CHAPTER 4: Using the Excel Solver on a Single Variable Unconstrained Optimization Problem

PURPOSE OF THIS CHAPTER:

   • To introduce you to Microsoft Excel's Solver

   • To continue to gain confidence and mastery of single variable unconstrained optimization problems

INTRODUCTION TO CHAPTER 4:

The optimization problem we will look at in this chapter (as described in detail in C4Lab.xls) is to *minimize* the time it takes a lifeguard to reach a drowning victim. We'll use the computer to solve the problem. In the next chapter, we'll show you how to do it by hand so that you can appreciate the usefulness of the Solver tools.

We have learned how to solve an optimization problem via the Direct Method or Method of Marginalism.

Excel's Solver provides a THIRD WAY of solving optimization problems. It can be fast, easy, and accurate. It is not, however, a 100% guaranteed silver bullet. We'll show you how to use Solver and demonstrate how it can mislead you.

The C4Lab.xls spreadsheet is essentially self-contained—it includes everything you need to learn about how Excel's Solver works. This accompanying handout merely documents the various features of Excel's Solver. *We STRONGLY recommend that you read this document first as preparation for the lab.* This document contains valuable information that could save you countless hours of frustration and pain. Do NOT jump right into the assignment.

> **Please refer to this handout if needed during this chapter's lab assignment or as you run Excel's Solver in future applications.**

The last page contains important information about numerical algorithms and Excel's Solver.

Using Excel's Solver

To use the Solver, click on the Tools heading on the menu bar and select the Solver . . . item.

If Solver is not listed, you must manually include it in the algorithms that Excel has available. To do this, select Tools from the menu bar and choose the "Add-Ins . . ." item. In the Add-Ins dialog box, scroll down and click on the Solver add in as shown by the picture below:
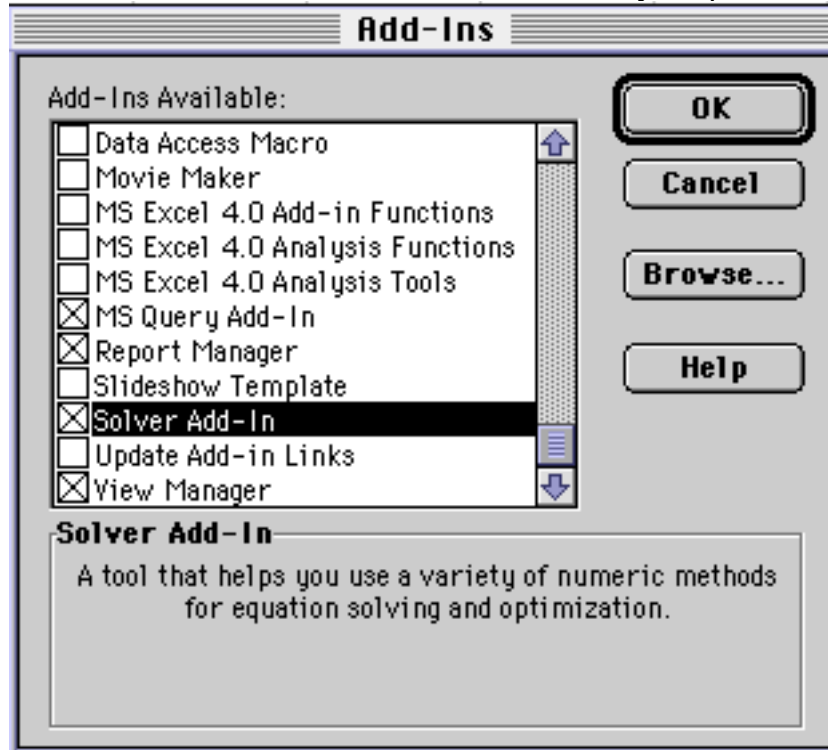

Excel takes a moment to call in the Solver "add in" and adds it to the Tools menu.

If you have problems accessing the Solver add-in, click on the Select or Browse . . . button and navigate to the Solver add-in (called solver.xla in Windows and Solver on the MacOS) and open it. It should be in the Library directory in the folders where Microsoft Office is installed.

If you cannot find the Solver Add-In, try using the Mac's Find File or Find in Windows to locate the file. Search for "solver." Note the location of the file, return to the Add-Ins dialog box above, click on Select or Browse, and open the Solver Add-In file.

Still can't find it? Then it is likely that your installation of Excel failed to include the Solver Add-In. Run your Excel or Office Setup again from the original CD-ROM and install the Solver Add-In. You should now be able to use the Solver by clicking on the Tools heading on the menu bar and selecting the Solver . . . item.

After executing Tools: Solver . . . , you will be presented with the Solver Parameters dialog box below:
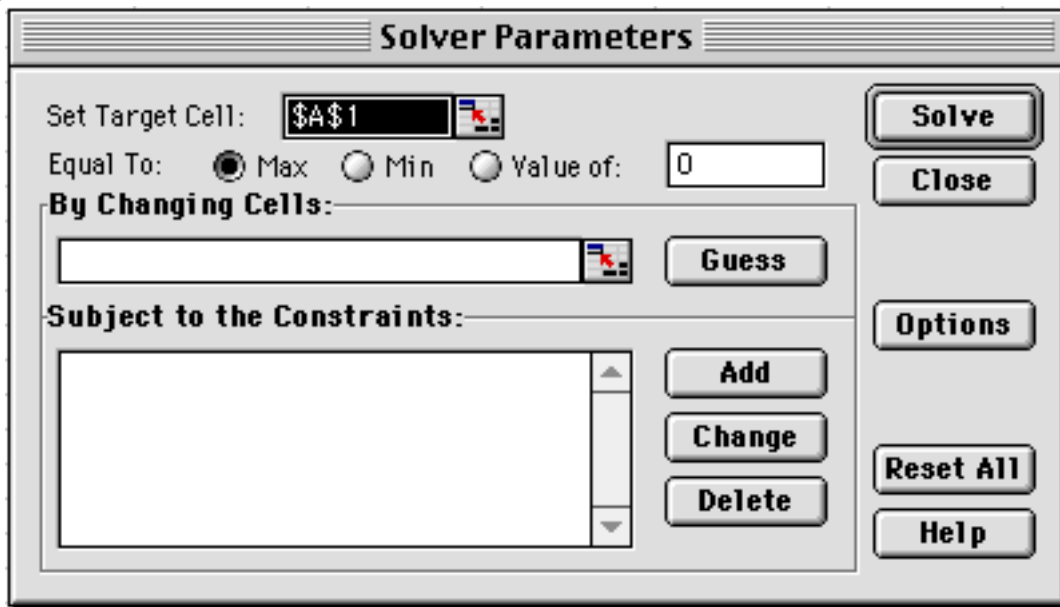
Let's review each part of this dialog box, one at a time.

Set Target Cell is where you indicate the objective function (or goal) that is to be optimized. This cell must contain a formula that depends on one or more other cells (including at least one "changing cell"). You can either type in the cell address or click on the desired cell. (NOTE: If you click on the Collapse Dialog button, the dialog box disappears and it's easier to select a cell.) **Equal to:** gives you the option of treating the Target Cell in three alternative ways. **Max** (the default) tells Excel to maximize the Target Cell; **Min** to minimize; while **Value** is used if you want to reach a certain particular value of the Target Cell by choosing a particular value of the endogenous variable. If you choose Value, you must enter the particular value you want to attain in the box to the immediate right unless you want the value to be zero (which is the default). **By Changing Cells** is where you indicate which are the adjustable cells (i.e., endogenous variables). As in the Set Target Cell box, you may either type in a cell address or click on a cell in the spreadsheet. Excel handles multivariable optimization problems by allowing you to include additional cells in the By Changing Cells box. Each non-contiguous choice variable is separated by a comma. If you use the mouse technique (clicking on the cells), the comma separation is automatic. **Guess** controls the initial position of the changing cells. Excel uses the current values of the cells as the default. **Subject to the Constraints** is used to impose constraints on the endogenous variables. We will rely on this important part of Solver when we do Constrained Optimization problems. You can also use the Constraints part of Solver to help it find a solution. For example, in our profit maximization problem, we could have told Excel that Quantity must be greater than or equal to zero, i.e., that negative values of Q are not allowed. If Excel has trouble finding a solution to a problem, limiting the possible values of the choice variables will help it find a solution.

Add..., Change..., Delete buttons are used to create and alter the constraints you set. These buttons lead to dialog boxes where you indicate your choices, then hit OK. We will learn how to use these buttons in future labs and exercises.

Returning to the top right-hand side of the Solver Parameters dialog box, we have:

Solve, obviously, the button you click to get Excel's Solver to find a solution. This is the last thing you do in the Solver Parameters dialog box.

Close is just like cancel; it closes the Solver dialog box and no changes are made.

Options...allows you to adjust the way in which Solver approaches the solution..
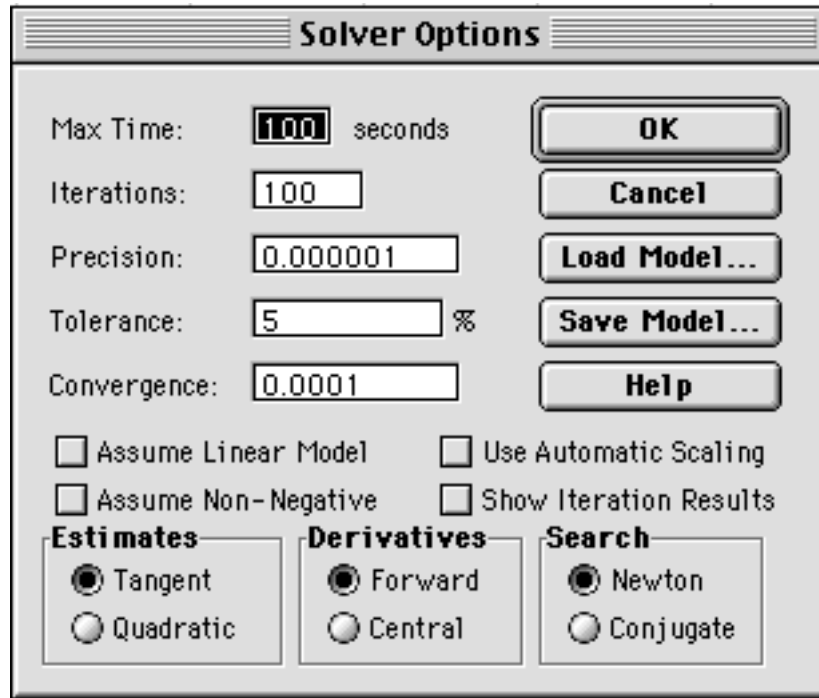

We really shouldn't ever have to worry about the Solver Options dialog box. As you can see, a series of default choices are included that direct Solver's search for the optimum solution and for how long it will search. These options may be changed if Solver is having difficulty finding the optimal solution. The Load and Save Model buttons enable you to recall and keep a complicated set of constraints or choices so that you do not have to re-enter them every time.

Returning to the middle right-hand side of the Solver Parameters dialog box, we have:

Reset All. This button changes everything back to the original, default choices, blanking out the Set Cell, By Changing Cells, and Subject to the Constraints options. *It is important to understand that a saved Excel workbook will remember the information included in the last Solver run.* If you wish to explore a different problem and want to quickly begin with a "clean" Solver, then click on the Reset All button. If you wish to keep a particular Solver run, then use the Options and Save Model . . . Buttons.

Help brings up the Excel Help menu on the Solver.

When you run Excel's Solver, it executes a series of "add-in" files and routines. Upon completion of the various programs, Excel presents the user with the following Solver Results dialog box:
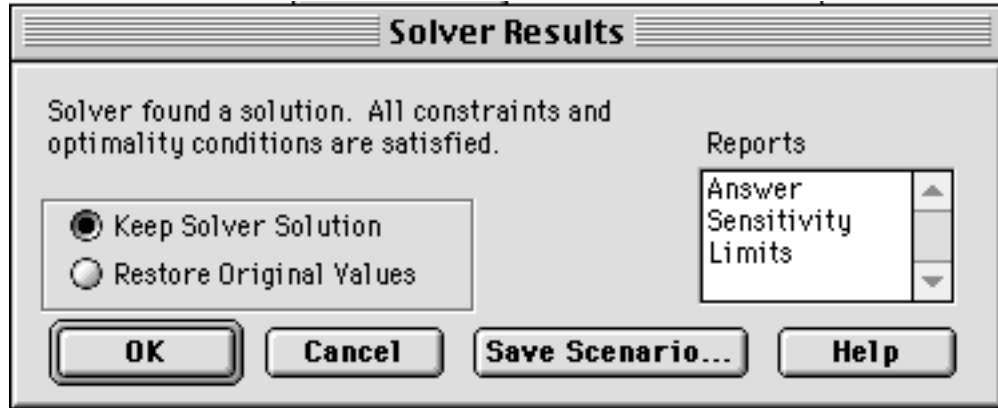
A message appears on the top left-hand side of the box. In this case, Excel reports that "Solver has found a solution. All constraints and optimality conditions are satisfied." This is good news!

Bad news is a message like, "Solver could not find a solution." If this happens, you must diagnose, debug, and otherwise think about what went wrong and how it could be fixed. We will provide some guidelines.

In C4Lab.xls, as in all MINIMIZATION problems, a *common error* is that the Solver is trying to Max instead of Min the time it takes to get to the drowning victim. "Max" is Excel Solver's default. You must change it to Min for a solution to be found.

From the Solver Results dialog box, you elect whether to have Excel write the solution it has found into the Changing Cells (i.e., Keep Solver Solution) or whether to leave the spreadsheet alone and NOT write the value of the solution into the Changing Cells (i.e., Restore Original Values). When Excel reports a successful run, you would usually want it to Keep the Solver Solution.

On the right-hand side of the Solver Results dialog box, Excel presents a series of reports. The Answer, Sensitivity, and Limits reports are additional sheets that are inserted into the current workbook. They contain diagnostic and other information and should be selected if Excel Solver is having trouble finding a solution.

Along the bottom of the Solver Results dialog box, are four buttons:
OK, obviously, the button you click after reading and choosing various options that you want to keep. This is the last thing you do in the Solver Results dialog box.
Cancel closes the Solver Results dialog box and no changes are made.
Save Scenario... enables the user to save particular solutions for given configurations.
Help brings up the Excel Help menu on the Solver.

REFER BACK TO THIS HANDOUT IF PROBLEMS ARISE USING SOLVER.

A Brief Aside on Numerical Optimization

This is probably the first time you will use a numerical algorithm to solve an optimization problem. While a full explanation of numerical methods for optimization is beyond the scope of our work, two basic ideas deserve review before you proceed

1) Interpretation of Solver's Results Needed
Solver determines if it has reached a solution by using a convergence criterion. Once it cannot improve the current solution by more than 0.0001 (the default convergence value in the Options dialog box), it announces that it has found a solution and reports its value in 16-bit precision. The reported solution might be a number like 2.99999999999999.

An important consequence of the convergence criterion is that Solver will rarely get a truly exact answer. Once it's close enough to meet the convergence criterion, it stops improving. Usually, that's not a problem because we do not need the absolutely exact answer.

Unfortunately, some people seem to think that an answer to the 15th decimal place is really exact. That's crazy. Most of the time, Solver will stop short of the absolutely exact answer. ***Thus, there is no point in using all of the digits presented by Solver.***

You should always format Solver result cells so that they are easy for humans to read and understand. If you get a Solver result like the one above, you should display it as 3. In general, you'll want to cut down on the many digits Solver displays.

2) Solver May Fail
A bigger problem concerns the ability of Solver (or any numerical algorithm) to find the correct solution. In "The Numerical Reliability of Econometric Software" (*Journal of Economic Literature*, June 1999, pp. 633-665), McCullough and Vinod draw a distinction between a *miserable* and a *disastrous* result. They might sound the same, but they are very different. A miserable result is obtained when a numerical algorithm gives up and says that a solution cannot be found, an error occurred, or convergence cannot be achieved. The result is miserable because the computer can't find the answer. If this happens to you, we recommend changing the initial values from which Solver begins its work. Avoid extremely large or small numbers and zero. Another simple strategy is to add constraints or to reformulate the problem. A large literature exists on ways to improve the performance of numerical algorithms, especially in the realm of non-linear problems.

A disastrous result is much worse than a miserable one. Solver happily announces that a solution has been found and offers up a 15 or 16 digit number for your inspection. The problem, however, is that the solution is way off. Not in the millionth or even tenth decimal place, but completely, totally wrong. How this might happen takes us too far afield, but suffice it to say that it is good Solver practice to check the solution by trying slightly different numbers to test Solver's answer and by asking yourself if the answer makes sense. We'll show you how.

We hope this discussion hasn't scared or disappointed you. Solver really is a powerful way to solve optimization problems, but it isn't perfect. You need to be aware of this. Remember to always format Solver's results with eye toward ease of understanding. Do not give up if you get a miserable result and stay alert even if Solver claims to have hit paydirt—it may be a disastrous result!