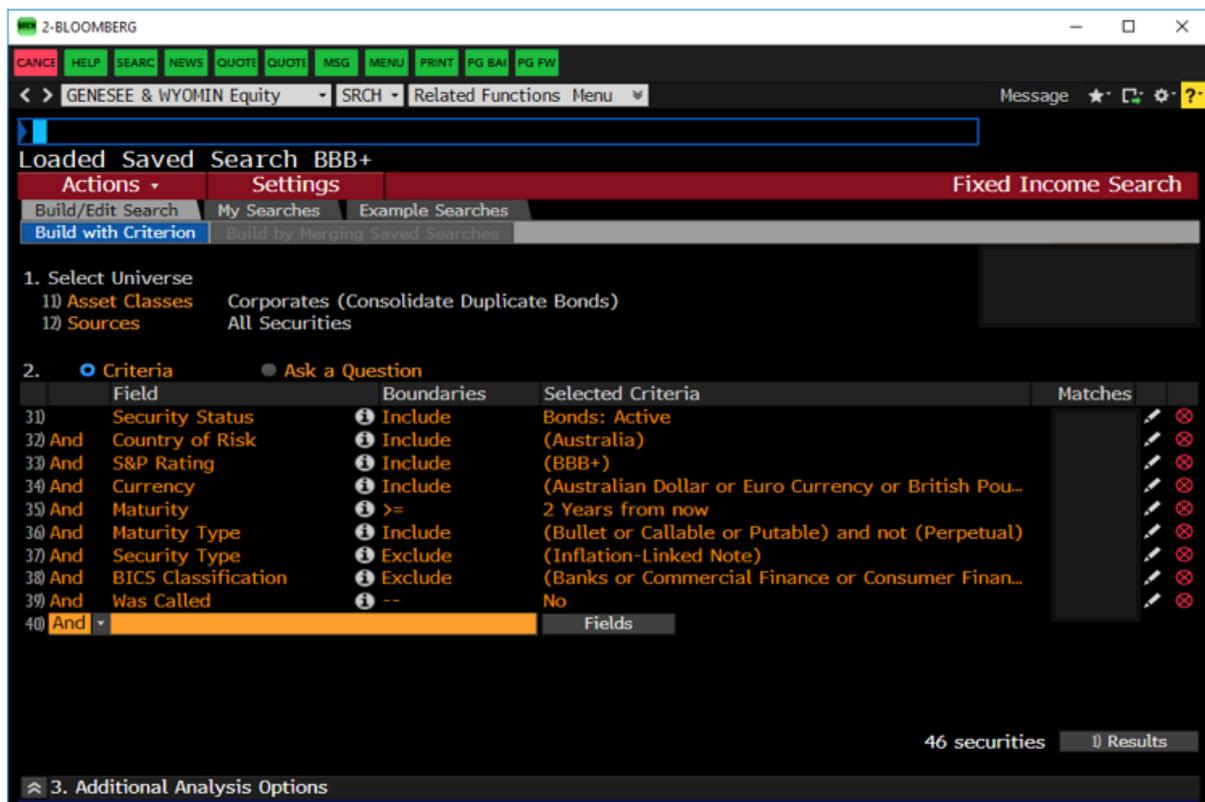
Source: Bloomberg

31. Search criteria can be saved via "My Searches" button for future reference.

32. 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'.

33. 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.

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[9]   For the maturity date change the boundary condition to 'years from now' by selecting 'Y'.

34. 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.[10]

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"[11]

35. 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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[10] It is recommended that formulas presented in these Excel structure tables are copied and pasted from an electronic copy of this document.

[11] If the downloaded Bloomberg ID already have "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.

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

36. 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.

37. 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

38. To set these as the default sources in the Bloomberg terminal for each currency use FMPS <GO> shown in Figure 2.[12]

39. 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.

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[12] 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 **Error! Reference source not found.Error! Reference source not found.** 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
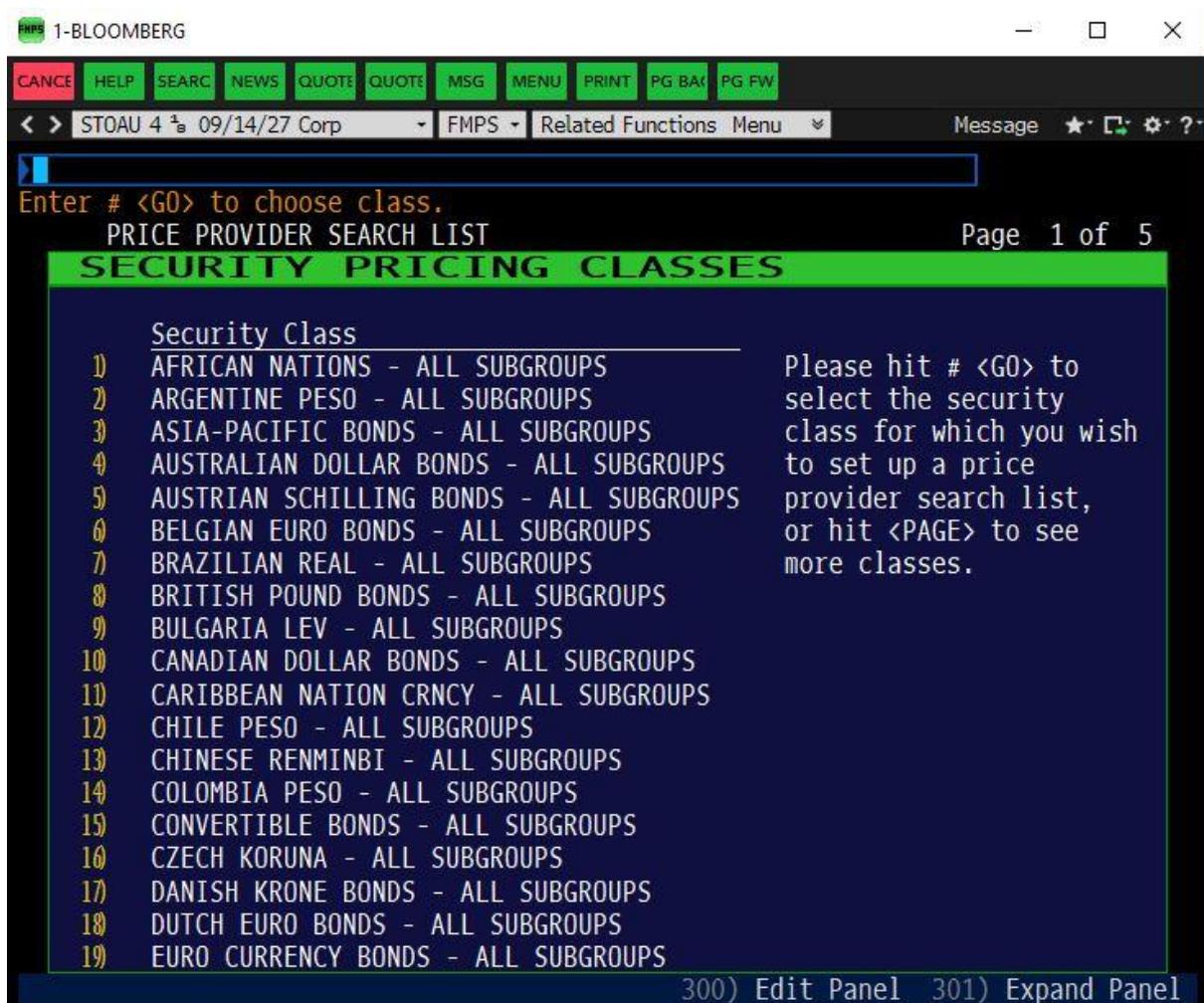
Source: Bloomberg

40.   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.

41.   In particular, the first pricing source should be entered to the right of '1st' and the second pricing source to the right of '2nd'.

42.   Once this is complete select <GO> followed by 1 <GO> to save.

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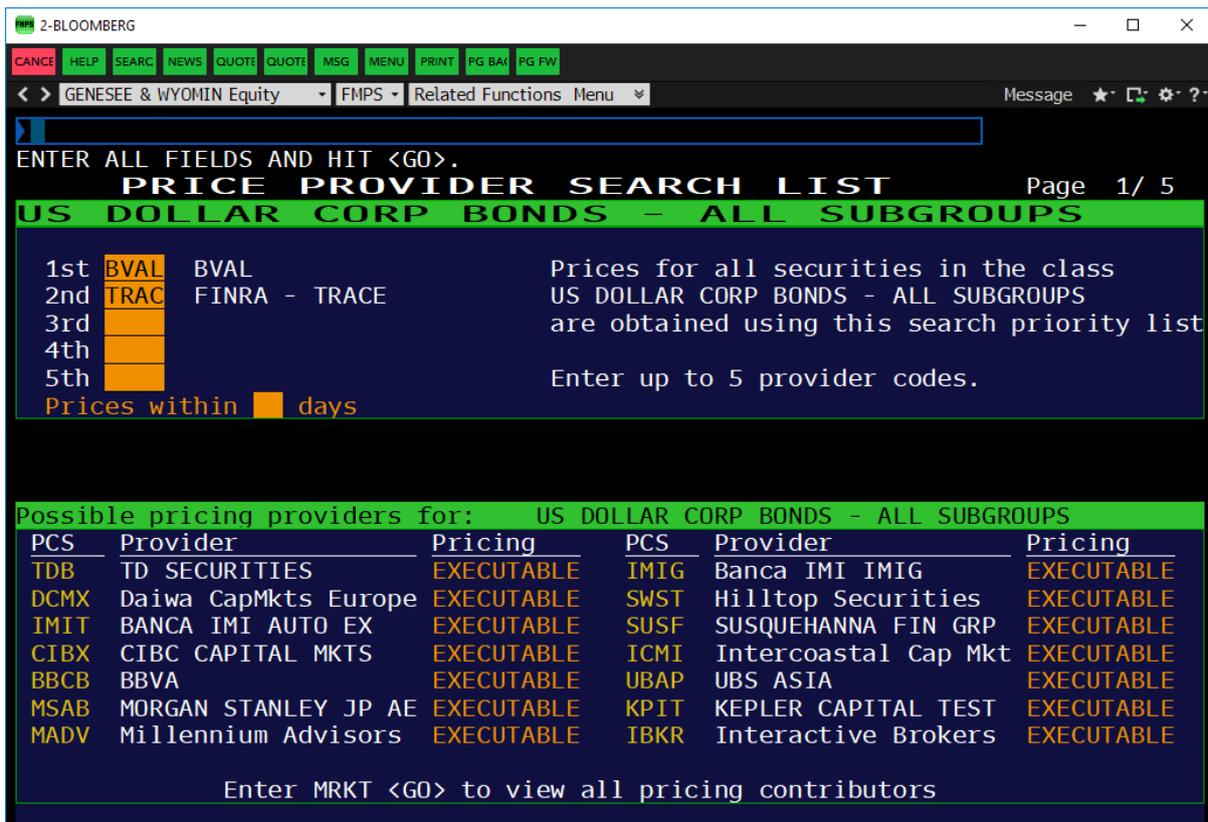
Source: Bloomberg

43.   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.

44.   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.

45.   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.[13]

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[13]   The space before " Corp" is intentional. BDP retrieves current values while BDH is used to retrieve historical data.

46. Data acquisition is performed using the provided template "DRP_update_template.xlsm". This worksheet is only functional via access to the Bloomberg API.

47. 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).

48. The Bloomberg bond information retrieved in the "Input" worksheet do not vary with trading days.

49. 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.

50. Formulas or entries for "input" sheet are summarised in **Error! Reference source not found.**.

51. All formulas from B11 to Q11 should be filled/copied down to retrieve the attributes for the entire cross section of bonds.

52. 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.[14]

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.[15]
Number of trading days	B4	Number of trading days used in the determination.[16]
Target tenor	B5	10 years.
IRS Security	B6	ADSWAP10 CMPN Curncy[17]
Sigma (Gaussian kernel: years)	B7	1.5[18]
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"))

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[14] Click the drop down window in Cell N10 and select "sort from A to Z".

[15] Not implemented, as controlled for in the stored Bloomberg SRCH request.

[16] 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.

[17] The Bloomberg ticker of the security defining the swap rate adjustment of the cost of debt.

[18] 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)))

53. 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.

54. 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[19]	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

55. 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.[20]

- 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.

- For each trading day worksheet, all formulas B4 through to I4 in Table 7 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.

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[19] 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).

[20] 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.

- 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.

56.   The Bloomberg Swaps Toolkit is used for converting international bond data to hedged AUD equivalent yields. As detailed in Table 7, deal structure ID and valuation ID are established using the Bstrucutre and Bprice formulas. The Bview formula is applied to extract the Australian dollar equivalent yield from the established cross currency fixed floating interest rate swaps.

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	=IF($B$1="","",IF(Inputs!A11="","",Inputs!B11))
Bond bid price[21]	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$1, "QuoteType", "P","fill","P"))
Asset swap spread bid[22]	D4 down	=IF(A4="","",BDP(A4,"asset swap spd bid",$B$3,$B4,"ASW_SWAP_CURRENCY",Inputs!$D$2,"ASW_SWAP_PAY_RESET_FREQ",Inputs!$E$2,"SETTLE_DT",TEXT($B$1,"YYYYMMDD"),"OAS_CURVE_DT",TEXT($B$1,"YYYYMMDD")))
Asset swap spread ask[23]	E4 down	=IF(A4="","",BDP(A4,"asset swap spd ask",$C$3,$C4,"ASW_SWAP_CURRENCY",Inputs!$D$2,"ASW_SWAP_PAY_RESET_FREQ",Inputs!$E$2,"SETTLE_DT",TEXT($B$1,"YYYYMMDD"),"OAS_CURVE_DT",TEXT($B$1,"YYYYMMDD")))
Asset swap spread mid	F4 down	=IF(A4="","",AVERAGE(D4:E4))
Deal Structure ID (called from Bloomberg terminal)	G4 down	=IF(A4="","",BSTRUCTURE(Inputs!$H$2,"Leg[2].Currency",Inputs!$D$2,"Leg[1].Currency",Inputs!$D$2,"Leg[2].Spread",F4,"EffectiveDate",$B$1,"MaturityDate",Inputs!M11,"Leg[1].PayFrequency",Inputs!$G$2,"Leg[2].PayFrequency",Inputs!$G$3,"Leg[2].ResetFrequency",Inputs!$G$3))
Valuation ID (called from Bloomberg terminal)	H4 down	=IF(A4="","",BPRICE(G4,"Target=Leg[1].FixedCoupon","Premium=0","Leg[2].Spread",$F4,"ValuationDate",$B$1,"MarketDate",$B$1,"headers=false"))
Australian dollar equivalent yield	I4 down	=IF(A4="","",BView($H4,"Leg[1].FixedCoupon","headers=false"))

Source: ERA Research, Bloomberg

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[21]   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.

[22]   ERA considers that using the option adjusted spread curve date is an appropriate override in order to explicitly fix this curve date to the trading day date entered through Excel.

[23]   ERA considers that using the option adjusted spread curve date is an appropriate override in order to explicitly fix this curve date to the trading day date entered through Excel.

57.   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 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.

7.1 Bloomberg connectivity

58. Once the download is complete, confirm by visual inspection any failed data requests across the different sheets.

59. The main weakness of the workflow is connectivity with the Bloomberg platform. The majority 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.

60. 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.

61. Hence, it is critical that a complete download of the data is checked before running the DRP calculation process.

62. 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.

63. 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.

64. 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.

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

65. 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.

66. A table of AUD equivalent bond yields is established for each bond with observations for every day across the averaging period.

67. To build up this time series, the AUD equivalent yield in column I 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.

68. 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.

69. The data download must be completed in the live worksheet before the data can be pasted to the static 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 I4 down of each individual trading day worksheet.
Averaging Yield over the average period	BL2 down	=AVERAGE(D:BK)

70. 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.

71. 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.

72. 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.

9. DRP Process Step 4: Apply curve fitting techniques

9.1 Estimation techniques

73. 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.

74. 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,[24] weighted by bond face value and has existed in the literature since at least 2001.[25]

75. 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'.[26]

76. The NS estimator of the yield curve, given a tenor τ, consists of three parametric components:[27]

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

where

β_0 is the constant, long-run yield level

β_1 is the weighting for the short-end shift, defined as a downward or upward shift that then decays

β_2 is the weighting for the medium-term 'hump' $(\beta_2 > 0)$ or 'trough' $(\beta_2 < 0)$

λ_1 is the decay factor.

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[24] Bowman, and Azzalini, *Applied Smoothing Techniques for Data Analysis: the Kernel Approach with S-Plus Illustrations*, Oxford University Press, Oxford, 1997

[25] Linton, Mammon, Nielson. and Tanggard, '*Yield curve estimation by kernel smoothing methods*', *Journal of Econometrics*, 105, 2001, pp. 185-223.

[26] Reserve Bank of Australia, '*New Measures of Australian Corporate Credit Spreads',* Bulletin, December Quarter 2013.

[27] Nelson, and Siegel, '*Parsimonious modelling of yield curves'*, *Journal of business, 60, 1987, pp. 473-489.*

77. The decay factor λ determines the rate of decay of both the short-end shift and the hump/trough. The factor loadings β_1 and β_2 determine the magnitude of the shift or hump/trough, respectively.

78. The NSS estimator extends the NS estimator by adding a further hump/trough factor to the equation:[28]

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

where

β_3 is the weighting of a second medium-term 'hump' $(\beta_3 > 0)$ or 'trough' $(\beta_3 < 0)$

λ_2 is the decay factor for the second hump/trough.

79. The factor loading parameterised by β_3 and λ_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.

9.2   Running the R process

80. The R process can be implemented with the following seven steps:

R Step 1:   Copy and paste the DRP R package "DRP Methods" into your desired folder.

R Step 2:   Open "code" folder within the "DRP Methods" and then double click "drp_bloomberg_automation.R" within the "code" folder, as shown in Figure 6. This will open the RStudio program, as shown in Figure 5.

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[28] 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.

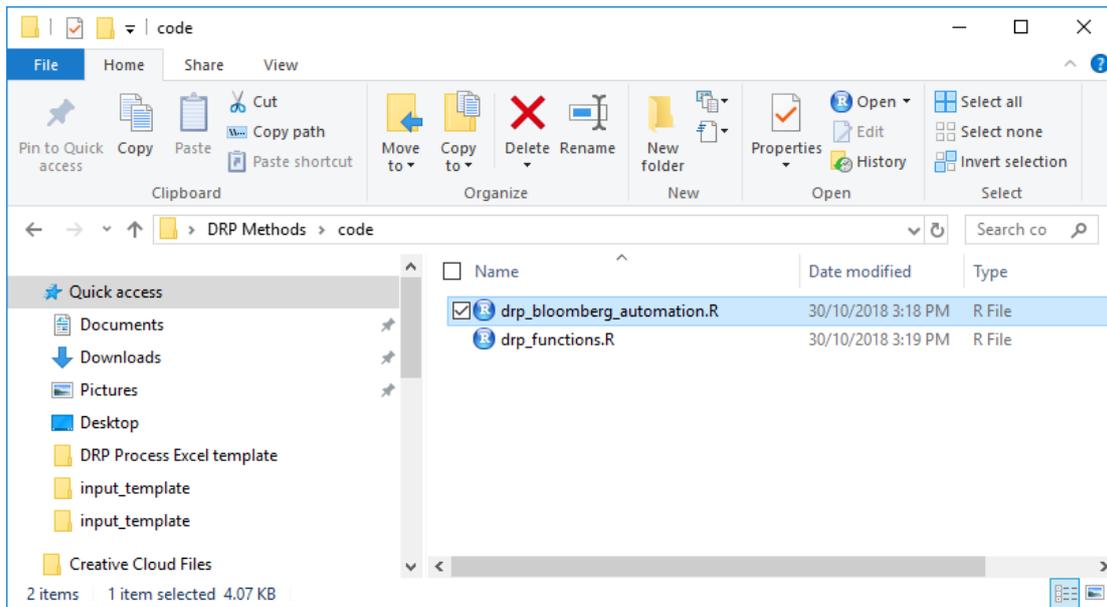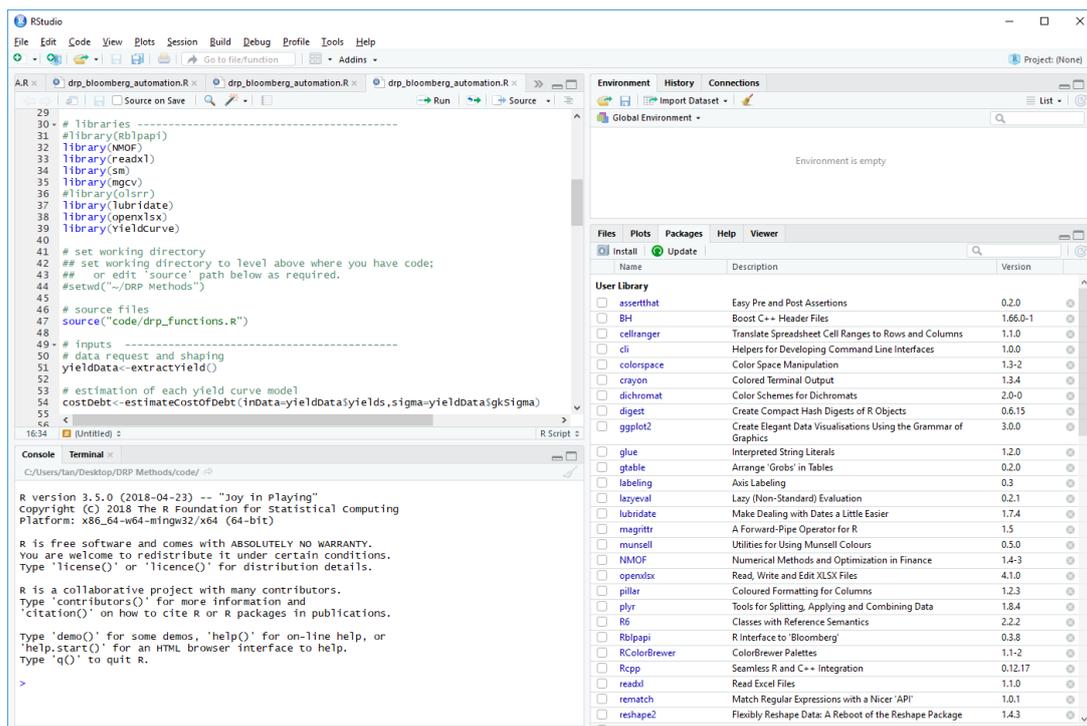## Figure 4   Initiation of R code for DRP

Figure 5   RStudio interface

R Step 3: The R automation script requires that the package dependencies are installed in the R environment. The DRP R Process requires installation of packages for NMOF, readxl, sm, YieldCurve, lubridate, openxlsx, Rblpapi. Install each of the package using the following command in the "Console". A successfully installed package example is shown in Figure 6. Use this command for the seven packages.

```
install.packages("package name")
```

Figure 6   Example of installing an R package
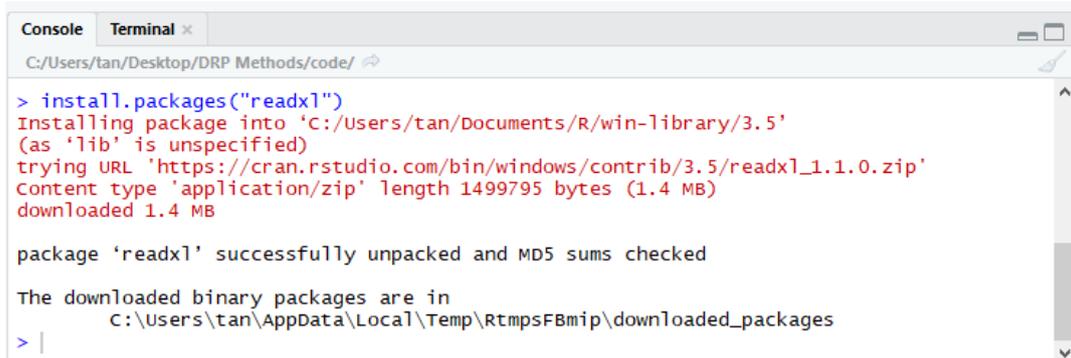

R Step 4: Once all the required packages are installed, type "Ctrl+Shift+H" to set working directory to the folder "DRP Methods".[29]   Then click Open. Screenshots of this step are shown in Figure 7 and Figure 8.

Figure 7   Setting working directory folder

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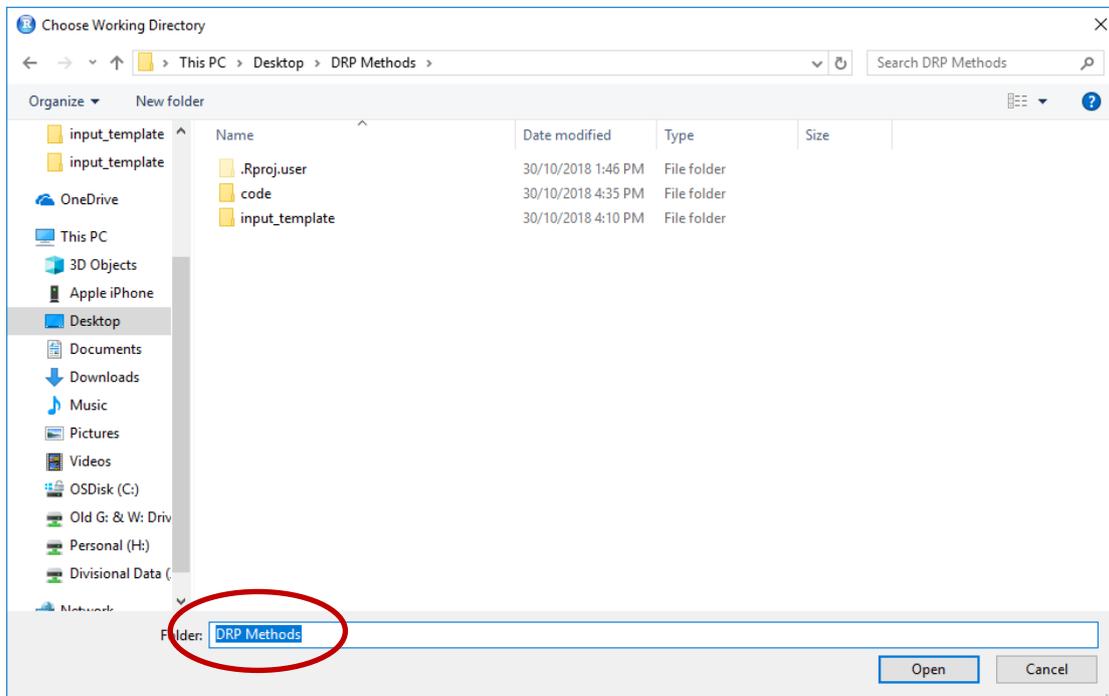
[29]   For the process to work the working directory must be set, the R automation script depends on the file *drp_functions.R* being in the same directory as the R automation script.

Figure 8   Successfully set a working directory
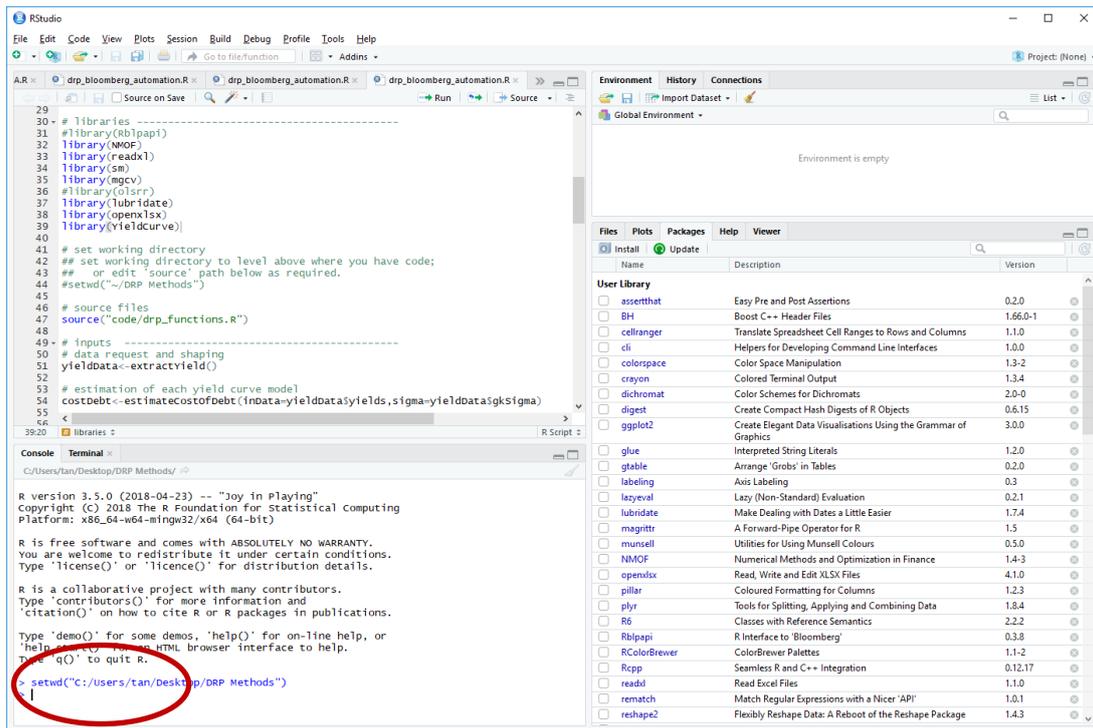
R Step 5:   Once a working directory folder is set, type "Ctrl+Alt+R" to run the code.

R Step 6:   This script will request a file to be uploaded (Figure 9). Select the "input_template" folder and then select "DRP_update_template.xlsm". This file is a copy of the Excel downloader template with tickers and trading days inputted for a given date of determination.[30]

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[30]   The DRP_update_template.xlsm is the Excel file that was successfully updated and check for the required Bloomberg data in the earlier steps.

Figure 9   Selecting the input data file
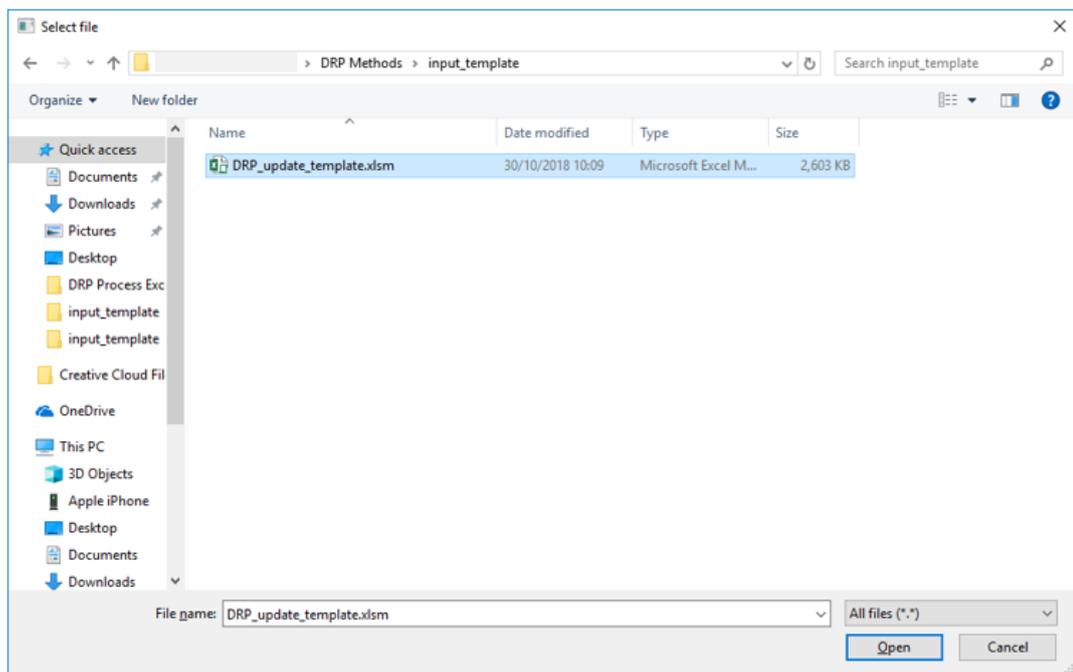
R Step 7:	Once the file is selected then the DRP estimation will proceed. The result will be printed out to an output.xlsx file in the same directory as the input Excel file, as shown in Figure 10.[31] The Excel output is shown in Figure **11** (dates and output have been removed).

---

[31]   Please note that any existing output file in the input_template folder will be overwritten and replaced with the new output file run by the R code.

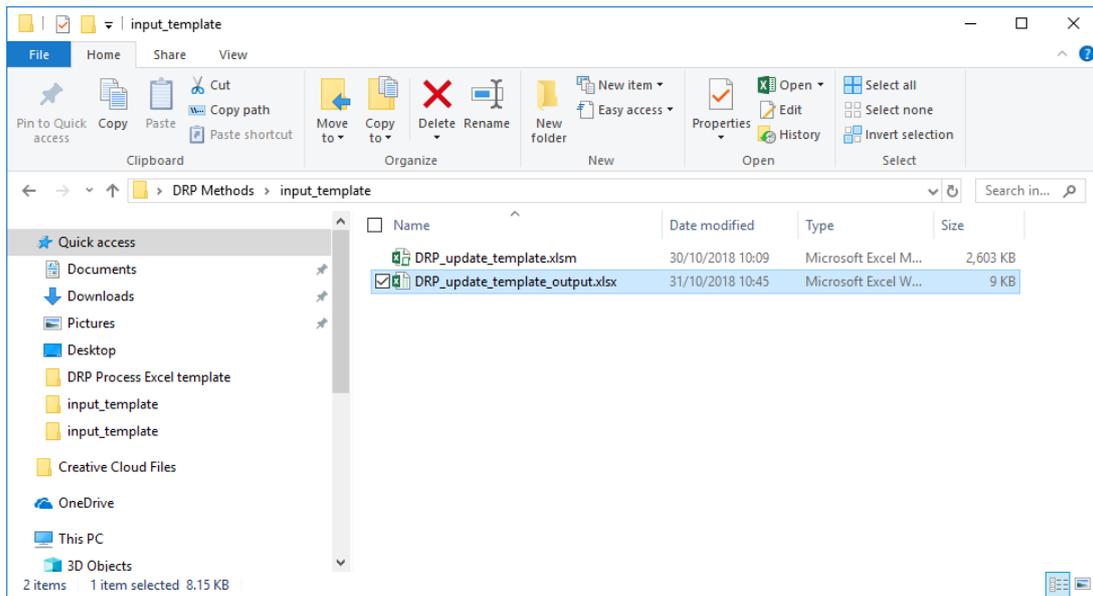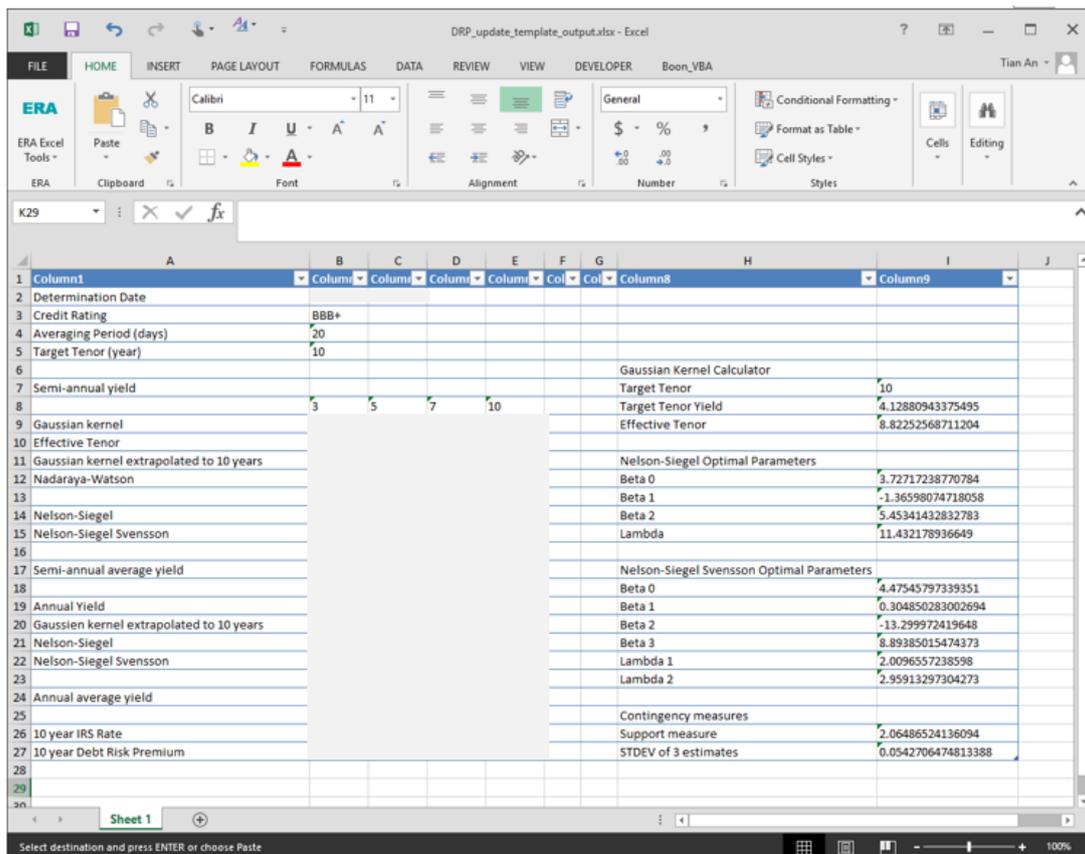**Figure 10   Creation of new _output.xlsx file**

Figure 11   Screenshot of the Output sheet of the R DRP estimation results

81. The output file will be unformatted and comprised of two sheets: Output and Daily_yield[32]. The "output" sheet contains following information in Figure 11:

- Semi-annual and annual cost of debt results using Gaussian Kernel, Nelson Siegel and Nelson Siegel Svensson estimation methods.

- Parameters for generating the cost of debt estimates.

- 10-year IRS rate.

- 10-year DRP estimate (Cell E27).

82. The DRP estimation for approximately 100 bond tickers across 20 trading days takes less than a couple of seconds on an 8GB RAM, Intel i5-7300U CPU @ 2.60GHz on a 64-bit Windows 10 enterprise operating system.

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[32] The Daily_yield sheet provides the daily yields for each bond ticker for each day, thereby summarising the sheets requesting bond yield data for each day. This provides the same information as the DRP_data_static worksheet from the DRP_update_template.xlsm.

9.3 Details of the R process

83. The R process accepts as input the Australian dollar equivalent yields for each bond computed over the set of trading days.

84. These yields are then averaged over the set of trading days, and form the input data for each bond along-side the maturity of the bond at the date of determination and the face value of that bond issue.

85. The 10-year IRS rate for each trading day is also read from the Excel downloader template.

86. The Gaussian kernel estimate of the cost of debt is computed. This is computed in the same way as the *Excel DRP Process*.

    - The Gaussian Kernel estimate is supplemented with a Nadaraya-Watson Gaussian Kernel estimate. The Nadaraya-Watson estimate is a convention in the statistical literature[33] and is included in R outputs for comparison purposes only. It has no influence on the final DRP estimate produced.

87. The NS parameters are estimated using the *YieldCurve* package in R.[34] The *Nelson.Siegel* function applies a grid search to profile an optimal solution over a range of λ decay rate values.

    - The R grid search approach is unlike the Excel DRP Process solution, which employs a local search starting from one initial value based on a maturity tenor of 2.5 years. The initial λ value in the Excel DRP Process is determined by optimising the factor loading for the β_2 factor for a given tenor.

    - R applies a grid search through selecting a λ that optimises the factor loading of β_2 at the maturity tenor given by each bond in the bond sample.

    - For each λ estimate the regression of bond yield on the factor loadings is then performed. The optimal solution is then the regression that minimises the residual sum of squares across the (irregular) grid of λ values. The parameter estimates for the NS model are then the parameter estimates of the optimal regression, alongside the λ value corresponding to that regression.

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[33] Bowman, A.W. and Azzalini, A. (1997). *Applied Smoothing Techniques for Data Analysis: the Kernel Approach with S-Plus Illustrations.* Oxford University Press, Oxford.

[34] Consiglio A. and Guirreri S.S. Simulating the Term Structure of Interest Rates with arbitrary marginals. *International Journal of Risk Assessment and Management*, 15(4), September 2011.

88. The NSS solution in R applies a differential evolution algorithm, as set out by Storn and Price (1997).[35]

- This algorithm performs well when the two λ values are constrained to mutually exclusive sets of allowable values (λ_1 is constrained to between 0-2.5, and λ_2 to between 2.5-5.5, as per Gilli et al. 2010).

- The differential evolution algorithm is population based, and so does not require initial starting values, and generally has a lower risk of getting trapped in locally optimal but not globally optimal model fitting solutions.

89. The functions for identifying best fitting solutions for each model to the data are defined in the *drp_functions.R* script called on by the *drp_bloomberg_automation.R* script.

90. The estimated model for each solution (Gaussian Kernel, NS and NSS) are then each applied to estimate a cost of debt.

91. These cost of debt estimates are in turn annualised, before being averaged.

92. The 10-year IRS swap rate (averaged over the set of trading days and then annualised) is subtracted from this cost of debt to give the annualised debt risk premium.

93. The outputs of the estimation process are provided in the workbook with *output.xlsx* as a suffix.

94. The R scripts were developed and tested on behalf of ERA by Pink Lake Analytics (www.pinklake.com.au).

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[35] Manfred Gilli, Stefan Große, and Enrico Schumann. Calibrating the Nelson–Siegel–Svensson model. COMISEF Working Paper Series No. 31, 2010. URL: http://comisef.eu/?q=working_papers.

Gilli, M., Maringer, D. and Schumann, E. (2011) *Numerical Methods and Optimization in Finance*. Elsevier.

Storn, R., and Price, K. (1997) Differential Evolution – a Simple and Efficient Heuristic for Global Optimization over Continuous Spaces. *Journal of Global Optimization*, **11**(4), pp. 341–359.

10. DRP Process Step 5: Estimating the cost of debt

95. 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.

96. This step is automated through the R code.

97. Cost of debt output can be found from rows 9 – 24 of the output worksheet. There are semi-annual and annual 10-year bond yield estimates from the three methods.

11. DRP Process Step 6: Estimating annual DRP

98.   10-year DRP is the difference between 10-year cost of debt and 10-year IRS rate.

99.   This step is automated through the R code.

100.   10-year DRP output can be found from cells E27 of the output worksheet.

12. DRP Process Step 7: Trailing average DRP estimate

102. The estimate of the DRP for each year will be a simple trailing average.

103. The trailing average estimate of the DRP will average the most recent 10 years of annual DRP estimates.

104. 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.

105. The automatic formula for the equally weighted trailing average of the DRP to apply in any regulatory year is 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 $t = 0, -1, -2…. , -9$.

106. 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.

107. 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.

108. 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.

13.   Contingency events

109.   In the event that there are unexpected problems with the data or results of applying the automatic formulas, the ERA will adopt the following actions outlined in Table 9.

Table 9　Contingency approaches to data related issues

Event	Changes to Approach
Contingency A – Bond Size	**Expansion of credit rating sample**
The contingency is triggered when the total number of bonds in the sample for the benchmark credit rating is less than 15. The ERA has carried out heuristic testing and considered other market yield curve providers' practice to arrive at this minimum bond requirement.　Bloomberg requires at least 15 bonds;[36] while Thomson Reuters requires at least 5 bonds for the yield curve to be constructed.[37]	Once the event being triggered, the sample of bonds will be expanded to include the credit ratings above and below the benchmark credit rating.　Expanding the sample credit rating band will increase the number of bonds in the sample. For example, if the total number of bonds in the BBB+ credit rating sample is less than 15, the bond sample criteria will be expanded to include the BBB, BBB+ and A- credit ratings. The same DRP estimation method will be used on this larger bond sample.
Contingency B – Estimation divergence	**Use of Gaussian estimate**
The three curve estimation techniques diverge to a large extent. Contingency triggered when the standard deviation of the three yield estimates (Gaussian Kernel, NS and NSS) is equal to or greater than 100 basis points. The standard deviation result can be found at cell I27 of "output" worksheet in the "DRP_update_template_for R_output.xlsx"	The divergence indicates that the bond sample results in non-robust parametric curve estimates from techniques. Under this circumstance the Gaussian will be used as the sole method to estimate DRP.　The Gaussian estimate is that produced from the method detailed in the steps above.
Contingency C – Bloomberg data unavailable	**Use of RBA bond curves**
Bloomberg stops producing bond data and bond data becomes unavailable.	This contingency will use the RBA Table F3 "Aggregate Measures of Australian Corporate Bond Spreads and Yields" data.[38] If the effective tenor is less than 10 years, extrapolation is required to extend their term to exactly 10 years using formula outlined in paragraph110. The monthly RBA estimates are interpolated to daily estimates as formula outlined in paragraph 111; and a simple average of daily estimates for the averaging period is then made. The RBA only publishes 10-year broad A-rated and broad BBB-rated estimates. Therefore, under this contingency, the 10-year BBB+ cost of debt estimate will be calculated by the sum of: • 1/3 of the broad A-rated estimate • 2/3 of the broad BBB-rated estimate. The DRP estimate will then be calculated by removing the risks free rate.

110. If effective tenor of the bond is less than 10-year target tenor, the following formula allows the RBA spread data to be extrapolated to 10 years[39]:

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

where:

$y_t[et(10)]$ is the RBA's 10-year bond spread data

$y_t[et(7)]$ is the RBA's 7-year bond spread data

$et(10)$ is the effective tenor corresponding the RBA's 10-year estimate

$et(7)$ is the effective tenor corresponding the RBA's 7-year estimate.

111. As RBA spread to swap data is only published at the end of each month, the following interpolation formula will be used to calculate the daily spread:

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

where:

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

$Y_{month\ end}$ is the spread 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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[36] ACCC, Regulatory Economics Unit, *Return on debt estimation: a review of the alternative third party data series*, August 2014, p. 18.

[37] ACCC, Regulatory Economics Unit, *Thomson Reuters Credit Curve Methodology Note for the AER*, April 2017, p. 5.

[38] RBA Table F3: Aggregate Measures of Australian Corporate Bond Spreads and Yields – Non-financial Corporate Bonds:

[39] 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.