

Optimisation in Excel

Overview

- Objectives
 - Solve optimisation (maximisation and minimisation) problems using the Excel Solver:
 - What Solver will do
 - Problems it can solve
 - Limitations of Solver
 - Solver hugely extends the power of Excel by allowing iterative procedures to be carried out very quickly

Goal Seek

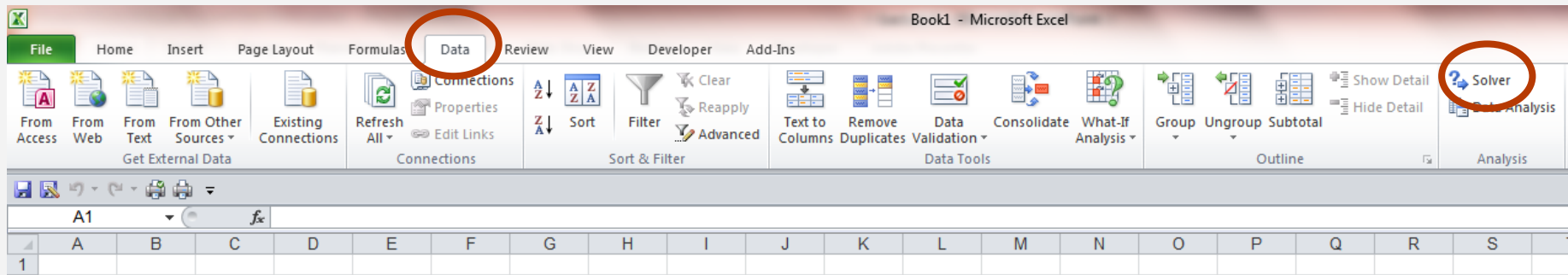
- Basic Excel has a basic backwards calculation routine called ‘Goal Seek’, which is found under ‘What If Analysis’ on the Data tab.
- In this, you specify a value for a given cell (in ‘Set cell’ and ‘To value’) and the cell you can change to get it (the ‘By Changing Cell’). Goal Seek calculates the value for the changing cell.
- Goal Seek is very limited. It only allows one variable, does not allow constraints and sometimes requires several goes to get it right.

The Excel Solver

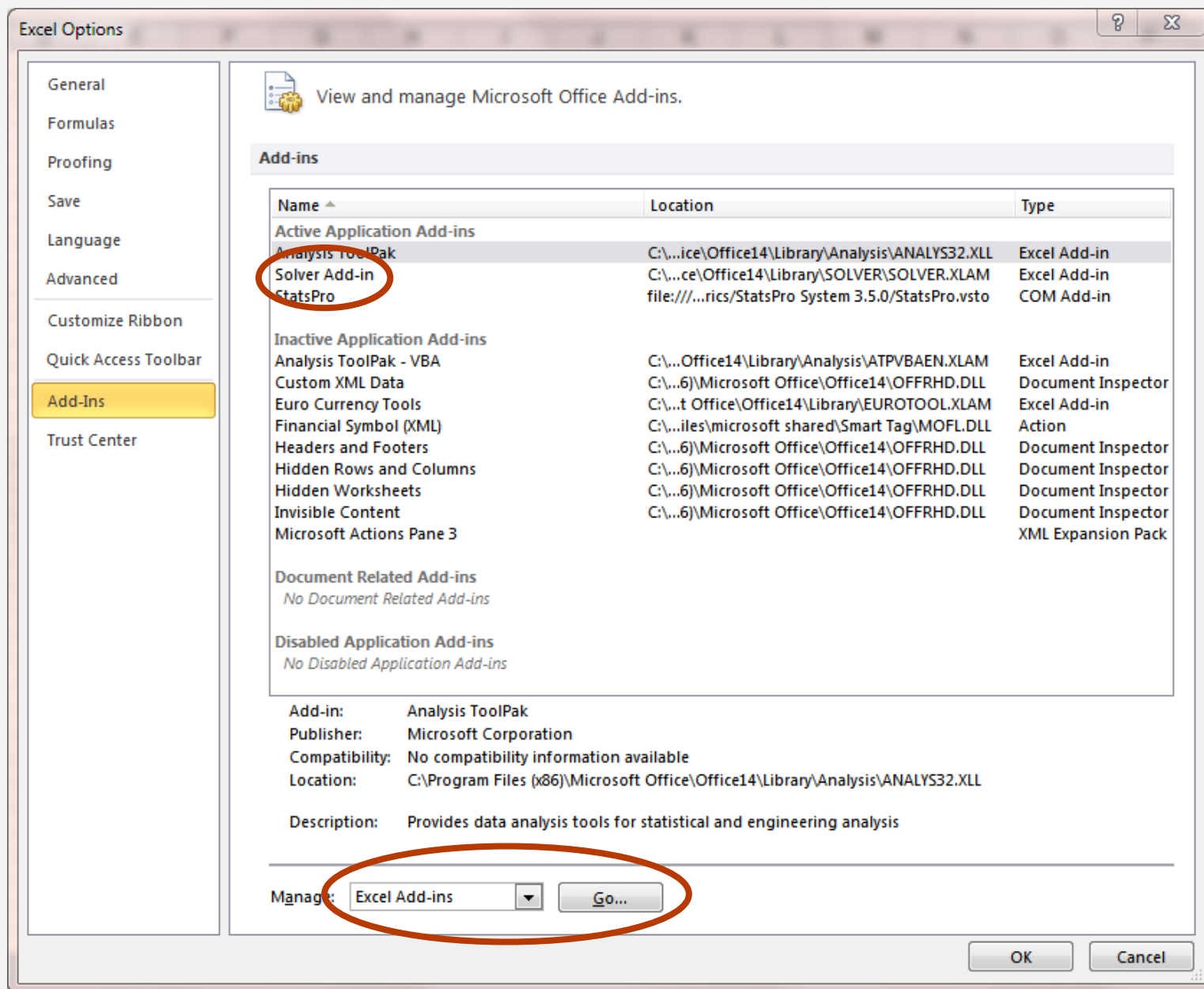
- If you want to use Goal Seek, look it up. We are just going to use the more sophisticated *Excel Solver*.
- Solvers are programs that can do the same as Goal Seek but also much more. There is a basic solver add-in with Excel, provided by Frontline Systems, but more sophisticated paid for versions are available.
- Help on Solver is available from <http://www.solver.com/excel-solver-help>.

Finding Solver

- In Excel 2010, Solver can be found on the far right of the 'Data' tab in the ribbon.

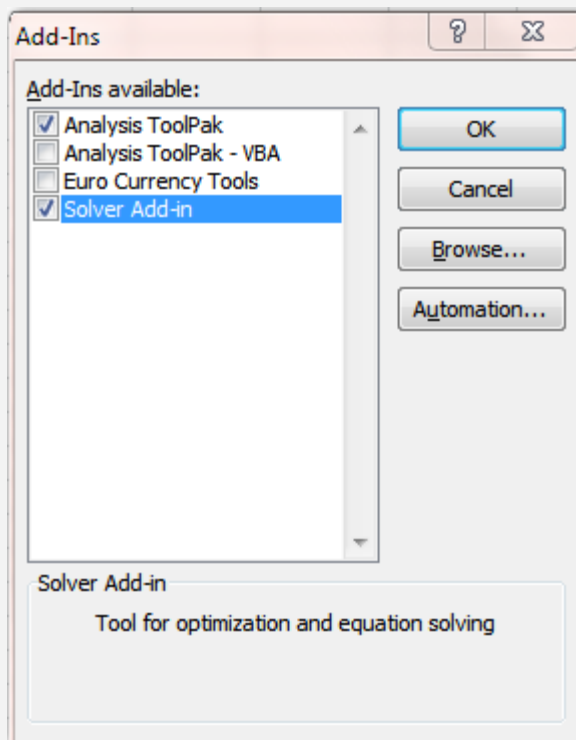


- If it is not there, you will need to activate it. To do this, go to 'Options' - 'Add-ins' on the 'File' tab. That will bring up the following dialogue box.



Activating Solver

- Clicking 'Go' on 'Manage Excel Add-ins' brings up this dialogue box.



- Now simply check the box next to 'Solver Add-in' and it will appear in the ribbon.
- It is already checked here because it has already been activated on my computer.

What does Solver do?

Even the basic solver packaged with Excel is a very powerful tool. It can be used for:

- Backwards calculations
- Finding maxima and minima of functions
- Finding optimal solutions to problems such as LPs

LP (Linear Programming) is finding min or max of a **linear** function subject to **linear** constraints, e.g.

find max of $f(x,y,z)=2x+3y-7z$ subject to

constraints: $2x+z \leq 5$

$3x+y-z \leq 7$

What does Solver do?

- Examples of the uses of Solver can be found in the spreadsheet Solvsamp.xls in the Microsoft Office Samples folder on your computer.
- Here are some more.

C3 fx 2.23606415474259

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Finding Square Roots												
2													
3		x =	2.236064										
4		x ² =	4.999983										
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
26													
27													
28													
29													
30													

Solver Results

Solver found a solution. All Constraints and optimality conditions are satisfied.

☒ Keep Solver Solution
☐ Restore Original Values

☐ Return to Solver Parameters Dialog ☐ Outline Reports

OK Cancel Save Scenario...

Reports
Answer
Sensitivity
Limits

Solver found a solution. All constraints and optimality conditions are satisfied.
When the GRG engine is used, Solver has found at least a local optimal solution. When Simplex LP is used, this means Solver has found a global optimal solution.

Best to leave this box unchecked

Excel Solver Results dialog box overlaid on a spreadsheet titled "Finding a Minimum".

The spreadsheet shows the following data:

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Finding a Minimum												
2													
3		x =	-2.5										
4		$x^2 + 5x + 9 =$	2.75										

The Solver Results dialog box displays the following information:

- Solver found a solution. All Constraints and optimality conditions are satisfied.**
- ☒ **Keep Solver Solution**
- ☐ **Restore Original Values**
- ☐ **Return to Solver Parameters Dialog**
- ☐ **Outline Reports**
- Reports**
 - ☐ **Answer**
 - ☐ **Sensitivity**
 - ☐ **Limits**
- OK** **Cancel** **Save Scenario...**

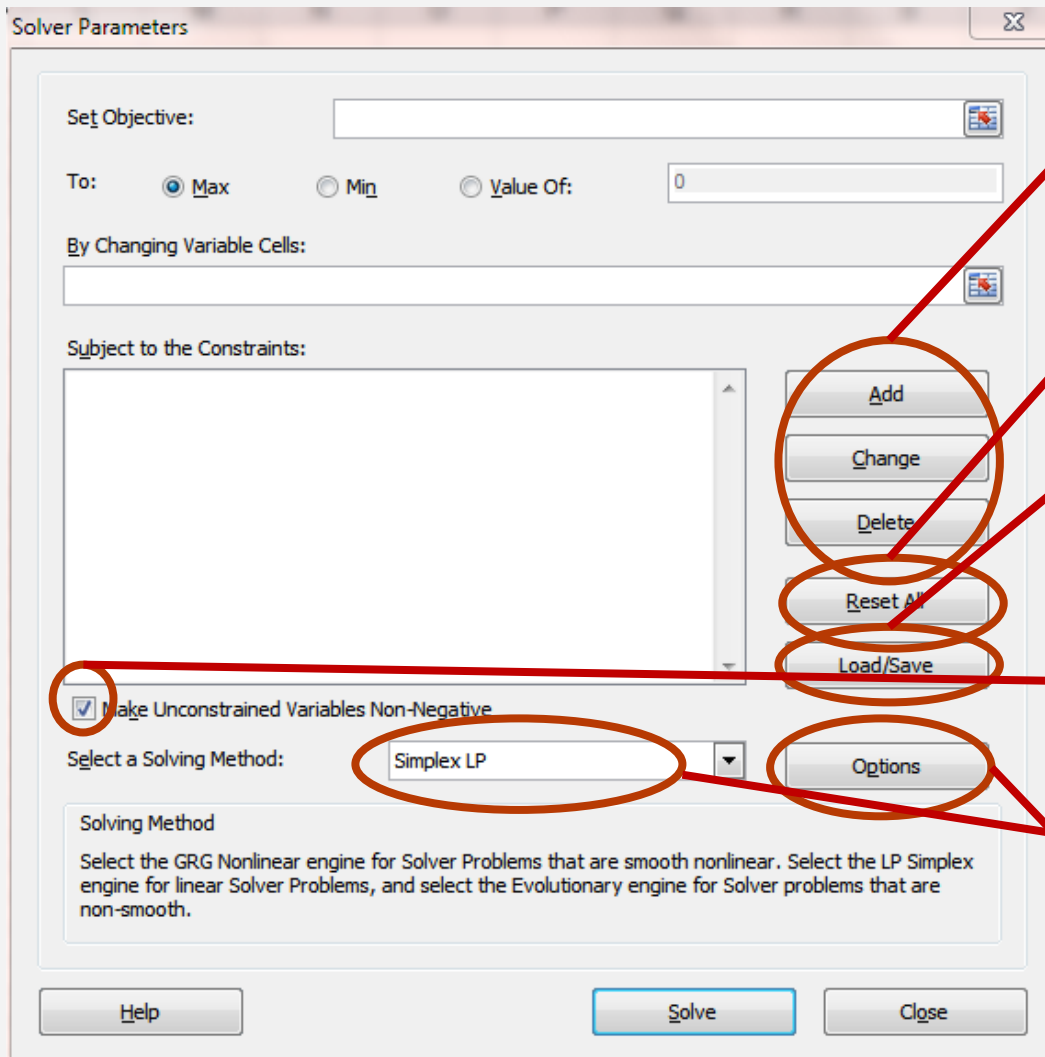
Additional text in the dialog box:

Solver found a solution. All Constraints and optimality conditions are satisfied.

When the GRG engine is used, Solver has found at least a local optimal solution. When Simplex LP is used, this means Solver has found a global optimal solution.

Red annotations highlight the solution values in the spreadsheet and the "Solved" status in the dialog box.

Solver options



The screenshot shows the 'Solver Parameters' dialog box with several elements highlighted by red circles and arrows pointing to explanatory text on the right:

- Buttons on the right:** A group of five buttons (Add, Change, Delete, Reset All, Load/Save) is circled. An arrow points from this group to the text 'Add, change or delete constraints'.
- Reset All button:** The 'Reset All' button is circled. An arrow points from it to the text 'Reset all options to default values'.
- Make Unconstrained Variables Non-Negative checkbox:** The checkbox is checked and circled. An arrow points from it to the text 'Check if only positive values permitted'.
- Solving Method dropdown:** The dropdown menu is set to 'Simplex LP' and is circled. An arrow points from it to the text 'Simplex LP for linear problems'.
- Options button:** The 'Options' button is circled. An arrow points from it to the text 'See next slide'.

The dialog box itself contains the following fields and controls:

- Set Objective:** A text box for the objective cell.
- To:** Radio buttons for 'Max', 'Min', and 'Value Of:'. The 'Max' radio button is selected.
- By Changing Variable Cells:** A text box for the variable cells.
- Subject to the Constraints:** A list box for constraints.
- Buttons:** 'Add', 'Change', 'Delete', 'Reset All', 'Load/Save', and 'Options' buttons are located to the right of the constraints list.
- Make Unconstrained Variables Non-Negative:** A checked checkbox.
- Select a Solving Method:** A dropdown menu currently showing 'Simplex LP'.
- Solving Method:** A text box containing instructions: 'Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.'
- Buttons at the bottom:** 'Help', 'Solve', and 'Close' buttons.

Add, change or delete constraints

Reset all options to default values

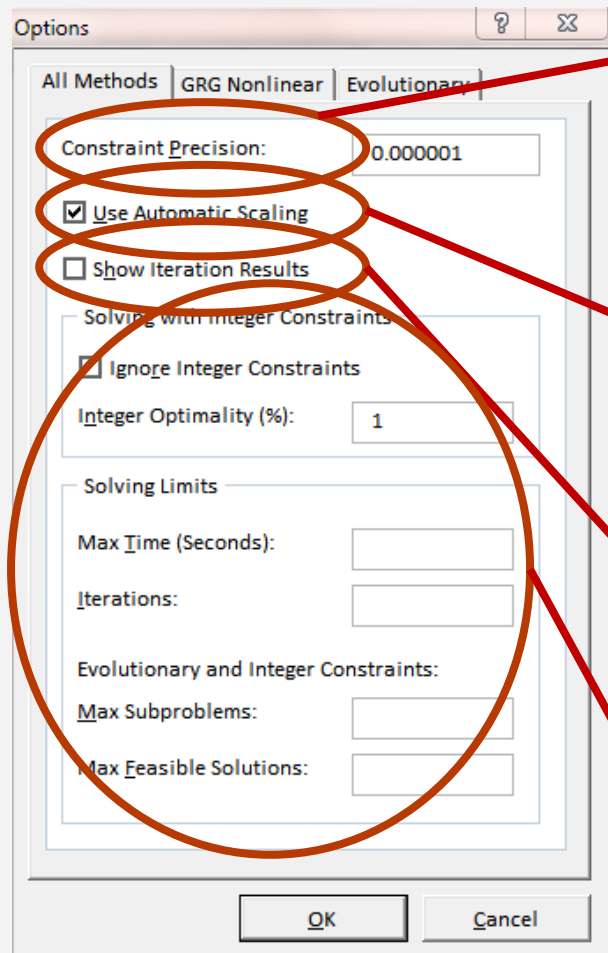
Save solutions or load saved solutions

Check if only positive values permitted

Simplex LP for linear problems

See next slide

More options



Precision of results. Higher precision will increase calculation times but this will not usually be a problem for LP problems

Scales variables to similar magnitudes to reduce potential error (normally checked)

Shows the intermediate calculations (useful for debugging)

No need to worry about these for LP problems

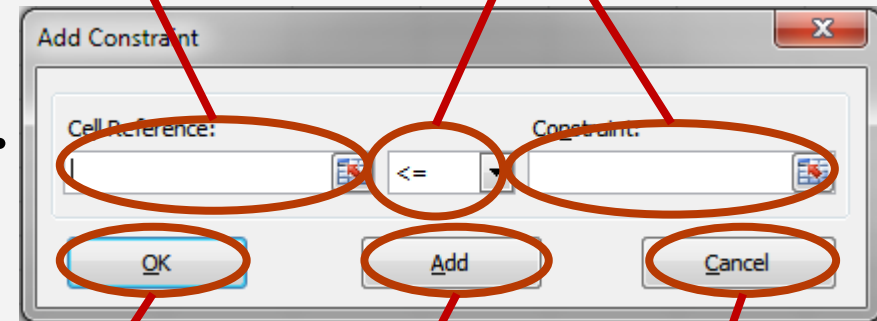
Working with constraints

The cells whose
values you want
to constrain

The type of
constraint

The value you want
them constrained to.

- When you click on the ‘Add constraint’ option. A new dialogue box allows you to add a range of different types of constraint.
- You select the cells to be constrained and the values or formulae that constrain them. You can have any number of different constraints.
- Then ‘OK’ to accept or ‘Add’ to add another constraint.



Accept

Add another

Cancel

An example

- Suppose you have £100 to save in three different banks, which pay 2%, 2.5% and 3% interest respectively.
- Obviously, you save with the Bank paying the highest interest rate.
- But suppose you want to spread your cash in case a Bank goes bust. Suppose you decide not to invest more than 40% of your money in any one bank.

Total amount
to invest

Amount to
invest in each
Bank

Total invested
=SUM(B6:D6)

	A	B	C	D	E	F	G
1	Maximising interest						
2							
3	Amount to invest		£100				
4						Total	
5		Anytown Bank	Bigtown Bank	Chinatown Bank			
6	Amount invested					£0.00	
7							
8	Interest rate	2.0%	2.5%	3.0%			
9	Amount after one year	102.00%	102.50%	103%			
10	Value after one year	£0.00	£0.00	£0.00		£0.00	
11							
12							

Total amount
after one year
=SUM(B10:D10)

Interest rates and
amount after one
year

Values after one
year

The objective:
maximise amount
after one year

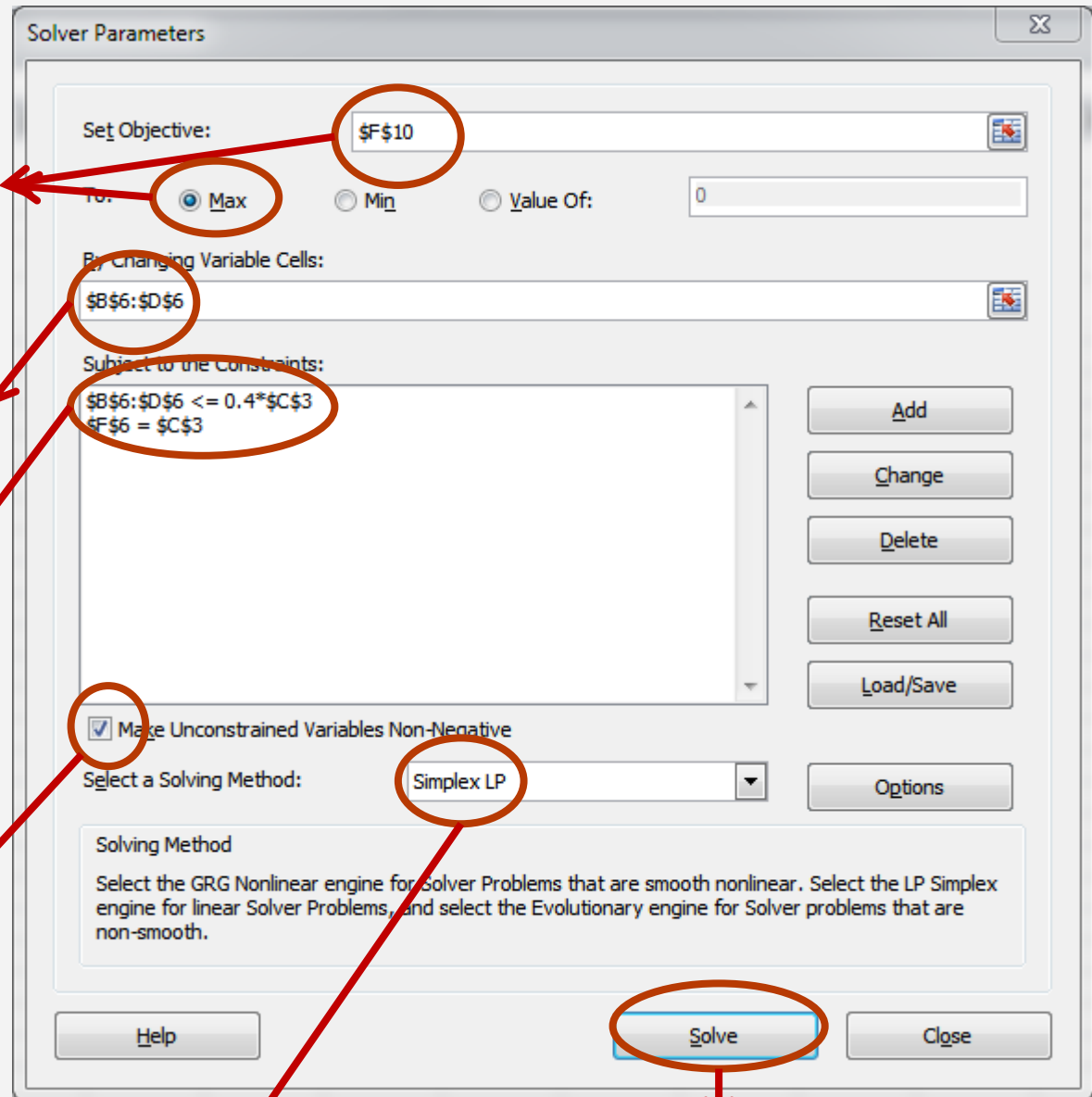
The variables:
amount invested in
each bank

The constraints:
The amount in each
Bank is at most
40% of the total
and the sum must
equal the total
amount

Check
this box

Choose Simplex LP

Solve!



Solver Parameters

Set Objective: \$F\$10

To: ☒ Max ☐ Min ☐ Value Of: 0

By Changing Variable Cells: \$B\$6:\$D\$6

Subject to the Constraints:

\$B\$6:\$D\$6 <= 0.4*\$C\$3
\$F\$6 = \$C\$3

☒ Make Unconstrained Variables Non-Negative

Select a Solving Method: Simplex LP

Solving Method
Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

Buttons: Add, Change, Delete, Reset All, Load/Save, Options, Help, **Solve**, Close

	A	B	C	D	E	F	G
1	Maximising interest						
2							
3	Amount to invest		£100				
4						Total	
5		Anytown Bank	Bigtown Bank	Chinatown Bank			
6	Amount invested	£20.00	£40.00	£40.00		£100.00	
7							
8	Interest rate	2.0%	2.5%	3.0%			
9	Amount after one year	102.00%	102.50%	103%			
10	Value after one year	£20.40	£41.00	£41.20		£102.60	
11							
12							

Solver
calculates
these
variablesthis box

This is the maximum
amount after one year

Constraint types

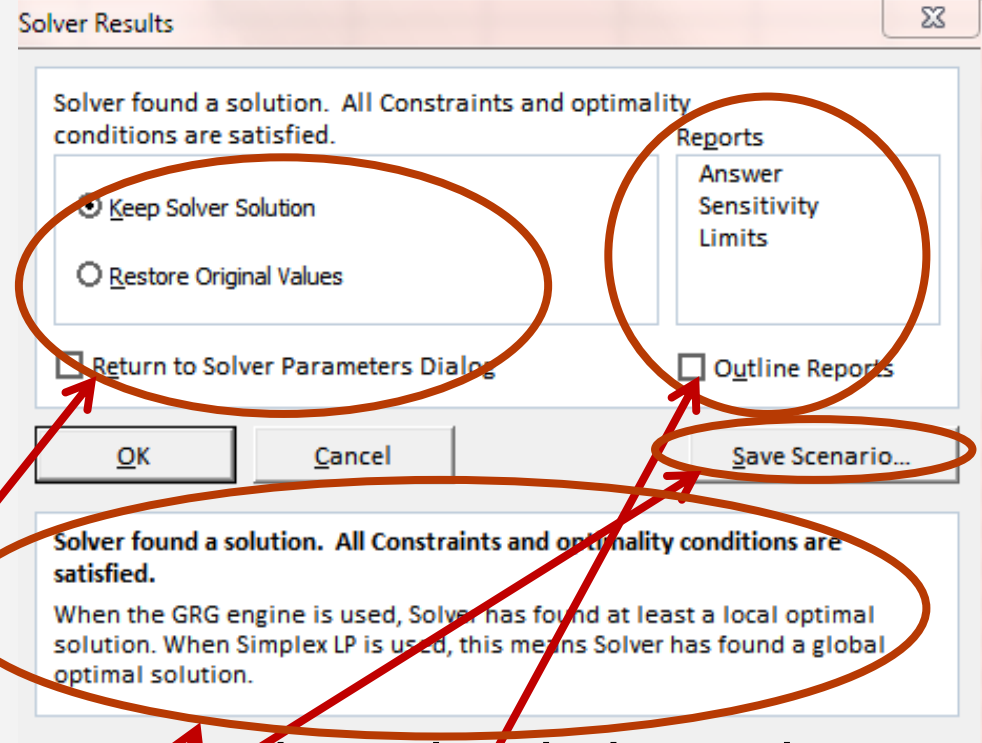
- Solver has 6 types of constraint:
 - \leq - the variables selected must be less than or equal to (note, not less than) the constraint value(s)
 - \geq - the variables selected greater than or equal to (note, not greater than) the constraint value(s)
 - $=$ - the variables selected must be equal to the constraint value(s)
 - int - the variables selected must take integer values
 - bin - the variables selected must take binary (0, 1) values
 - dif - the variables selected must all take different values

Solving methods

- Solver has three solving methods:
 - Simplex LP (go to Operational Research in Year 3 to find out what this means) will find exact solutions to linear problems and global maximum or minimum solutions to constrained linear solutions. It is fast.
 - Generalized Reduced Gradient (GRG) non-linear is used to find local solutions to smooth non-linear problems. It is usually reasonably fast but you may need to adjust the starting point.
 - Evolutionary is used to find solutions to non-smooth problems. It can be slow and, trial and error may be needed to find the best solution.

Output options

- The results dialogue box allows you to:
 1. Keep the Solver solution, revert to the original solution or go back to the dialogue box.
 2. Request more detailed reports on the answer, sensitivity and limits, either in outline or in full.
 3. Save the scenario.
- Make the appropriate selection and press 'OK'.
- Solver reports an error if it does not find a solution.



Limitations of Solver

- Solver is a powerful tool and will be sufficient for most everyday tasks. Its main limitations are:
 1. It can only handle up to 200 variables. This may seem a lot but with the data sets available these days is insufficient for major tasks.
 2. Its solving algorithms are fairly basic. This can make it slow and sometimes unreliable. This is not a problem for Simplex LP and rarely for GRG non-linear but the Evolutionary method can be slow and will not always give the right answer first time.