Hands-on guide to scenario analysis

Scenario and sensitivity analysis

Scenario and sensitivity analysis is an important part of financial modelling: Although we would like to predict the future exactly - unfortunately we cannot. So it is useful to model a range of scenarios and also to look at key outcomes and measure their sensitivity to their drivers. In this document we show how scenario and sensitivity analyses may be done in Excel.

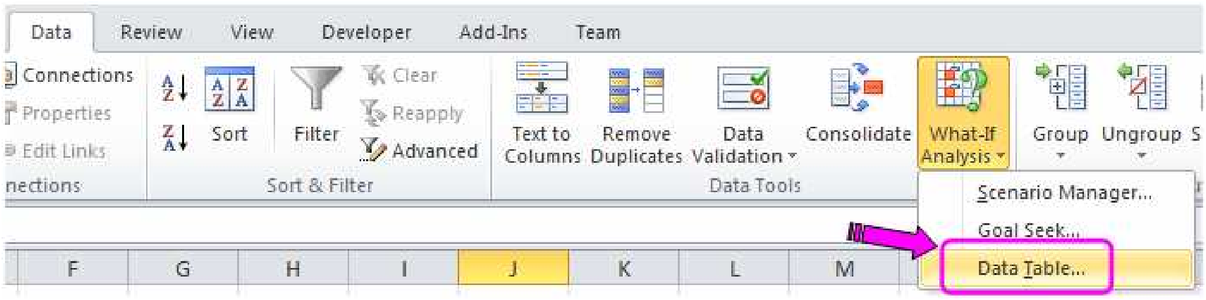
The spreadsheet examples discussed in this document may be downloaded from this web location:

www.tykoh.com/downloads/sa.xls

An Excel feature - data tables - will be central part of our analyses. We'll begin by showing how data tables work. In later sections we show how scenario and sensitivity analyses may be done with data tables.

Overview of data tables

Data tables are used for "what-if" analyses. A Data Table icon can be found in the Data Tools section of Excel's Data ribbon. The Data Tools section contains an icon labelled "What-If" Analysis. Click on that icon and a menu appears. The third item in that menu is "Data Table".



The following example illustrates how data tables can be used.

Imagine we have a simple model that forecasts revenues ...

E8 f_x =D8*(1+$D$3)

	A	B	C	D	E	F	G
2		*Assumptions*					
3		Yearly revenue growth	[%]	2%			
4							
5		*Forecast*					
6		Year	[yr]	2013	2014	2015	2016
7		Actual/Estimated	[Act/Est]	Act	Est	Est	Est
8		Revenue	[$m]	45.0	45.9	46.8	47.8

In the downloadable spreadsheet this model is on the tab labelled Overview_step_1.

Cell D3 contains an assumption about yearly growth in revenues. Currently we assume revenues will grow by 2% each year.

The formulae in cells E8:G8 forecast revenues by increasing the preceding year's revenue by the growth factor in cell D3.

Suppose we are interested in the forecast 2016 revenue: We want to know how sensitive that is to our growth assumption. We will use a data table to find out.

Begin by listing a set of growth assumptions. We'll put the assumptions into column B (highlighted in the following figure).

	A	B	C	D	E	F	G
2		*Assumptions*					
3		Yearly revenue growth	[%]	2%			
4							
5		*Forecast*					
6		Year	[yr]	2013	2014	2015	2016
7		Actual/Estimated	[Act/Est]	Act	Est	Est	Est
8		Revenue	[$m]	45.0	45.9	46.8	47.8
9							
10		*Table of estimated 2016 revenue*					
11		*Yearly revenue growth*	*Revenue*				
12							
13		-2%					
14		0%					
15		1%					
16		2%					
17		4%					

Overview_step_2 in the example spreadsheet shows the result of this step.

The growth assumptions need not be evenly spaced or in any particular order. We can have any assumptions we want either listed as separate numbers or perhaps generated by a formula. In this example we have simply entered a list of numbers.

We next construct a data table. The data table will generate results in the "Revenue" column (currently empty).

At the top of the Revenue column we define what the data table will tabulate - it needs to tabulate the 2016 forecast revenue. Begin by selecting the top cell in the Revenue column (C12). Type an = into the cell and then click on the cell we want to tabulate – the 2016 forecast revenue - cell G8.

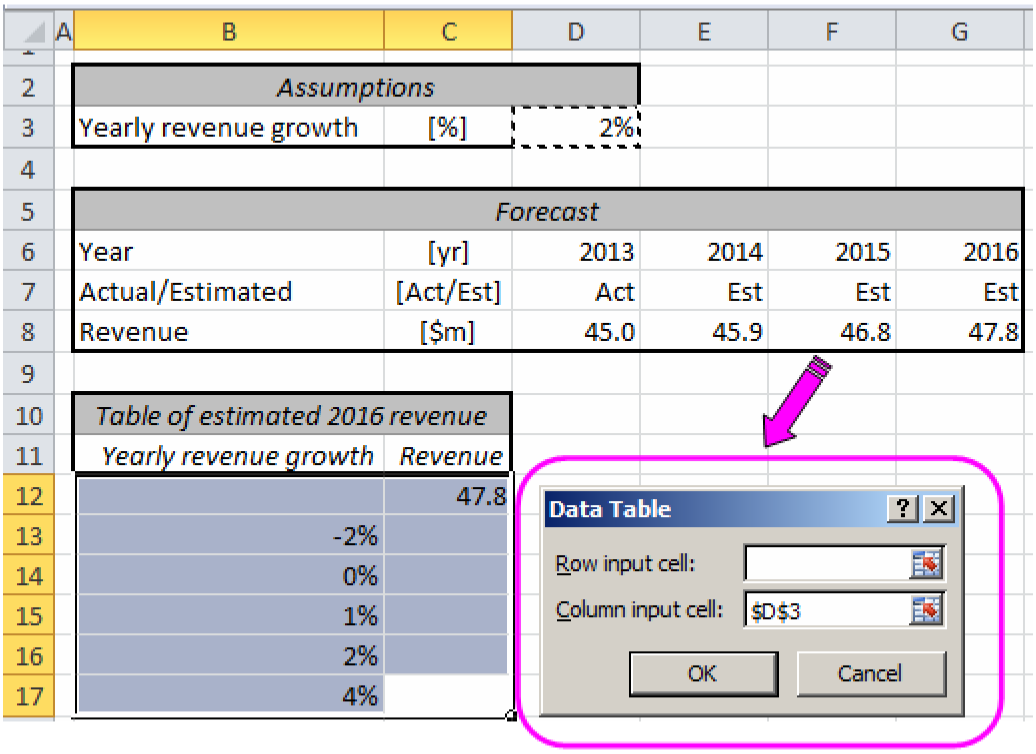
	A	B	C	D	E	F	G
2		*Assumptions*					
3		Yearly revenue growth	[%]	2%			
4							
5		*Forecast*					
6		Year	[yr]	2013	2014	2015	2016
7		Actual/Estimated	[Act/Est]	Act	Est	Est	Est
8		Revenue	[$m]	45.0	45.9	46.8	47.8
9							
10		*Table of estimated 2016 revenue*					
11		*Yearly revenue growth*	*Revenue*				
12			=G8				
13		-2%					
14		0%					
15		1%					
16		2%					
17		4%					

Then press the ENTER key. We have defined the item the data table will tabulate. The tab Overview_step_3 in the example spreadsheet shows the result of this step.

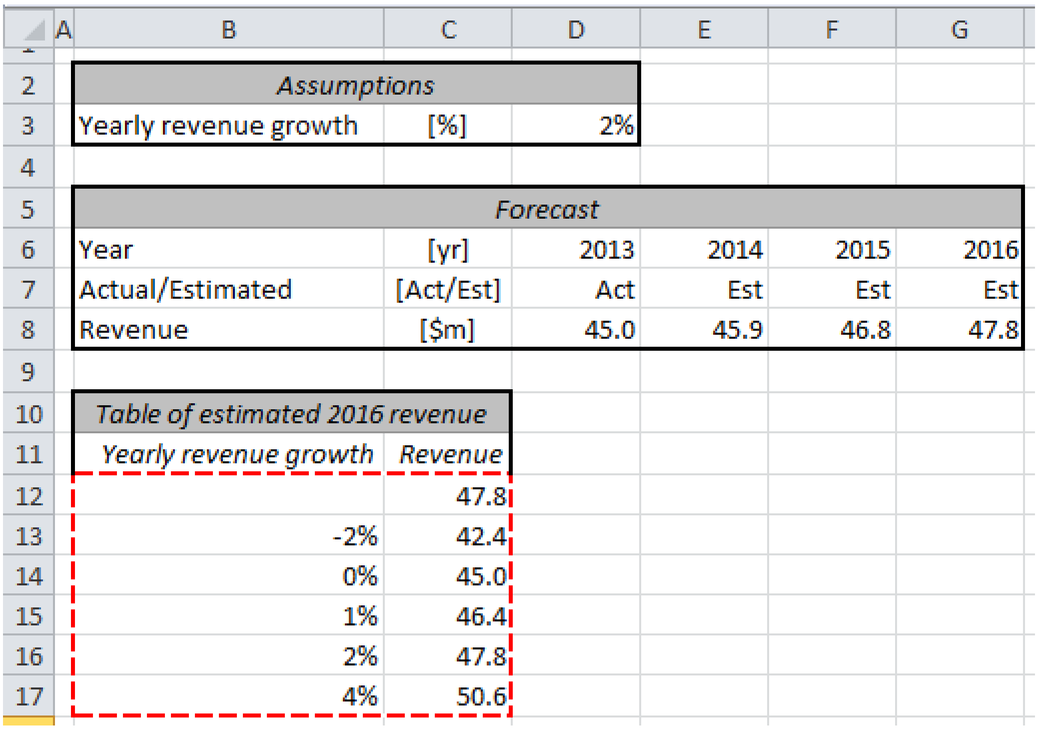
Next, select the area the data table will occupy. The leftmost column of the selection has to be the growth rate assumptions in column B. And the second column is the revenue column. The top row of the selection should be row 12 – which details what is to be tabulated.

	A	B	C	D	E	F	G
2		*Assumptions*					
3		Yearly revenue growth	[%]	2%			
4							
5		*Forecast*					
6		Year	[yr]	2013	2014	2015	2016
7		Actual/Estimated	[Act/Est]	Act	Est	Est	Est
8		Revenue	[$m]	45.0	45.9	46.8	47.8
9							
10		*Table of estimated 2016 revenue*					
11		*Yearly revenue growth*	*Revenue*				
12			47.8				
13		-2%					
14		0%					
15		1%					
16		2%					
17		4%					

Next, bring up the Data Table dialog. Do that from the Data ribbon or with the keyboard shortcuts: ALT, A, W, T.

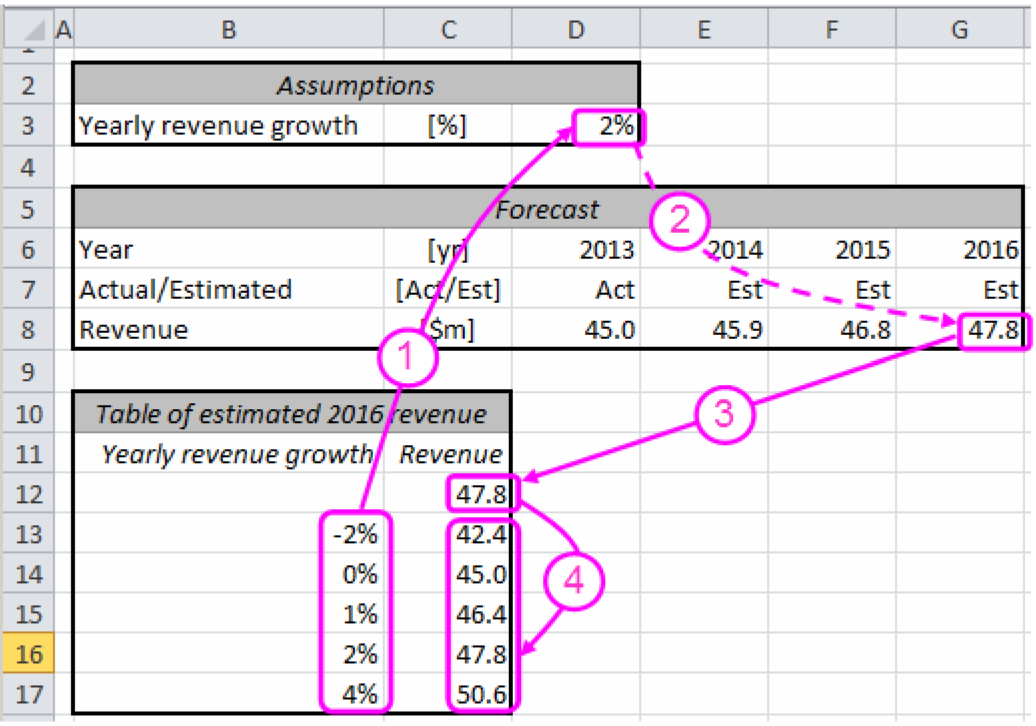


A dialog has appeared. Data tables can be arranged in columns or rows. Here we are using a column layout. In the dialog leave the "Row input cell" blank and click in the "Column input cell" field. Then click on the cell that the data table will "drive" – cell D3 – the growth assumption. Press the OK button and the data table will be constructed. The completed data table is outlined with dashes in the following illustration.



	A	B	C	D	E	F	G
2		*Assumptions*					
3		Yearly revenue growth	[%]	2%			
4							
5		*Forecast*					
6		Year	[yr]	2013	2014	2015	2016
7		Actual/Estimated	[Act/Est]	Act	Est	Est	Est
8		Revenue	[$m]	45.0	45.9	46.8	47.8
9							
10		*Table of estimated 2016 revenue*					
11		*Yearly revenue growth*	*Revenue*				
12			47.8				
13		-2%	42.4				
14		0%	45.0				
15		1%	46.4				
16		2%	47.8				
17		4%	50.6				

Overview_step_4 in the example spreadsheet shows the result of this step. The following illustration shows the steps Excel uses to fill the data table.



	A	B	C	D	E	F	G
2		*Assumptions*					
3		Yearly revenue growth	[%]	2%			
4							
5		*Forecast*					
6		Year	[yr]	2013	2014	2015	2016
7		Actual/Estimated	[Act/Est]	Act	Est	Est	Est
8		Revenue	[$m]	45.0	45.9	46.8	47.8
9							
10		*Table of estimated 2016 revenue*					
11		*Yearly revenue growth*	*Revenue*				
12			47.8				
13		-2%	42.4				
14		0%	45.0				
15		1%	46.4				
16		2%	47.8				
17		4%	50.6				

1) Excel takes the growth rates in cells B13 to B17 and puts them – one by one – into the driven cell D3. 2) Excel the recalculates the formulas that depend on cell D3. That causes the forecasts to be recalculated. 3) After each re-calculation Excel samples the cell to be tabulated - G8 and 4) puts the result into the revenue column in cells C13 to C17.

The data table recalculates automatically if any of its inputs change. In the following example we've changed the baseline 2013 revenue and that has triggered an update of the table.

Assumptions		
Yearly revenue growth	[%]	2%

Forecast					
Year	[yr]	2013	2014	2015	2016
Actual/Estimated	[Act/Est]	Act	Est	Est	Est
Revenue	[$m]	48.0	49.0	49.9	50.9

Table of estimated 2016 revenue	
Yearly revenue growth	*Revenue*
	50.9
-2%	45.2
0%	48.0
1%	49.5
2%	50.9
4%	54.0

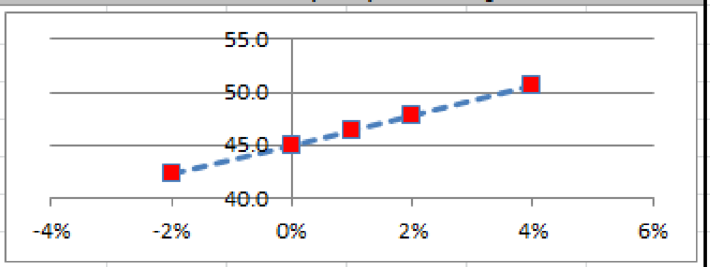
To finish this example we add a chart to display the data table results graphically. The chart is on the spreadsheet tab named Overview_final.

Assumptions		
Yearly revenue growth	[%]	2%

Forecast					
Year	[yr]	2013	2014	2015	2016
Actual/Estimated	[Act/Est]	Act	Est	Est	Est
Revenue	[$m]	45.0	45.9	46.8	47.8

Table of estimated 2016 revenue	
Yearly revenue growth	*Revenue*
	47.8
-2%	42.4
0%	45.0
1%	46.4
2%	47.8
4%	50.6

2016 Revenue vs yearly revenue growth



We have chosen a "Scatter" plot for the chart because the "x" (horizontal) data points are unevenly spaced and we need to accurately represent the relationship between the x and y variables.

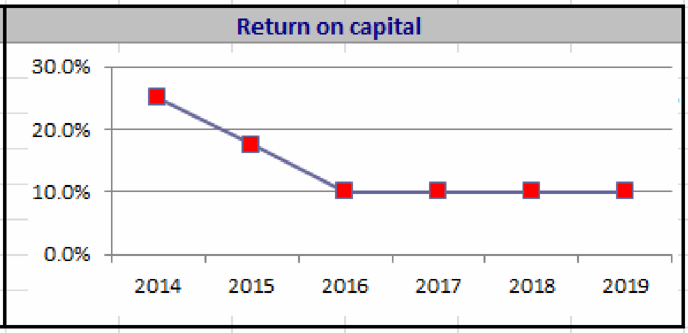
The model to be analysed

The scenario and sensitivity techniques we will next discuss may be applied to any financial model. The model we use in this document is a simple DCF (discounted cash flow) model. It is shown next. In the downloadable spreadsheet the model is on the tab named Base model. These are the main parts of the model:

Assumptions section

Model inputs or assumptions are shown in blue font and can be changed. There are three inputs: Return on capital, cost of capital and reinvestment rate. These three inputs all have two phases: 1) An initial phase and 2) a steady-state phase - making six inputs in total. The user can select a “taper period” that determines the number of years over which the model transitions from the initial phase to the steady-state phase.

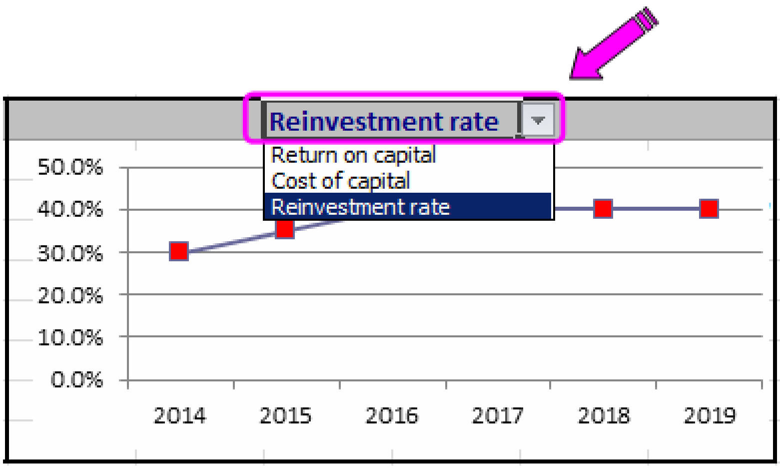
Assumptions		
Return on capital [2014]	[%]	25%
Return on capital [2016+]	[%]	10%
Cost of capital [2014]	[%]	12%
Cost of capital [2016+]	[%]	11%
Reinvest rate [2014]	[%]	30%
Reinvest rate [2016+]	[%]	40%
Taper period (years)	[1-4]	2



In the preceding example the initial return on capital is 25%, the taper period is 2 years, and the steady-state return on capital is 10%. Now look at the chart to the right above. The chart shows the return on capital. In the first year the return on capital will be its initial value of 25%, in the third year it will be steady-state value of 10% and in the second year midway between 10% and 25% (17.5%).

Charts section

A chart shows the evolution of the assumptions parameters. The user can select which input parameter they wish to chart.



Forecasts and valuation section

The model's calculations are performed in the forecasts and valuations section using a standard DCF methodology. For our purposes the most important number in this section – and the one we will focus on – is the last one: The enterprise value. The enterprise value is the present value of the forecast free cash flows.

Forecasts & Valuation								
Year	**[yr]**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Actual / Estimated	[Act/Est]	Act	Est	Est	Est	Est	Est	Est
Taper fraction	[%]		0%	50%	100%	100%	100%	100%
Last model period	[0/1]		0	0	0	0	0	1
Return on capital	[%]		25.0%	17.5%	10.0%	10.0%	10.0%	10.0%
Cost of capital	[%]		12.0%	11.5%	11.0%	11.0%	11.0%	11.0%
Reinvestment rate	[%]		30.0%	35.0%	40.0%	40.0%	40.0%	40.0%
Capital	[$m]	1,000	1,075	1,141	1,186	1,234	1,283	1,335
Earnings	[$m]		250	188	114	119	123	128
Reinvestment	[$m]		75	66	46	47	49	51
Free cash flow	[$m]		175	122	68	71	74	77
Growth in free cash flow	[%]			-30.1%	-44.0%	4.0%	4.0%	4.0%
PV of free cash flows	[$m]	1,153	1,153	1,096	1,085	1,129	1,174	1,221
Enterprise value	[$m]	**1,153**						

Scenario analysis

Currently our model works with a single scenario. If we want to study alternate scenarios we can extend the model. And we will do that now: We will add a set of scenarios to our model and allow the user to select any scenario in the set.

The first step is to define extra scenarios as shown in the following illustration.

	A	B	C	D	E	F	G	H	I
2		*Assumptions*				*Scenarios & Valuations*			
3							*1*	*2*	*3*
4		Return on capital [2014]	[%]	21%			**25%**	**21%**	**18%**
5		Return on capital [2016+]	[%]	8%			**10%**	**8%**	**7%**
6		Cost of capital [2014]	[%]	14%			**12%**	**14%**	**15%**
7		Cost of capital [2016+]	[%]	12%			**11%**	**12%**	**13%**
8		Reinvest rate [2014]	[%]	40%			**30%**	**40%**	**40%**
9		Reinvest rate [2016+]	[%]	50%			**40%**	**50%**	**50%**
10		Taper period (years)	[1-3]	3					
11		Chosen scenario	[1-3]	2					

In the spreadsheet example this stage of the model is on the tab named Scenarios_step_1. We have defined three scenarios. If we need to add more scenarios they can be added to the right of scenario 3. We have coloured the scenario inputs blue to keep to our convention of displaying inputs in that colour.

We have also added another user input – a scenario selection cell.

	A	B	C	D	E	F	G	H	I
1									
2		*Assumptions*				*Scenarios & Valuations*			
3							*1*	*2*	*3*
4		Return on capital [2014]	[%]	21%			25%	21%	18%
5		Return on capital [2016+]	[%]	8%			10%	8%	7%
6		Cost of capital [2014]	[%]	14%			12%	14%	15%
7		Cost of capital [2016+]	[%]	12%			11%	12%	13%
8		Reinvest rate [2014]	[%]	40%			30%	40%	40%
9		Reinvest rate [2016+]	[%]	50%			40%	50%	50%
10		Taper period (years)	[1-3]	3					
11		Chosen scenario	[1-3]	2					

This is a data-validated cell: We allow the user only three inputs: 1, 2 or 3.

Note that the Chosen scenario input (in cell D11) and the Taper period input (in cell D10) are shown in blue. But the other parameters in column D are no longer in blue – we have changed them back to the default – black – font. The reason is that those numbers should no longer be set directly by the user. Instead, an Excel formula should set the number based on the user's scenario choice. What formula do we use for those cells? There are a range of possibilities. We will use the following.

	A	B	C	D	E	F	G	H	I
1									
2		*Assumptions*				*Scenarios & Valuations*			
3							*1*	*2*	*3*
4		Return on capital [2014]	[%]	21%			25%	21%	18%
5		Return on capital [2016+]	[%]	=LOOKUP($D$11,$G$3:$I$3,G5:I5)			10%	8%	7%
6		Cost of capital [2014]	[%]	14%			12%	14%	15%
7		Cost of capital [2016+]	[%]	12%			11%	12%	13%
8		Reinvest rate [2014]	[%]	40%			30%	40%	40%
9		Reinvest rate [2016+]	[%]	50%			40%	50%	50%
10		Taper period (years)	[1-3]	3					
11		Chosen scenario	[1-3]	2					

A LOOKUP function is used. Consider the preceding illustration. The LOOKUP's first parameter is $D$11 – the user's scenario choice. The LOOKUP looks for that number in the range specified in its second parameter: $G$3:$I$3. When LOOKUP finds a match it returns the number in the corresponding position in its third argument: G5:I5. In this example LOOKUP will return 8%.

As constructed, the LOOKUP function can be copy-and-pasted down. It will also cope if additional scenarios are defined.

Our model with scenarios is now working: The user can select a scenario and the model will perform the calculations for the chosen scenario.

Extend the model – Add an executive summary

We next want to add an "Executive summary".

The summary should show the model's valuation figure for all three scenarios **at the same time**. We would like the summary to look something like this:

How can we show the three scenario's outputs without duplicating the calculations? By using a data table. We will show how.

Scenarios & Valuations			
	1	*2*	*3*
	25%	**21%**	**18%**
	10%	**8%**	**7%**
	12%	**14%**	**15%**
	11%	**12%**	**13%**
	30%	**40%**	**40%**
	40%	**50%**	**50%**
Enterprise value:	1,217	748	566

We will construct a data table in cells F10:I11 (highlighted in the following illustration). This data table will have a horizontal orientation rather than the vertical orientation illustrated earlier.

	A	B	C	D	E	F	G	H	I
2		*Assumptions*				*Scenarios & Valuations*			
3							*1*	*2*	*3*
4		Return on capital [2014]	[%]	25%			**25%**	**21%**	**18%**
5		Return on capital [2016+]	[%]	10%			**10%**	**8%**	**7%**
6		Cost of capital [2014]	[%]	12%			**12%**	**14%**	**15%**
7		Cost of capital [2016+]	[%]	11%			**11%**	**12%**	**13%**
8		Reinvest rate [2014]	[%]	30%			**30%**	**40%**	**40%**
9		Reinvest rate [2016+]	[%]	40%			**40%**	**50%**	**50%**
10		Taper period (years)	[1-3]	3			*1*	*2*	*3*
11		Chosen scenario	[1-3]	1		=D27			
13					*Forecasts*				
14		**Year**	**[yr]**	**2,013**	**2,014**	**2,015**	**2,016**	**2,017**	**2,018**
15		Actual / Estimated	[Act/Est]	Act	Est	Est	Est	Est	Est
16		Taper fraction	[%]		0%	33%	67%	100%	100%
17		Last model period	[0/1]		0	0	0	0	1
18		Return on capital	[%]		25.0%	20.0%	15.0%	10.0%	10.0%
19		Cost of capital	[%]		12.0%	11.7%	11.3%	11.0%	11.0%
20		Reinvestment rate	[%]		30.0%	33.3%	36.7%	40.0%	40.0%
21		Capital	[$m]	1,000	1,075	1,147	1,210	1,258	1,308
22		Earnings	[$m]		250	215	172	121	126
23		Reinvestment	[$m]		75	72	63	48	50
24		Free cash flow	[$m]		175	143	109	73	75
25		Growth in free cash flow	[%]			-18.1%	-24.0%	-33.4%	4.0%
26		PV of free cash flows	[$m]	1,217	1,217	1,167	1,143	1,151	1,197
27		Enterprise value	[$m]	**1,217**					

With this format of data table we specify the value to be tabulated in the bottom left corner of the data table. So in cell F11 we define what is to be tabulated: It is the enterprise value calculated in cell D27.

Then, in cells G10:I10, we list the three scenario numbers: 1,2 and 3.

This stage of the model is shown on the tab Scenarios_step_2.

Next, select cells F10:I11 and then bring up the data table dialog. We will define the cell to be "driven" by the data table.

	A	B	C	D	E	F	G	H	I
1									
2		*Assumptions*				*Scenarios & Valuations*			
3							*1*	*2*	*3*
4		Return on capital [2014]	[%]	25%			25%	21%	18%
5		Return on capital [2016+]	[%]	10%			10%	8%	7%
6		Cost of capital [2014]	[%]	12%			12%	14%	15%
7		Cost of capital [2016+]	[%]	11%			11%	12%	13%
8		Reinvest rate [2014]	[%]	30%			30%	40%	40%
9		Reinvest rate [2016+]	[%]	40%			40%	50%	50%
10		Taper period (years)	[1-3]	3			*1*	*2*	*3*
11		Chosen scenario	[1-3]	1		1,217			
13		*Forecasts*							
14		**Year**	**[yr]**	**2,013**	**2,014**	**2,(**			
15		Actual / Estimated	[Act/Est]	Act	Est				
16		Taper fraction	[%]		0%	:			
17		Last model period	[0/1]		0				
18		Return on capital	[%]		25.0%	20			
19		Cost of capital	[%]		12.0%	11			
20		Reinvestment rate	[%]		30.0%	33.3%	36.7%	40.0%	40.0%
21		Capital	[$m]	1,000	1,075	1,147	1,210	1,258	1,308
22		Earnings	[$m]		250	215	172	121	126
23		Reinvestment	[$m]		75	72	63	48	50
24		Free cash flow	[$m]		175	143	109	73	75
25		Growth in free cash flow	[%]			-18.1%	-24.0%	-33.4%	4.0%
26		PV of free cash flows	[$m]	1,217	1,217	1,167	1,143	1,151	1,197
27		Enterprise value	[$m]	**1,217**					

Data Table

Row input cell: $D$11

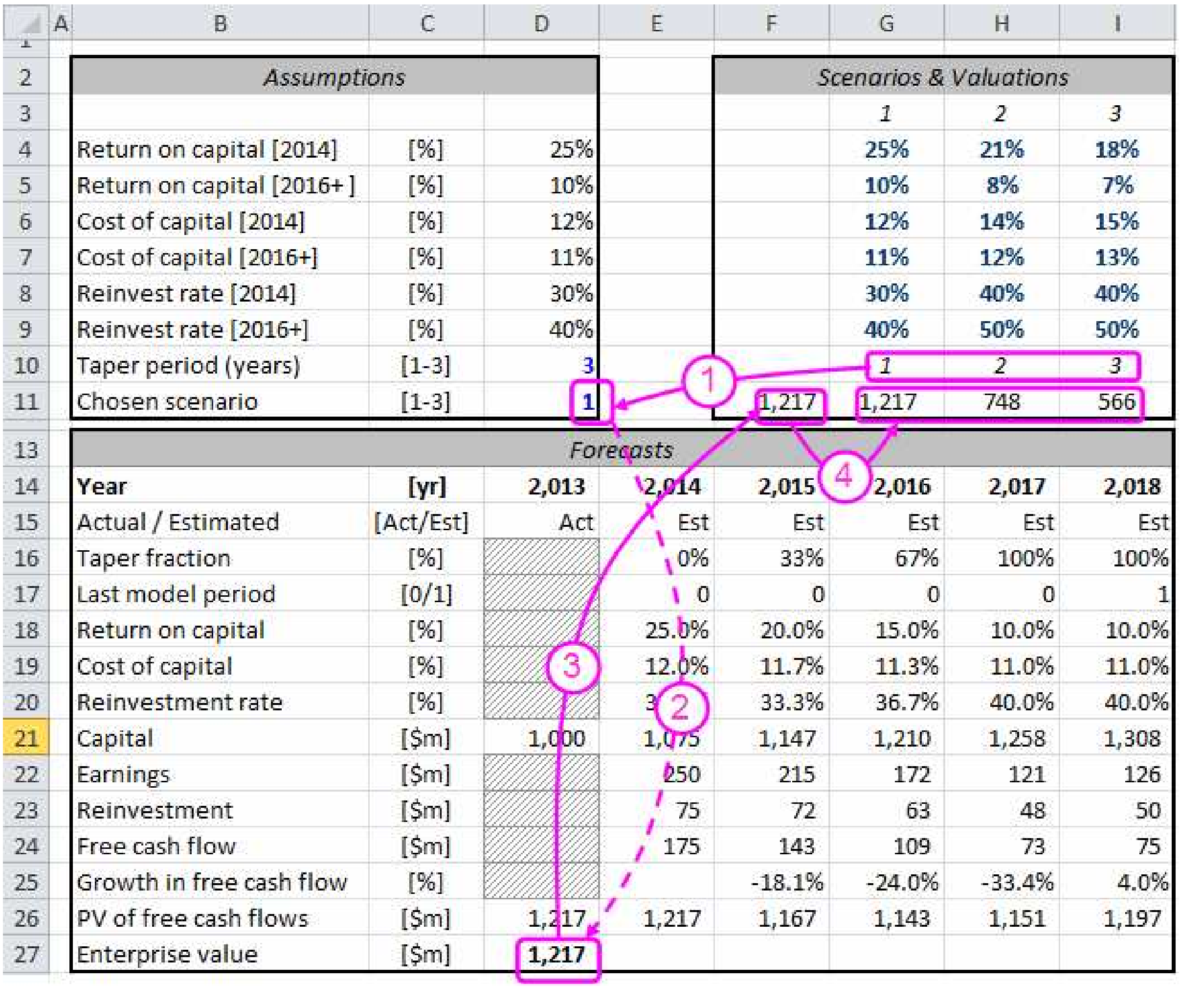
Column input cell:

OK Cancel

The cell to be driven is the scenario choice cell (D11).

Press OK and the data table is complete. The "executive summary" is calculated and shown. This stage of the model is on tab Scenarios_step_3.

This is the flow of information through the model (refer to the following illustration):



	A	B	C	D	E	F	G	H	I
2		Assumptions				Scenarios & Valuations			
3							1	2	3
4		Return on capital [2014]	[%]	25%			25%	21%	18%
5		Return on capital [2016+]	[%]	10%			10%	8%	7%
6		Cost of capital [2014]	[%]	12%			12%	14%	15%
7		Cost of capital [2016+]	[%]	11%			11%	12%	13%
8		Reinvest rate [2014]	[%]	30%			30%	40%	40%
9		Reinvest rate [2016+]	[%]	40%			40%	50%	50%
10		Taper period (years)	[1-3]	3			1	2	3
11		Chosen scenario	[1-3]	1		1,217	1,217	748	566
13		Forecasts							
14		Year	[yr]	2,013	2,014	2,015	2,016	2,017	2,018
15		Actual / Estimated	[Act/Est]	Act	Est	Est	Est	Est	Est
16		Taper fraction	[%]		0%	33%	67%	100%	100%
17		Last model period	[0/1]		0	0	0	0	1
18		Return on capital	[%]		25.0%	20.0%	15.0%	10.0%	10.0%
19		Cost of capital	[%]		12.0%	11.7%	11.3%	11.0%	11.0%
20		Reinvestment rate	[%]		3[illegible]	33.3%	36.7%	40.0%	40.0%
21		Capital	[$m]	1,000	1,075	1,147	1,210	1,258	1,308
22		Earnings	[$m]		250	215	172	121	126
23		Reinvestment	[$m]		75	72	63	48	50
24		Free cash flow	[$m]		175	143	109	73	75
25		Growth in free cash flow	[%]			-18.1%	-24.0%	-33.4%	4.0%
26		PV of free cash flows	[$m]	1,217	1,217	1,167	1,143	1,151	1,197
27		Enterprise value	[$m]	1,217					

1) Excel reads cell G10 (the first cell in the top row of the data table). It puts G10's value [1] into the driven cell D11. D11 is the chosen scenario. 2) The model then recalculates all the cells that depend on the scenario choice. A new enterprise value is generated in cell D27. D27 is the enterprise value corresponding to scenario 1. 3) Excel samples D27's value and 4) places it into cell G11 in the data table. Excel repeats: It puts H10's value [2] into the driven cell D11. The model recalculates. Excel samples the new enterprise value in D27 and places it into cell H11. And so on.

We'll improve the spreadsheet's presentation a little: Although cells F11 and G10:I10 are needed to make the data table work they give no useful information to the spreadsheet user. We will hide the cells G10:I10 and will relabel cell F11.

The easiest way of hiding G10:I10 is simply to change the font colour to white.

We will relabel F11 to show "Value" instead of a number. But we cannot do that by simply typing "Value" into the cell because that cell is the input to the data table. If we did that then the whole data table would simply show "Value". So we want the data table to see a number but want the reader of the spreadsheet to see "Value". To achieve that we use Custom Formatting.

Begin by right-mouse-clicking on cell F11 and choose "Format Cells…" from the pop-up menu that appears. A Format Cells dialog will appear. Make sure the Number tab is selected. In the Category list in the left of the dialog click on the Custom entry near the bottom. In the “Type” field type “Value”. That forces Excel to display any number as the word “Value”.

The final version of the scenarios model is shown on the spreadsheet tab Scenarios_final.

Attribution / Waterfall analysis

Consider the valuations we obtained for scenarios 1 and 2 in the preceding section.

Assumptions		
Return on capital [2014]	[%]	25%
Return on capital [2016+]	[%]	10%
Cost of capital [2014]	[%]	12%
Cost of capital [2016+]	[%]	11%
Reinvest rate [2014]	[%]	30%
Reinvest rate [2016+]	[%]	40%
Chosen scenario	[1-3]	1

Scenarios & Valuations		
	1	*2*
	25%	**21%**
	10%	**8%**
	12%	**14%**
	11%	**12%**
	30%	**40%**
	40%	**50%**
Value	1,217	748

Scenario 1 generated an enterprise value of 1,217 and scenario 2 - 748. Those values differ by 469. Suppose you show those results to your boss and you’re asked this question: “Where does the 469 difference come from?” It comes from differing assumptions: Scenario 1 assumes the initial return on capital is 25% whereas scenario 2 assumes the initial return on capital is 21%. That explains part of the 469 difference between scenario outcomes. But how much does it explain? A large amount? Or a small amount? And the other assumptions that differ – what is their contribution? We will find out by doing an attribution analysis. To do that we will use a data table.

We begin by making a revision to the assumptions section: We add a parameter – we will call it a “blending index”.

	A	B	C	D	E	F	G	H	I
2		*Assumptions*				*Scenarios*			*Index*
3		Taper period (years)	[1-3]	3		*1*	*2*		
4		Blending index	[0-6]	2					0
5		Return on capital [2014]	[%]	21%		**25%**	**21%**		1
6		Return on capital [2016+]	[%]	8%		**10%**	**8%**		2
7		Cost of capital [2014]	[%]	12%		**12%**	**14%**		3
8		Cost of capital [2016+]	[%]	11%		**11%**	**12%**		4
9		Reinvest rate [2014]	[%]	30%		**30%**	**40%**		5
10		Reinvest rate [2016+]	[%]	40%		**40%**	**50%**		6

We next put numbers into column I. The numbers start at zero and step up by one. Those numbers are parameter numbers: The number 1 in the Ith column is on row 5. And row 5 contains the first assumption that feeds into the model – the initial return on capital. Number 2 is on row 6. Row 6 contains the second model assumption – steady state return on capital. Number 3 is on row 7. Row 7 contains the third model assumption – initial cost of capital. And so on.

Then we modify the formulae in column D. We want the formulae to choose a mix of numbers – some from scenario 1 and the others from scenario 2. The blending index in cell D4 determines which numbers come from scenario 1 and which from scenario 2? The following diagram illustrates. The blending index is 2.

	A	B	C	D	E	F	G	H	I
2		*Assumptions*				*Scenarios*			*Index*
3		Taper period (years)	[1-3]	3		*1*	*2*		
4		Blending index	[0-6]	2					0
5		Return on capital [2014]	[%]	21%		25%	21%		1
6		Return on capital [2016+]	[%]	8%		10%	8%		2
7		Cost of capital [2014]	[%]	12%		12%	14%		3
8		Cost of capital [2016+]	[%]	11%		11%	12%		4
9		Reinvest rate [2014]	[%]	30%		30%	40%		5
10		Reinvest rate [2016+]	[%]	40%		40%	50%		6

The first two parameters in column D are obtained from scenario 2. The remaining parameters come from scenario 1. The blending index controls how many of scenario 2's assumptions are passed to the model: If the index is zero then none of scenario 2 is used and the model uses all of scenario 1's assumptions. If the index is six then all of scenario 2 is used and none of scenario 1. By iterating the blending index from 0 to 6 we can "morph" scenario 1 into scenario 2. The formula for column D is short and simple. In the following illustration look at the formula in cell D5.

	A	B	C	D	E	F	G	H	I
2		*Assumptions*				*Scenarios*			*Index*
3		Taper period (years)	[1-3]	3		*1*	*2*		
4		Blending index	[0-6]	2					0
5		Return on capital [2014]	[%]	=IF(I5<=$D$4,G5,F5)		25%	21%		1
6		Return on capital [2016+]	[%]	8%		10%	8%		2
7		Cost of capital [2014]	[%]	12%		12%	14%		3
8		Cost of capital [2016+]	[%]	11%		11%	12%		4
9		Reinvest rate [2014]	[%]	30%		30%	40%		5
10		Reinvest rate [2016+]	[%]	40%		40%	50%		6

This is what the formula does: It looks at the parameter number in I5 and tests if is less than or equal to the blending index in $D$4. If it is less then the formula chooses scenario 2's parameter - G5. Otherwise it chooses scenario 1's parameter – F5.

In the example spreadsheet the tab labelled Attribution_step_1 corresponds to this stage of the attribution model.

Next we add a data table. The table will drive the blending index and sample the enterprise value. In cell J3 define what the data table will tabulate.

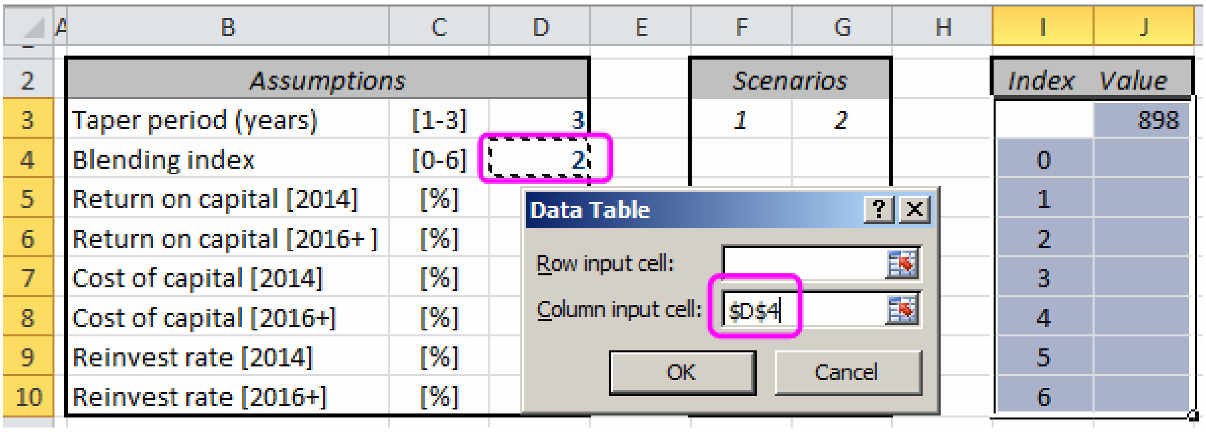
	A	B	C	D	E	F	G	H	I	J
2		Assumptions				Scenarios			Index	Value
3		Taper period (years)	[1-3]	3		1	2			=D27
4		Blending index	[0-6]	2					0	
5		Return on capital [2014]	[%]	21%		25%	21%		1	
6		Return on capital [2016+]	[%]	8%		10%	8%		2	
7		Cost of capital [2014]	[%]	12%		12%	14%		3	
8		Cost of capital [2016+]	[%]	11%		11%	12%		4	
9		Reinvest rate [2014]	[%]	30%		30%	40%		5	
10		Reinvest rate [2016+]	[%]	40%		40%	50%		6	
11										
13		Forecasts								
14		Year	[yr]	2,013	2,014	2,015	2,016	2,017	2,018	
15		Actual / Estimated	[Act/Est]	Act	Est	Est	Est	Est	Est	
16		Taper fraction	[%]		0%	33%	67%	100%	100%	
17		Last model period	[0/1]		0	0	0	0	1	
18		Return on capital	[%]		21.0%	16.7%	12.3%	8.0%	8.0%	
19		Cost of capital	[%]		12.0%	11.7%	11.3%	11.0%	11.0%	
20		Reinvestment rate	[%]		30.0%	33.3%	36.7%	40.0%	40.0%	
21		Capital	[$m]	1,000	1,063	1,122	1,173	1,210	1,249	
22		Earnings	[$m]		210	177	138	94	97	
23		Reinvestment	[$m]		63	59	51	38	39	
24		Free cash flow	[$m]		147	118	88	56	58	
25		Growth in free cash flow	[%]			-19.7%	-25.8%	-35.8%	3.2%	
26		PV of free cash flows	[$m]	898	898	841	807	801	827	
27		Value	[$m]	898						

The data table will tabulate the enterprise value generated in cell D27. Next, select the area that the data table will occupy.

	A	B	C	D	E	F	G	H	I	J
2		Assumptions				Scenarios			Index	Value
3		Taper period (years)	[1-3]	3		1	2			898
4		Blending index	[0-6]	2					0	
5		Return on capital [2014]	[%]	21%		25%	21%		1	
6		Return on capital [2016+]	[%]	8%		10%	8%		2	
7		Cost of capital [2014]	[%]	12%		12%	14%		3	
8		Cost of capital [2016+]	[%]	11%		11%	12%		4	
9		Reinvest rate [2014]	[%]	30%		30%	40%		5	
10		Reinvest rate [2016+]	[%]	40%		40%	50%		6	

Bring up the data table dialog: Data | What-If Analysis | Data Table. In the Data Table dialog set the Column input cell to $D$4 (the blending index).

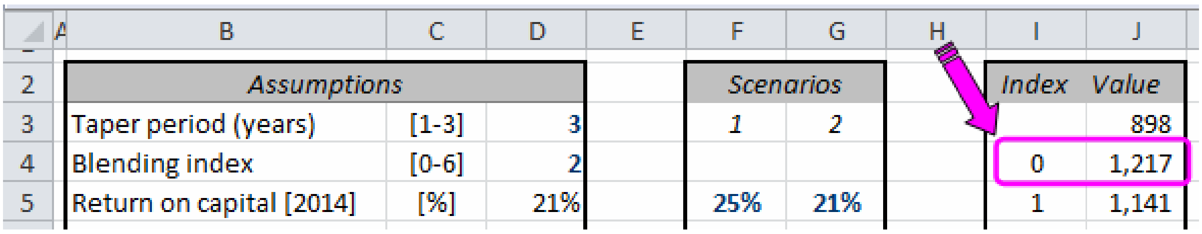
Hands-on guide to scenario analysis



	B	C	D	E	F	G	H	I	J
2	*Assumptions*				*Scenarios*			*Index*	*Value*
3	Taper period (years)	[1-3]	3		*1*	*2*			898
4	Blending index	[0-6]	2					0	
5	Return on capital [2014]	[%]						1	
6	Return on capital [2016+]	[%]						2	
7	Cost of capital [2014]	[%]						3	
8	Cost of capital [2016+]	[%]						4	
9	Reinvest rate [2014]	[%]						5	
10	Reinvest rate [2016+]	[%]						6	

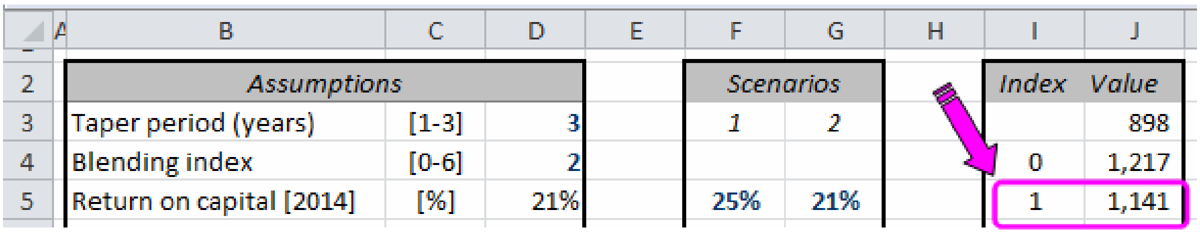
Press the OK button. The data table will be complete. In the example spreadsheet the tab labelled Attribution_step_2 corresponds to this stage of the model.

We can now begin interpreting the models' results. The enterprise value for a blending index of 0 is 1,217. A blending index of 0 corresponds to a scenario that is entirely composed of scenario 1's assumptions. So 1,217 is scenario 1's enterprise value.



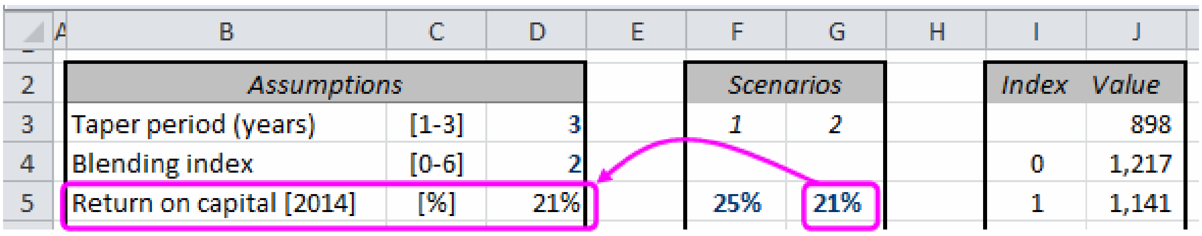
	B	C	D	E	F	G	H	I	J
2	*Assumptions*				*Scenarios*			*Index*	*Value*
3	Taper period (years)	[1-3]	3		*1*	*2*			898
4	Blending index	[0-6]	2					0	1,217
5	Return on capital [2014]	[%]	21%		25%	21%		1	1,141

A blending index of 1 gives an enterprise value of 1,141.



	B	C	D	E	F	G	H	I	J
2	*Assumptions*				*Scenarios*			*Index*	*Value*
3	Taper period (years)	[1-3]	3		*1*	*2*			898
4	Blending index	[0-6]	2					0	1,217
5	Return on capital [2014]	[%]	21%		25%	21%		1	1,141

A blending index of 1 corresponds to a parameter set composed entirely of scenario 1's parameters but with the exception that scenario 2's assumption is used for the initial return on capital.



	B	C	D	E	F	G	H	I	J
2	*Assumptions*				*Scenarios*			*Index*	*Value*
3	Taper period (years)	[1-3]	3		*1*	*2*			898
4	Blending index	[0-6]	2					0	1,217
5	Return on capital [2014]	[%]	21%		25%	21%		1	1,141

The difference between the two enterprise values of 1,217 and 1,141 is a decrease of 76. We can conclude that $76 of the $748 difference between the two scenario's enterprise values is due to the differing assumptions about initial return on capital.

It is helpful to see the attribution results graphically in the form of a "waterfall" chart. And that is what we will do next.

The waterfall calculations are shown in the illustration to the right.

Index	*Value*
	898
0	1,217
1	1,141
2	898
3	874
4	811
5	797
6	748

Waterfall		
	Base	Height
Scenari	1,217	0
Return	=MIN(J5,J4)	
Return	898	243
Cost of	874	24
Cost of	811	63
Reinves	797	14
Reinves	748	49
Scenari	748	0

A waterfall chart is best constructed from a stacked column chart composed of two series: A "base" series and a "height" series. The preceding illustration shows one possible formula for the base series: =MIN(…). The base is set to the minimum of the current enterprise value and the preceding enterprise value.

This illustration to the right shows one possible formula for the "height" series: =ABS(…).

Index	*Value*
	898
0	1,217
1	1,141
2	898
3	874
4	811
5	797
6	748

Waterfall		
	Base	Height
Scenari	1,217	0
Return	1,141	=ABS(J5-J4)
Return	898	243
Cost of	874	24
Cost of	811	63
Reinves	797	14
Reinves	748	49
Scenari	748	0

The height is set to the absolute value of the difference between the current and preceding enterprise values.

Why do we need to use the MIN and ABS functions? The reason is that stacked column charts do not display properly if the height parameter is negative. So we need to ensure the "stacking" always uses positive numbers.

This stage of the model is shown on the tab labelled Attribution_step_3.

Next we add a chart. This is shown on example spreadsheet on the tab labelled Attribution_step_4. The attribution model currently looks like this.

Hands-on guide to scenario analysis

Assumptions		
Taper period (years)	[1-3]	3
Blending index	[0-6]	2
Return on capital [2014]	[%]	21%
Return on capital [2016+]	[%]	8%
Cost of capital [2014]	[%]	12%
Cost of capital [2016+]	[%]	11%
Reinvest rate [2014]	[%]	30%
Reinvest rate [2016+]	[%]	40%

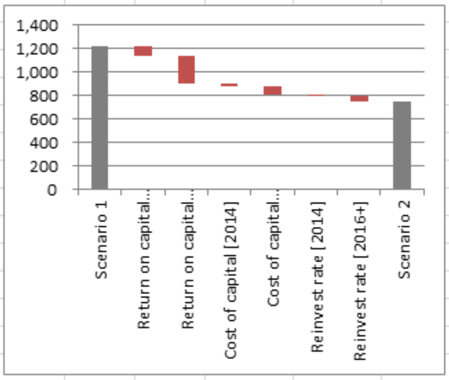
Scenarios	
1	2
25%	21%
10%	8%
12%	14%
11%	12%
30%	40%
40%	50%

Index	Value
	898
0	1,217
1	1,141
2	898
3	874
4	811
5	797
6	748

Waterfall		
	Base	Height
Scenari	1,217	0
Return o	1,141	75
Return o	898	243
Cost of	874	24
Cost of	811	63
Reinves	797	14
Reinves	748	49
Scenari	748	0

Forecasts							
Year	**[yr]**	**2,013**	**2,014**	**2,015**	**2,016**	**2,017**	**2,018**
Actual / Estimated	[Act/Est]	Act	Est	Est	Est	Est	Est
Taper fraction	[%]		0%	33%	67%	100%	100%
Last model period	[0/1]		0	0	0	0	1
Return on capital	[%]		21.0%	16.7%	12.3%	8.0%	8.0%
Cost of capital	[%]		12.0%	11.7%	11.3%	11.0%	11.0%
Reinvestment rate	[%]		30.0%	33.3%	36.7%	40.0%	40.0%
Capital	[$m]	1,000	1,063	1,122	1,173	1,210	1,249
Earnings	[$m]		210	177	138	94	97
Reinvestment	[$m]		63	59	51	38	39
Free cash flow	[$m]		147	118	88	56	58
Growth in free cash flow	[%]			-19.7%	-25.8%	-35.8%	3.2%
PV of free cash flows	[$m]	898	898	841	807	801	827
Value	[$m]	**898**					

Enterprise value waterfall



If we want the waterfall chart to cope with all possible results we need to make one further elaboration: The current version will not display correctly if the quantity being modelled becomes negative.

We can demonstrate this effect by changing one of the calculations: Instead of calculating the enterprise value we will instead calculate economic value added. Economic value added is the enterprise value less the capital employed to generate that enterprise value. The required change is shown to the right.

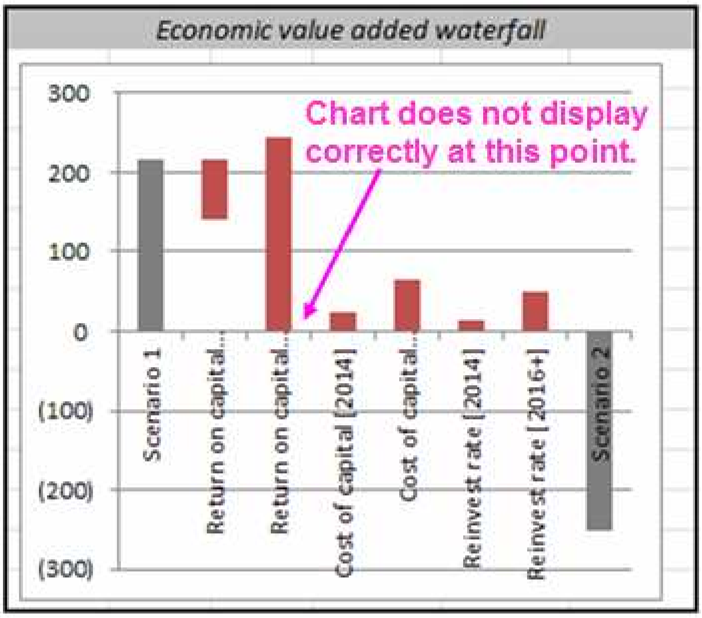
	A	B	C	D
18		Return on capital	[%]	
19		Cost of capital	[%]	
20		Reinvestment rate	[%]	
21		Capital	[$m]	1,000
22		Earnings	[$m]	
23		Reinvestment	[$m]	
24		Free cash flow	[$m]	
25		Growth in free cash flow	[%]	
26		PV of free cash flows	[$m]	898
27		Economic value added	[$m]	=D26-D21

We have changed the calculation in cell D27. The new formula takes the enterprise value (898 in this example) and subtracts the capital employed (1,000 in this example).

The economic value added (EVA) is therefore 898 less 1,000 = minus 102.

That calculation feeds through into the waterfall chart (which now becomes an "Economic value added waterfall chart").

We can see that the chart does not display correctly when the EVA becomes negative.

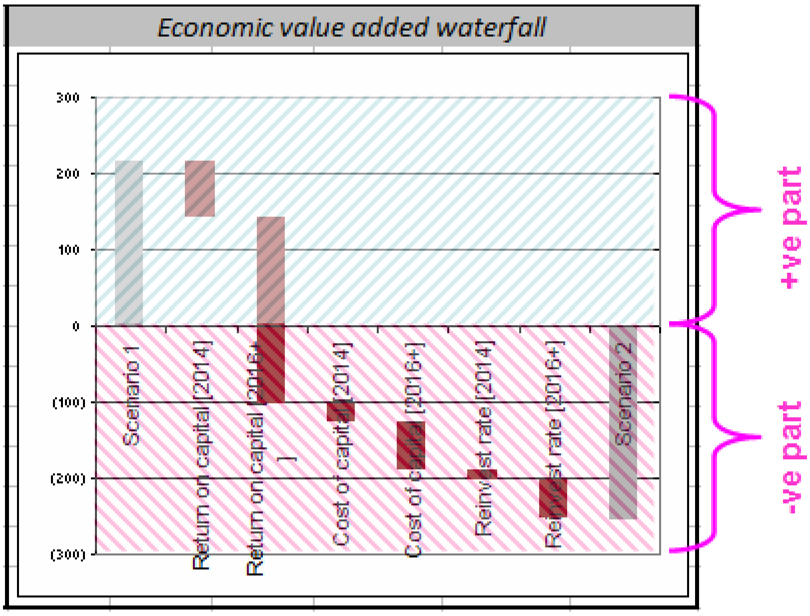


Instead, when displayed properly, the chart should look like this:

Notice that the third – return on capital – column crosses the zero axis.

To make this more general version of the waterfall chart display properly we maintain both positive and negative parts.

We arrange for the positive and negative parts to show the same colour so that the chart appears to cross through the zero axis.



Look at the tab labelled Attribution_final on the example spreadsheet to see how this version of the waterfall chart works.

Columns L through O contain the formulae needed to construct the chart.

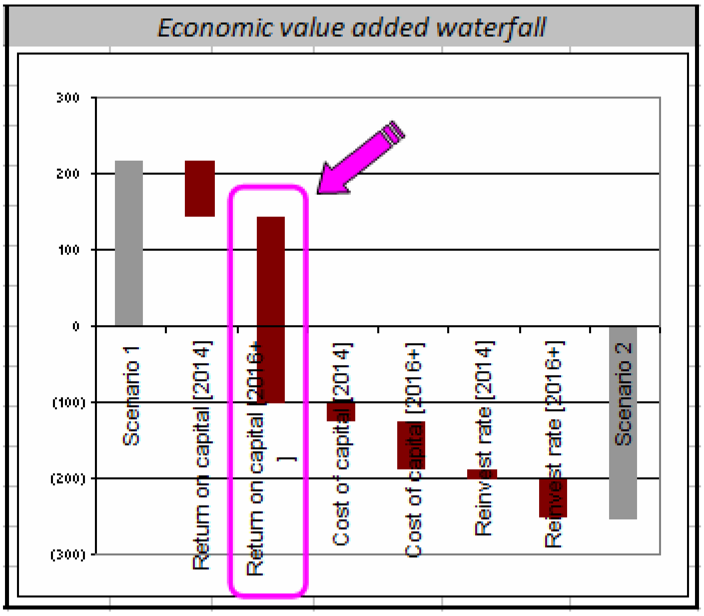
Note that both negative and positive bases and heights are calculated.

Columns L and M maintain the negative parts and N and O the positive.

J	K	L	M	N	O
Waterfall					
	Start&E	Base -	Height -	Base+	Height+
Scenari	217				
Return on capita		0	0	141	75
Return on capita		0	(102)	0	141
Cost of capital [2		(102)	(24)	0	0
Cost of capital [2		(126)	(63)	0	0
Reinvest rate [2		(189)	(14)	0	0
Reinvest rate [2		(203)	(49)	0	0
Scenari	(252)				

Sensitivity Analysis

Let's revisit the attribution chart we derived earlier (shown to the right).



The dominant driver of the difference between the two scenarios is the steady-state return on capital parameter (highlighted). This is the column with the greatest height.

What determines the height? Two effects: 1) The extent to which that parameter differs between the two scenarios, and 2) the sensitivity of the model output to the parameter.

We can be more precise and write a formula for the height of any parameter in the attribution chart:

This is the formula: A = Δ * S

A is the height of a column in the attribution chart, Δ is the amount by which the parameter differs between the two scenarios and S is the model's sensitivity to the parameter.

And where does S - the sensitivity figure - come from? That is the subject of this section. We will look at a technique (using data tables) to determine a model's sensitivity to its drivers.

We restructure the model. Look at the following illustration.

	A	B	C	D	E	F	G	H	I
2		*Assumptions*				*Bumped*			*Index*
3		Taper period (years)	[1-3]	3		*assumptions*			
4		Bump index	[0-6]	0					0
5		Return on capital [2014]	[%]	25%			=D5+IF(I5=$D$4,1%,0)		1
6		Return on capital [2016+]	[%]	10%			10%		2
7		Cost of capital [2014]	[%]	12%			12%		3
8		Cost of capital [2016+]	[%]	11%			11%		4
9		Reinvest rate [2014]	[%]	30%			30%		5
10		Reinvest rate [2016+]	[%]	40%			40%		6

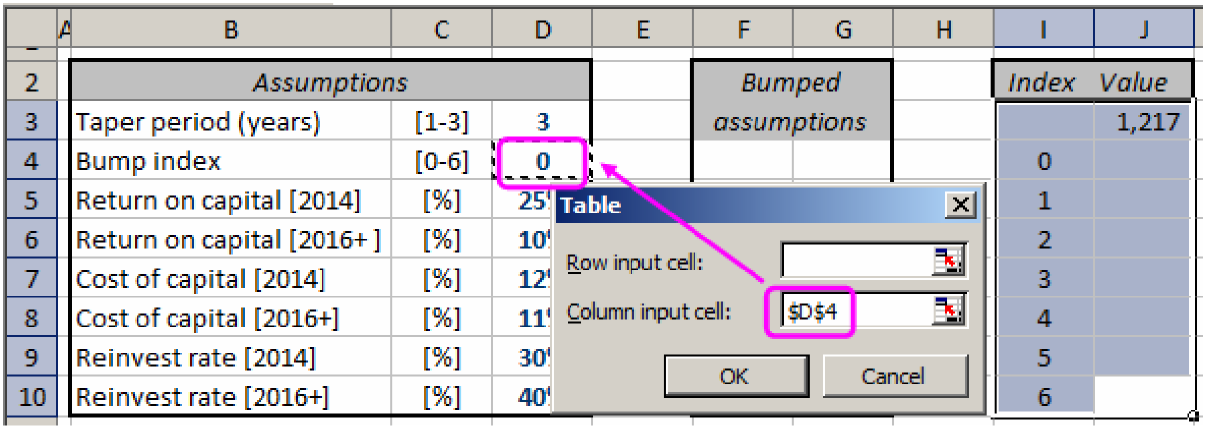
The assumption parameters are put back in the D column. We add a new column - G – which we call "Bumped" assumptions. The Bumped assumptions are the same as those in column D but with one exception: One of the parameters is increased by 1%. Which parameter? That is determined by the "Bump index" in cell D4. Each parameter is assigned a number and whichever parameter's number matches the bump index is the one that is incremented. The formula in cell G5 illustrates how that works. The bumped assumption in G5 is the same as in D5 but is increased by 1% if the bump index in $D$4 matches the parameter number in I5. The bumped assumptions then fed through into the rest of the model.

This stage of the model is in the example spreadsheet on the tab labelled Sensitivities_step_1.

Next we begin constructing a data table. In cell J3 define what is to be tabulated – the enterprise value in D27.

	B	C	D	E	F	G	H	I	J
2	*Assumptions*				*Bumped assumptions*			*Index*	*Value*
3	Taper period (years)	[1-3]	3						=D27
4	Bump index	[0-6]	0					0	
5	Return on capital [2014]	[%]	25%			25%		1	
6	Return on capital [2016+]	[%]	10%			10%		2	
7	Cost of capital [2014]	[%]	12%			12%		3	
8	Cost of capital [2016+]	[%]	11%			11%		4	
9	Reinvest rate [2014]	[%]	30%			30%		5	
10	Reinvest rate [2016+]	[%]	40%			40%		6	
11									
13	*Forecasts*								
14	**Year**	**[yr]**	**2,013**	**2,014**	**2,015**	**2,016**	**2,017**	**2,018**	
15	Actual / Estimated	[Act/Est]	Act	Est	Est	Est	Est	Est	
16	Taper fraction	[%]		0%	33%	67%	100%	100%	
17	Last model period	[0/1]		0	0	0	0	1	
18	Return on capital	[%]		25.0%	20.0%	15.0%	10.0%	10.0%	
19	Cost of capital	[%]		12.0%	11.7%	11.3%	11.0%	11.0%	
20	Reinvestment rate	[%]		30.0%	33.3%	36.7%	40.0%	40.0%	
21	Capital	[$m]	1,000	1,075	1,147	1,210	1,258	1,308	
22	Earnings	[$m]		250	215	172	121	126	
23	Reinvestment	[$m]		75	72	63	48	50	
24	Free cash flow	[$m]		175	143	109	73	75	
25	Growth in free cash flow	[%]			-18.1%	-24.0%	-33.4%	4.0%	
26	PV of free cash flows	[$m]	1,217	1,217	1,167	1,143	1,151	1,197	
27	Value	[$m]	**1,217**						

Then select the area the data table will occupy (cells I3:J10) and bring up the data table dialog. Click on the field labelled "Column input cell" and specify the cell the data table will drive – the bump index in $D$4.



Press the OK button and the data table will be complete.

	A	B	C	D	E	F	G	H	I	J
2		*Assumptions*				*Bumped*			*Index*	*Value*
3		Taper period (years)	[1-3]	3		*assumptions*				1,217
4		Bump index	[0-6]	0					0	1,217
5		Return on capital [2014]	[%]	25%			25%		1	1,236
6		Return on capital [2016+]	[%]	10%			10%		2	1,364
7		Cost of capital [2014]	[%]	12%			12%		3	1,200
8		Cost of capital [2016+]	[%]	11%			11%		4	1,113
9		Reinvest rate [2014]	[%]	30%			30%		5	1,216
10		Reinvest rate [2016+]	[%]	40%			40%		6	1,214

This stage of the model is on the tab labelled Sensitivities_step_2.

In the preceding illustration we can see that when no parameters are bumped the model output is $1,217m. If the first parameter is bumped then the model output is $1,236m. So bumping the first parameter changes the model's output from $1,217m to $1,236m i.e. an increase of $19m. We can conclude that the model's sensitivity to the first parameter is $19m per % increase.

Bumping the second parameter causes the model's output to change from $1,217m to $1,364m i.e. to increase by $147m. We can conclude that the model's sensitivity to the second parameter is $147m per % increase.

In column M we calculate sensitivities using the method just described.

	A	B	C	D	E	F	G	H	I	J	K	L	M
2		*Assumptions*				*Bumped*			*Index*	*Value*			
3		Taper period (years)	[1-3]	3		*assumptions*				1,217			
4		Bump index	[0-6]	0					0	1,217		*Sensitivities [$m]*	
5		Return on capital [2014]	[%]	25%			25%		1	1,236			=J5-$J$4
6		Return on capital [2016+]	[%]	10%			10%		2	1,364			147
7		Cost of capital [2014]	[%]	12%			12%		3	1,200			(17)
8		Cost of capital [2016+]	[%]	11%			11%		4	1,113			(104)
9		Reinvest rate [2014]	[%]	30%			30%		5	1,216			(0)
10		Reinvest rate [2016+]	[%]	40%			40%		6	1,214			(2)

This stage of the model is in the example spreadsheet on the tab labelled Sensitivities_step_3.

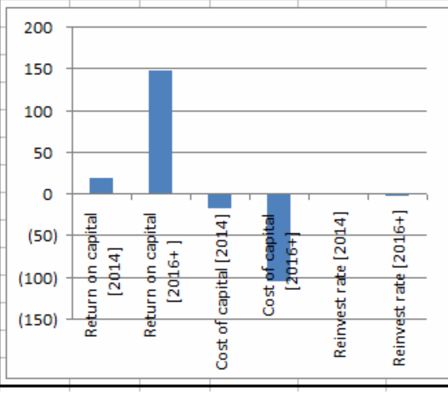
Finally we add a chart to show the sensitivities we have calculated.

Hands-on guide to scenario analysis

Assumptions			Bumped assumptions	Index	Value	Sensitivities [$m]
Taper period (years)	[1-3]	3			1,217	
Bump index	[0-6]	0		0	1,217	
Return on capital [2014]	[%]	25%	25%	1	1,236	19
Return on capital [2016+]	[%]	10%	10%	2	1,364	147
Cost of capital [2014]	[%]	12%	12%	3	1,200	(17)
Cost of capital [2016+]	[%]	11%	11%	4	1,113	(104)
Reinvest rate [2014]	[%]	30%	30%	5	1,216	(0)
Reinvest rate [2016+]	[%]	40%	40%	6	1,214	(2)

Forecasts							
Year	**[yr]**	**2,013**	**2,014**	**2,015**	**2,016**	**2,017**	**2,018**
Actual / Estimated	[Act/Est]	Act	Est	Est	Est	Est	Est
Taper fraction	[%]		0%	33%	67%	100%	100%
Last model period	[0/1]		0	0	0	0	1
Return on capital	[%]		25.0%	20.0%	15.0%	10.0%	10.0%
Cost of capital	[%]		12.0%	11.7%	11.3%	11.0%	11.0%
Reinvestment rate	[%]		30.0%	33.3%	36.7%	40.0%	40.0%
Capital	[$m]	1,000	1,075	1,147	1,210	1,258	1,308
Earnings	[$m]		250	215	172	121	126
Reinvestment	[$m]		75	72	63	48	50
Free cash flow	[$m]		175	143	109	73	75
Growth in free cash flow	[%]			-18.1%	-24.0%	-33.4%	4.0%
PV of free cash flows	[$m]	1,217	1,217	1,167	1,143	1,151	1,197
Enterprise value	[$m]	**1,217**					

Enterprise value: Sensitivity to 1% increase in driver



This stage of the model is in the example spreadsheet on the tab labelled Sensitivities_step_4.

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