Technology Enhanced Learning: Monte Carlo Simulation of a Cash Budget

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Abstract

With digitization, organizations have access to unprecedented amounts of data pertaining to customers, suppliers, marketing operations and activities throughout the value chain. Additionally, increasing uncertainty and volatility in supply chains and business operations observed during the COVID pandemic are now part and parcel of the economic environment. Consequently, in order to be relevant and succeed in today's data science world and heightened uncertainty, accountants will have to learn new skills and competencies. This article proposes teaching Monte Carlo simulation as a technology enhance learning methodology for supplementing cash budgets taught in accounting courses to address the above. The probabilistic budget facilitates better decision-making using data modelling and statistical inferences facilitating better risk assessment and management compared to traditional cash and functional budgets.

Keywords: Budgeting, probabilistic cash budgets, Monte Carlo simulation, financial risk analysis, functional budgets.

1. Introduction

Traditional cash and functional budgeting are primarily suited for planning under stable and predictable business environments. Much of the accounting courses in managerial accounting taught at universities and syllabuses detailed for example in Chartered Professional Accountants of Ontario (CPA Ontario) and Certified Public Accountants in Ireland (CPA Ireland) knowledge maps also emphasize traditional cash and financial budgets [1], [2]. Teaching traditional cash and functional budgeting under deterministic assumptions is the predominant approach worldwide as most textbook examples focus on deterministic settings. However, for most organizations due to uncertainties it is difficult to predict reliable estimates of future operations. In an article on budgeting, Boston Consulting Group (BCG) poses the following question: "How should we run financial budgets in these turbulent times? ; "The traditional budgeting approach which relies on single-point estimates will certainly be wrong" [3]. One of the core limitations pointed out by BCG of that approach is low-quality predictions due to non-consideration of inherent uncertainties. To overcome these limitations BCG proposes using budgeting based on low, medium, and high-risk scenarios, which allows businesses to think through plausible variances and prepare accordingly. Textbooks chapters on budgeting recommends sensitivity analysis tools such as what-if-analysis and scenario planning to deal with uncertainty.

At the consulting firm EPIX Analytics, budgeting is taken a step further by incorporating risk and uncertainty into company-wide budgets for its clients. The main criticism of traditional budgeting is, "It wasn't that companies were ignoring risk in budgeting but often it is difficult to determine the cumulative effects of risks without developing a well-thought out risked-model." The benefit of a risked budget, or more formally a stochastic financial budget (SFB), according to EPIX Analytics, is it provides answers which traditional budgets do not to the following questions: "How realistic was the client's current budget? "What was their confidence that they would meet or exceed the budget? What uncertainties have the greatest possible impact on the budget? What risks, if any, could be mitigated to reduce their negative impact on the budget? and What should the budget be set at given all the relevant uncertainties?"[4]. As proposed in [5], probabilistic budgets or the concept of recognizing uncertainties in an organization's financial plans and control systems will alleviate the difficultly in predicting reliable estimates of future financial and operating activities. To the best of authors knowledge, probabilistic approach to cash and financial budgeting based on Monte Carlo simulation techniques are not illustrated in cost and managerial accounting textbooks.

Business analytics is defined as the use of data, information technology, probability and statistics, and computer-based mathematical and/or quantitative methods to gain insights and make sound, fact-based decisions of business operations [6]. Most companies now have access to large amounts of internal and

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external data ("big data"), which management accountants can use to answer questions such as what has happened (descriptive analytics), what will happen (predictive analytics), and what is the optimal solution (prescriptive analytics) [7]. While the role of management accountants has changed over the years, some suggest that the nature and scope of managerial accounting has barely changed; the focus is still on descriptive analytics, some predictive analytics but rarely prescriptive analytics [7]. Descriptive reporting deals with past business events, management accountants are additionally required to make predictions which include consequences for uncertainty and risk in decisions [8]. Business analytics or data science tools are hence useful for management accountants in conducting prescriptive analysis to help decision makers navigate uncertainties. One of the statistical techniques that can be used by management accountants in predictive and prescriptive analytics is Monte Carlo studies/simulation ([7], pp. 33, 38).

Simulation methods are not discussed in managerial and cost accounting curriculums even though Richard Mattessich in 1961 proposed using computer simulation to improve traditional periodic budgeting [9]. In a seminal article, he undertook an initial attempt to formalize a mathematical model of a traditional budget as a prerequisite for electronic data processing [9]. While almost all cost and managerial accounting budgeting is taught based on deterministic business settings, with few exceptions, risk and uncertainty using probability concepts applied to functional and cash budgets are rarely presented, discussed, and used as teaching material. Nevertheless, as suggested in [7], techniques such as Monte Carlo simulation and or simulation studies may have some appeal to today's CPAs and managers for several reasons. First, it is important to understand the characteristics of uncertainty to make decisions in today's uncertain business and economic environments. Second, risk management is an issue of paramount importance, as it provides insight into transformative decision making. Finally, advances in the power of computing and data capacity allow the increased use of computing technology by organizations to handle large volumes of data, making complex computations required by advanced statistical functions relatively easy.

The paper is organized as follows. Section 2 provides brief summary of the Monte Carlo Simulation technique. Section 3 provide an example along with data and assumptions for simulating a cash budget. . Section 4 presents the deterministic cash budget. detail how to build a probabilistic budget. Section 5 illustrates the implementation of Monte Carlo simulation in Microsoft Excel. Section 6discusses the cash budget simulation results and inferences for risk management. Section 7 concludes. Appendix A provides a step-by-step instructions on how to set up the cash budget in a spreadsheet.

2. Monte Carlo Simulation Technique

Monte Carlo simulation relies on random sampling from given probability distributions and statistical analysis to determine the likelihood of an uncertain outcome of interest. Computers are used to execute the simulation based on random numbers or pseudo random numbers. Monte Carlo simulation uses mathematical models to imitate the real-world situations. Uncertainty in the input variables are represented by probability distributions. The specified distribution could be based on objective probabilities using data from experience or subjective probabilities based on expert opinion and estimates. The RAND( ) function in MSExcel generates a random number between 0 and 1 which is used in this article. Once the random number is generated, the "*inverse transformation method*" is used to sample from a distribution. For example, in Excel, built-in functions such as NORMINV(*probability*, *mean*, *standard deviation*) and the RANDBETWEEN(L,H) can be directly used to sample from a normal and a uniform distribution.

The basic procedure of Monte Carlo simulation has three steps.

- Step 1. Setting up the model:
- Step 2. Identify probability distributions
- Step 3. Running the simulation

3. Simulating a Cash Budget

The example is developed by modifying a deterministic budget example which appears in "Cost Management" [10].

3.1. Data and assumptions

ABT Inc. manufactures and sells concrete blocks for residential and commercial buildings. ABT Inc. faces significant uncertainties: sales demand, unit selling price, cost per direct labor hour, budgeted fixed overhead, and variable marketing expenses cost. ABT Inc. uses historic data modified with expert opinion to estimate some of the parameters of the probabilistic cash budget model. The unknown parameters (random variables) considered in the simulation of ABT Inc. master budget are:

- X: Sales demand

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- Y: Unit selling price
- R: Average cost per direct labor hour
- F: Budgeted fixed overhead cost
- v: variable marketing expenses

The distribution and the parameter values for the five random variables in the ABT Inc. example are summarized below.

- Sales demand is lognormal with a log mean of 15.208 and log standard deviation of 0.634284,$X \sim \text{lognormal}(15.208, 0.634284)$
- Unit selling price is lognormal with a log mean of -0.28991 and log standard deviation of 0.077094, $Y \sim \text{lognormal}(-0.28991, 0.077094)$
- Average cost per direct labor hour follows a uniform distribution with lower bound of 12 and upper bound of 16, $R \sim \text{Uniform}(12, 16)$
- Budgeted fixed overhead cost follows a uniform distribution with a lower bound of 280,000 and upper bund of 360,000, $F \sim$Uniform $(280000, 360{,}000)$
- Variable marketing expenses is normal with a mean value of 0.05 and standard deviation of 0.01, $v \sim \text{Normal}(0.05, 0.01^2)$.

Further assumptions, inventory rules and known parameters values pertaining to the cash budget are given below.

- The December 31, 20x0 balance in the cash account is $100,000
- All sales are on account. The 20x0 sales revenue is $10,000,000. The expected sales for 20x1 are $4XY$
- On average 80% of the sales are collected in the year of sales (20x1) and the remaining 20% are collected in the coming year.
- All raw material is purchased on account. The raw material purchases for 20x0 were $3,900,000. The raw material purchases for 20x1 is expected to be $1.03454X + 20{,}020$. Eighty-five (85%) of the purchases are paid in the year of purchase. The remaining 15% of the purchases are paid the following year.
- All of wages for workers are paid in the year they are earned. Budgeted wages for 20x1 is $R(0.06X + 375)$.
- Manufacturing overhead costs are paid in cash and amounts to $0.48X + 4F + 3{,}000$ for 20x1.
- The company outsources to a well-established marketing and distribution firm. Of the annual marketing expense budget 70% is paid in the year expenses are incurred and remaining 30% are paid in the next year. The marketing and distribution budget for 20x0 is $850,000. The budgeted marketing and distribution expenses for 20x1 is $4vX + 152{,}000$
- Administration expenses of $212,000 is paid in cash.

3.2. Mathematical Expressions

The first step in Monte Carlo simulation of a probabilistic cash budget is to develop a model. The model takes the form of a mathematical expression of the traditional cash budget. The method proposed in this article uses mathematical expressions as models because they can be extended to running the simulations in Python or R easily. For example, CPA syllabuses in several countries have suggested accounting students to be familiar with R or Python for data scrubbing, statistical modelling and analysis. (See for example the https://www.cpacanada.ca/en/members-area/profession-news/2018/july/adas-practical-learning and CPA Ireland https://www.cpaireland.ie/become-a-student/CPA-Qualifications/Data-Analytics-for-Finance .

The mathematical expressions are derived using the five unknown random variables in the ABT Inc. master budget which are the economic value drivers that are subject to uncertainties. The mathematical expressions for the probabilistic cash budget are shown in Table 1. The mathematical expression for simulating total cash available for 20x1 is $3.2\text{XY} + 2{,}100{,}000$. Similarly, the mathematical models for simulating the total cash disbursements is

$$1.3594\text{X} + 2.8\text{vX} + 0.06\text{RX} + 375\text{R} + 4\text{F} + 1{,}178{,}417.$$

The net difference of the total cash available and total cash disbursements is the ending cash balance of ABT Inc. as of 31st December 20x1 given by

$$3.2\text{XY} - (1.3594\text{X} + 2.8\text{vX} + 0.06\text{RX} + 375\text{R} + 4\text{F} + 921{,}583).$$

One of the main advantages of preparing the probabilistic cash budget is the ability to disaggregate uncertainty in ending cash balance into uncertainty in the total cash available and uncertainty in total cash payments. Such detailed information which is extremely useful from treasury function is not available in the traditional deterministic cash budget.

Table 1. Probabilistic Cash Budget for ABT Inc. for 20X1

Beginning cash balance (1/1/20x1)	100,000
Received on account from sales in	
Year 20x0 (20% of 10,000,000)	2,000,000
Year 20x1 (80% of $4XY$)	$3.2XY$
Total cash available	$3.2XY + 2{,}100{,}000$
Disbursements	
Payments made for purchases made in	
Year 20x0 (15% of 3,900,000)	585,000
Year 20x1[85% of $(1.03454X + 20{,}020)$]	$0.8794X + 17{,}017$
Wages paid	$R(0.06X + 375)$
Manufacturing overhead expenses	$0.48X + 4F + 3{,}000$
Payments for distribution and marketing expenses made in	
Year 20x0 (30% of 850,000)	255,000
Year 20x1 [70% of $(4vX + 152{,}000)$]	$2.8vX + 106{,}400$
Administration expenses	212,000
Total disbursements	$1.3594X + 2.8vX + 0.06RX + 375R + 4F + 1{,}178{,}417$
Ending cash balance (31/12/20X1)	$3.2XY - (1.3594X + 2.8vX + 0.06RX + 375R + 4F) + 921{,}583$

4. Traditional Deterministic Cash Budget

The traditional deterministic cash budget of ABT Inc. for the year 20X1 is presented in Table 2. Based on the operational budgets for 20X1, forecast total revenues are $12,000,000; purchase cost of raw material is $4,168,060; direct wages amount to $3,365,250; forecast manufacturing overhead expenses are $3,203,000; marketing and distribution. expenses equal $952,000; and administration expenses amount to $212,000.

The total disbursements which amount to $11,829,501 consists of the following cash payments.

- Payments made for 20x0 purchases amounting to 15% of $3,900,000.
- Payment made for 20x1 purchases amounting to 85% of 4,168,060.
- Wages and manufacturing overheads amounting to $3,365,250 and $3,203,000.
- 20x0 Marketing and distribution expenses (30% of $850,000).
- 20X1 Marketing and distribution expenses (70% of $952,000).
- Administration expenses $212,000.

The ending cash balance based on the traditional budgeting amounts to a deficit of ($129,501).

5. Simulating Ending Cash Balance

The model for simulating the ending cash balance for 20X1 is:

$$3.2XY - (1.3594X + 2.8vX + 0.06RX + 375R + 4F) + 921{,}583.$$

In modelling the ending cash balance, all five random variables are included in the model. They are, sales demand given by X~lognormal(15.208,0.634284); unit selling price given by Y~lognormal(-0.28991,0.077094); variable marketing expenses given by v~Normal(0.05, 〖0.01〗^2); direct labor rate given by R~Uniform(12,16); and fixed overhead costs given by F~Uniform(280000,360,0000). Using the built-in Excel function =LOGNORM.INV (RAND(), 15.208,0.634284) for sales demand, the function, =LOGNORM.INV(RAND(),-0.28991,0.077094) for unit selling price, function =RANDBETWEEN (12, 16) for direct labor rate, function =RANDBETWEEN (280000, 360000) for fixed overhead cost and the function =NORMINV(RAND(), 0.05, 0.01) for the variable marketing expenses, ending cash balance for 20x1 can be computed using the formula 3.2XY-(1.3594X+2.8vX+0.06RX+375R+4F)+921,583. In order to generate a probability distribution for ending cash balance, 2000 values are sampled, and a relative frequency distribution is prepared. Alternatively, the simulated values can also be obtained by taking the difference between the 2000 previously simulated values for total cash available and the total cash disbursements. The relative frequency distribution for the simulated ending cash balance is shown in Figure 1. The descriptive statistics of the simulated probabilistic ending cash balance is shown in Table 3.

As per traditional budgeting the ending cash balance in 20X1 amounts to a deficit of (-$129,501). In contrast, the ending cash balance as per the Monte Carlo simulations is on average a deficit of (-$52,543.89) with a standard deviation of $12,250,440. This volatility of 233 times in the ending cash balance for ABT Inc. indicate that the random variables that drive uncertainty in ABT Inc.'s operating activities have an aggregating effect on the ending cash balance. Under the traditional deterministic approach these uncertainties are ignore although they provide valuable information for managing financial risks including working capital management. Another interesting observation from Figure 1 is that the ending cash balance seems to be symmetrically distributed. The simulated values for the ending cash balance include negative values (i.e. minimum ending cash balance is negative $--182,521,184). Therefore, it may be more reasonable to fit a normal distribution for the ending cash balance. There normal distribution fitted has a mean μ=-$52,543.89 and a standard deviation σ=$12,250,440. The normal distribution fit is shown in Figure 2. While the simulated values (in blue) exhibit a higher peak, for purpose of inference a normal distribution fit for ending cash balance (ω) seems reasonable. More formally the fitted normal distribution is is $\omega \sim N(-52543, 12250440^2)$.

Table 2. Deterministic Cash Budget -ABT Inc. for 20X1

Beginning Cash Balance	100,000
Received on Account from Sales in	
Year 20x0	2,000,000
Year 20x1	9,600,000
Total Cash Available	11,700,000
Disbursements	
Payment for Purchases made in	
Year 20x0	585,000
Year 20x1	3,542,851
Wages Paid	3,365,250
Manufacturing Overhead Paid	3,203,000
Payment for Marketing and Distribution made in	
Year 20x0	255,000
Year 20x1	666,400
Administration Expenses	212,000
Total Cash Disbursements	11,829,501
Ending Cash Balance	(129,501)

Table 3. ABT Inc. Ending Cash Balance

Descriptives	
Mean	-52543.89
Standard Error	273928.17
Median	-180809.49
Mode	#N/A
Standard Deviation	12250440
Sample Variance	1.50073E+14
Kurtosis	27.58028751
Skewness	-1.264190714
Range	257770560.1
Minimum	-182521184.3
Maximum	75249375.83
Sum	-105087776.8
Count	2000

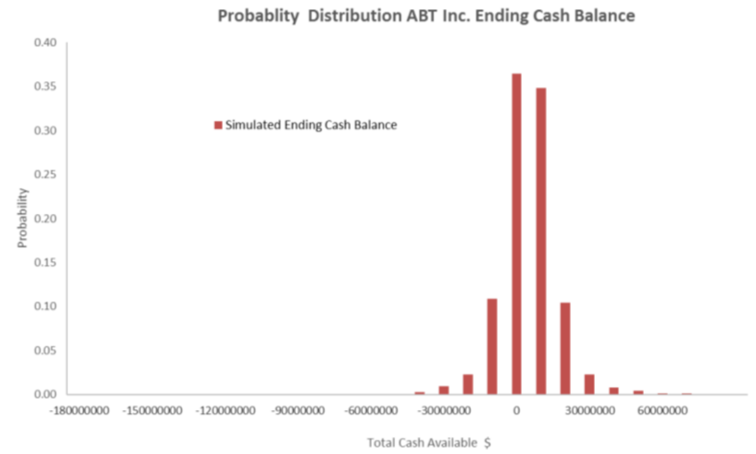

Figure 1. Ending Cash Balance in 20X1

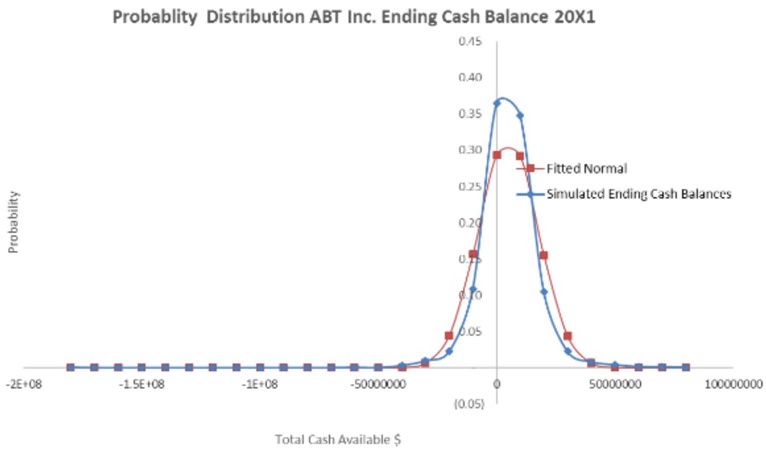

Figure 2. Normal Distribution Ending Cash Balance

6. Statistical Inferences

The normal distribution fit for ABT Inc.'s ending cash balance provides an opportunity to perform detailed risk analysis regarding it financial position in 20X1. For example, there are several symmetric intervals that can be developed which provide insight for managing risk pertaining to ending cash balance. They are:

- There is a 68% chance that ending cash balance (ω), will line in the interval $(\mu - \sigma \le \omega \le \mu + \sigma)$. More to the point, with 68% confidence the accountant can be assured that ending cash balance will range from

$$(-\$12{,}302{,}984 \ \le \omega \le \$\ 12{,}197{,}896\ ).$$

- There is a 95% chance that ending cash balance (ω), will line in the interval $(\mu - 2\sigma \le \omega \le \mu + 2\sigma)$. A 95% confidence level that ending cash balance will range from

$$(-\$24{,}553{,}424 \ \le \omega \le \$\ 24{,}448{,}336\ ).$$

- Similarly, there is a 99% chance that ending cash balance (ω), will line in the interval $(\mu - 3\sigma \le \omega \le \mu + 3\sigma)$. More specifically, a 99% confidence level that ending cash balance will range from

$$(-\$36{,}803{,}864 \ \le \omega \le \$\ 36{,}698{,}777).$$

There are other probability assessments regarding ABT Inc.'s ending cash balance that can be determined. For example, under traditional budgeting, the ending cash balance is a shortfall of (-$129,501). ABT Inc.'s accountant can find the probability of realizing an ending cash balance less than (-$129,501), i.e., $P(\omega < -\$129{,}501)$.

To find $P(\omega < -\$129{,}501)$

First calculate:

$$P(\omega = -\$129{,}501)=P\left(\frac{\Omega-\mu}{\sigma} = \frac{-129501-(-52543)}{12250440}\right) = P(Z = -0.01) = 0.00399 = 0.399\%$$

Hence the desired probability equals 50%-0.399% = 49.60%, which means that there is a 49.6% chance that the realized cash balance will be less than $-\$129{,}501$. Consequently, such information can be used by ABT Inc.'s Treasurer or accountants for planning cash and funding management.

Another probability assessment regarding ABT Inc.'s ending cash balance perhaps would be to determine the chance that ending cash balance will be greater than zero, i.e.,

$P(\omega > \$0)$. To find $P(\omega > \$0)$

First calculate:

$$P(\omega = \$0)=P\left(\frac{\Omega-\mu}{\sigma} = \frac{0-(-52543)}{12250440}\right) = P(Z = 0.004) = 50\%.$$

Which means that there is a 50% chance that the realized cash balance will be greater than $0. The probabilistic model for ending cash balance reveal that the expected cash flows given the uncertainty in the five random variables is not a large cash shortfall.

ABT Inc.'s management can also determine the probability of ending cash balance falling within a given range for instance $500,000 to $1,000,000 computed as i.e., $P(\$500{,}000 < \omega < \$1000{,}000)$. The latter can be computed in two parts.

First calculate:

$$P(\omega = \$500{,}000)=P\left(\frac{\Omega-\mu}{\sigma} = \frac{500000-893617}{12599167}\right) = P(Z = -0.03124) = 0.01197.$$

Then calculate:

$$P(\omega = \$1{,}000{,}000)=P\left(\frac{\Omega-\mu}{\sigma} = \frac{1000000-893617}{12599167}\right) = P(Z = 0.00844) = 0.00399.$$

Hence the desired probability equals (0.01197 + 0.00844 = 1.6%, which means that there is an only a 1.6% chance that the realized cash balance will between $500,000 and $1000,000.

7. Conclusion

Monte Carlo simulation technique combined with traditional cash budgeting is illustrated using a step-by-step approach in Microsoft Excel. The traditional cash budgeting taught in management accounting courses does not incorporate uncertainty using probability distributions although what-if-type analysis and scenario planning approaches are sometimes used. As per [11], modelling uncertainty using input probability distributions provide more realistic information of actual risks. Using Microsoft Excel to carry out the Monte Carlo simulation is valuable from a pedagogical perspective for several reasons. Commercial simulation software is expensive and not accessible to accounting students. Simulation via Microsoft Excel provides hands-on discovery learning. Most accounting undergraduates are familiar with Microsoft Excel so the learning curve for modelling Monte Carlo budgets less steep. Consequently, as illustrated in this article using Microsoft Excel to teach stochastic financial budgeting would be a worthwhile experience for both accounting instructors and students in the emerging setting where accounting analytics is gaining traction.

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A. Appendix- Excel Simulation

Monte Carlo simulation using Microsoft Excel can be performed for the ending cash balance using the following mathematical equation in Section 5. This appendix illustrates Excel modelling and simulations.

A.1. Excel Modelling

The mathematical equation for simulating a probabilistic sales budget from Table 1 is $\text{Ending Cash Balance} = 3.2XY - (1.3594X + 2.8vX + 0.06RX + 375R + 4F) + 921{,}583)$ where the uncertain input random variables are demand $X \sim \text{lognormal}(15.208, 0.634284)$, unit price $Y \sim \text{lognormal}(-0.28991, 0.077094)$, variable marketing expenses $v \sim \text{Normal}(0.05, 0.01^2)$, direct labor rate $R \sim \text{Uniform}(12, 16)$ and fixed overhead costs $F \sim \text{Uniform}(280000, 360{,}0000)$. The first step is to enter the relevant data which are the mean (m) and the standard deviation (s) of the log-converted values for X and Y, the lower (low) and upper (high) cost estimates for R and F, and the mean and standard deviation for v .

In Figure A-1, cells B1:E10 contain the means and standard deviations of lognormal distributions for demand and price; the low and high cost estimates for the labor rate and fixed overhead costs; and the mean and standard deviation values for variable marketing expenses. The next step is to simulate the ending cash balance as seen in cells A12:I23 in Figure A-2. The formulas must be entered only in cells B14:G14 as follows. Enter the iteration number in cell B14 which starts at 1, in cell C14 enter the formula =LOGNORM.INV(RAND(),$D$3,$E$3) to simulate a value for demand, next in cell D14 enter the formula =LOGNORM.INV(RAND(),$D$4,$E$4) to simulate a value for price, in cell E14 enter the formula =RANDBETWEEN($D$6,$E$6) to simulate a value for the wage rate, in cell F14 enter the formula =RANDBETWEEN($D$7,$E$7) to simulate value for the fixed overhead cost and in cell G14 enter the formula =NORMINV(RAND(),$D$9,$E$9) to simulate value for the variable marketing expenses. In cell H14 enter the formula to compute the ending cash balance. In order replicate 2000 values, first set a counter for iteration number cell B15 by entering =B14+1. Next copy the cells B14:H14 and paste to cell range B15:H15. In order to generate 2000 iterations of the simulated values, copy the cells B15:H15 and paste to cell range B16:H2013. Notice that only ten iterations are shown in Figure A-2. After simulating the 2000 values for ending cash balance, you should freeze the values in the spreadsheet by copying cells H14:H2013 and pasting them in cells I14:I2013 using the command “Paste Special as Values”.

A.2. Visualization and Analysis of Output

Using the fixed simulated value cells I14:I2013, numerous statistical analyses and visualizations can be performed on the output.

- To generate descriptive statistics shown in cells K19:L33 in Figure A-3, click on “Data,” then click on “Data Analysis,” and from the dropdown menu in “Analysis Tools” select “Descriptive Statistics” and click the “OK” button. For the “Input Range,” select the fixed simulated 2000 values in cell I14:I2013. Next select the “Summary statistics” box, then for the “Output Range” select a few cells K19:L25 and click on the “OK” button. The output will be displayed as shown in cells J19:L33.
- A simple set of statistics for simulated total sales revenues using some well-known Excel formulas is shown in cells J12:L17 in Figure A-3. Use the following formulas:

  cell K14 max =MAX(I14:I2013), cell K15 min =MIN(I14:I2013)

  cell K16 mean =AVERAGE(I14:I2013), and cell K17 standard deviation =STDEV(I14:I2013).
- Create a frequency table shown in cells M36:N64 in Figure A-4 using the “Histogram” tool. Select the bins K37:K63 to include the minimum and maximum simulated ending cash balances. An analyst can decide on the bin size (e.g., $10,000,000).

  For example:

  In cell K37 enter -$180,000,000, then in cell K38 enter =K37+10,000,000 and copy and paste cell K38 as formula cells to range K39 to K63. Next click on “Data,” then click on “Data Analysis,” and from the dropdown menu in "Analysis Tools" select "Histogram" and click the "OK" button. For the "Input Range" select the fixed simulated 2000 values in cell I14:I2013, for the "Bin Range" select cells $K$37:$K$63, and for "Output Range" select a few cells M36:N40 and click on the "OK" button.

The Excel will create a frequency table using the bins as shown in cells M37:N65. In order to see if all 2000 simulated values are used, enter =SUM(N38:N65) in cell N66, which will show 2000. Using these values, the relative frequency is computed as shown in cells O38:O65. To do so, first enter =N38/2000 in cell O38 and then copy cell O38 and paste as formulas in cell range O39:O65.

	A	B	C	D	E	F
1		DATA for Simulation				
2			Random variables	mean(ln(.))	sd(ln(.)	
3		Demand	*X-Lognormal*	15.208	0.634284	
4		Price	*Y-lognormal*	-0.2899092	0.077094385	
5			Random variables	Low	Hiigh	
6		Labour rate	*R-Uniform*	12	16	
7		Fixed Overhead	*F-Uniform*	280000	360000	
8			Random variables	Mean	Stdev	
9		Variable Mkt. Exp	*v-Normal*	0.05	0.01	
10		Constant value	921583			
11						

Figure A-1. Excel Data Setup

	A	B	C	D	E	F	G	H	I
12		CASH BUDGET SIMULATION							Fixed
13	Iteratic	Iteration	X	Y	R	F	v	End-Cash-Bal	End-Cash-Bal
14	1	1	3,098,874.29	0.6960994	13.00	317572	0.06557397	(649,488.68)	-15921.75587
15	2	2	2,587,557.50	0.8469219	15.00	346814	0.04890028	340,753.30	18587200.96
16	3	3	17,784,598.62	0.8557529	12.00	339855	0.06215158	8,182,922.07	-10303635.75
17	4	4	5,085,318.30	0.7985233	13.00	356846	0.03379126	1,123,028.17	-7233799.592
18	5	5	3,501,254.50	0.7307377	16.00	334179	0.06383698	(980,574.10)	6966773.776
19	6	6	3,489,956.01	0.7567008	13.00	349803	0.04526273	59,510.35	-3401886.602
20	7	7	11,937,493.78	0.6714262	13.00	347648	0.04515046	(1,873,644.01)	5835683.173
21	8	8	1,408,576.73	0.7057811	16.00	292221	0.05467959	(554,741.17)	8995209.482
22	9	9	2,020,920.62	0.6528025	13.00	326087	0.04618982	(750,927.69)	10345130.22
23	10	10	4,686,471.19	0.7785594	12.00	288715	0.06463418	844,865.98	12094720.73

Figure A-2. A Sample Set of Simulated Values

- Graph the frequency distribution for ending cash balances as in main text Figure 1. Select the data in the frequency table cells M38:N64 and use "Insert" and select Scatter with smooth lines and markers" under "Charts" to plot the frequency distribution. Notice that the frequency distribution for ending cash balances include negative values like a normal distribution. Hence it may be prudent to check if a normal distribution fits the simulated output values for the ending cash balances.
- Fitting a normal distribution to the simulated output. To fit a normal distribution to the output data as shown in cells P36:Q64, do the following. Use the built-in Excel cumulative normal function with mean and standard deviations computed as in Figure A-3 cells K116 and K17; that is, in cell P38 enter =NORMDIST(M38,$K$16,$K$17,TRUE) which will give the cumulative probability. Next copy cell P36 and paste to cell range P39:P64. In order to obtain the probabilities (see cells Q38:Q64) from cumulative probability, do the following. First in cell Q38 enter =P38. Then in cell Q39 enter =P39-P38 and thereafter copy cell Q39 to cells Q40:Q64, which are the probabilities of the normally distributed ending cash balance distribution pertaining to the bin values.
- Graph the relative frequency distribution and normal distribution on the same chart to visually see the fit. For the relative frequency distribution, under the "Insert" option select "Charts" and "Scatter with Smooth Lines".

  For horizontal (x-axis) use the bin range cells M38:M64 and vertical (y-axis) to select the relative frequencies cells O38:O64 computed earlier. In the same graph, for the normal ending cash balance distribution, as horizontal axis values use same bin ranges cells M38:M64 and for vertical axis values use the computed probabilities cells Q38:Q64. The two distributional plots are shown in main text Figure 2. The normal seems a relatively good fit as an output distribution for the simulated ending cash balance to assess risks pertaining to ABT Inc treasury and cash management functions.

	J	K	L	M
11				
12		**Fitted**		
13		**Ending Cash Balance**		
14	**Max**	75,249,375.83		
15	**Min**	(182,521,184.31)		
16	**Mean**	(52,543.89)		
17	**SD**	12,250,440.14		
18				
19		***Descriptive Statistics***		
20				
21		Mean	-52543.89	
22		Standard Error	273928.1691	
23		Median	-180809.4886	
24		Mode	#N/A	
25		Standard Deviation	12250440.14	
26		Sample Variance	1.50073E+14	
27		Kurtosis	27.58028751	
28		Skewness	-1.264190714	
29		Range	257770560.1	
30		Minimum	-182521184.3	
31		Maximum	75249375.83	
32		Sum	-105087776.8	
33		Count	2000	
34				

Figure A-3. Descriptive Statistics of Simulated Ending Cash Balance

	J	K	L	M	N	O	P	Q	R	S
35										
36		**Bin**					**Fitted Normal**			
37		-180000000		***Bin***	***Frequency***	**RelFreq**	**Cumulative Prob**	**Probability**		
38		-170000000		-180000000	1	0.00	0.00	0.00		
39		-160000000		-170000000	0	0.00	0.00	0.00		
40		-150000000		-160000000	0	0.00	0.00	0.00		
41		-140000000		-150000000	0	0.00	0.00	0.00		
42		-130000000		-140000000	0	0.00	0.00	0.00		
43		-120000000		-130000000	0	0.00	0.00	0.00		
44		-110000000		-120000000	0	0.00	0.00	0.00		
45		-100000000		-110000000	0	0.00	0.00	0.00		
46		-90000000		-100000000	0	0.00	0.00	0.00		
47		-80000000		-90000000	0	0.00	0.00	0.00		
48		-70000000		-80000000	0	0.00	0.00	0.00		
49		-60000000		-70000000	0	0.00	0.00	0.00		
50		-50000000		-60000000	1	0.00	0.00	0.00		
51		-40000000		-50000000	0	0.00	0.00	0.00		
52		-30000000		-40000000	6	0.00	0.00	0.00		
53		-20000000		-30000000	19	0.01	0.01	0.01		
54		-10000000		-20000000	45	0.02	0.05	0.04		
55		0		-10000000	218	0.11	0.21	0.16		
56		10000000		0	730	0.37	0.50	0.29		
57		20000000		10000000	696	0.35	0.79	0.29		
58		30000000		20000000	209	0.10	0.95	0.16		
59		40000000		30000000	45	0.02	0.99	0.04		
60		50000000		40000000	16	0.01	1.00	0.01		
61		60000000		50000000	8	0.00	1.00	0.00		
62		70000000		60000000	3	0.00	1.00	0.00		
63		80000000		70000000	2	0.00	1.00	0.00		
64				80000000	1	0.00	1.00	0.00		
65				More	0	0.00				
66					2000					

Figure A-4. Using the Histogram Tool

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