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Financial Simulation Modeling in Excel

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A Step-by-Step Guide

Keith Allman Josh Laurito Michael Loh

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Preface

Regardless of where I work, simulation has crept into my financial career. After nearly a decade of working with it in many capacities I've found it to be a mixed blessing. In many investment companies when the term *simulation* is simply brought up there are a variety of reactions. The two most visible camps of thought seem to be the utilizers, who think the results of a simulation have value and the skeptics, who think simulation overcomplicates analyses.

The utilizers believe that when a concept or instrument is researched correctly, information parsed and calculated properly, and a simulation constructed in a statistically correct manner, the results can be used to make decisions. I tend to fall into this camp, with a few caveats I will mention later, because I have seen its utility in a variety of settings. Infrastructure deals that I saw early in my career that involved vehicular traffic, trade, or passenger flows, made more sense through simulation results given the wide variety of scenarios that could play out over time. A commodity company investment that I worked on at Citigroup involving soybeans seemed more appropriate after seeing the historic volatility of soybean prices and how their expected evolution might affect our exposure. In my structured finance career, the value of simulation on a very granular level for distressed mortgage-backed securities provided insight into obligor delinquency, default, and eventually expected security value loss. More recently, as I moved into private equity, simulating pools of corporate exposures and fund performance has become an important tool in assessing portfolio risk.

With all of these positives, there are some valid criticisms of simulation that are espoused by the skeptics. Relating to the overcomplication arguments is the thought that simulation is complex and that many mistakes can be made. I agree with this criticism, and one of the caveats that I alluded to earlier is that simulation must be implemented correctly for it to be useful and productive. I have seen simulations fail for a number of reasons, but most relate to poor implementation. In one transaction that I saw taken to a credit committee, the simulation implemented was purely derived from Excel's random number generator creating numbers based on a uniform distribution. No analysis was done around the appropriate distribution, and the CEO, who had an actuary background, instantly criticized the presentation.

In another transaction at an investment bank, a transaction specialist asked me to use a third-party simulation program to assist in modeling a structured

product. I used the model exactly as it was intended and provided the results to the specialist. I knew that the time frame for the transaction was limited, but I was surprised that later in the day the specialist was preparing the results to use for the investment committee. The results that he had were a simulation of the asset side only and had no bearing on the liability structure being implemented. Trying to use such results in the manner he intended would have been erroneous. Luckily, the problem was caught in time and the proper analysis later done.

Even worse are systemic failures of simulation that we have recently seen. Before the 2007/2008 global financial crisis, the market assumed a lower correlation level for mortgage-backed securities than was actually intrinsic to the system. Simulations were run, and securities were poorly sized against default partly relating to this correlation underestimation. As the crisis evolved, the correlations were rerun and noticeably higher, meaning that the securities structured via simulations using lower correlations were much riskier than originally thought.

The intent of exposing my negative experiences with simulation is by no means to dissuade readers from using it and therefore throwing into question what the many pages that follow this preface could possibly be about. The purpose is to show that many of the problems related to financial simulation are caused by improper construction, use, or interpretation. Historical data that provides probabilities, volatility, or correlations might not be scrubbed and analyzed correctly, the implementation of simulation methods might be against the wrong distribution or structurally incorrect, and interpretation of results could be construed to arrive at fallacious conclusions.

The problems seem surmountable when enough time is taken to use simulation correctly. To be able to do this in a financial context, many people encounter difficulties because the bulk of the texts that explain simulation methodologies are extremely dense and theoretical. Few try to distill the important concepts into a readily accessible format with meaningful and practical examples. Like the other books in my step-by-step series, this book attempts to bridge the gap between basic technical implementation and purely theoretical explanations.

A noticeable difference with this book compared to my others is the appearance of two other names on the cover: Michael Loh and Josh Laurito. Simulation is a highly complex topic, and to thoroughly dig into the details their unique experiences and abilities were absolutely necessary. Michael's technical background in physics and finance brings a high mathematical acumen, which is reflected in the most difficult Model Builders seen on the website and throughout many sections of the text. Josh has deep industry experience and firsthand experience using simulation in a variety of contexts on Wall Street. Frequently we will use the terms "I" and "we" throughout the book. In both cases we are referring to all three of us from a collective perspective.

It's my belief that the combination of our skills and experience has been conveyed in an approachable, unintimidating, and clear manner. I hope that the pedagogical approach allows readers to walk away with a new tool in their analytical skill set and a feeling of personal value addition. If readers feel that something is still not clear or that they have found a possible typo or error, I encourage them to check the book's website for errata or to contact me personally at keith.allman@enstructcorp.com.

KEITH ALLMAN

Acknowledgments

I can definitively state that this book would not have been possible without my coauthors, Michael Loh and Josh Laurito. At times it was difficult, but both persisted through complex Excel/VBA work, tedious explanations, and long nights writing. Thank you, Mike and Josh. I must also thank the staff at John Wiley & Sons once again for allowing me the opportunity to add to the body of financial knowledge that the Wiley Finance series offers. Specifically, Bill Falloon, Jennifer MacDonald, and Tiffany Charbonier were critical to this book printing.

—Keith Allman

I would like to thank Keith Allman for providing me with this opportunity to help him write this book. Working with my coauthors on this project has been an amazing and enlightening experience for me. I am grateful, especially to Josh Laurito, for the patience my coauthors have shown me and for all the fantastic work that they have put into this book. I would also like to thank our publisher, John Wiley & Sons, because without their support none of this would have been possible.

—Michael Loh

Writing a book under almost any circumstances is a time-consuming endeavor. But writing one with three authors, on two continents, across eight time zones involves an extraordinary amount of dedication and patience. Mike and Keith were fantastic through the entire process, and I want to thank them for all the time and expertise they devoted to putting together the best text possible. I also want to thank the people at Wiley for their guidance and openness through the process of writing this book. In addition, special thanks to my partners, Gregg and Tim, as well as the whole team at Lumesis: Abdullah, Alex, Chong, Jacob, Justin, Lev, and Louis, for supporting me and our vision despite the hours this project took away from our venture. Most importantly, I want to thank my family and friends for their encouragement and patience as I disappeared for weeks at a time to work through what seemed like an endless project. Mom, Dad, Aaron, Becca, Jess, Shruti, and everyone else: thank you so much for your love and support.

—Josh Laurito

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MICHAEL LOH is a software developer at Tech-X Corporation in Boulder, Colorado. He is working on electrostatic and electromagnetic particle-in-cell simulation code with applications in particle-beam physics, plasma fusion, and electron-hole transport in semiconducting detectors. Before joining Tech-X, he was a software developer and quantitative analyst at RangeMark Financial Services, where he developed the theory and application software to simulate the performance of residential and commercial mortgage-backed securities. Mr. Loh has a background in physics and was engaged in a Ph.D. program at the University of Chicago before joining RangeMark. His research focused on determining the evolution of matter distribution throughout the universe from observations of galaxy clusters at high redshifts. He left with a masters in physics. He also has a bachelor's degree in physics from UCLA.

Financial Simulation Modeling in Excel

CHAPTER 1

Introduction

Projecting future performance in finance is rarely an endeavor that will lead to results that exactly mimic reality. Equity products vary as the market evolves, seemingly simple fixed-income products may fluctuate in value due to changing interest rates, and overall most financial products have an ebb and flow of value. None of this is shocking, since much of finance is about the risk of the unknown. Understanding, measuring, and making decisions with future performance risk in mind is the focus of most financial professionals' day-to-day jobs. To understand this risk, models can be built to project what would happen given a set of certain circumstances. Depending on the sophistication of the financial analyst and the level of detail justified for a transaction, a range of techniques are available. The most basic isolated calculations form the starting point for these techniques, which then become more complicated when interconnected concepts are tied together in a deterministic model, and eventually a simulation may be constructed when a simple closed form solution is not appropriate or even possible. This book intends to focus on the last of those three methods, simulation, by taking readers through basic theory and techniques that can be instantly applied to a variety of financial products.

WHAT IS SIMULATION?

In general, simulation is typically a process that attempts to imitate how events might take place in real life. Simulations can be extraordinarily simple, such as conducting a mock interview with a peer, or incredibly complex, such as using a flight simulator to mimic a Mars landing. A simulation can also be for a tangible real-life process or for something abstract. For instance, the military often engages in simulations that try to replicate real-life war scenarios. Soldiers storm faux buildings with people playing different roles in accordance with situations they would expect in a real war. However, there are also abstract simulations such as those conducted in finance.

Even though simulations in finance may be somewhat intangible, the events that we worry about are very real. Perhaps a fund manager has a portfolio of

corporate exposures. The most obvious real-life event that would be of concern is the default of one or more of these corporate exposures. Simulating defaults would be an important exercise for the fund manager to undertake. Similarly, a fixed-income specialist might invest in fixed-rate products; however, the specialist might be funded by floating rate debt returns. Basis risk exists in such a system, and the evolution of interest rates is the real-life event that the specialist would worry about. A simulation of interest rates could greatly help the specialist design a portfolio to reduce risk.

CHARACTERISTICS OF A SIMULATION

Regardless if one is entering into a military simulation or creating a code-based simulation, there are similarities. The starting point for most simulations is the assumptions that go into it. For a military simulation that is preparing for urban warfare, this might include the number of soldiers per unit, the weapons and supplies that each solider carries, the standard and unique training of the soldiers, and the possible buildings, enemies, weather, and so forth that they could encounter. In a financial simulation, such as the corporate default example, you might have characteristics of the companies, such as the industry, regional operating location, historical asset levels, historical liability levels, and so forth.

Once the assumptions of the topic that we are trying to simulate are understood, a method for assembling the system and rules for how the system works are required. In our military simulation example, we would have a training area where the soldiers arrive with all of the training and gear one would expect, and then have an area with buildings and enemies they would expect to face. A mission with an objective would be established, and certain rules might be integrated to help make the simulation as real as possible. For instance, even though a soldier could theoretically leave the simulation area to get around an obstacle, a rule could define the simulation area and state that soldiers are not allowed to go beyond its perimeter. Similarly, in a financial simulation we would need a medium in which to conduct the simulation, which in modern times is done within the confines of a computer application. We program rules to guide our assumptions' behavior through processes that simulate how real-life events might unfold.

Another characteristic of simulations is that they may be repeated to determine varying outcomes. In the military situation, soldiers may choose one path through the buildings in one iteration of the simulation and then choose a different path in another iteration. The outcomes in both scenarios could be markedly different. Similarly, in a financial simulation asset levels for the same company in a future period could be assumed to be different from one simulation iteration to the next. This could mean that the default outcomes are also different.

At the end of the simulation, there should always be an analysis. Multiple aspects of the military simulation would be analyzed, such as speed of completion of the simulation, effectiveness at achieving the mission objective, supplies used,

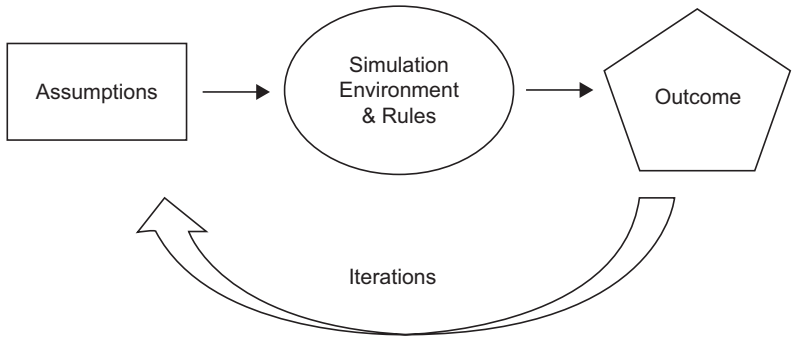

FIGURE 1.1 Most simulations will follow a similar process of selecting or creating assumptions, constructing a simulation environment with rules, analyzing the outcome, and possibly repeating the process.

and so forth. In the financial simulation, we would want to see the frequency of companies defaulting, which types of companies defaulted, the characteristics of those companies, the balance of exposures for the ones defaulting, the time at which they defaulted in the future, and so forth.

Finally, we should be concerned about the validity of our results. Numerous flaws could occur in the construction of the military simulation. Perhaps the individuals posing as enemy soldiers are not as aggressive as in real life or the equipment used is different. In the financial simulation, perhaps we assumed lower correlation than really exists or measured historical volatility wrong. All of these could lead to error that should be taken into account. See Figure 1.1.

INSTRUCTIONAL METHODOLOGY

Financial simulation can be a tricky subject for readers and authors since people have a multitude of reasons for using simulation in finance. To approach this unique issue, the book is laid out in a specific manner. Chapters 2 and 3 are what I would call "tool set" chapters. They focus on core elements of simulations that are inherent to most financial simulations (and to many simulations in other fields as well). Chapter 2 works through random number generation and eventually to explaining a common term heard in finance, Brownian motion. After that, in Chapter 3, correlation between variables is explained with examples on how correlated random numbers are generated. These tools are invaluable for constructing simulations and require a thorough understanding. For instance, one of the most common errors I have noticed financial analysts make when implementing simulations for the first time is an incorrect method of generating random numbers. Similarly, incorrectly accounting for correlation can lead to massive problems in a simulation.

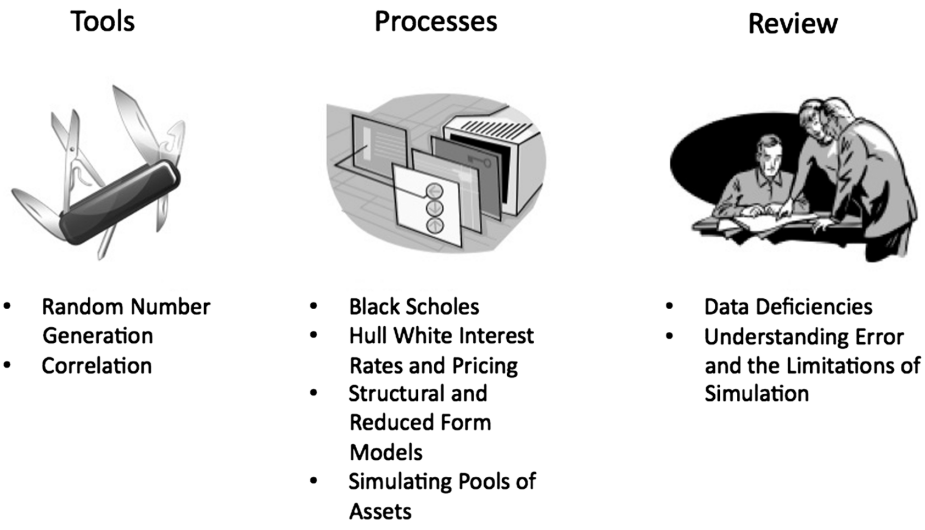

FIGURE 1.2 The chapters in this book follow a logical and intended order.

Once the tools are developed, readers begin to use them for different purposes. Chapter 4 takes readers through simulating interest rate paths to price bonds using methods credited to Hull and White. Chapter 5 expands the reader's knowledge of simulation by creating a corporate default simulation based on structural and reduced form models. Default is taken further in Chapter 6 with a thorough look at simulating pools of assets. Clearly, as authors, we cannot anticipate every reader's specific need, but the topics we have chosen reflect the most frequent and current topics related to simulation.

Finally, integrated throughout the chapters, but also a focus of chapters themselves is analysis, interpretation, and advanced thoughts on the simulation process. Chapter 7 shows readers data deficiencies and how to manage data as it relates to a simulation. Exercises, in the form of Model Builder examples, are used to help demonstrate these concepts. Although not as technically demanding, these sections should not be skipped over since they focus on the proper use of simulation; which is just as important as implementing it correctly. See Figure 1.2.

HOW THIS BOOK WORKS

There are notable differences and many similarities between this book and the others in my Step-by-Step Guide series. All rely on theory and practical exercises to transform financial concepts into dynamic, usable models. A common theme to the other books is that they work through individual "modules" that culminate