Session two – Simulation

- Objective:
  - Generate random numbers
  - Set up simulation by Data Table
  - Generate statistics for simulation
  - Draw histogram and cumulative distribution function (CDF)
Questions for “Big or small”

From the base case spreadsheet, we know the NPV’s. We assume deterministic demands in year 1, 2 and 3, however. It is not a valid assumption since actual demands must vary. How can we study the minimum, maximum, and expected NPV’s? And their distributions?

Outline

• Set up random number generator
• How does Monte Carlo simulation work
• Set up simulation by Data Table
• Get statistics for simulation results
• Draw cumulative distribution function (CDF)
Random number generator

Follow the instructions, step by step

1. Download http://web.mit.edu/tao/www/ESD70/S2/1.xls
2. Click “Worksheet” under “Insert” to add a new sheet, name it “Rand”
3. Type in “Year” in cell B2, “Random demand” in cell B3, type “1”, “2”, “3” in cell C2, D2, E2 respectively

6. Click “Chart” under “Insert” menu
7. “Standard types” select “XY(Scatter)”, “Chart subtype” select any one with lines, click “Next”
8. “Data range” select B2:E3, click Next
9. “Chart options” select whatever pleases you, click “Next”
10. Choose “As object in” and click “Finish”
11. Press “F9” several times to see what happens

We have built a random demands generator for the 3 years.
Explanation

• **Rand() function**
  Returns an evenly distributed random number greater than or equal to 0 and less than 1. A new random number is returned every time the worksheet is calculated.

• **Formula in cell C3:** “=Entries!C9*((1-Entries!C25)+2*Entries!C25*RAND())”
  Returns an evenly distributed random demand for year 1 around 300, but may differ by plus or minus 50%.

  Same logic for cell C4 and C5

How Monte Carlo Simulation works

Calculate two NPV_A’s corresponding to two random demand realizations

<table>
<thead>
<tr>
<th>Demand in Year 1</th>
<th>Demand in Year 2</th>
<th>Demand in Year 3</th>
<th>NPV_A</th>
</tr>
</thead>
<tbody>
<tr>
<td>345</td>
<td>678</td>
<td>1001</td>
<td></td>
</tr>
<tr>
<td>189</td>
<td>579</td>
<td>690</td>
<td></td>
</tr>
</tbody>
</table>

How about generating many sets of random demands, and get the corresponding NPV_A’s
Monte Carlo Simulation (Cont)

Generate many sets of random demands for the three-year span

Calculate corresponding big number of NPV_A's

Statistical analysis

Generate distribution of NPV_A

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Set up simulation by Data Table

Follow the instructions, step by step:

1. Link demand in sheet for Plan A to the random demand generated, specifically, Plan A!E5 = Rand!C3; Plan A!G5 = Rand!D3; Plan A!I5 = Rand!E5

2. Click “Worksheet” under “Insert” menu to add a new sheet, and name the new sheet “Simu”

3. In “Simu” sheet, Type “NPVA” in cell A1, type “=Plan A!C16” in cell B1 (“Plan A!C16” is the output of result for NPV_A)

Explanation

- For the one-way Data Table, we do not bother to set up the input values in a list, since each row of the Data Table (for example A2:B2) stimulates a run of rand() and generates a realization of NPV\textsubscript{A}.
- We have 2000 rows in the Data Table, so we have simulated 2000 times.
- Click “F9” to try another simulation run.

Check this again

- Generate many sets of random demands for the three-year span.
- Calculate corresponding big number of NPV\textsubscript{A}'s.

Statistical analysis

- Generate distribution of NPV\textsubscript{A}. 

Get statistics for the simulation results

- We want to get the mean, maximum, and minimum value for the simulated results of 2000 $NPV_A$

Follow the following instructions, step by step:

1. In “Simu” sheet, type “Mean” in cell D1, “Maximum” in cell D2, “Minimum” in Cell D3

Comparison of deterministic and dynamic results

- From the base case spreadsheet, we learn $NPV_A$ is $162.1$ million
- What is your result for the expected $NPV_A$ when considering demand uncertainty?
- Jensen’s inequality:

\[ f[E(x)] \neq E[f(x)] \]
Draw cumulative distribution function (CDF)

Follow the instructions, step by step:

1. In sheet “Simu”, type “Bound” in E6, “Count” in F6, and “CDF” in G6
2. Type in “0, 1, 2, ... , 20” in cell D7 to D27
3. Set Cell E7 “=$E$3+D7*(E$2-$E$3)/20”, and drag the formula down to E27
4. Set Cell F7 “=COUNTIF($B$2:$B$2001,"<"&TEXT(E7,"#.00 000"))”, and drag the formula down to F27
5. Set Cell G7 “=F7/2000”, and drag down to cell G27
6. Click “Chart” under “Insert” menu
7. “Standard types” select “XY(Scatter)”, “Chart subtype” select anyone with lines, click “Next”
9. “Chart options” select whatever pleases you, click “Next”
10. Choose “As object in” and click “Finish”
11. In the chart, double click Value (x) axis, “Format axis” window popped out, go to “scale” menu, change “Value (Y) axis crosses at” into “-400”
12. Click “F9”, see the CDF moves
Now you get the CDF for the simulation
Explanation

• We set up 20 equal-width intervals to study how many data points sitting in each interval
• “countif” function counts the number of cells within a range that meet the given criteria.
• “text” function converts a value to text in a specific number in a specific format
  – #: format code for displaying only significant digits and does not display insignificant zeros
  – 0: format code for displaying insignificant zeros if a number has fewer digits than there are zeros in the format.

Explanation (Cont)

• “Text” function used here to circumvent some stubborn Excel idiosyncrasy that makes “countif” not working
  – See if it works if you type in “=COUNTIF($B$2:$B$2001,<E7)
• Each point on the CDF curve calculated by fraction of the 2000 simulation results that is smaller than a certain bound
• More refined CDF plots and histograms can be found at http://web.mit.edu/tao/www/ESD70/S2/2.xls
Summary

• Random number generator
• Using Data Table to simulate

• Now we have all basic knowledge to establish various Excel Monte Carlo simulation

Next class…

This session uses a evenly distribute random variable to model the demand uncertainty. This is not a good model in practice, though it is easy and suitable for educational purpose.

Next class will show better models for uncertainties in reality!