Introducing Uncertainty

If we lived in a world of perfect certainty, the catfish fillet project would be accepted without question. After all, it appears that it will increase shareholder wealth by $91,272.55. Unfortunately, the world is not certain. Even in this simplified example, it should be clear that many sources of uncertainty may arise. For example, the marketing department doesn't really *know* that the firm will sell 200,000 pounds of catfish fillets in the first year. Likewise, it doesn't know that it will be able to get the assumed $2.50 per pound or that demand will grow at an annual rate of 8% per year. Consumer demand may be far less than expected. This could lead to a double whammy: Not only would unit demand be less than expected, but the wholesale price would likely be less than $2.50 per pound. Poor first year acceptance could also mean lower subsequent growth rates. These and many other uncertainties naturally result in uncertainty surrounding our expected annual cash flows that, in turn, results in uncertainty surrounding the estimated NPV.

In such an uncertain world, it is helpful to develop models that allow us to determine how much uncertainty surrounds our estimate of the NPV. For example, we might like to make an educated guess as to the probability that the NPV will actually turn out to be less than zero. The following sections will lead us to an answer to this question.

Sensitivity Analysis

As noted above, many uncertain variables exist in our catfish fillet example. In fact, we could say that virtually all of the variables are uncertain, as are many others that we have not explicitly considered. However, some of these variables have more of an impact on the NPV than others. Since it would take a lot of time and effort to generate precise forecasts of every variable, it is helpful to concentrate on only the most important variables. Sensitivity analysis is the tool that helps us to identify the variables that deserve the most attention.

The idea is to make small changes in variables, one at a time, and observe the effect on the NPV (or any other decision criteria). For example, we might change the selling price from $2.50 per pound to $2.25 (a change of –10%) and then calculate that the NPV would decline to $34,291.68. Record this fact and reset the selling price to its original value. Now, reduce the terminal value of the land to $315,000 (a change of –10%) and note that the NPV declines to $77,146.59. Reducing the selling price by 10% leads to a much bigger decline in the NPV than does a similar reduction in the terminal value of the land. Therefore, we should devote more resources to accurately determining the selling price, and not spend much time estimating the value of the land.
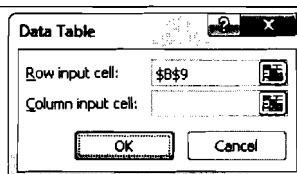
There are two problems with the procedure outlined above. First, by making only a single small change to each variable, we may miss nonlinear relationships. Second, to carry out this procedure for each uncertain variable would be cumbersome. We would have to change a

variable, write down the resulting NPV, reset the variable to its original value, change another variable, write down the resulting NPV, and so on. To solve the first problem, we can simply make several changes in each variable, both up and down. For example, we could change the selling price per pound by –30% to +30% in, say, 10% increments. This, however, exacerbates the second problem by making the analysis even more onerous. Fortunately, Excel provides a solution.

Using Data Tables

A data table is an Excel tool that automatically performs the process described previously. To see how they work, let's set up a simple example. Suppose that we wish to see what happens to the expected NPV as the selling price varies from $1.50 to $3.50 per pound. To start, enter $1.50 in G5 and $2.00 in H5.[4] Now use AutoFill to create the rest of the price series. The next step is to enter a formula into F6. In this case, we are interested in the NPV so we need to enter: =NPV(B14,C28:G28)+B28.

FIGURE 12-3
THE DATA TABLE DIALOG BOX

When we execute the data table command, Excel will automatically substitute the values from G5:K5 into our model (in cell B9) one at a time and record the resulting NPVs in the table. Select F5:K6 (this is the entire area of the table, including the NPV formula) and then choose Data Table... from the What-If Analysis button on the Data tab. In the resulting dialog box, type B9 into the Row input cell edit box as shown in Figure 12-3. After clicking the OK button, this section of your worksheet should look like the one in Exhibit 12-3.

EXHIBIT 12-3
THE DATA TABLE FOR DIFFERENT PRICES

	F	G	H	I	J	K
5	Unit Price	$1.50	$2.00	$2.50	$3.00	$3.50
6		(136,650.91)	(22,689.18)	91,272.55	205,234.27	319,196.00

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4. The data table can be created anywhere on this worksheet, but it cannot be in another worksheet. You can get around this limitation by carefully constructing your formulas.

The values in G6:K6 are the NPVs. For example, if the price per pound was $1.50 the NPV would be –$136,650.91. Similarly, if the price was $3.50 the NPV would be $319,196. If necessary, you can change any or all of the prices in row 5 and the table will automatically update.

Note that the original NPV formula in F6 is not a part of the table per se, and it might confuse some people. It is only there so that Excel knows what formula to use when calculating the table. We can easily hide this value by simply selecting F6 and changing the font color to white. This will make the table easier to read.

Excel allows for other types of data tables than we have demonstrated here. The data table in Exhibit 12-3 is called a row-oriented one-variable table because our prices are in a row. If the prices were in a column instead, we could create a column-oriented one-variable table. To create a column-oriented table, the only difference is that you would enter the changing cell (B9) into the Column input cell edit box (see Figure 12-3). The result would be exactly the same, except for the orientation table. We can also create two-variable data tables that allow for two changing variables. The procedure is similar, but you should check the online help for the details.

Since we have more than one uncertain variable in our catfish fillet problem, we will need several data tables. It will also be helpful, for comparison purposes, to deviate a bit from the methodology described above. Specifically, we can set up several data tables based on percentage changes in our uncertain variables. This will make it easier to compare the result from a change in unit sales to the result from a change in the growth rate.

EXHIBIT 12-4
THE INPUT AREA SET UP FOR SENSITIVITY ANALYSIS

	A	B	D
1	Frozen Catfish Fillet Project Inputs		
2	Cost of Land	250,000	
3	Cost of Buildings & Equipment	400,000	
4	MACRS Class	20	
5	Life of Project (Years)	5	Sensitivity %
6	Terminal Value of Land	350,000	0%
7	Terminal Value of Buildings & Equipment	200,000	0%
8	First Year Catfish Sales (lbs)	200,000	0%
9	Price per Pound	2.50	0%
10	Unit Sales Growth Rate	8%	0%
11	Variable Costs as % of Sales	60%	0%
12	Fixed Costs	80,000	
13	Tax Rate	35%	
14	WACC	10%	

Let's start by changing the input area of the worksheet so that it can accommodate this type of sensitivity analysis more easily. In D5 enter: Sensitivity %, and then in D6:D11 enter: 0% in each cell. Change B6 so that it has a formula rather than a number: =350000*(1+D6). Now if we put 10% into D6, for example, the terminal value of the land will change from $350,000 to $385,000. Make similar changes in cells B7:B11 so that those values change as we change the corresponding percentages. Your input area should now look like the one in Exhibit 12-4. Note that we will be doing the sensitivity analysis on only six of the variables.

At this point, we can proceed in a similar manner as we did above. Let's first create a percentage-based data table for the terminal value of the land. Go to A38 and enter: Terminal Value of Land. In B38:H38 enter a series of numbers from –30% to +30% in 10% increments (–30%, –20%, –10%, etc.). In A38, enter the **NPV** function: =NPV(B14,C28:G28)+B28. We have now set up the table and all that remains is to select it and execute the Data Table... command. In this case the row input cell is D6, which is the percentage that corresponds to the terminal value of the land. The data table will plug –30% into D6, which will change the terminal land value in B6 resulting in a different NPV. Next, it will plug in –20% and so on.

Using the same procedure, create data tables for each of the uncertain variables, each time changing the row input cell (D7, D8, etc.). You should end up with six data tables as shown in Exhibit 12-5. Note that, as mentioned above, we have hidden the original NPV formula so that the table is easier to read.

EXHIBIT 12-5
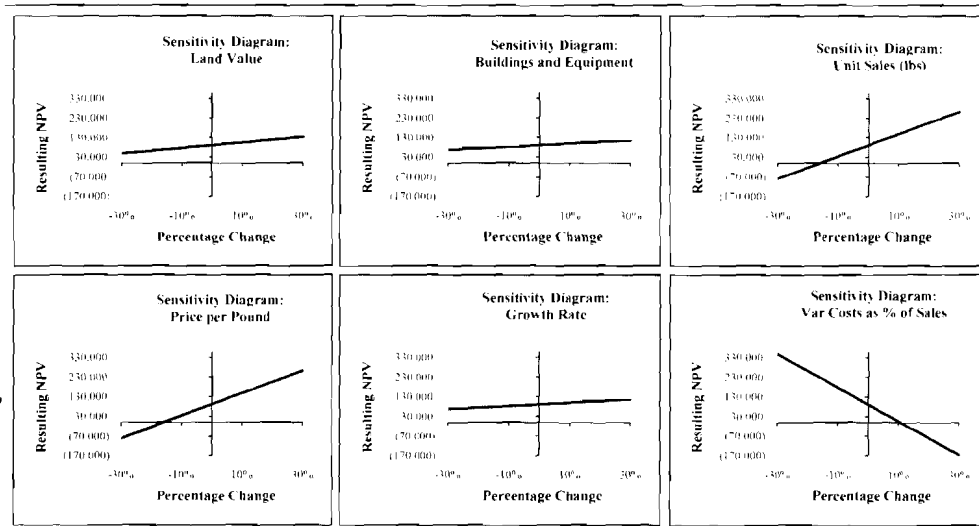### DATA TABLES FOR THE UNCERTAIN VARIABLES

	A	B	C	D	E	F	G	H
37	Sensitivity Tables							
38	Terminal Value of Land	-30%	-20%	-10%	0%	10%	20%	30%
39		48,895	63,021	77,147	91,273	105,399	119,524	133,650
40								
41	Value of Buildings & Equipment	-30%	-20%	-10%	0%	10%	20%	30%
42		67,057	75,129	83,201	91,273	99,345	107,417	115,488
43								
44	First Year Catfish Sales (lbs)	-30%	-20%	-10%	0%	10%	20%	30%
45		(79,670)	(22,689)	34,292	91,273	148,253	205,234	262,215
46								
47	Price per Pound	-30%	-20%	-10%	0%	10%	20%	30%
48		(79,670)	(22,689)	34,292	91,273	148,253	205,234	262,215
49								
50	Unit Sales Growth Rate	-30%	-20%	-10%	0%	10%	20%	30%
51		66,954	74,941	83,046	91,273	99,620	108,091	116,686
52								
53	Variable Costs as % of Sales	-30%	-20%	-10%	0%	10%	20%	30%
54		347,686	262,215	176,744	91,273	5,801	(79,670)	(165,141)

Sensitivity Diagrams

Some people can look at the data tables and see at a glance that the most important variables are the unit sales, price per pound, and the variable cost as a percentage of sales. Others, however, find it helpful to create charts of the data. The most appropriate type of chart for this analysis is a Scatter chart. We can either create a separate chart for each variable or put all of the variables in one chart.

To create one chart that shows all of the variables, we must first start with a chart of one of the variables. Select B38:H38, and then Ctrl+click each of the NPV series. Create a Scatter chart and place it somewhere convenient in the worksheet. For this example problem, it turns out that some of the lines overlap, so it is impossible to tell them apart on the chart. This is not generally the case. However, even when we don't have this problem, it can be much easier to see which variables are most important if they are all in separate charts. This is particularly true when we have a lot of variables.

FIGURE 12-4
SENSITIVITY DIAGRAMS FOR EACH VARIABLE

Creating a separate chart for each variable is more time consuming, and you need to make sure that the scaling of the axes is the same in each chart. The advantage to this approach is that it is much easier to identify the individual data series. As can be seen in Figure 12-4, the lines with the steepest slopes are the same as those previously identified as the most important variables. In order to make this comparison, it is vital that the axis scaling is identical in each chart. To make creating all of these charts easier, you can copy and paste the first one and then simply change the data ranges. To change the data series in a chart,

right-click in the chart and choose Select Data... In the dialog box, select a series and then click the Edit button to change the data ranges.

An alternative to the visual approach is to use the SLOPE function to determine the slope of each line. This function calculates a regression equation and returns the slope. It is defined as:

$$\text{SLOPE}(KNOWN\_Y'S, KNOWN\_X'S)$$

where *KNOWN_Y'S* and *KNOWN_X'S* are the Y and X data ranges, respectively. For our purpose, the Y variables are the NPVs, and the X variables are the percentage changes. For example, we can use =SLOPE (B39:H39, B38:H38) to find that the slope of the line for the terminal land value is 141,259.60. This can then be numerically compared to the slopes of the other lines. The larger the slope, the more important the variable. Note that if any of the slopes might be negative, then it is helpful to use the ABS function to return the absolute value of the slope. Adding this function to the formula will change it to: =ABS (SLOPE (B39:H39, B38:H38)). This allows us to compare magnitudes without regard to signs.

Clearly, the most important variables are the unit sales, price per pound, and the variable cost as a percentage of sales. These are the variables that we will use in our scenario analysis in the next section.

Scenario Analysis

The sensitivity analysis has identified the three most important variables, but we've only seen their impact on the NPV in isolation. A *scenario analysis* will allow us to see the combined effects of changing all of these variables simultaneously. Suppose that after seeing the sensitivity analysis report, a meeting was held to determine three possible scenarios. The best and worst cases are shown in Table 12-3 along with the base case, which represents the original expectations. It also shows the probability that each scenario will actually occur.

TABLE 12-3
THREE SCENARIOS

Variable	Worst Case 20%	Base Case 60%	Best Case 20%
Unit Sales	125,000	200,000	275,000
Price per Pound	$2.25	$2.50	$2.65
Variable Cost %	65%	60%	55%

Note that the worst case scenario is one in which all of the variables are at their worst possible values. Similarly, the best case assumes that all of the variables take on their best possible values simultaneously. While such outcomes are unlikely, they are useful for determining the extreme boundaries around the expected NPV.