MICHIGAN ROSS

Applying Binomial Real Options to Technology Firm Valuation

by

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Abstract

The technology industry is seeing a spike in valuations due to an influx of capital to invest in these inefficient markets. Competition, which enforces fair pricing, has shifted from between the companies seeking investment to between the investors. Investors are tending to pay too much money in order to be able to invest because the power is in the hands of the entrepreneur. As a result, the intrinsic value of technology companies is misaligned with what they are valued at during the time of an investment. The focus of this research is to add objectivity to the valuation of technology companies by using the real options method, which hasn’t been applied in the private technology markets. I will be using binomial options valuation method to explore the myriad of possibilities of investments that are “out-of-the-money” and “in-the-money.” These valuations will be compared with their true market value, which will be deduced by their post IPO and fund raising value.

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INTRODUCTION

This senior thesis paper examines the valuation of unicorn (>$1B valuation) technology firms in private markets by using binomial real options pricing. Expanding on the real options teachings of Professor Kaul and Professor Damodaran, I study the volatility, cash flow, exercise price, capital expenditure, and asset price of 4 key startups that went public in 2019. Furthermore, we establish the placement of their funding rounds on this timeline and examine the value of an option to invest in the firm and the myriad of possibilities of investments that are “out-of-the-money” and “in-the-money.” The results of this study will carry broad private/public valuation insights for the technology sector. It will help expand our understanding, and limitations, of using options pricing to value entire firms.

RESEARCH PROBLEM

Statement and justification of Problem

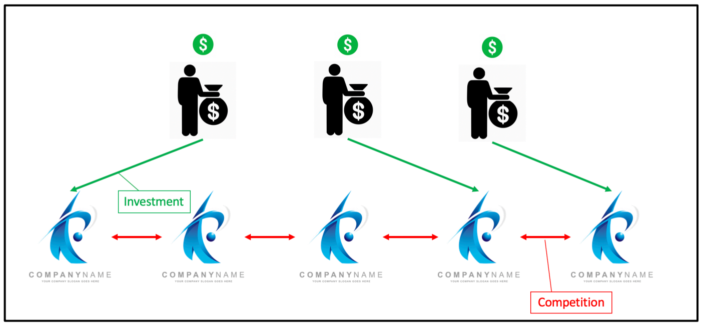
Statement of problem

The purpose of this research is to bring more information symmetry to the technology investing market by creating a fundamental, objective model to value technology companies—being able to easily derive a value for the firm instead of pricing the value using venture money standards.

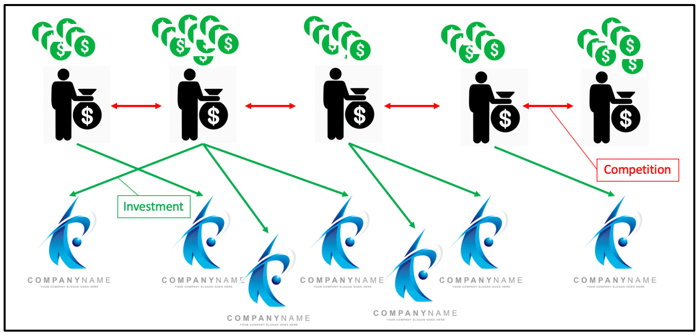
The buy-side financial markets suffer from severe information asymmetry. Venture capital and private equity investment money intended for technology companies is oversubscribed, meaning there are too many investors for investment firms, and there is too much money for high potential companies. As a result, entrepreneurs can choose their investors from a large assortment of offers. This means investing in technology companies involves arbitrary pricing decided by the entrepreneur. As of late, the intrinsic value of companies eyeing investment is not equivalent to valuations in which they are being invested in. It is commonplace to see headlines such as “Uber’s IPO Valuation Makes No Sense” (Forbes), “WeWork’s downfall shows how ridiculously overvalued so many startups are” (CNN), or “Silicon Valley tech bubble is larger than it was in 2000, and the end is coming” (CNBC). Investors are not pricing the companies they invest in. They are, instead, pricing against other investors to beat them to get the opportunity to invest in said company.

Venture and technology investing have changed an incredible amount because the hype cycle for technology is at an all time. Nonetheless, technology is extremely valuable to invest in, as it is the future of efficiency and optimization.

Venture investing took place in a more selective market between the dotcom boom period and the current technology boom. During this in-between period, investors were selective with their capital because they had a limited amount of money, and there was a smaller amount of companies. They could look at a company fully and value it with objectivity to make an informed decision. As a result, the competition was primarily between companies seeking investment.



During boom markets, such as the time we are in now and during the dot come bubble, there is an influx of companies, but an even larger influx of capital to invest in these companies. As a result, the competition shifts from between companies raising money to between investors under pressure from LPs to invest large sums of capital.



This shift in competition causes investors to overvalue companies because they are competing to be able to invest. Because the entrepreneurs have an advantage in raising capital, there is a severe misalignment between the intrinsic value of the company and the value at which it is invested in. A startup CEO may be thinking… “We have 4 investment offers for us to raise our $4M Series A round. I am going make these investors bid against each other so that I get the best deal on my equity”. On the other hand, a venture investor may be thinking… “My goal is to provide solid returns to my LP investors ASAP, so I will compete with other investors and deploy as much capital as I can in companies I believe in.”

Justification of Problem

This research problem is important because technology investments are at an all-time high, and many “traditional” companies are mutating their financing and operations to be similar to those of technology companies.

US public markets are in a 10-year bull run, which confirms the assumptions that there is a misalignment between the intrinsic value of companies and the value at which they are invested in. This problem is solvable by using intrinsic valuation methods. We often use DCF and comparable methods, but these are challenging to apply to early stage companies without other metrics. As a result, there is room for research and development of a method to align the value at investment and intrinsic value. This is a real problem, and innovation and major capital markets are at stake without providing this alignment.

Literature Review

The vast majority of literature focused similarly to this thesis are segmented into two categories—technology valuations or options pricing. Technology valuation literature is typically focused on improving valuation methods, while options pricing literature shows the mathematical operation of options and how to apply them to business decision making.

Technology valuations

In the report, *Squaring venture capital valuations with reality*, Gornall and Strebulaev confirm the above claims of rampant overvaluation of technology firms in the private markets. To address these confirms, the authors calculate fair market value for all private technology firms valued at over $1B using a combination of discounted cash flow (DCF), series of payoffs, and distribution based on share types. Their results stated, on average, the 135 unicorn companies in the US were overvalued by roughly 48%. Many other reports tackle similar questions in the *Journal of Business Venturing*, all generally with a slightly deviated method of applying DCF to technology firms. For example, Goedhart discusses in a McKinsey article, *Valuing high-tech companies*, how to create weighted scenarios for technology firm DCFs. Most written reports create a feeling of uncertainty around technology investing, which can be solved with enough due diligence and trial and error. Additional literature reviewed can be noted in the references section and the Thesis Proposal document.

Real options

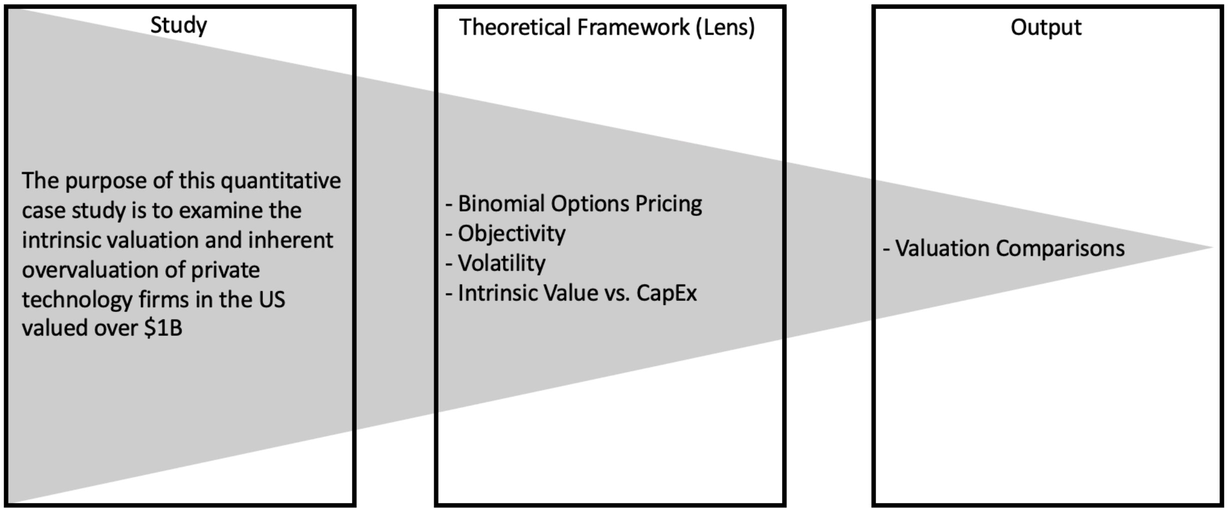
Options are often written about in two main groupings—industrial application and theoretical. On the theoretical side, I've reviewed the original *Black–Scholes–Merton model*, but reading these papers I lost sight of the big picture. As a result, I started focusing on real options methods. The work in Damodaran's *The Promise and Peril of Real Options* is integral to this report, and its contents are highlighted in sections below. Additionally, I have reviewed *Investment Opportunities as Real Options: Getting Started on the Numbers* by Timothy A. Luehrman in the Harvard Business Review. Building off of this first report, he wrote another—*Strategy as a Portfolio of Real Options*. These guide readers to think in financial terms and of businesses as portfolios of options and projects. However, Damodaran's literature posed more real-world application to valuing a company. Nonetheless, no literature on real options directly shows methods to value whole firms, the literature simply hints at this possibility. Many other sources discuss real options for energy projects, such as Vogstad's wind energy evaluation. It still points out that assumptions, such as volatility, are key and should remain the same whether valuing a project, market, or company. I find that that this option quantitative approach has been thought about and strategized, but not built for private technology companies.

THEORY AND HYPOTHESIS

Hypothesis

It is challenging to initially gauge the value added by applying options pricing—most likely, it will serve as an augmented view of valuation and forecast. In this case, generally, the model will confirm the majority of technology firms are overvalued. However, I am predicting that the option value will be relatively high (investing on private market), as this option value is driven by exclusivity and inability for everyone to participate in private rounds of funding. Additionally, I anticipate the observed technology firms to have a far lower capital expenditure per share in perpetuity compared to intrinsic valuation, as they are typically not capital intensive businesses.

Theoretical Framework



Focusing on technology firm valuation through the lens of options pricing will place a particular emphasis on objectivity, volatility, and evaluating intrinsic value versus capital expenditures.

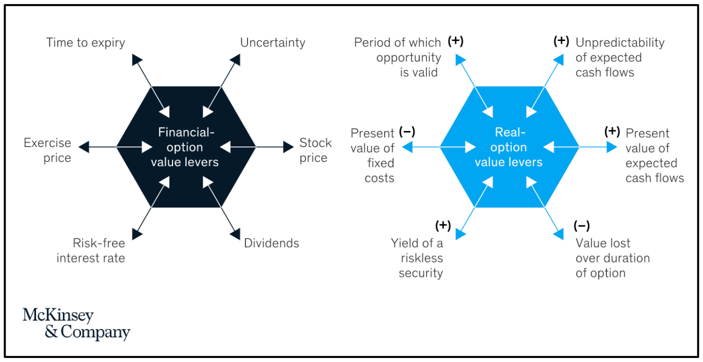
A real option is embedded in an action if (1) it provides the holder with the right to buy or sell a specified quantity of an underlying asset at a fixed price (2) there is a clearly defined underlying asset whose value changes over time in unpredictable ways (3) the payoffs on this asset are contingent on a specified event occurring within a finite period.

A real option has significant economic value when there is a restriction on competition in the event of the contingency. In a perfectly competitive market, no contingency. An option is most valuable when it has exclusivity—only this particular investor can take advantage of the contingency. They become less valuable as barriers to competition become less steep.

The value can be estimated using an option pricing model if (1) the underlying asset is traded (2) there is an active marketplace for the option (3) the cost of exercising the option is known with some certainty. Nonetheless, the value estimates will be imprecise, as the value can deviate much more than marketplace due to difficulty of arbitrage.

I will be focusing on binomial options pricing as opposed to the Black Scholes. The Binomial Model is a statistical method, while the Black Scholes model requires a solution of a stochastic differential equation. There is no significant difference between the results of the above two models. Overall, the Binomial model is better for having "options" to invest over time and tracking these.

Applying real options is viable for 3 main reason: (1) Companies in every type of industry have to allocate resources to competing opportunities—in existing businesses or new ventures. Companies must decide whether to invest now, to take preliminary steps reserving the right to invest in the future, or to do nothing. Because each of these choices creates a set of payoffs linked to further choices down the line, all management decisions can be thought of in terms of options (2) Options theory is notoriously arcane, so people have not thought to apply it to modern technology companies (3) People are turned away by the math, so it is underutilized in private market investing.



McKinsey & Co.

This research area is novel because I am looking into using traditional options pricing models to purely calculate the volatility of technology companies. (1) This is applying a currently used method (real options) to a new application—modeling the volatility of private and public technology companies has not been done before using an options pricing model because venture investing shies away from modeling. (2) This is a new approach to valuing to technology companies. Applying real options is viable and novel. (3) This is replicating the real options method with new data.

This new method is viable with enough qualitative and quantitative modeling to encompass all aspects of an investment deal. Additionally, there are so many companies to invest in now that a model can be validated and should be built to compare the many companies available for investment.

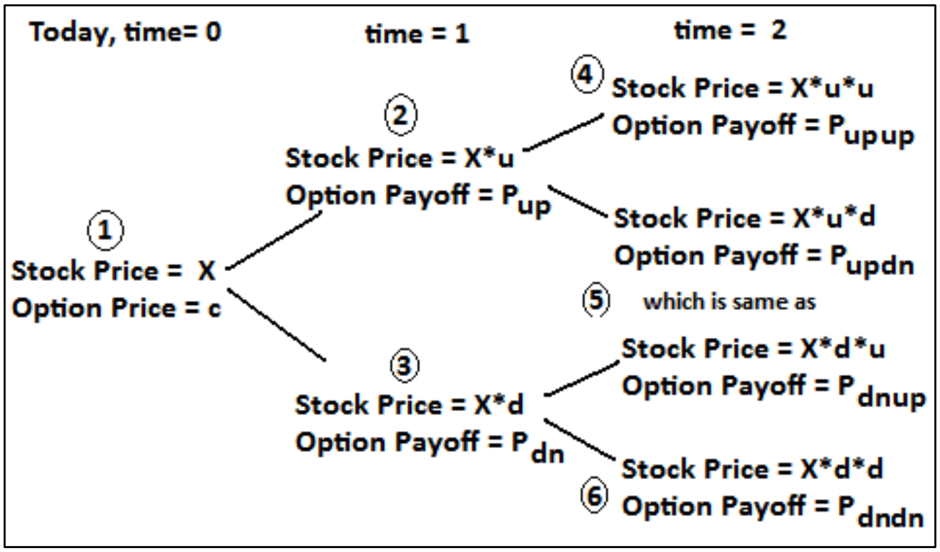
METHODOLOGY AND DATA

Methodological Framework

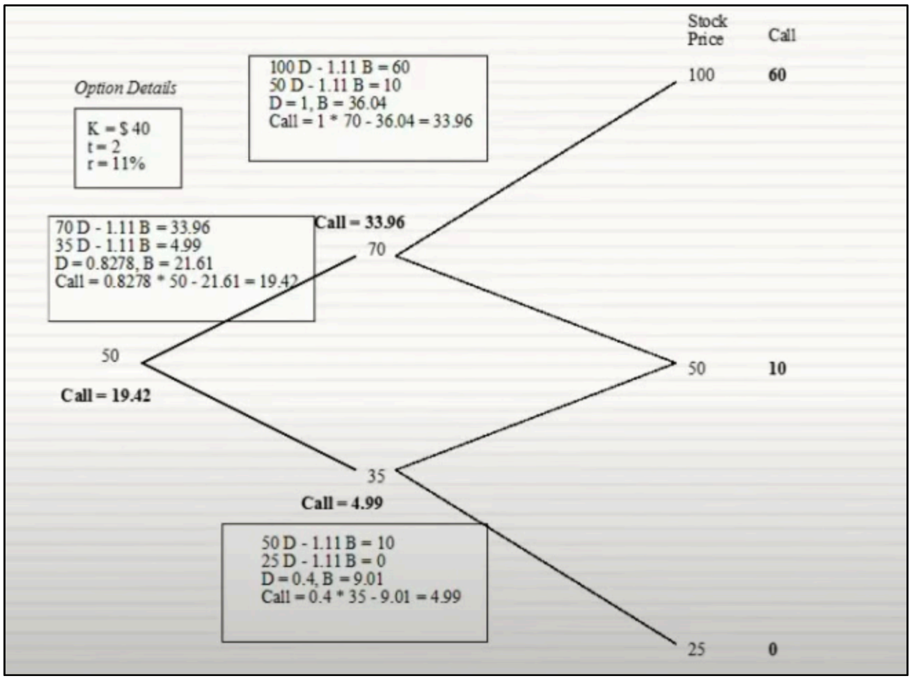
Conceptual

Mathematically, binomial options pricing is simple, but it is challenging applying the right lens for yielding assumptions and understanding.

Variable	Meaning	Calculation
S	Asset price (stock price)	Market-based
E	Exercise price (strike price)	Market-based
u	Magnitude of up-jump between nodes	$u=(\exp)^{\sigma\sqrt{t}}$
d	Magnitude of down-jump between nodes	$d=\frac{1}{u}$
σ	Volatility	Market-based
rf	Riskless rate	Market-based
q	Probability of up-jump between nodes	$q=\frac{(1+r_f)-d}{u-d}$
qu	Probability of down-jump between nodes	$qu=1-q$
t	Time between nodes (1 = year)	0.08 (1 month)



Investopedia



Professor Damodaran

Practical

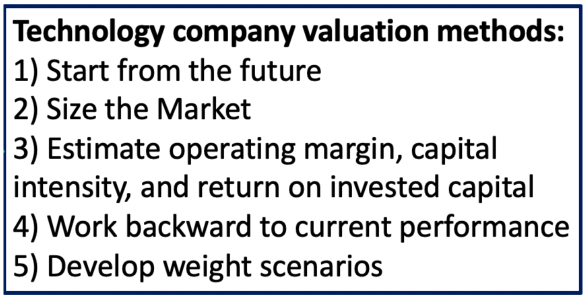
The tree and calculations for options pricing remain the same, but the modeling must now use intricate, real world inputs and assumptions for asset price, exercise price, volatility, and riskless rate.

Variable	Meaning	Calculation	Real world
S	Asset price (stock price)	Market-based	NPV (DCF per share basis of firm or target price projection)
E	Exercise price (strike price)	Market-based	CapEx of firm in with terminal value in perpetuity
u	Magnitude of up-jump between nodes	$u=(\exp)\sigma\sqrt{t}$	(math remains the same)
d	Magnitude of down-jump between nodes	$d=\frac{1}{u}$:	(math remains the same)
σ	Volatility	Market-based	Figures from Damodaran's deviation in firm value by sector
rf	Riskless rate	Market-based	Taken from 10 Year T-Bonds, broken up by monthly rates
q	Probability of up-jump between nodes	$q=\frac{(1+r_f)-d}{u-d}$	(math remains the same)

qu	Probability of down-jump between nodes	$qu = 1 - q$	(math remains the same)
t	Time between nodes (1 = year)	0.08 (1 month)	(math remains the same)

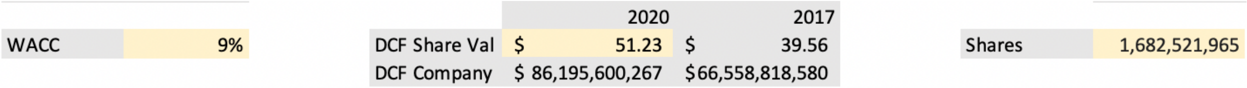
Asset Price

Stock price can be readily found for a publicly traded company, as determined by the market. On the other hand, it is difficult to gauge true value of a technology firm in the private market due to overvaluation in private rounds and lack of information on private firm financials. I, instead, took common assumptions from readily available DCF models built at the time of IPO or beginning of 2020 for these various technology firms. These are built on the company S1 when filing for an IPO, which reveal the nitty gritty financials.



Technology company valuation methods:
1) Start from the future
2) Size the Market
3) Estimate operating margin, capital intensity, and return on invested capital
4) Work backward to current performance
5) Develop weight scenarios

Following the usual DCF form, the model projects unlevered FCFs (UFCFs) on a discount rate, calculates the TV, calculates the enterprise value (EV) by discounting the projected UFCFs and TV to net present value, and calculate the equity value by subtracting net debt from EV. I then divide this final value by shares outstanding to achieve per share intrinsic value. I then use WACC to discount this back to two years prior to the IPO, when it was being invested in on private markets. On the other hand, these price outputs can be compared or replaced by the average of stock price targets made by analysts to ensure an objective valuation. For example,



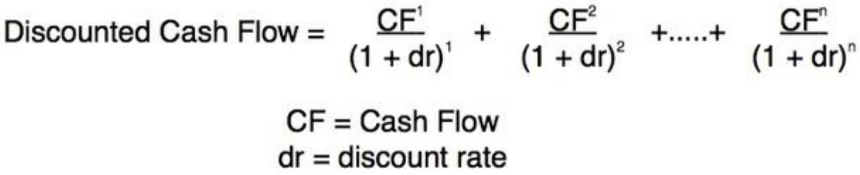
WACC	9%

	2020	2017
DCF Share Val	$ 51.23	$ 39.56
DCF Company	$ 86,195,600,267	$66,558,818,580

Shares	1,682,521,965

$$\text{WACC} = \text{Cost of Equity} * \%\text{Equity} + \text{Cost of Debt} * \%\text{Debt} * (1\text{-Tax Rate}) + \text{Cost of Preferred Stock} * \%\text{Preferred Stock}$$

CFI



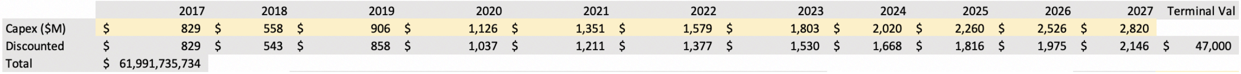
$$\text{Discounted Cash Flow} = \frac{CF^1}{(1+dr)^1} + \frac{CF^2}{(1+dr)^2} + \dots + \frac{CF^n}{(1+dr)^n}$$

CF = Cash Flow
dr = discount rate

Axial

Exercise Price

This exercise price, which can normally viewed as the expenditure needed to attain a certain share price can be correlated to the capital expenditure of the firm. Using DCF projections, we can project out 5-10 years, and, in the final year of the projection, calculate the value of CapEx in perpetuity by dividing it by the WACC less growth rate of CapEx. All of these CapEx values are discounted back to 2 years prior to IPO using the 2017 10 Year T-Bill riskless rate. This cumulative sum can be divided by the total number of shares to achieve “CapEx per share”. This will be used as the exercise price (strike price). For example,

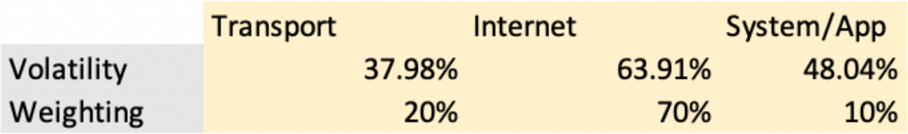


	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	Terminal Val
Capex ($M)	$ 829	$ 558	$ 906	$ 1,126	$ 1,351	$ 1,579	$ 1,803	$ 2,020	$ 2,260	$ 2,526	$ 2,820	
Discounted	$ 829	$ 543	$ 858	$ 1,037	$ 1,211	$ 1,377	$ 1,530	$ 1,668	$ 1,816	$ 1,975	$ 2,146	$ 47,000
Total	$ 61,991,735,734											

$$Terminal\ Value\ CapEx = \frac{final\ projected\ year\ CapEx}{WACC - CapEx\ growth\ rate}$$

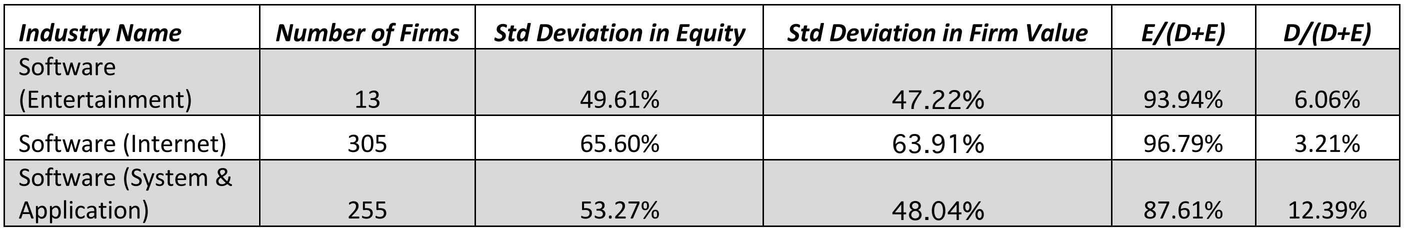
Volatility

The volatility is integral to this options pricing method because the higher the volatility, the greater the opportunity to earn and the larger the up jump between nodes is. At the same time, this can also work against an investor's favor. In order to provide a robust volatility figure, I turned to Professor Damodaran's analysis of volatility by sector (public markets). While they are not specifically the same for private markets, the public markets will provide a strong correlation. Developing volatility in private markets could be another thesis in itself. I calculated a weighted average of volatility based on the most relevant 2-3 sectors. For example,



	Transport	Internet	System/App
Volatility	37.98%	63.91%	48.04%
Weighting	20%	70%	10%

The most relevant sectors and volatility data include:

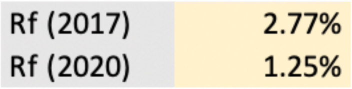


Industry Name	*Number of Firms*	*Std Deviation in Equity*	*Std Deviation in Firm Value*	*E/(D+E)*	*D/(D+E)*
Software (Entertainment)	13	49.61%	47.22%	93.94%	6.06%
Software (Internet)	305	65.60%	63.91%	96.79%	3.21%
Software (System & Application)	255	53.27%	48.04%	87.61%	12.39%

Professor Damodaran

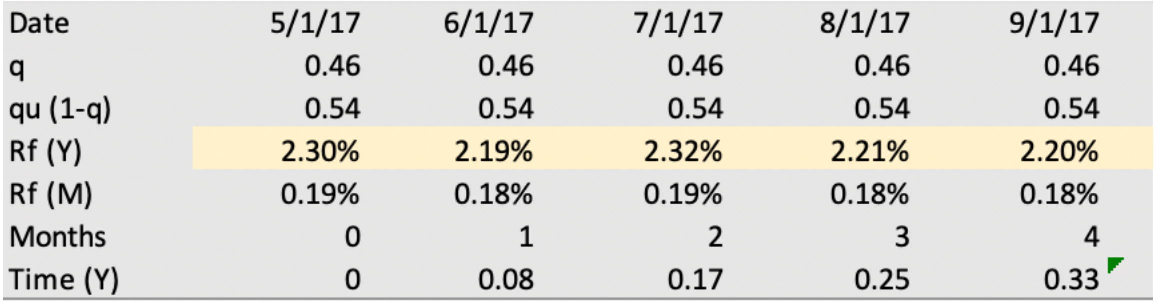
Riskless Rate

I used historical riskless rates for 10 Year T-Bills for the riskless rate. For year by year calculations I used:



Rf (2017)	2.77%
Rf (2020)	1.25%

For the nodes, which were 1 month apart, I found each historical monthly fluctuation and converted it into a monthly rate. For example,



Date	5/1/17	6/1/17	7/1/17	8/1/17	9/1/17
q	0.46	0.46	0.46	0.46	0.46
qu (1-q)	0.54	0.54	0.54	0.54	0.54
Rf (Y)	2.30%	2.19%	2.32%	2.21%	2.20%
Rf (M)	0.19%	0.18%	0.19%	0.18%	0.18%
Months	0	1	2	3	4
Time (Y)	0	0.08	0.17	0.25	0.33

The riskless rate is extremely integral to the entire operation, especially when discounting back from end of time. It heavily guides the probability of an up-tick or down-tick and ensure that this model is risk neutral. This is a key component courtesy of the Fed.

FRED Graph Observations
Federal Reserve Economic Data
Link: https://fred.stlouisfed.org
Help: https://fred.stlouisfed.org/help-faq
Economic Research Division
Federal Reserve Bank of St. Louis

DGS10 10-Year Treasury Constant Maturity Rate, Percent, Monthly, Not Seasonally Adjusted

Frequency: Monthly

observation_date	DGS10
2017-05-01	2.30
2017-06-01	2.19
2017-07-01	2.32
2017-08-01	2.21
2017-09-01	2.20
2017-10-01	2.36
2017-11-01	2.35
2017-12-01	2.40
2018-01-01	2.58
2018-02-01	2.86
2018-03-01	2.84
2018-04-01	2.87
2018-05-01	2.98
2018-06-01	2.91

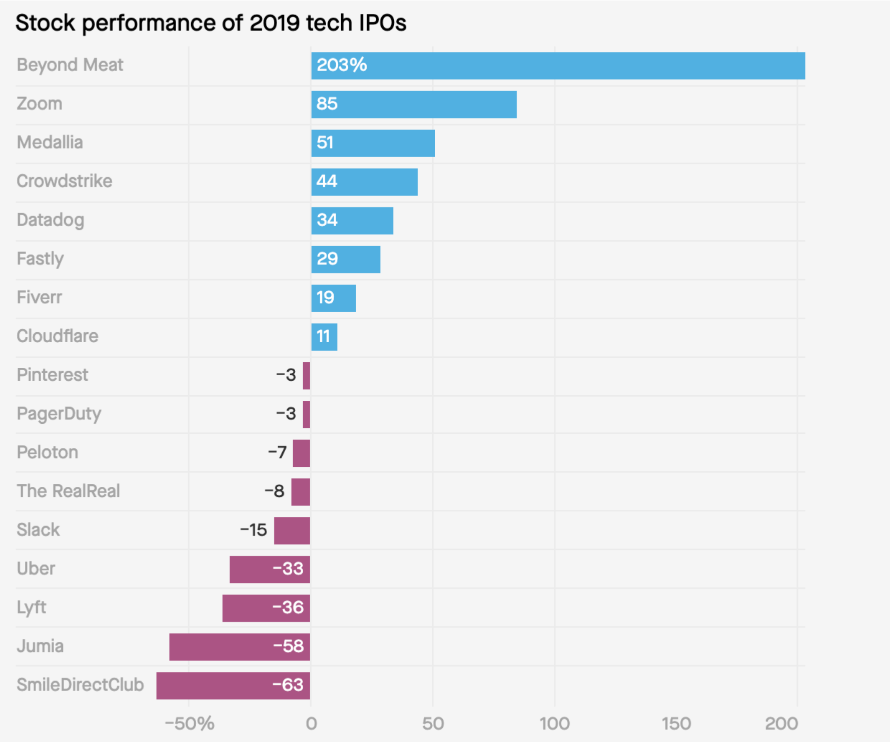
2018-07-01	2.89
2018-08-01	2.89
2018-09-01	3.00
2018-10-01	3.15
2018-11-01	3.12
2018-12-01	2.83
2019-01-01	2.71
2019-02-01	2.68
2019-03-01	2.57
2019-04-01	2.53
2019-05-01	2.40

Data Selection

The key here is not pumping in a mass amount of data, as the model will inherently be miscalculating. The key is to find a few key firms which we can look at closely. I am focusing on four companies:

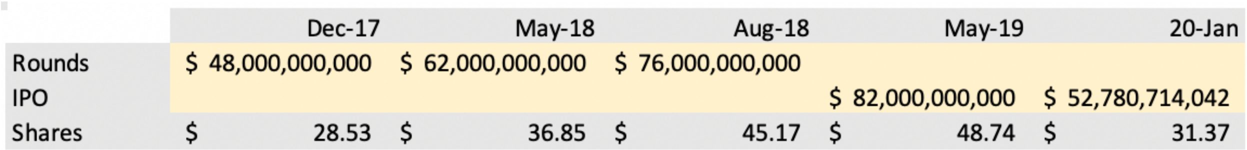
Company	**Sector**	**IPO date**	**Post-IPO performance**
Uber	Consumer software & transportation	May, 2019	Negative
Slack	Enterprise & consumer software	April, 2019	Negative
Crowdstrike	Enterprise software & security	June, 2019	Positive
Zoom	Enterprise & consumer software, entertainment	April, 2020	Positive

These firms present a unique lens because they were founded in the last 12 years, have had massive amounts of venture funding leading to unicorn status, and they have gone public in the last year—providing observable results after the market has fairly priced each company. Additionally, each firm is in a differing sector within technology to provide some breadth. For each of these firms, we will be utilizing their S1 filing, 10K reports, projections, and DCF assumptions.



Quartz

In addition to the post IPO data, we will be looking into private round funding, dividing by total shares, to see the price per share during the late rounds of funding. We can then place these share prices on the binomial tree to test for trends. For example,

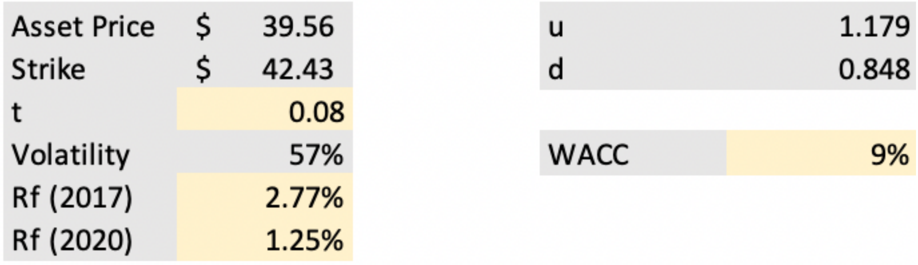


	Dec-17	May-18	Aug-18	May-19	20-Jan
Rounds	$ 48,000,000,000	$ 62,000,000,000	$ 76,000,000,000		
IPO				$ 82,000,000,000	$ 52,780,714,042
Shares	$ 28.53	$ 36.85	$ 45.17	$ 48.74	$ 31.37

RESULTS

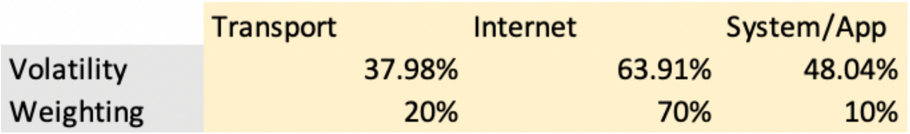
Uber

Assumptions



Asset Price	$ 39.56
Strike	$ 42.43
t	0.08
Volatility	57%
Rf (2017)	2.77%
Rf (2020)	1.25%

u	1.179
d	0.848
WACC	9%



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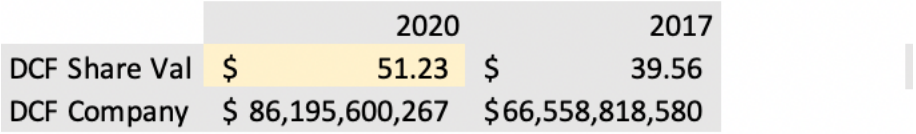

	2020	2017
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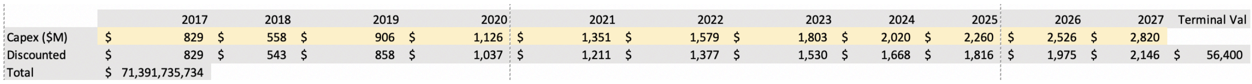
Shares	1,682,521,965

Capex Growth	4%



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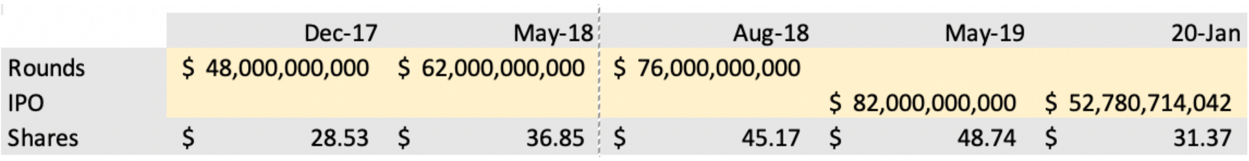
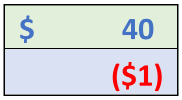


	Dec-17	May-18	Aug-18	May-19	20-Jan
Rounds	$ 48,000,000,000	$ 62,000,000,000	$ 76,000,000,000		
IPO				$ 82,000,000,000	$ 52,780,714,042
Shares	$ 28.53	$ 36.85	$ 45.17	$ 48.74	$ 31.37

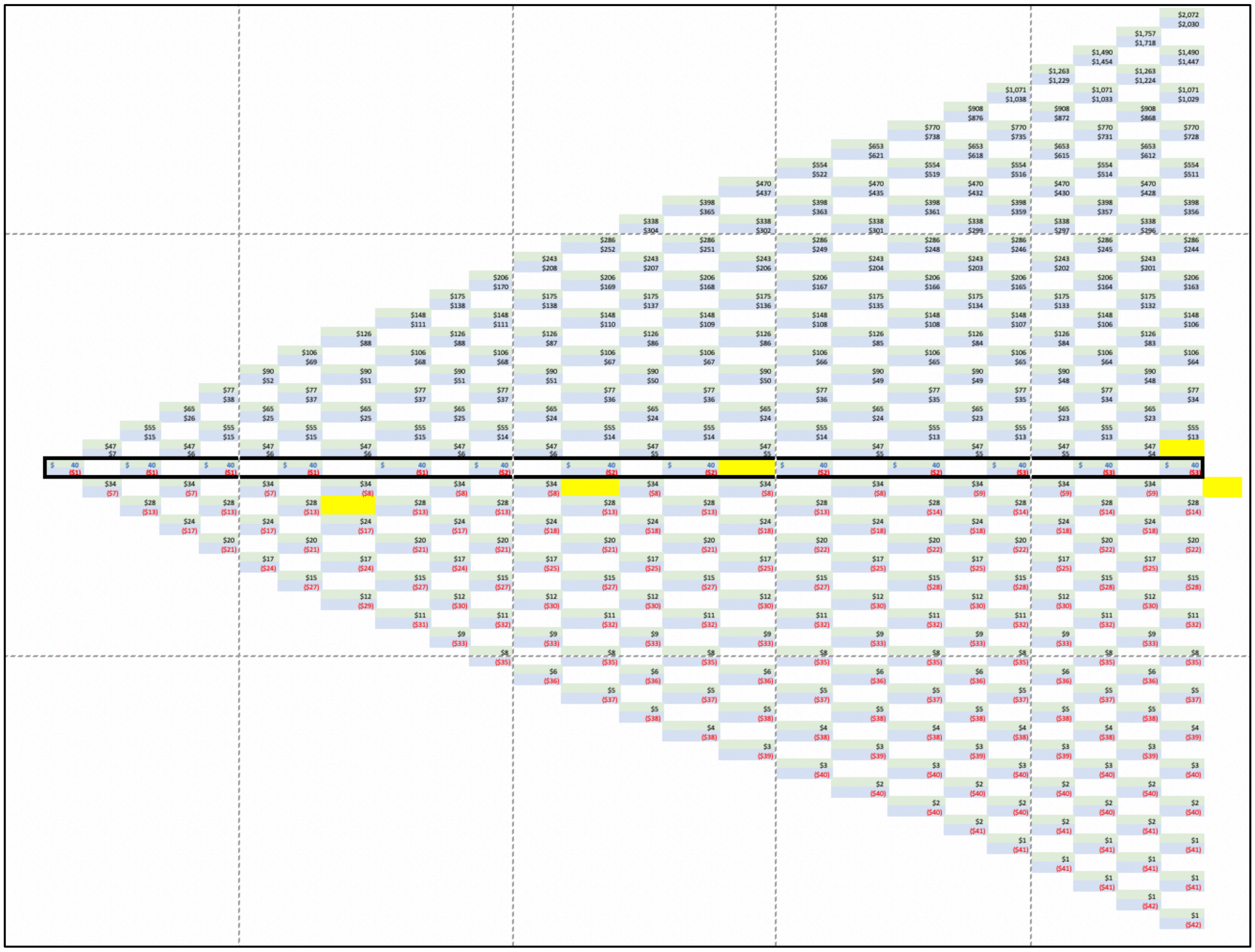
Performance

Out-of-the-money option on model’s first date, May 1st, 2017:



$ 40
($1)

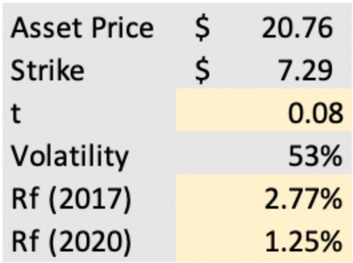
For the following tree graphs, red denotes out of the money options, and yellow denotes where fundraising or IPO at that time valued the share.



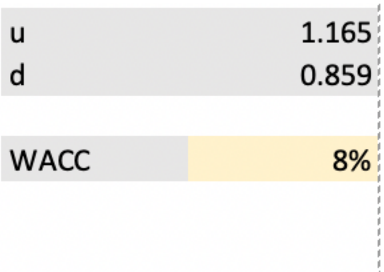
Recombination line and below are out of the money.

Slack

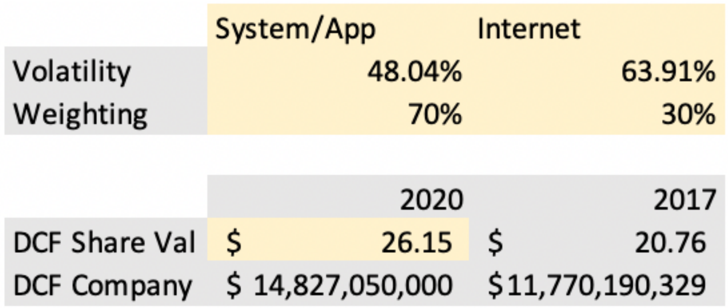
<u>Assumptions</u>



Asset Price	$	20.76
Strike	$	7.29
t		0.08
Volatility		53%
Rf (2017)		2.77%
Rf (2020)		1.25%

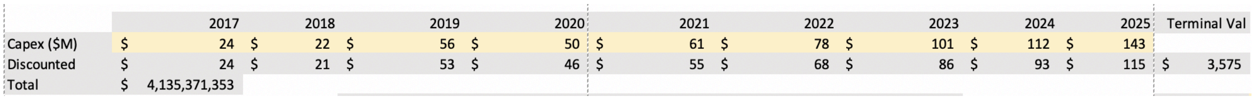


u	1.165
d	0.859
WACC	8%



	System/App	Internet
Volatility	48.04%	63.91%
Weighting	70%	30%

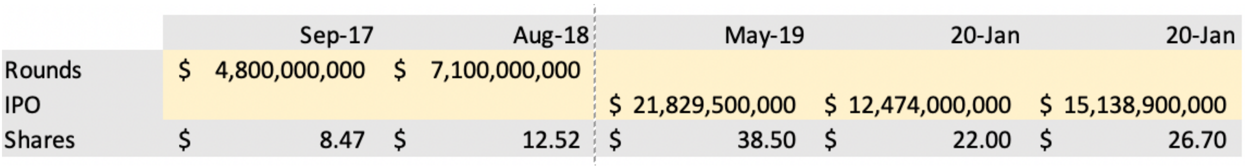
	2020	2017
DCF Share Val	$ 26.15	$ 20.76
DCF Company	$ 14,827,050,000	$11,770,190,329



	2017	2018	2019	2020	2021	2022	2023	2024	2025	Terminal Val
Capex ($M)	$ 24	$ 22	$ 56	$ 50	$ 61	$ 78	$ 101	$ 112	$ 143	
Discounted	$ 24	$ 21	$ 53	$ 46	$ 55	$ 68	$ 86	$ 93	$ 115	$ 3,575
Total	$ 4,135,371,353									

Shares	567,000,000

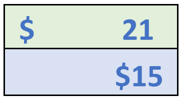
Capex Growth	4%



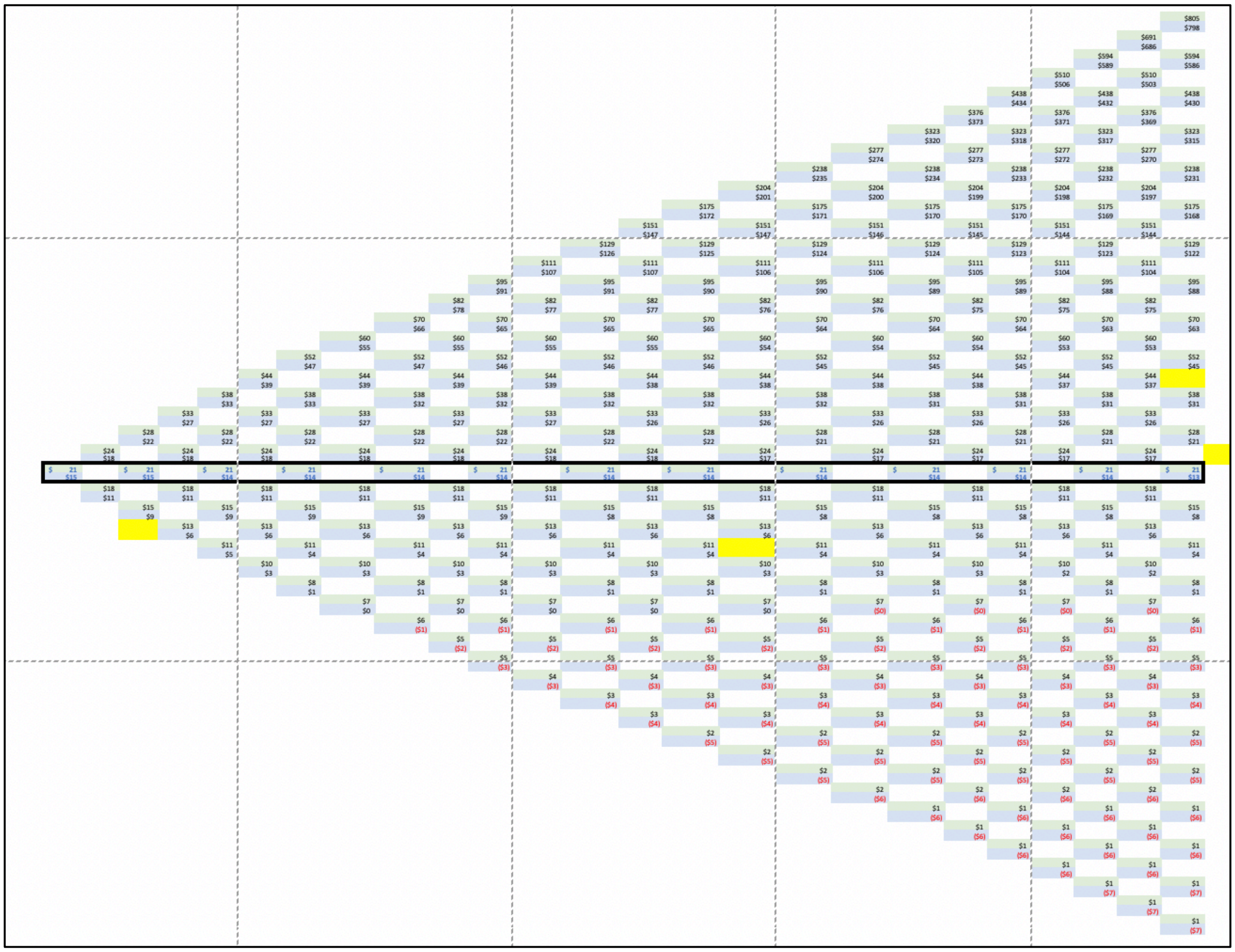
	Sep-17	Aug-18	May-19	20-Jan	20-Jan
Rounds	$ 4,800,000,000	$ 7,100,000,000			
IPO			$ 21,829,500,000	$ 12,474,000,000	$ 15,138,900,000
Shares	$ 8.47	$ 12.52	$ 38.50	$ 22.00	$ 26.70

<u>Performance</u>

High value option on May 1st, 2017:

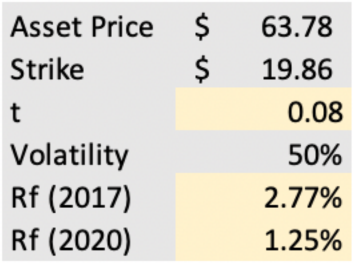


$ 21
$15

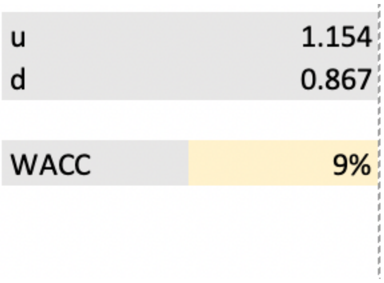


Crowdstrike

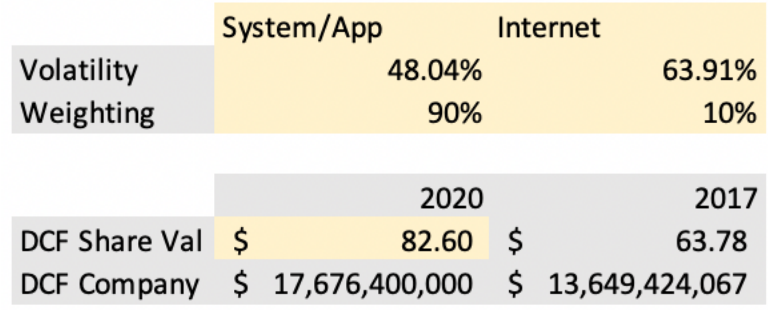
Assumptions



Asset Price	$	63.78
Strike	$	19.86
t		0.08
Volatility		50%
Rf (2017)		2.77%
Rf (2020)		1.25%



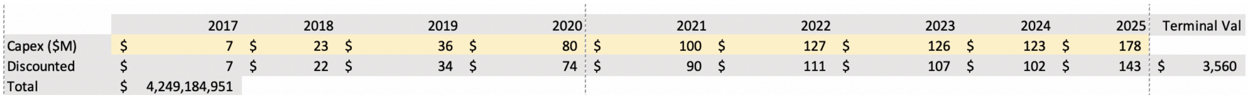
u	1.154
d	0.867
WACC	9%



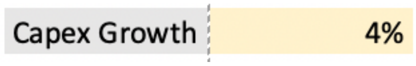
	System/App	Internet
Volatility	48.04%	63.91%
Weighting	90%	10%

	2020	2017
DCF Share Val	$ 82.60	$ 63.78
DCF Company	$ 17,676,400,000	$ 13,649,424,067

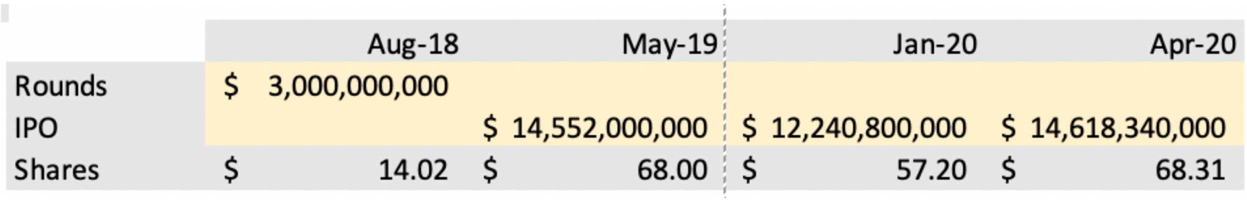
Shares	214,000,000



	2017	2018	2019	2020	2021	2022	2023	2024	2025	Terminal Val
Capex ($M)	$ 7	$ 23	$ 36	$ 80	$ 100	$ 127	$ 126	$ 123	$ 178	
Discounted	$ 7	$ 22	$ 34	$ 74	$ 90	$ 111	$ 107	$ 102	$ 143	$ 3,560
Total	$ 4,249,184,951									



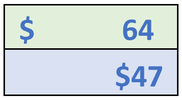
Capex Growth	4%



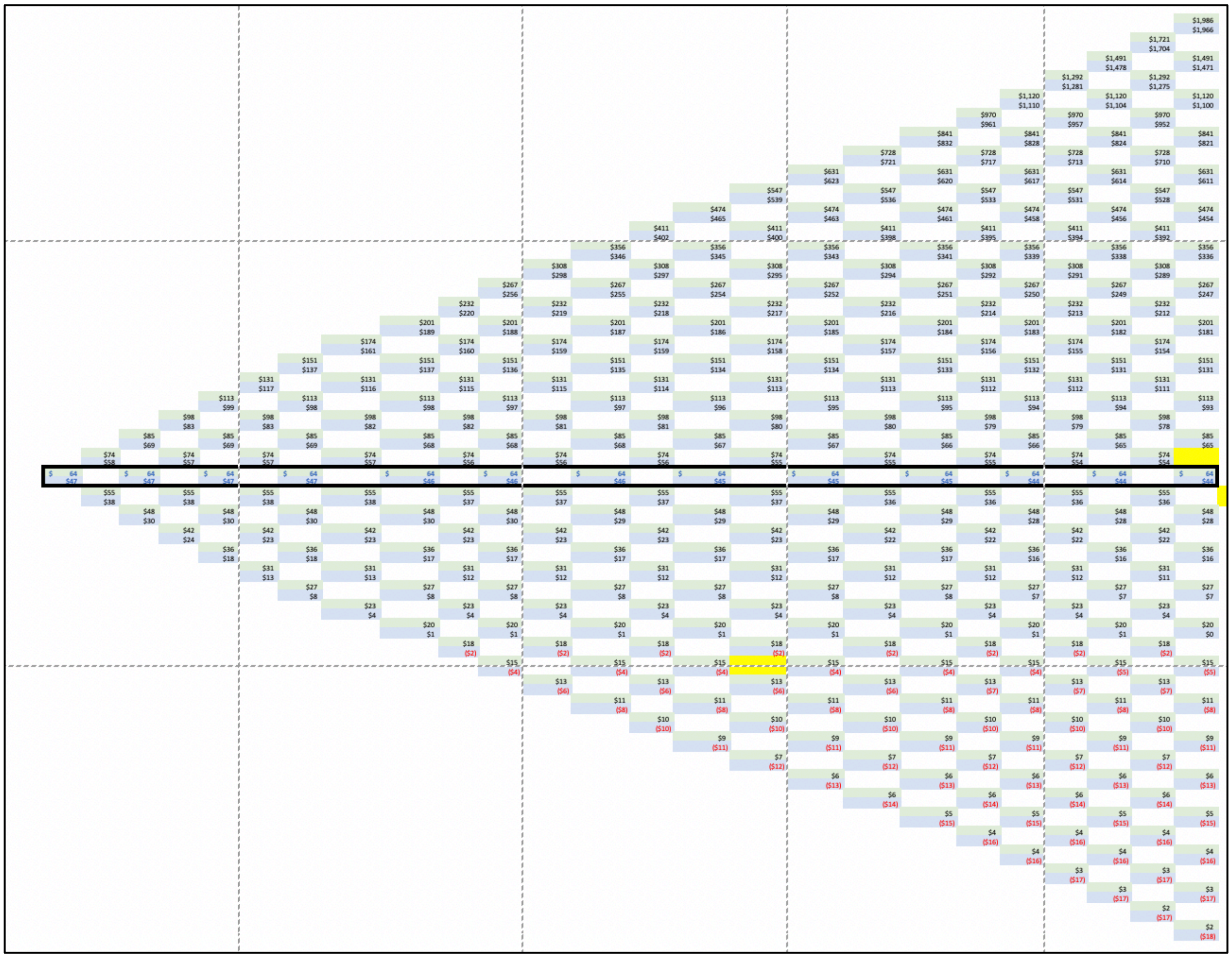
	Aug-18	May-19	Jan-20	Apr-20
Rounds	$ 3,000,000,000			
IPO		$ 14,552,000,000	$ 12,240,800,000	$ 14,618,340,000
Shares	$ 14.02	$ 68.00	$ 57.20	$ 68.31

Performance

High in the money option value on May 1st, 2017:

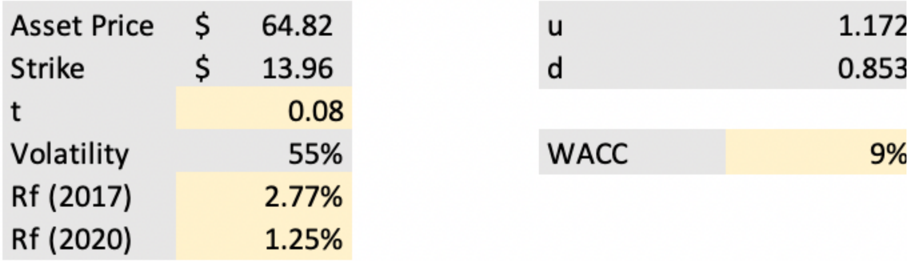


$ 64
$47



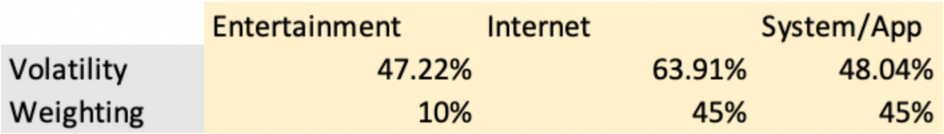
Zoom

Assumptions

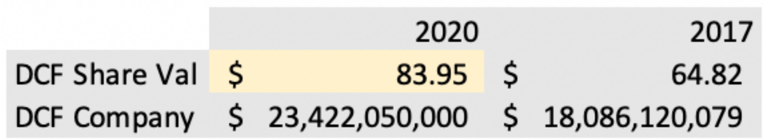


Asset Price	$	64.82
Strike	$	13.96
t		0.08
Volatility		55%
Rf (2017)		2.77%
Rf (2020)		1.25%

u	1.172
d	0.853
WACC	9%

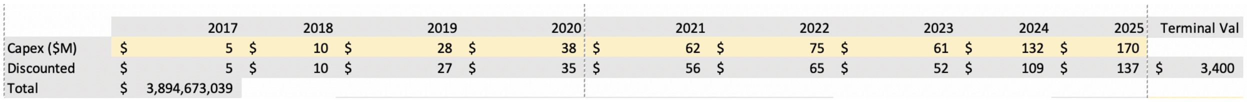


	Entertainment	Internet	System/App
Volatility	47.22%	63.91%	48.04%
Weighting	10%	45%	45%

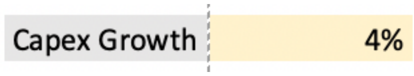


	2020	2017
DCF Share Val	$ 83.95	$ 64.82
DCF Company	$ 23,422,050,000	$ 18,086,120,079

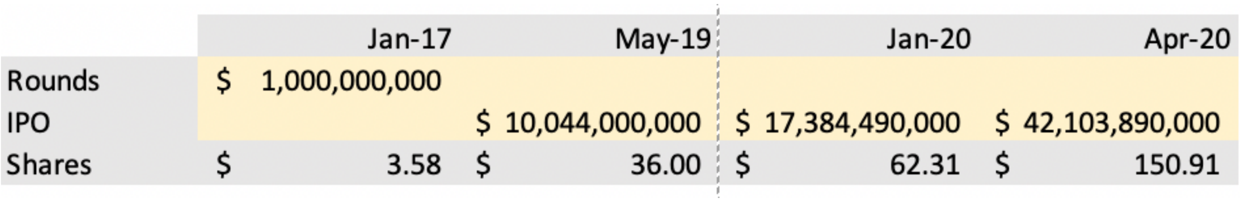
Shares	279,000,000



	2017	2018	2019	2020	2021	2022	2023	2024	2025	Terminal Val
Capex ($M)	$ 5	$ 10	$ 28	$ 38	$ 62	$ 75	$ 61	$ 132	$ 170	
Discounted	$ 5	$ 10	$ 27	$ 35	$ 56	$ 65	$ 52	$ 109	$ 137	$ 3,400
Total	$ 3,894,673,039									



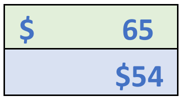
Capex Growth	4%



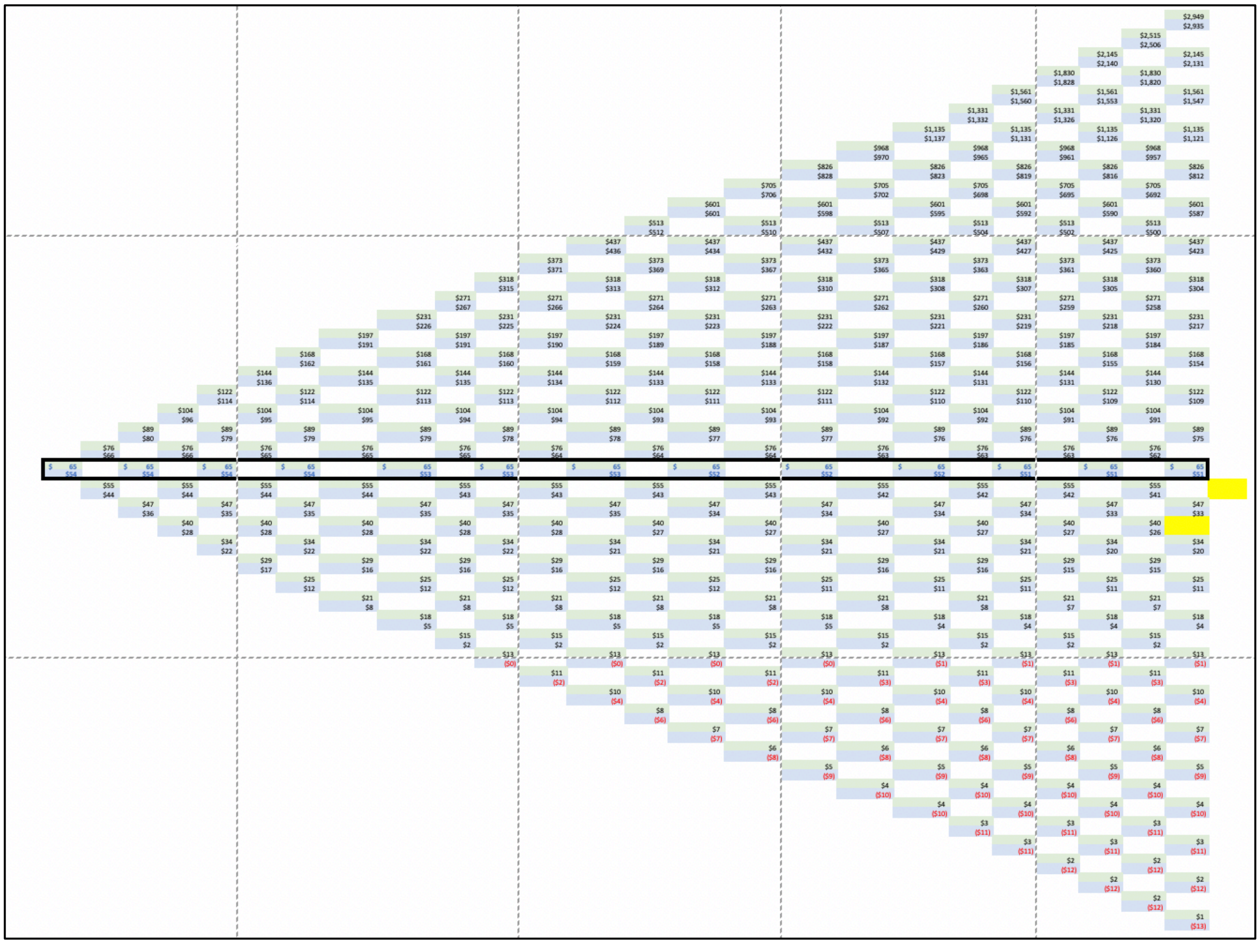
	Jan-17	May-19	Jan-20	Apr-20
Rounds	$ 1,000,000,000			
IPO		$ 10,044,000,000	$ 17,384,490,000	$ 42,103,890,000
Shares	$ 3.58	$ 36.00	$ 62.31	$ 150.91

Performance

High in-the-money option value on May 1st, 2017:



$ 65
$54



																								$2,949 $2,935	
																							$2,515 $2,506		
																						$2,145 $2,140		$2,145 $2,131	
																					$1,830 $1,828		$1,830 $1,820		
																				$1,561 $1,560		$1,561 $1,553		$1,561 $1,547	
																			$1,331 $1,332		$1,331 $1,326		$1,331 $1,320		
																		$1,135 $1,137		$1,135 $1,131		$1,135 $1,126		$1,135 $1,121	
																	$968 $970		$968 $965		$968 $961		$968 $957		
																$826 $828		$826 $823		$826 $819		$826 $816		$826 $812	
															$705 $706		$705 $702		$705 $698		$705 $695		$705 $692		
														$601 $601		$601 $598		$601 $595		$601 $592		$601 $590		$601 $587	
													$513 $512		$513 $510		$513 $507		$513 $504		$513 $502		$513 $500		
												$437 $436		$437 $434		$437 $432		$437 $429		$437 $427		$437 $425		$437 $423	
											$373 $371		$373 $369		$373 $367		$373 $365		$373 $363		$373 $361		$373 $360		
										$318 $315		$318 $313		$318 $312		$318 $310		$318 $308		$318 $307		$318 $305		$318 $304	
									$271 $267		$271 $266		$271 $264		$271 $263		$271 $262		$271 $260		$271 $259		$271 $258		
								$231 $226		$231 $225		$231 $224		$231 $223		$231 $222		$231 $221		$231 $219		$231 $218		$231 $217	
							$197 $191		$197 $191		$197 $190		$197 $189		$197 $188		$197 $187		$197 $186		$197 $185		$197 $184		
						$168 $162		$168 $161		$168 $160		$168 $159		$168 $158		$168 $158		$168 $157		$168 $156		$168 $155		$168 $154	
					$144 $136		$144 $135		$144 $135		$144 $134		$144 $133		$144 $133		$144 $132		$144 $131		$144 $131		$144 $130		
				$122 $114		$122 $114		$122 $113		$122 $113		$122 $112		$122 $111		$122 $111		$122 $110		$122 $110		$122 $109		$122 $109	
			$104 $96		$104 $95		$104 $95		$104 $94		$104 $94		$104 $93		$104 $93		$104 $92		$104 $92		$104 $91		$104 $91		
		$89 $80		$89 $79		$89 $79		$89 $79		$89 $78		$89 $78		$89 $77		$89 $77		$89 $76		$89 $76		$89 $76		$89 $75	
	$76 $66		$76 $66		$76 $65		$76 $65		$76 $65		$76 $64		$76 $64		$76 $64		$76 $63		$76 $63		$76 $63		$76 $62		
$ 65 $54		$ 65 $54		$ 65 $54		$ 65 $54		$ 65 $53		$ 65 $53		$ 65 $53		$ 65 $52		$ 65 $52		$ 65 $52		$ 65 $51		$ 65 $51		$ 65 $51	
	$55 $44		$55 $44		$55 $44		$55 $44		$55 $43		$55 $43		$55 $43		$55 $43		$55 $42		$55 $42		$55 $42		$55 $41		🟨
		$47 $36		$47 $35		$47 $35		$47 $35		$47 $35		$47 $35		$47 $34		$47 $34		$47 $34		$47 $34		$47 $33		$47 $33	
			$40 $28		$40 $28		$40 $28		$40 $28		$40 $28		$40 $27		$40 $27		$40 $27		$40 $27		$40 $27		$40 $26	🟨	
				$34 $22		$34 $22		$34 $22		$34 $22		$34 $21		$34 $21		$34 $21		$34 $21		$34 $21		$34 $20		$34 $20	
					$29 $17		$29 $16		$29 $16		$29 $16		$29 $16		$29 $16		$29 $16		$29 $16		$29 $15		$29 $15		
						$25 $12		$25 $12		$25 $12		$25 $12		$25 $12		$25 $11		$25 $11		$25 $11		$25 $11		$25 $11	
							$21 $8		$21 $8		$21 $8		$21 $8		$21 $8		$21 $8		$21 $8		$21 $7		$21 $7		
								$18 $5		$18 $5		$18 $5		$18 $5		$18 $5		$18 $4		$18 $4		$18 $4		$18 $4	
									$15 $2		$15 $2		$15 $2		$15 $2		$15 $2		$15 $2		$15 $2		$15 $2		
										$13 ($0)		$13 ($0)		$13 ($0)		$13 ($0)		$13 ($1)		$13 ($1)		$13 ($1)		$13 ($1)	
											$11 ($2)		$11 ($2)		$11 ($2)		$11 ($3)		$11 ($3)		$11 ($3)		$11 ($3)		
												$10 ($4)		$10 ($4)		$10 ($4)		$10 ($4)		$10 ($4)		$10 ($4)		$10 ($4)	
													$8 ($6)		$8 ($6)		$8 ($6)		$8 ($6)		$8 ($6)		$8 ($6)		
														$7 ($7)		$7 ($7)		$7 ($7)		$7 ($7)		$7 ($7)		$7 ($7)	
															$6 ($8)		$6 ($8)		$6 ($8)		$6 ($8)		$6 ($8)		
																$5 ($9)		$5 ($9)		$5 ($9)		$5 ($9)		$5 ($9)	
																	$4 ($10)		$4 ($10)		$4 ($10)		$4 ($10)		
																		$4 ($10)		$4 ($10)		$4 ($10)		$4 ($10)	
																			$3 ($11)		$3 ($11)		$3 ($11)		
																				$3 ($11)		$3 ($11)		$3 ($11)	
																					$2 ($12)		$2 ($12)		
																						$2 ($12)		$2 ($12)	
																							$2 ($12)		
																								$1 ($13)	

DISCUSSION

Results Discussion

The above results can be further viewed in the attached model. This model changed the way I think about investing. It is truly challenging to truly discern the results, as they are purely based on projections and terminal values, but a useful exercise. We can see that a high CapEx can bring down a company's value, such as Uber. On the other hand, Crowdstrike and Zoom had very little CapEx per share, and it makes their shares in-the-money. Each firm's prior to IPO investment rounds were at or below the recombination line, besides Uber. Uber's pre-IPO investment erred above the line, and even its recombination line was out of the money options. A good gauge of CapEx and taking on the company as an opportunity is using this model and seeing the number of cells that are out-of-the-money—the number of out of the money possibilities given such a high CapEx. On the other hand, an optimistic model can greatly reduce these by pumping up the DCF per share value. Additionally, discounting back using WACC from 2020 pricate target found that funding rounds were relatively close to those targets. As a result, it is difficult to test the overvaluation (as stated in hypothesis) different than a normal method of observing post-IPO fair value. Overvaluation is inherently baked into the model via intrinsic value.

Limitations

<u>DCF valuation</u>

Using widely accepted price targets and DCF assumptions made this exercise more objective, but they were ultimately made when the company was not private. The model has two more years of data. Making a DCF for a private company is extremely challenging. So, using these assumptions in 2020 I discounted back to 2017 using WACC. It turns out that this was accurate to the funding rounds, but likely inaccurate to the models built by the VCs.

Total shares

The total number of shares fluctuates for each of these firms. For example, Slack doubled its shares outstanding this year. Additionally, there are varying types and preferences of stocks that are given to early, late, and public investors which can greatly change payouts and values. The early investors could be getting better preference, but this was not evaluated here.

Capital Expenditure

It is challenging to understand the meaning of CapEx to a technology firm. It is something that is associated with traditional businesses and investment opportunities, such as mining or launching a new product, etc. On the contrary, technology firms look to intrinsic and intangible value. It is difficult to correlate CapEx to this, as something could take minimal CapEx and disrupt an industry—this is the whole goal of tech venture investing.

Volatility

Public market deviation in firm value is very different from private market, A smaller, private startup will always be more risky. Correlating public to private market volatility is a sizeable jump. The up-jumps and down-jumps will likely be a lot greater in magnitude.

Areas of Future Inquiry

In the future, it would be interesting to build multiple DCFs dating back to two years prior to IPO, input all share preferences, calculate private market volatility for each firm. With these components, the model would be more accurate. Additionally, this model could be applied to many more companies to provide a data set of options pricings in private market. This precedence can be used by VCs to value potential investment. I'd also just be interested in analyzing all technology firm's CapEx per share.

CONCLUSION

There are a few key takeaways:

(1) VCs have high option values because of their exclusivity in investing

(2) CapEx is very important (CapEx per share is a uniquely important metric)

(3) DCFs and price targets are highly biased, but they are the core to valuation

(4) Volatility is key and rives higher returns

(5) Modeling will rarely produce a definite, accurate results

While investors may not directly use this guide to invest, it is a useful tool to have in the background. More data means more alignment of valuations. In the end, the financials are important, but what is more important is the means in which I create the model and the ideas behind it.

My final recommendation is that this model will be excellent to be used as a football field graph alongside an investment proposal or model. It can give a new insight on the option to invest in a company. It also gives an eye into the operator's perspective. It emphasizes value and capital needed to attain said value.

Thank you

This was an amazing experience reading literature, building this model, and learning from my thesis advisor (Professor Gautam Kaul). Thank you so much for this opportunity! This mode of thinking will carry on with me and be an essential tool in my technology and business pursuits.

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