XIII. WHAT-IF SOLUTION TOOLS

THE WHAT-IF ANALYSIS BUTTON (EXCEL 2007)

DATA TABLE

This is a method of building one (one variable) and two (two variables) way tables based on using a placeholder cell at the upper-left corner of the table.

SCENARIO MANAGER

This is a method of building tables that are computed values from more complicated relationships using up to 32 variables.

GOAL SEEK

It is described below.

CIRCULAR REFERENCE RECALCULATIONS (EXCEL 2007)

Circular references show up in computions where the sequence depends on one cells value that is also the outcome of the calculation. A warning message shows up. Tracer arrows show up indicating the cells involved. In Excel 2007, an option is available to allow a set number of repeats (100 is the default) or until the differences iterations is less than the number in the Maximum Change text box. However this re-occurs automatically whenever there is any other cell change (or entry) on the worksheet. Therefore this option should be carefully exercised.

GOAL SEEK (EXCEL 97, 2000, 2003 AND 2007)

The “Goal Seek” is a one-cell back-solver, that will change values in a selected cell until another cell attains a set value. It is under the Tools menu as “Goal Seek”. There is an input data box that appears when “Goal Seek” is selected. For example, if the statistical problem is about the value of one parameter that is to be changed (by changing cell box xxx) and the result is a measure of residuals (cell: yyy) and the value in cell yyy is to be reduced to some acceptable value (to value: vvv), then Goal Seek would be a way to achieve this. Excel would display an error if the designated “To value” could not be attained.

Goal seek has very limited capabilities for statistical purposes, and was not tested for accuracies.

SOLVER (EXCEL 97, 2000, 2003 AND 2007)

WHAT SOLVER IS

Nonlinear regression depends on getting an approximate solution and then iteratively improving the approximation, until some stopping criteria is reached. There is no direct solution, as there is in linear regression. It is essentially an optimization process.

Solver is the only method provided by Microsoft in Excel for general optimization and equation fitting in problems that involve more than one parameter. Solver was however, not designed to solve least squares problems, which are the type of problems involved in non-linear regression.

Microsoft states “The Microsoft Excel Solver utilizes the GRG2 (General Reduced Gradient 2) nonlinear optimization code developed by Leon Lasdon, University of Texas, at Austin, and Allan Waren, Cleveland State University. Linear and integer problems utilize the simplex method with bounds on the variables and the branch and bound method implemented by John Watson and Dan Fylstra, Frontline Systems, Inc.” (Microsoft 1992). Microsoft’s Knowledge Database KBA 82890 provides some additional information. Frontline’s website (Frontline 2000) also has information on the use of Solver.

Fylstra, Lasdon, Watson and Waren (1998) have issued a paper giving more details on the Solver version in Excel. Solver was introduced in 1991 and modified for the Excel 97 version. Users of Solver should read this paper, since it is free from the Solver web site. Frontline the company that has Solver, has more advanced versions that can be purchased and used as an add-in to Excel. The version in Excel 97 is the current version in Excel 2007. Frontline considers this version as their free bundled version of Solver.

Solver is intended to solve for an optimum value of a cell, dependent on all the relationships and variable constraints on the parameters related to that cell. It was intended to be used in business applications, where there is no direct equation defining the relationships of the worksheet cells to the target cell. A file distributed with Excel (or available from “Office OnLine” (C:\Program Files\Microsoft Office\Office\Samples\solvsamp.xls) has six examples on how Solver was intended to be used. Ivens (2000) has another illustration of how Solver is used for a business application, on pages 381 to 391.

Although there are more powerful optimizers available for use in Excel, Solver has the ability to meet specified constraints on linked or related cells. This capability is not available with these other optimizers.

Frontline says, “A popular use of the Microsoft Excel Solver is for the construction of *efficient portfolios* of securities -- often called *portfolio optimization*. Inputs to this process consist of a set of securities (stocks, bonds, etc.), their projected rates of return, their riskiness as measured by the variance (or standard deviation) of price changes, and the covariance (or correlation) between different securities. A simple Solver model will then determine the best allocations of funds to each security, to yield the highest rate of return for a given level of risk, or the lowest risk for a given rate of return.”

THE SOLVER ROUTINE:

Solver is basically a routine that is started by different methods, depending on what version of Excel you are using:

Versions 97, 2000 and 2003: Clicking on “Tools” which brings up a menu list, and by selecting “Solver”, the starting “Solver Parameters” box appears.

Version 2007: Select the “Data” tab on the starting ribbon, then select “Solver” (extreme right side) and this will bring up the “Solver Parameters” box

By entering information into the input box and clicking on the Solver button, Solver starts. Since it is not a function, it will not automatically re-run when any data cell is changed (will not automatically update when the F9 key is pressed.). The starting sequence must be repeated when changes are made. Information on how to use Solver, and the required entries into the input message box are given below under the topic "Optimization of Non-Equation Relationships, The Business Model" below,

Microsoft Excel Solver uses iterative numerical methods that involve changing the values in the parameter cells and observing the results calculated by the constraint cells and the objective cell. The iteration step comes from numeric estimates (as finite differences) of the first derivative of each of the parameters being solved for, and the value of the objective function. This provides the information to make both the direction of the step in the parameter space and the magnitude of the step. Solver can use either forward differencing or central differencing, as controlled by the derivatives choice on the Solver Options dialog box. There is also a choice to use tangent or quadratic projections for estimates, and a choice to use the Newton or conjugate search methods to obtain the location of the next step. This is all described in the Solver Help screen.

Fylstra, Lasdon, Watson and Waren (1998) indicate that a quasi-Newton method is being used. The later does not depend on obtaining and updating an approximation to the Hessian.

Gill(1981) says that the quasi-Newton methods are the most successful of all methods when non-derivative, finite difference methods are being used. Gill says, "Errors in the gradient can have a substantial effect on performance, and hence the logic of a quasi-Newton method must be modified." They easily get trapped at points where the calculated numerical differences (numerical differences are not smooth functions) about the point are small, but a true global minimum was not reached.

The number of cells (unknowns) that are being changed in the iteration process is limited to be 100 or less. This is more than adequate for any statistical application.

THE END POINT WITH SOLVER

There usually are no external criteria to judge if Solver gave an adequate solution. Solver at the stopping point does not give any information other than parameter values. Solver stops when:

- it finds an optimal solution
- the objective appears to be unbounded
- it can find no feasible solution
- it reaches the time limit
- it reaches the maximum number of iterations

Optimal solution means that the Solver has found a local optimum where the Kuhn-Tucker conditions are satisfied to within the convergence interval. Solver also stops when the current solutions meets a slow progress test. The slow progress test is when the relative change in the objective is less than the convergence tolerance for the last five iterations." Solver outputs different messages, depending on the stopping method (Fylstra, et al, 1998).

HELP ON USING SOLVER

In Excel 2007, select the Data tab, then select Solver at the upper right of the ribbon. This brings up the Solver Parameters box, and Help at this point brings up s brief description of entries into the parameter box. There is no direct access to more extensive "Help" at this point.

In Excel you can get the Office Online for help.

The book, "Microsoft Excel Data Analysis and Business Modeling", by Wayne L. Winston (10/28/2004) is recommended by Microsoft. The book has problem sets and the problem sets are available as a file "ExcelDBAM.exe". (Paperback with CD, new and used from $13 to $40)

The file "SOLVSAMP.xls" can also be downloaded which shows how solver can be used to solve several business problems.

USING SOLVER TO FIT NON-LINEAR EQUATIONS

This area of application of Solver is covered in section 10.

In general where the error measure response surface has steep gradients, one can get reasonable fits. It the surface is very shallow or the gradients change slowly, one can bad fits. One finds a wide degree of success using Solver, it fails standard tests, but will give acceptable fits in many other cases. The limited diagnostics make it difficult to be sure that an acceptable fit was attained.

COMMERCIAL VERSIONS OF SOLVER

Frontline sells several expanded versions of Solver as stand-alone packages. Their website (Frontline) includes information and pricing on these new versions. The sales literature indicates a greatly expanded capability. Frontline has never stated that these larger commercial versions would pass the NIST non-linear equation set test (see section 11).. This implies that the new versions are not able to do any better than that reported by McCullough and Wilson (1999 and 2000) and that Frontline has no interest in developing a Solver version that will pass the NIST tests.

OTHER COMMERCIAL SOFTWARE ADD-INS

For Excel 2007, the "What'sBest!" program by Lindo systems is listed. This has **NOT BEEN TESTED. IT'S A BLACK BOX.**

OPTIMIZATION OF NON-EQUATION RELATIONSHIPS, THE BUSINESS MODELS

This is a general class of problems that frequently occur in business applications where relationships, constraints, sub-objectives, branching (IF-THEN-ELSE), etc occur that cannot be easily connected by equations. The objective may be to find solutions within complex relationships and constraints, where the objective may be to minimize costs, maximize gains, minimize risks, optimize use of resources, build optimum portfolios, etc. This is the general type of problem the Solver was designed to do.

The following material is from the Microsoft Help article, “Introduction to Optimization with the Excel Solver Tool and it is from Winston, W.L., “Microsoft Excel Data Analysis and Business Modeling”. It illustrates the business view. (This book and the supporting file “ExcelDABM.exe” is listed in the ‘Office Online for Office 2003, but is not listed in ‘Office Online’ for Office 2004.)

THE TARGET CELL

“The target cell represents the objective or goal. We want to either minimize or maximize the target cell. In the example of a drug company's product mix, the plant manager would presumably want to maximize the profitability of the plant during each month. The cell that measures profitability would be the target cell. The target cells for each situation described at the beginning of the article are listed in the following table.

Table 13-1: Typical Target Cells

Model	Maximize or minimize	Target cell
Drug company product mix	Maximize	Monthly profit
Xbox shipping	Minimize	Distribution costs
Xbox pricing	Maximize	Profit from Xbox consoles and games
Microsoft project initiatives	Maximize	Net present value (NPV) contributed by selected projects
NFL ratings	Minimize	Difference between scores predicted by ratings and actual game scores
Retirement portfolio	Minimize	Riskiness of portfolio

“Keep in mind that in some situations, you might have multiple target cells. For example, Microsoft might have a secondary goal to maximize Xbox market share.

CHANGING CELLS

“Changing cells are the spreadsheet cells that we can change or adjust to optimize the target cell. In the drug company example, the plant manager can adjust the amount produced for each product during a month. The cells in which these amounts are recorded are the changing cells in this model. The following table lists the appropriate changing cell definitions for the models described at the beginning of the article.

Table 13-2: Typical Variables That are Changed

Model	Changing cells
Drug company product mix	Amount of each product produced during the month
Xbox shipping	Amount produced at each plant each month that is shipped to

	each customer
Xbox pricing	Console and game prices
Microsoft program initiatives	Which projects are selected
NFL ratings	Team ratings
Retirement portfolio	Fraction of money invested in each asset class

CONSTRAINTS

"Constraints are restrictions you place on the changing cells. In our product mix example, the product mix can't use more of any available resource (for example, raw material and labor) than the amount of the available resource. Also, we should not produce more of a product than people are willing to buy. In most Solver models, there is an implicit constraint that all changing cells must be nonnegative. I'll discuss non-negativity constraints in more detail in later chapters. Remember that a Solver model does not need to have any constraints. The following table lists the constraints for the problems presented at the start of the chapter.

Table 13-3: Typical Complex Constraints

Model	**Constraints**
Drug company product mix	Product mix uses no more resources than are available. Do not produce more of a product than can be sold
Xbox shipping	Do not ship more units each month from a plant than plant capacity. Make sure that each customer receives the number of Xboxes they need
Xbox pricing	Prices can't be too far out of line with competitors' prices
Microsoft project initiatives	Projects selected can't use more money or skilled programmers than are available
NFL ratings	None
Retirement portfolio	Invest all our money somewhere (cash is a possibility) Obtain an expected return of at least 10 percent on our investments

RECOMMENDED USE OF SOLVER

Solver should only be used within a limited range of applications. For business models with complex constraints, Solver is the only tool that is provided. The issue of accuracy is not that large a concern, because many of the inputs are to an extent, "approximate".

In any case where Solver is used, one should try different options, such as tangent and quadratic estimates, forward and central derivatives, and Newton and conjugate search methods. Sometimes Solver seems to arrive at a better solution (smallest sum-of-squares value) directly from a starting set with a small convergence criterion, and sometimes a stepped approach, with difference coarse convergence setting and a final fine convergence setting.

Because of the use of numerical differencing for derivatives, numerical accuracy and the tolerance settings (used when there are parameter constraints) have to be set low or numerical instability occurs. This has been noted on the Excel discussion lists