Creating a Dynamic DCF Analysis: A Detailed Excel Approach Utilizing Monte Carlo Methodology

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The Discounted Cash Flow (DCF) analysis usually involves long-term asset valuations yet assumptions are made to allow static variables to be introduced into this potential dynamic model. This paper advances pedagogical literature by offering a detailed Excel walkthrough incorporating a Monte Carlo Simulation to account for changes in both the growth rate in free cash flows (FCF) and the cost of capital. The empirical results are startling as projects that 'pass' the NPV acceptance rule, reveal possible negative values or extremely low positive ones that would have gone un-noticed in a traditional DCF analysis and would have resulted in a non-acceptance decision. This paper posits and empirically shows that MCS complements the DCF with results that more closely approximate the 'true' net present value (NPV) by incorporating a set of dynamic variables that directly measure the anticipated cash inflow-outflow valuation relationship.

INTRODUCTION

In the area of valuation, the Discounted Cash Flow (DCF) method is widely viewed as an acceptable means to measure the net present value (NPV) of firms, projects, and securities (Downes and Goodman 1998). In a project valuation, the DCF is dependent upon determining the expected after-tax free cash flows associated with an asset and then discounting these cash inflows and outflows to find the aggregate net present value (NPV) contributing to the decision making process. The model's major components for valuation are the estimated future cash flows and the accompanying cost of capital (Seitz and Ellison 1999). In an academic setting, students use these to arrive at decisions of acceptance/rejection. These involve long-term valuations yet assumptions are made to allow static variables to be introduced into a potential dynamic model. This paper addresses the issue that the DCF is conducted under uncertainty and as such, the estimated future cash flows need to reflect deviations over the time horizon. A Monte Carlo Simulation (MCS) is utilized to account for changes in both the growth rate (g) in the free cash flows (FCF) and the cost of capital (k) of the asset. While 'canned' programs exist for the MCS, this paper advances the pedagogical literature by offering a detailed walkthrough of creating a DCF analysis based on a MCS in an Excel spreadsheet. The latter creates a normal distribution of at least one hundred different iterations based upon changing growth rates and cost of capital. The empirical results are startling as projects that normally 'pass' the NPV acceptance rule, reveal possible negative values or extremely low positive ones that would have gone un-noticed in a traditional DCF analysis and would have resulted in a non-acceptance. This paper posits and empirically shows that coupling the DCF and MCS together more closely approximates the 'true' net present value by incorporating a set of dynamic variables that directly measure the anticipated cash inflow-outflow valuation relationship. The

complementary use of the Monte Carlo Simulation makes the DCF method a more precise and reliable means of asset valuation.

RELATED LITERATURE

In approaching asset valuation, whether it's a business entity or a capital budgeting project, the decision making process normally takes place under uncertainty and is subject to risk. In the Sharpe(1966), Lintner (1965), and Black (1972) works on market equilibrium, their cash flow models depended upon periodic discount rates. These rates, in turn, needed to be adjusted over the respective investment horizons in order to reassess future cash flows (Lucas and Prescot, 1971), (Fama, 1977), (Levy and Sarnat, 1984), and (Huang and Litzenberger, 1988). A weakness in traditional asset valuation situations is that it is generally accepted that investors follow a rigid set of rules and seldom modify the valuation process at specific stages over an asset's economic useful life (Trigeorgis and Mason, 1987) and (Trigeorgis, 1993).

Within the DCF context, the analyst is required to find a 'true' and 'dependable' net present value. Textbooks put forth assumptions that the growth rates in future cash flows are expected to be consistent for the foreseeable future (remaining economic useful life). The required rate of return or cost of capital is also held static. This is not likely to be realistic and the factors impacting the DCF model must reflect the dynamic nature over the investment horizon. The means to accomplish this is through a Monte Carlo Simulation which creates a 'what if' scenario analysis utilizing hundreds and/or thousands of possible iterations that continually change the major model inputs of cash flow growth rates (g) and cost of capital discount rates (k). The results will not only give a better depiction of the possible 'true' net present cash flow (NPV) value but will also present both the probability of a negative NPV and the true NPV exceeding a given desired value.

The remaining portion of this paper focuses on the data and methodology used in the study followed by the empirical tests and their results. A summary and conclusion segment is then presented.

DATA

In this hypothetical pedagogical case, management is assessing a project with a known cost of $1,000,000 and a future after-tax free cash flow for the next period of $200,000. It is recognized that there is uncertainty regarding both the growth in future annual free cash flows (FCF) as well as the future annual cost of capital percentages. The following two tables present the 'certain' and 'uncertain' inputs:

TABLE 1
DCF ANALYSIS W/MONTE CARLO SIMULATION: CERTAIN INPUTS

'Certain' Inputs	
Initial outlay (year 2014) Time Period 0	**$1,000,000**
After-tax Free Cash Flow in year 2015	**$200,000**
Investment Time Horizon	**10 years**

TABLE 2
DCF ANALYSIS W/MONTE CARLO SIMULATION: UNCERTAIN INPUTS

'Uncertain' Inputs	
Growth Rate in Future After-Tax FCF	**3%**
Future Annual Cost of Capital	**14%**

METHODOLOGY

It's important to note that in this analysis, the cost and expected free cash flows are correlated. If it were true that the cash flows were uncorrelated (meaning that each cash flow would be independent of each other), the DCF valuation process would not be able to use prior year's growth in cash flows to estimate the future cash flow figures.

In an attempt to learn how a system will react in various scenarios, a simulation model can be introduced. Specifically, the Monte Carlo Simulation randomly selects data points "but with the probability that each draw is controlled to approximate the actual probability of occurrence (McLeish 2005)." Excel has the capability of creating a random number generator. As stated, management is uncertain about the expected growth (g) in its free cash flows and the impact of dynamic discount rates (k) over the investment horizon. Based on the latter and its relation to the known initial outlay, the net present value (NPV) is computed. With each random change in the (g) and (k) percentages, a new NPV is calculated. This procedure is duplicated one thousand times or iterations. The proportion of iterations that results in a range of NPVs, approximately equals the probability of that range of NPVs happening. A detailed excel walkthrough is available in the appendix.

A traditional NPV model is used to measure the present value of the expected future free cash flows but is modified here for random annual growth rates in these future cash flows. Netted against these is the present value of the cash cost outlay other than financing costs. Each cash flow is discounted at a dynamic average cost of capital. The net present value (NPV) is defined as:

$$\text{NPV} = \Sigma \ \frac{\text{FCF}_{t-1}\,(1 + g_r)}{(1 + K_r)^t} \ - I_0 \quad\quad\quad (1)$$

where FCF_{t-1} = After-tax free cash flow of prior period t
$\quad g_r$ = growth rate in FCF randomly chosen
$\quad K_r$ = cost of capital randomly chosen
$\quad I_0$ = initial outlay in time period zero

Example of future FCF: FCF_1 = $200 (known period one cash flow)
$\quad\quad\quad\quad\quad\quad\quad$ $\text{FCF}_2 = (\$200*(1+g_r))$
$\quad\quad\quad\quad\quad\quad\quad$ $\text{FCF}_3 = \text{FCF}_2*(1+g_r)$

The key in being able to format Excel for a Monte Carlo Simulation for this DCF analysis is the formation of the two uncertain variables of (g) and (K). Both a mean and standard deviation are selected as a starting point. They can be assumed to be historical averages that management has calculated (Table 2). The proper excel formula, cells $D$8 and $I$8, with the random number creator is shown in Table 3 below:

TABLE 3
SET UP OF RANDOM GROWTH RATES (G) AND COST OF CAPITAL (K)

Uncertain Inputs	Cell Address	Creation of Random Variables for the Normal Distribution	Historical Averages	
g	$D$8	=NORMINV(Rand(),mean,stddev)	3%	Mean
			1%	Std. Deviation
K	$I$8	=NORMINV(Rand(),mean,stddev)	14%	Mean
			1%	Std. Deviation

The interesting and critical occurrence is that once the variables are determined, while seeming to be fixed at first, they will continue to change as the excel spreadsheet is refreshed reflecting their randomness and ultimately helping to create the normal distribution in the Monte Carlo Simulation. A detailed walkthrough appears in the appendix showing how to run a Monte Carlo Simulation in an excel spreadsheet.

EMPIRICAL EVIDENCE

The investment horizon is ten years, the initial outlay is $1,000, and the after-tax free cash flow in year one is $200 as shown in Table 1 above. Table 4 presents the initial mean growth rates in the FCF and the cost of capital along with the creation of the random variables for the distribution. Remember that the figures for (g) and (K), while appearing to be fixed, continually change as the spreadsheet is refreshed. The DCF spreadsheet format is shown in Table 5 while the respective formulas and proper cell addressing is presented in Table 6.

TABLE 4
SET UP OF RANDOM GROWTH RATES (G) AND COST OF CAPITAL (K)

Uncertain Inputs	Cell Address	Creation of Random Variables for the Normal Distribution	Historical Averages	
g	$D$8	3.97%	3%	Mean
			1%	Std. Deviation
K	$I$8	15.11%	14%	Mean
			1%	Std. Deviation

TABLE 5
DCF ANALYSIS WITH RANDOM NUMBER FACTOR DISTRIBUTION

	A	B	C	D	E	F	G
14	Year	2014	2015	2016	2017	2018	2019
15	n	0	1	2	3	4	5
16	After-tax FCF	(1,000)	200	208	216	225	234
17	Discount Factor	1.0000	.8687	.7547	.6556	.5695	.4947
18	Discount FCF	(1,000)	174	157	142	128	116
19	Cumulative FCF	(1,000)	(826)	(669)	(528)	(400)	(284)

	A	B	H	I	J	K	L
14	Year	2014	2020	2021	2022	2023	2024
15	n	0	6	7	8	9	10
16	After-tax FCF	(1,000)	243	253	263	273	284
17	Discount Factor	1.0000	.4298	.3733	.3243	.2817	.2448
18	Discount FCF	(1,000)	104	94	85	77	69
19	Cumulative FCF	(1,000)	(180)	(85)	(0)	77	146

TABLE 6
DCF ANALYSIS WITH RANDOM NUMBER FACTOR DISTRIBUTION
EXCEL FORMULAS WITHIN CELLS

	A	B	C	D	E	F	G
14	Year	2014	2015	2016	2017	2018	2019
15	n	0	1	2	3	4	5
16	After-tax FCF	=B7	=B8	C16*(1+$D$8)	D16*(1+$D$8)	E16*(1+$D$8)	F16*(1+$D$8)
17	Discount Factor	=1/(1+$I$8)^B15	=1/(1+$I$8)^C15	=1/(1+$I$8)^D15	=1/(1+$I$8)^E15	=1/(1+$I$8)^F15	=1/(1+$I$8)^G15
18	Discount FCF	=B16*B17	=C16*C17	=D16*D17	=E16*E17	=F16*F17	=G16*G17
19	Cumulative FCF	=B18	=B19+C18	=C19+D18	=D19+E18	=E19+F18	=F19+G18

	A	B	H	I	J	K	L
14	Year	2014	2020	2021	2022	2023	2024
15	n	0	6	7	8	9	10
16	After-tax FCF	=B7	G16*(1+$D$8)	H16*(1+$D$8)	I16*(1+$D$8)	J16*(1+$D$8)	K16*(1+$D$8)
17	Discount Factor	=1/(1+$I$8)^B15	=1/(1+$I$8)^H15	=1/(1+$I$8)^I15	=1/(1+$I$8)^J15	=1/(1+$I$8)^K15	=1/(1+$I$8)^L15
18	Discount FCF	=B16*B17	=H16*H17	=I16*I17	=J6*J17	=K16*K17	=L16*L17
19	Cumulative FCF	=B18	=G19+H18	=H19+I18	=I19+J18	=J19+K18	=K19+L18

Table 7 depicts the results of typical capital budgeting techniques. The NPV is greater than zero while the internal rate of return (IRR) exceeds the cost of capital. The profitability index also indicates that the benefits exceed the costs. These measures are a result of specific parameters. However, this spreadsheet has the ability to keep changing its key metrics thereby creating a distribution of values to influence the ultimate decision.

TABLE 7
DCF ANALYSIS RESULTS

	A	B	B (excel formulas)
22	NPV	**146**	=SUM(B18:L18)
23	NPV	**146**	=B18+NPV($I$8,C16:L16)
24	IRR	**18.6%**	=IRR(B16:L16)
25	PI	**1.15**	=SUM(C18:L18)/B18
26	PAYBACK	**7.95**	=INTERCEPT(B15:L15,B19:L19)

The Monte Carlo Simulation is run for one thousand unique iterations. It's influenced by the two chosen uncertain metrics of (g) and (k) that randomly change their values and hence the NPV of the asset valuation. A condensed look at the spreadsheet is presented in Table 8 and Table 9. It is followed by the determination of descriptive statistics derived from the distribution itself (Table 10).

TABLE 8
MONTE CARLO SIMULATION FOR THE DCF ANALYSIS

Column/Row	A	B	C	D	E	F	G
39		**Sample**	**NPV**	**NPV Rounded**		**Sample**	**Normal Distribution**
40		1	146	146		1	.000259
41		2	194.3	194		2	.000270
42		3	75.9	76		3	.000261
1039		1000	164.4	164		1000	.00000

TABLE 9
MONTE CARLO SIMULATION FOR THE DCF ANALYSIS
EXCEL FORMULAS WITHIN CELLS

Column/Row	A	B	C	D	E	F	G
39		Sample	NPV	NPV Rounded		Sample	Normal Distribution
40		1	=B23	=ROUND (C40,0)		1	=NORMDIST (F40,$B$29,$B$31,)
41		2	=TABLE (,C39)	=ROUND (C41,0)		2	=NORMDIST (F41,$B$29,$B$31,)
42		3	=TABLE (,C39)	=ROUND (C42,0)		3	=NORMDIST (F42,$B$29,$B$31,)
1039		1000	=TABLE (,C39)	=ROUND (C1039,0)		1000	=NORMDIST (F1039,$B$29,$B$31,)

TABLE 10
MONTE CARLO SIMULATION FOR THE DCF ANALYSIS
DESCRIPTIVE STATISTICS

Column/Row	A	B	B (excel formula)
29	NPV MEAN	158	=AVERAGE(D40:D1039)
30	NPV MEDIAN	157	=MEDIAN(D40:D1039)
31	NPV STDDEV	62	=STDEV(D40:D1039)
32	MINIMUM	(24)	=MIN(D40:D1039)
33	MAXIMUM	438	=MAX(D40:D1039)
34	PROB NPV < 0	.631%	=NORMDIST(B23,B29,B31,0)

An interesting result is that while the NPV is positive, the Monte Carlo distribution reveals a negative minimum value. This is supported by the probability metric that shows an approximate 1% chance of a negative number. This situation is further brought into focus in Exhibit 1, shown below, which presents the distribution of the one thousand NPV iterations. Note that there are four instances where the NPV breaks into negative territory. Just as alarming, however, is the number of times the DCF analysis reveals the value approaching the breakeven line of the distribution. A major argument of this paper is that traditional acceptance/rejection rules need to be analyzed in more depth. The absolute acceptance of a project where the NPV > 0 does not tell the whole story. The empirical results imply that a project can deliver an unacceptable NPV even when it is positive as it's likely that management has a 'target' figure and not just the obvious rejection of a project with a negative value.

EXHIBIT 1
DCF ANALYSIS WITH MONTE CARLO SIMULATION
DISTRIBUTION OF THE NPV PROFILE
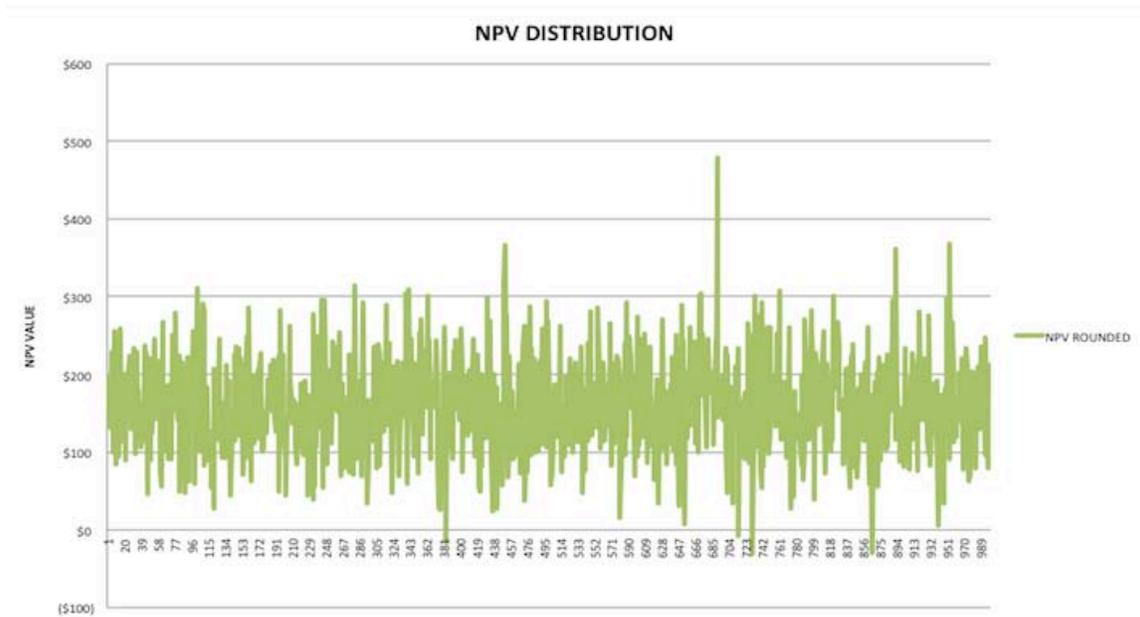
CONCLUSION

This paper advances pedagogical literature by conducting a DCF analysis that includes a detailed excel walkthrough (appendix) incorporating a Monte Carlo Simulation to account for changes in both the growth rate in free cash flows (FCF) and the cost of capital. The empirical results are startling as a project that 'passed' the NPV acceptance rule, revealed possible negative values and/or extremely low positive ones that would have gone un-noticed in a traditional DCF analysis. These results may now lead to a non-acceptance decision. A major argument of this paper is that the usual DCF analyses, needs to be complemented with a Monte Carlo Simulation for a more thorough review. The absolute acceptance of a project where the NPV > 0 does not tell the whole story.

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APPENDIX

DETAILED WALKTHROUGH OF A MONTE CARLO SIMULATION WITHIN EXCEL

Data Setup
Step 1 You have 'certain' and 'uncertain' inputs
Certain inputs are the initial outlay, the FCF in year 1, and the time period.
Management feels that the FCF will grow each year over a ten year horizon.
However, they realize that the future growth rate is variable.
In order to capture this in the DCF analysis, within the excel formulas, a random number generator factor is used.
Assume the distribution of expected future cash flows will follow a normal distribution (bell curve).
Management assumes a starting average growth rate of 3% and standard deviation of 1% while the assumed weighted average cost of capital is 14% with a 1% standard deviation.

In cell D8, type =NORMINV(Rand(),mean,stdev)
$\qquad$ =NORMINV(Rand(),\$E\$8,\$E\$9)

In cell I8, type $\quad$ =NORMINV(Rand(),mean,stdev)
$\qquad$ =NORMINV(Rand(),\$J\$8,\$J\$9)

A growth rate (g) and cost of capital rate (K) will appear.
It may look 'fixed' but it is not and will continually change in your spreadsheet!

Step 2 Set up a DCF schedule to measure the NPV where the future cash flows from year 2 through year 10 are based upon a random growth rate.
$\qquad$ FCF in Year Two = $FCF_1 * (1 + \$D\$8)^1$
$\qquad$ FCF in Year Three = $FCF_2 * (1 + \$D\$8)^1$
$\qquad$ Grow each FCF through year 10 in this manner.

Step 3 Determine the PVIF for each year based on variable cost of capital.
$\qquad$ PVIF in year 0 = $1/(1+\$I\$8)^{B15}$
$\qquad$ PVIF in year 1 = $1/(1+\$I\$8)^{C15}$
$\qquad$ Drag this formula through year 10.

Step 4 Find the Discounted FCF by multiplying the FCF by the discount factor.
$\qquad$ $FCF_0 = B16*B17$
$\qquad$ Drag this formula through year 10.

Step 5 Determine the Cumulative Discount FCF over the ten-year horizon.
Year 1   =B18
Year 2   =B19+C18
Drag this formula through year 10.

Step 6 NPV Results
Calculate the NPV in two ways.
Type NPV in A22 and in B22, type =(B18:L18)
Type NPV in A23 and in B23, type = B16+NPV($I$8,C16:L16)
Type IRR in A24 and in B24 type =IRR(C16:L16)
Type Profit Index (PI) in A25 and in B25 type =SUM(C18:L18)/-B18
Type Payback in A26 and in B26 type =INTERCEPT(B15:L15,B19:L19)

Step 7 Descriptive Statistics
Type NPV Mean in A29 and in B29 type =AVERAGE(D40:D1039)
Type NPV Median in A30 and in B30 type =MEDIAN(D40:D1039)
Type NPV STDEV in A31 and in B31 type =STDEV(D40:D1039)
Type Minimum in A32 and in B32 type = MINIMUM(D40:D1039)
Type Maximum in A33 and in B33 type = MAXIMUM(D40:D1039)
Type Probability NPV < Zero in A34 and in B34 type =NORMDIST(B23,B29,B31,0)

Monte Carlo Simulation
Step 1 Type SAMPLE in B39
In cell B40, type the number 1
While the cursor is still in B40, find the 'Fill' function on the toolbar.
Drop down menu appears and choose the following:
Series, Columns, Linear, Step Value (set as 1), Stop Value (set as 1000), OK.

Step 2 Type NPV in C39.
In cell C40, address the NPV value, =B23
Once done, Shade in both B39 and C39 (these are the labels)
Drag down for 1000 rows or whatever you have chosen.
Click on the "Data" tab on the toolbar.
Choose "What If" function.
Choose "Data Table"
Choose "Column Input" and type cell B39 (just the column label)
The column fills up with 1000 different NPV Values!

Step 3 Notice the NPV values are not uniform.
In cell D390, type NPV ROUNDED
In cell D40, type =ROUND(C40:C1039,0)
You may have to drag down the NPV column of C40:C1039)
Place cursor in corner of cell D40 and drag down to row D1039.

Step 4 Calculate the Descriptive Statistics from Step 7 above.

Step 5 In cell F39, type SAMPLE
In F40, type the number 1 and auto-fill as in Step 1

Step 6 In cell G39, type NORMAL DISTRIBUTION
In cell G40 type =NORMDIST(x,mean,stdev)

Specifically, in cell G40, type =NORMDIST(F40,$B$29,$B$31)
Place cursor in corner of cell G40 and drag it down to G1039.

Step 7 Graph the normal distribution from the data in
Cells F39:G1039 or any combination of cells.
Graph the NPV Distribution from the data in
Cells B39:B1039 and D39:D1039 or any combination of cells.
The X-axis will be the sample column.
The Y-axis will be either the Normal Distribution or
NPV-Rounded columns.