

Using *Crystal Ball*® Software To Simplify Simulation Analysis in Excel

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Using Monte Carlo simulation in the classroom allows students to better model risk inherent in forecasted models. Understanding the usefulness and limitations of Monte Carlo simulation provides students a framework in which to model a variety of uncertainties in the assumptions and the interrelationships between the assumptions placed in the model. This paper first describes how spreadsheet analysis traditionally has been used to quantify risk. Next the use of Crystal Ball® software to conduct Monte Carlo simulation is described along with a brief introduction of some of the capabilities and features of the software.

INTRODUCTION

The use of appropriate technology enhances the ability of individuals to make decisions under uncertainty. Conducting simulations to determine the distribution of possible outcomes from a forecast can improve the efficiency and accuracy of the information used in making these decisions. Crystal Ball® is a graphically oriented program that allows uncertainty in the assumptions and the correlations between those variables to be modeled. It can also be used to provide a visualization of benefits and consequences of choosing between various alternative actions which can aid in decision making. When many of the variables in a model have uncertainty it is difficult for students to visualize the impact of all the random factors at the same time on the forecasts being made by the model. Crystal Ball® is simple to use and piggybacks on an Excel spreadsheet. Any forecast that can be modeled in a spreadsheet can be analyzed by using Crystal Ball® to conduct a Monte Carlo simulation. The simulation allows us to examine the entire distribution of results possible for the forecast along with appropriate statistics associated with the various outcomes. The key drivers of risk are identified and quantified through the simulation as well. Understanding the distribution of possible outcomes and the drivers of risk provide individuals better information to make decisions under uncertainty.

The limitation of traditional spreadsheet analysis is due to the fact that the values in cells have to be changed one at a time to conduct a "what-if" analysis. The results provide point estimates of outcomes resulting from various combinations of point estimates of the underlying assumption. As the number of assumptions and possible values of each assumption increase, the quantity of possible outcomes grows exponentially. The probability of the occurrence of an individual forecasted point estimate approaches zero as the number of possible outcomes grow. One common approach to modeling uncertainty is to conduct scenario analysis. Scenario analysis involves changing the values of the variables to get a point estimate of the outcome if that scenario occurs. To examine the risk inherent in a forecast point estimates of the best case, most-likely case, and

worst case scenario are frequently forecasted. This allows students to compute the range of possible values between the best and worst case scenario as measure of risk. Intuitively the larger the range, or the difference between the best case scenario forecast and worst case scenario forecast, the greater the risk inherent in the forecasted values. Unfortunately this method of risk analysis does not provide any information about the probability of any of these extreme scenarios occurring or the probability of the forecasted value being above or below any of the values between the two extreme scenarios. It is very unlikely that best case scenario or worst case scenario will actually occur. Additional information can be provided by constructing more scenarios. This can lead to a paralysis of analysis as the additional information from alternative scenarios is being processed. Imagine being given the results of fifty different scenarios and then asked to make a decision based off of those results. It would be difficult to remember the numerous different results provided by the fifty scenarios presented. It would also be very time consuming to generate the various scenarios. Ignoring the time it would take to generate the scenarios and the difficulty in retaining all the information provided by those scenarios, you still would not be certain that the fifty scenarios are representative of the true distribution of possible outcomes. Many biases in the information generated could easily result from the selection of scenarios used to generate the results.

Understanding the drivers of risk in forecasted models allows the decision maker to focus efforts on the most relevant variables generating uncertainty in the forecast. Sensitivity analysis is a common technique used to determine the impact of the uncertainty in an assumption on the uncertainty in the forecast. Traditional spreadsheet analysis allows for individuals to conduct sensitivity analysis by the changing the value of one variable at a time to determine its impact on your forecasted variable. If the forecast alters dramatically as a result of the change in the variable then the forecasted variable is said to be very sensitive to the underlying variable. Procedures for conducting sensitivity analysis require changing the variable up and down from its expected value. The individual must decide if he is going to change the variable by a certain percentage of the expected value and what that percentage should be, change the variable by an absolute amount and what that amount should be, change the variable to its maximum and minimum amounts, or some combination of the three. The choice of how much the variable is allowed to vary in the sensitivity analysis will impact the results of the sensitivity analysis. Of course as the number of variables in the model increase, sensitivity analysis becomes very labor intensive. The results of this primitive sensitivity analysis do not allow you examine the impact of one variable as all the other variables are changing. Once all of the sensitivity analysis is conducted the information will still need to be aggregated into a convenient format to assist in determin-

ing the drivers of risk in the forecasted model.

When analyzing the benefits and costs associated with various choices under control of the decision maker (for example whether to pay a dividend, what price to charge, or how to incentivize employees, etc.), the goal is to make the optimal decision given the uncertainty in the forecast. To measure the impact of different decisions made in the model requires the model to be forecasted under each different decision. Then a scenario analysis and sensitivity analysis is conducted for each decision with the results being compared against each other. All of this information then needs to be aggregated into a decipherable format to assist in making informed decisions.

The difficulty and time involved in fully analyzing all possible outcomes due to variations in the assumptions and the impact of each variable on the overall risk of the forecast often leads decision makers to use a small sample of the possibilities to make their decisions. For example, the decision maker might just look at three scenarios (best case, most-likely case, and worst case), conduct a sensitivity analysis on a few variables using only the most-likely case scenario as a base and then look at the impact of a few decisions on the most-likely case scenario. The information set for making a decision could be improved by expanding the number of scenarios to include all possible combinations of events, conducting sensitivity analysis for each variable under each of these scenarios, examining the impact of each decision variable under each of the scenarios, and then aggregating the information into a graphical format to display the entire distribution of forecasts. Using Crystal Ball ® to conduct a Monte Carlo simulation allows this to be done quickly in a very user friendly format. Crystal Ball ® assists in decision making by performing simulations on spreadsheet models which results in forecasts that quantify the risks in these models and provide a more complete information set on which to base the decision being made under uncertainty.

CRYSTAL BALL ® FEATURES AND TERMS

Before using Crystal Ball ® students need to become familiar with the features of the software and some common terms used to describe those features. Once Crystal Ball ® is loaded onto Excel a new tab will appear with a ribbon that provides access to the features provided by Crystal Ball ®. A few key terms need to be defined to facilitate the explanation of how to use Crystal Ball ® in the classroom. First we must explain what Monte Carlo simulation does and why it is beneficial in modeling uncertainty in forecasts. Monte Carlo simulation is a process in which random numbers are used to measure the effects of uncertainty on forecasts. By generating random values from a distribution of values for each assumption and estimating the forecasted value for the model under those assumptions we are generating information about possible outcomes in the forecast. Each different combination of the assumption values is called a trial. The simulation can be set to run as many trials as necessary to describe the variety of possible outcomes for the forecast. The number of trials to be run on a simulation is directly related to the number of assumptions and possible values for each assumption. As the result from each trial is aggregated into a graphical format, the information about the distribution of forecasted values is provided visually along with key statistics on the distribution.

Simulation is useful when other forms of analysis are too difficult to perform by other means. Imagine having a forecast

that has twenty assumptions with each assumption having its own unique distribution and some of those variables are correlated. Generating the appropriate amount of trials manually to adequately describe the distribution of possible outcomes becomes a daunting task. This task can be made simple by using Crystal Ball ® to run a simulation and aggregate the results into a forecast chart. On each trial Crystal Ball ® generates random numbers from the distribution for the assumption cells, recalculates the spreadsheet model, and then displays the results in a forecast chart. The forecast chart provides the range of values for the forecasted variable, the probability of that event occurring, and the frequency of that occurrence in the simulation. It also provides a graphical representation of the distribution of forecasted variables. Outliers or extreme values are included in calculations but are excluded from the display range on the forecast chart. The certainty of the forecast variable being above, below, or between certain values can be determined by changing the certainty range field values. For instance, if the forecasted variable is the net present value of free cash flows it might be of interest to determine the probability of the net present value being greater than zero.

Once a basic spreadsheet model is developed the assumptions need to be defined for each assumption cell. Instead of placing a single point estimate for an assumption cell, Crystal Ball ® allows a probability distribution to be defined for the cell. The probability distribution provides the set of all possible values for the cell along the associated probabilities of those values. Several distributions are available for use, and each is described in a distribution gallery that appears once you begin to define the assumption cell. Along with the description of each distribution, the distribution gallery provides the parameters to be used for each distribution. Once a distribution has been selected the distribution dialog box appears. The assumption name and parameter values can now be entered for the variable. Crystal Ball ® will select a value from the distribution on each trial of the simulation being performed for each defined assumption. Once all of the assumptions are defined then forecast cells should be defined. The forecasts cells contain formulas that refer back to the assumption cells. Now students are ready to run the simulation. The simulation can be ran, stopped, and continued at their discretion. The run preferences of the simulation can be set to the desired number of trials for the simulation and seed value if desired. The seed value is the first number in a sequence of random numbers, and if used the same sequence of random numbers appear every time the simulation is ran. If no seed value is given the sequence of random numbers will be different every time you run the simulation.

DISTRIBUTION GALLERY

Crystal Ball ® includes twenty-two different distributions in the distribution gallery. For each distribution, a description along with the parameters for each distribution is provided. I will provide a brief description of some of the more common distributions used in finance and economics. A normal distribution is a continuous probability distribution useful in describing many natural phenomena such as inflation or profit margin. The normal distribution is described by its mean and standard deviation. The mean is the most likely value for the distribution with occurrences being symmetrical about mean. More occurrences are likely to appear closer to the mean. Normal distributions follow the 68-95-99 rule which states that 68 percent of the

observations fall within plus or minus one standard deviation of the mean, 95 percent of the observations fall within plus or minus two standard deviations of the mean, and 99 percent of the observations fall within plus or minus three standard deviations of the mean. A triangular distribution is a continuous probability distribution useful when you know the maximum, minimum and most likely value for a distribution and the values near the maximum and minimum value are less likely to occur than values near the most likely value. A triangular distribution is often used to describe a sales projection where the minimum, maximum and most likely values are known. A uniform distribution is a continuous probability distribution in which all values between the maximum and minimum are equally likely. The lognormal distribution is a continuous probability distribution used in situations where values are positively skewed. Stock and real estate prices are usually positively skewed because their price cannot fall below zero but can increase to any value. Three conditions underlying the lognormal distribution is that the unknown variable can increase without bound, but is confined to a finite value at the lower limit, exhibits a positively skewed distribution and the natural logarithm of the unknown variable will yield a normal curve. The logistic distribution is a continuous probability distribution commonly used to describe growth and the parameters for the logistic distribution are mean and scale. It is useful when describing the growth of a population over time. The Student's t distribution is similar to a normal curve, but with more outliers and high kurtosis in the central region. The Student's t distribution has a degrees of freedom parameter that controls the shape of the distribution which is sometimes preferred over the normal distribution for more precise modeling of nearly normal quantities found in many econometric and financial applications. The Pareto distribution is a continuous probability distribution commonly used for city population sizes, the size of companies, personal incomes, and stock price fluctuations. The parameters for the Pareto distribution are location and shape. The discrete uniform distribution has all integer values between the minimum and maximum equally likely to occur. A classic example of a discrete uniform distribution is the modeling the rolling of a dice. The parameters for the distribution are the minimum and maximum value. There are three conditions underlying the uniform discrete distribution is that the minimum is fixed, the maximum is fixed and all integer values between the maximum and minimum are equally likely. A custom distribution allows you to describe a series of unweighted values, weighted values, continuous ranges, or discrete ranges for unique situations that cannot be described by the other distribution types. This is a very flexible distribution that can be customized to meet the needs of the particular assumption being modeled.

CORRELATIONS

The values of assumption cells can be correlated with each other meaning that a dependency exists among the assumption cells. The price of a good and the quantity demanded or supplied of that good are often dependent on each other. As the price of a good increase, the quantity of that good demanded declines and the quantity of that good supplied increases. When choosing values for the assumption cell in each trial of the simulation these relationships need to be accounted for when selecting the random values for the assumption cells. The dependency between the assumption cell can be described the

correlation coefficient between those assumption cells. The correlation coefficient is a standardized number whose value is between negative one and positive one. If the correlation coefficient is positive one then the cells are said to be perfectly positively correlated. If the cells are positively correlated then they move in the same direction. In other words if one variable increases then so does the other. In our example the price and quantity supplied are positively correlated with each other. When the correlation coefficient is negative one the cells are said to be perfectly negatively correlated. If the cells are negatively correlated then the values of the cells move in the opposite directions. The price of the good and the quantity demanded are negatively correlated. It is rare to find variables that are perfectly positively or perfectly negatively correlated but correlation coefficients can be near one extreme or the other. The greater the absolute value of the correlations shows higher degrees of correlation. To set the correlations between the assumptions select the tools button. A drop down menu will provide the option to select a correlation matrix. The correlation matrix allows you to select variables and assign their corresponding correlations. Using the correlations between the variables improves the accuracy of the simulations when the variables are truly correlated. Note that correlation between a variable and itself will always be positive one. The correlation coefficient between two variables can be entered into the correlation matrix so that dependencies between those variables are properly accounted for when assigning the random values to the assumption cells in each trial of the simulation.

DECISION VARIABLES

Decision variables are not required to run simulations but can be extremely useful when comparing alternate scenarios. Decision variables are variable that you control. Examples include setting a dividend payout ratio, the price of products sold or the weights applied to assets in your portfolio. To define a decision variable select the cell or cells on which you will define as decision variables. The cells selected cannot include a formula or non-numeric value. Next select the define decision button under the Crystal Ball ® menu. This will open the define decision variable dialog box. Here you have the option to name the decision variable, provide upper and lower bounds for the decision variable, define whether the variable is continuous or discrete and define the interval between values for discrete variables. It can be difficult to see the impact of various choices made under uncertainty. To better understand the impact of decisions we need to compare the forecast results based on various values for the decision variables. The Decision Table tool in Crystal Ball ® can be used to perform several simulations to test decision values for one or two decision variables. To create a Decision Table select the tools button and then select the Decision Table option from the drop down menu. You will be prompted to enter a forecast or cell to be the target of the analysis and one or two decision variables to analyze. The tool tests values across the range for each of the decision variables and then puts the results in a table that can be analyzed using Crystal Ball ® trend, forecast, or overlay charts.

FORECAST CELLS

Spreadsheet models are frequently used to compute key variables of interest such as the net present value of projected cash

flows from a capital budgeting project. The uncertainty in the net present value results from the uncertainty in the assumptions used to project the cash flows. To analyze the uncertainty in net present value it can be defined as a forecast cell for the simulation. Forecast cells usually contain formulas that refer back to the assumption cells and decision variables in the model. To create a forecast cell go to cell that contains the variable and click on the define forecast button. Be sure to name the forecast and specify the units for the forecast when defining the forecast cells. By default crystal ball selects either the value in the cell to left of the forecast or the location of the cell as the name. Naming the forecast cell appropriately lets identify which forecast value the simulation is analyzing which is especially useful if you have selected more than one forecast variable. You also have the option to set additional forecast preferences at this stage by clicking the more button in the define forecast dialog box. The forecast preferences can be set to choose the type of display, to select whether to display the forecast window while the simulation is running or when it stops and whether to fit a continuous probability distribution to the forecast.

RUNNING THE SIMULATION

Once all the cells and variables have been properly defined it is time to run the simulation. It is often useful to run the simulation a single step at a time to demonstrate what is occurring during the simulation. By clicking the single step button the simulation will run a single trial. Students can observe the assumptions changing in each trial of the simulation. Once students understand what is going on in the trials the simulation can be ran by selecting the start simulation button. Once the simulation is completed Crystal Ball ® can generate a variety of reports to aggregate the data in a convenient format. To generate a report select the create button. A variety of predefined reports are available through Crystal Ball ® or a custom report can be created to provide the specific information desired. I recommend creating the full report to provide all the data generated from running the simulation.

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Corporate Mole: A Grouping Strategy for Minimizing the Free-Rider Problem in a Managerial Finance Course

Group projects in upper level finance courses are becoming common, both for the reflection of real-world group tasks in business firms and for their appropriateness in dealing with certain types of assignments in the classroom and beyond. Professors often lament over effective formation of groups and the task of managing group dynamics, including the problem of free-riders: those students who, knowing that the group gets the grade, will shirk their respective responsibilities in accomplishing group tasks. The following article represents one evolution of grouping methods over two decades and the observations surrounding each. The most successful, in this author's experience, is a recent marriage of a so-called "reality TV" recipe with structured groupings.

This study was carried out in a typical finance capstone course. The first part of the course involves a comprehensive review of the breadth of managerial finance in the first six weeks of the course, incorporating two exams on the selected topics. This portion of the course is very rigorous, and involves traditional lectures, website instruction, exercises and assignments on the review material, and several case studies that di-

rectly enhance the topical coverage. All of the solutions are presented during class time, with the objective of preparing students for the examination. It also establishes an approach to problem solving that is direct and quick, and one that weeds out information that may not be pertinent to the issue at hand.

The remainder of the course is dedicated to groupwork with the objective of developing solutions to business problems and issues. The material for the course is provided using a variety of cases in finance. The capstone course is typically taken in the senior year of the undergraduate experience for finance majors.

The grouping methods presented here were developed at two universities. One university (University A) is somewhat unique in terms of the student population. Most are of traditional college age, and camaraderie is easily established in the typical finance graduating class of twenty-five to thirty students. In much of the required coursework, a practical and real-world approach is stressed. Through substantial interaction with corporate and workplace representatives during their business education experience, students tend to realize the importance of working in groups, communicating effectively, and being ana-