

Teaching Monte Carlo Simulation Using a Multi-Sheet Excel Workbook

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One of the challenges in finance education is to get across the importance of taking risk into consideration when making capital investment decisions. Once risk information is collected, it is up to the decision maker how to use it, which brings in differing approaches from manager to manager. The availability of risk indicators, however, is a valuable element in the decision process.

One strategy that seems to provide robust input for these decisions is the use of simulation to illustrate the variability of critical values, such as a net present value. A simulation may capture several key input variables' deviations. Typical inputs exhibiting uncertainty are sales growth, fixed and variable costs, and tax rates. Some argue that the cost of capital is variable as well, although these are determined nominally at the time of financing, usually at the outset of a project, and thus may not be as needy of simulation. This article demonstrates a teaching technique for using a simulation case.

INTRODUCTION

Of the skills sought by employers in our finance graduates, capability with analytical tools like spreadsheet programs rank at or near the top. To meet those needs, we are continuously seeking better ways to provide opportunity for our students to develop a level of sophistication that would distinguish our students from the rest of the applicants for professional business positions. One of the best ways we have found to accomplish this is to bring elements of reality into the classroom via case studies. Students seem to appreciate that they are developing skills directly related to their potential careers and appreciate the reality of the actual business scenarios in these cases. They also seem to rise to the occasion when they are required to use some of the more sophisticated spreadsheet techniques to analyze these actual business scenarios.

SIMULATION

One of the more useful tools to aid in the perception of risk in capital asset decisions is simulation. While businesses often reinvest in routine assets and have confidence in their ability to replicate previous successes with those assets, managers are often concerned about projects that open up new processes or markets with which they are less familiar. The uncertainty surrounding sales, costs, and taxation is not captured in a simple decision criterion using numbers the manager deems "most likely." In situations like this, simulation can be very helpful to discern whether the uncertainty is significant or insignificant to the go-no go decision.

Simulation is also a technique easily handled using Excel's format and tools, even without subroutines for compiling summary data. The process of setting up a decision structure and running a monte Carlo simulation builds and reinforces a wide set of spreadsheet skills. We find that our students develop a sense of empowerment when they can

carry out a complex analytical process and use the output information to justify recommendations to an actual business.

Teaching Monte Carlo Simulation in Excel

To teach a risk assessment using an Excel simulation, a professor will need a writeup containing the pertinent information from a business scenario. One of the current case studies we have used is Risk Assessment via Simulation: The Wauhatchie Pike Proposal, by Xiaoman Duan and Robert Stretcher. This can be accessed by contacting the authors or by reference in the Journal of Finance Case Research, where the article is forthcoming in the 2022 issue of the Journal.

The case presents a capital asset expansion in the form of a regional extension of service capability for a shipping company, currently using a hub distribution model with only two spokes. The company is wanting to know, given the significant uncertainty surrounding a second location and switching to decentralized logistics, whether the proposed investment, even with the uncertainty, should be undertaken or not. The case presents distribution inputs (means and standard deviations) for sales growth, cash expenses as a percent of sales, and even for variation in tax rates over the 20-year assessment life for the project. Students are provided with the first page of an Excel workbook, containing the information to be referenced in the Monte Carlo simulation that they will build. Questions are provided that initiate their tasks and keeps them on track. A teaching note is available to instructors adopting the case for use in their classes, and access to a solution workbook available online.

Tasks in the Simulation

1. Sales sheet:

The first step in the simulation is to duplicate the inputs worksheet from the case into a sheet in the Excel workbook, and label it "Inputs." The second worksheet may then be constructed, the sales (or revenues) worksheet, where each of the twenty years of sales forecasts is estimated, the growth rate each year being a normally distributed random variable

with the specified mean and standard deviation from the inputs worksheet. Students will use the function NORM.INV (probability, mean, std_dev) from the function menu under the “statistical” selection. They will specify a random draw between 0 and 1 for probability by either typing or selecting RAND () for the probability. The mean and standard deviation cells from the inputs worksheet can be clicked to insert them in the mean and standard_dev fields. The function results in a growth rate that can be used to estimate sales for the first year of the project by multiplying the sales reference from the inputs worksheet times (1+g):

$$\text{Sales}_{2023} = \text{SalesRef}_{2022} * (1+g)$$

Rewritten, inserting the randomly selected growth rate:

$$\text{Sales}_{2023} = \text{SalesRef}_{2022} * (1 + [\text{NORM.INV}(\text{probability}, \text{mean}, \text{std_dev})])$$

Every subsequent years’ sales is based on the previous year’s sales times 1+g (only the first year’s sales references the SalesRef from the inputs worksheet). This is demonstrated in the teaching note for the instructor, complete with screenshots of the worksheet with the corresponding Excel functions displayed for specific cells. The instructor can then guide students through the entries for the sales sheet.

2. Cash Expenses sheet:

The third worksheet, the cash expenses worksheet, may then be constructed, where each of the twenty years of cash expense forecasts is estimated. Students will again use the function NORM.INV (probability, mean, std_dev) from the function menu and either type or select RAND() for the probability. The mean and standard deviation cells for the cash expenses as a percent of sales from the inputs worksheet can be clicked to insert them in the mean and standard_dev fields. The function results in a percentage that can be used to estimate cash expenses for each year of the project by multiplying the sales from the sales worksheet by the randomly determined percent of sales:

$$\text{Cash Expenses}_{2023} = \text{Sales}_{2023} * (\%)$$

Rewritten, inserting the randomly selected percentage:

$$\text{Cash Expenses}_{2023} = \text{Sales}_{2023} * [\text{NORM.INV}(\text{probability}, \text{mean}, \text{std_dev})]$$

Every years’ cash expense is based on the corresponding sales figure from the sales worksheet times sales times the randomly determined percent of sales. This is demonstrated in the teaching note for the instructor, complete with screenshots of the worksheet with the appropriate Excel function entry for certain cells. The instructor can then guide students through the entries for the cash expenses worksheet.

3. INOCF sheet:

The fourth worksheet may then be constructed, the incremental net operating cashflow (INOCF) worksheet, where each of the twenty years of INOCF forecasts is

estimated. Students will again use the function NORM.INV (probability, mean, std_dev) from the function menu to estimate a tax rate for use in the INOCF calculation: The mean and standard deviation cells for the tax rate from the inputs worksheet can be clicked to insert them in the mean and standard_dev fields. Again, students may either type or select RAND () for the probability. The function results in a percentage that can be used to estimate INOCF for each year of the project as follows:

$$\text{INOCF} = (S-C-D) * (1-T) + D$$

where S=sales

C = cash operating expense

D = depreciation expense

T = tax rate

Rewritten, inserting the randomly selected tax rate:

$$\text{INOCF} = (S-C-D) * (1 - [\text{NORM.INV}(\text{probability}, \text{mean}, \text{std_dev})]) + D$$

Every years’ INOCF is based on the corresponding sales figure from the sales worksheet and cash expense from the cash expenses worksheet. This is demonstrated in the teaching note for the instructor, complete with screenshots of the worksheet with the appropriate Excel function entry for certain cells. The instructor can then guide students through the entries for the INOCF worksheet.

4. PVINOCF sheet:

The fifth and final worksheet may then be constructed, the present value of incremental net operating cashflow (PVINOCF) worksheet, where each of the twenty years of PVINOCF forecasts is calculated as follows:

$$\text{PVINOCF}_t = \text{INOCF}_t / [1+\delta]^t (t-2022)$$

where δ = the discount rate from the inputs worksheet

Every years’ PVINOCF is based on the corresponding INOCF value from the INOCF worksheet. This is demonstrated in the teaching note for the instructor, complete with screenshots of the sheet with the appropriate fx entry for certain cells. The instructor can then guide students through the entries for the PVINOCF worksheet.

The remainder of the analysis may be placed on the PVINOCF worksheet. First, the PVINOCF’s are totaled, representing the present value of the cash inflows from the project. Then, in the column to the right, the net present value (NPV) can be calculated as the present value of cash inflows less the initial cash outlay for the project.

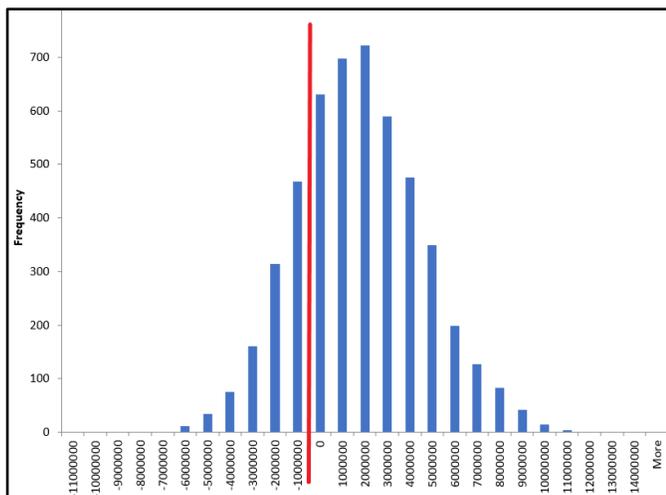
With appropriate absolute and relative cell referencing, the first line of calculations on each sheet may be copied to any number of iterations of the simulation; we suggest that 5,000 is sufficient to avoid simulation bias. The result is a column, on the PVINOCF page of 5,000 possible NPV results. This column may then be summarized for descriptive

statistics and may be used to create a histogram of the outcomes using the Data Analysis Toolpack in Excel. The Toolpack is an Excel add-in that is available with all full feature office software. Bins may be created encompassing the entire range of NPV outcomes to create an orderly chart of the NPV distribution, and bins should be selected to where a zero-bin identifier is present, since zero is the critical value for NPV decisions.

Interpreting an NPV Simulation Result

Figures 1 and 2 demonstrates the descriptive statistics and histogram chart for the random variables in one run of our simulation:

Figure 1: NPV Output Distribution.



Column1	
Mean	1161288.752
Standard Error	41022.70969
Median	1080031.832
Mode	#N/A
Standard Deviation	2900743.621
Sample Variance	8.41431E+12
Kurtosis	0.12904926
Skewness	0.184730838
Range	23115891.41
Minimum	-10063510.45
Maximum	13052380.95
Sum	5806443760
Count	5000
	0

The resulting descriptive statistics and histogram chart provides insight into the risk of the project in the following ways:

- It visually exhibits the portion of the NPV distribution falling above and below the critical value of zero
- It can be used to determine the probability of a positive versus a negative NPV
- It provides an idea of the range of possible extreme values of the NPV due to variation in the inputs

SUMMARY

We have found that use of the case, and teaching students this advanced technique, not only greatly improves understanding of risk in capital budgeting, it also builds skills critical to students’ success in their future careers. We encourage others to use this teaching method and to utilize this specific case as a tool to teach.

Until publication in the JFCR, the case is available at www.shsu.edu/fin_rhs/ptdcCASE.pdf and the teaching note at www.shsu.edu/fin_rhs/ptdcTN.pdf

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Figure 2: Summary Statistics.