Analytics

Risk Analysis

EMBA-J23

Hilary 2023

Overview

- Risk analysis
- Monte Carlo simulation
- Application of Monte Carlo to:
  - Financial model
  - Order quantity decision

Surprises are foolish things. The pleasure is not enhanced,
and the inconvenience is often considerable.
Emma, Jane Austen, 1816

Risk Analysis

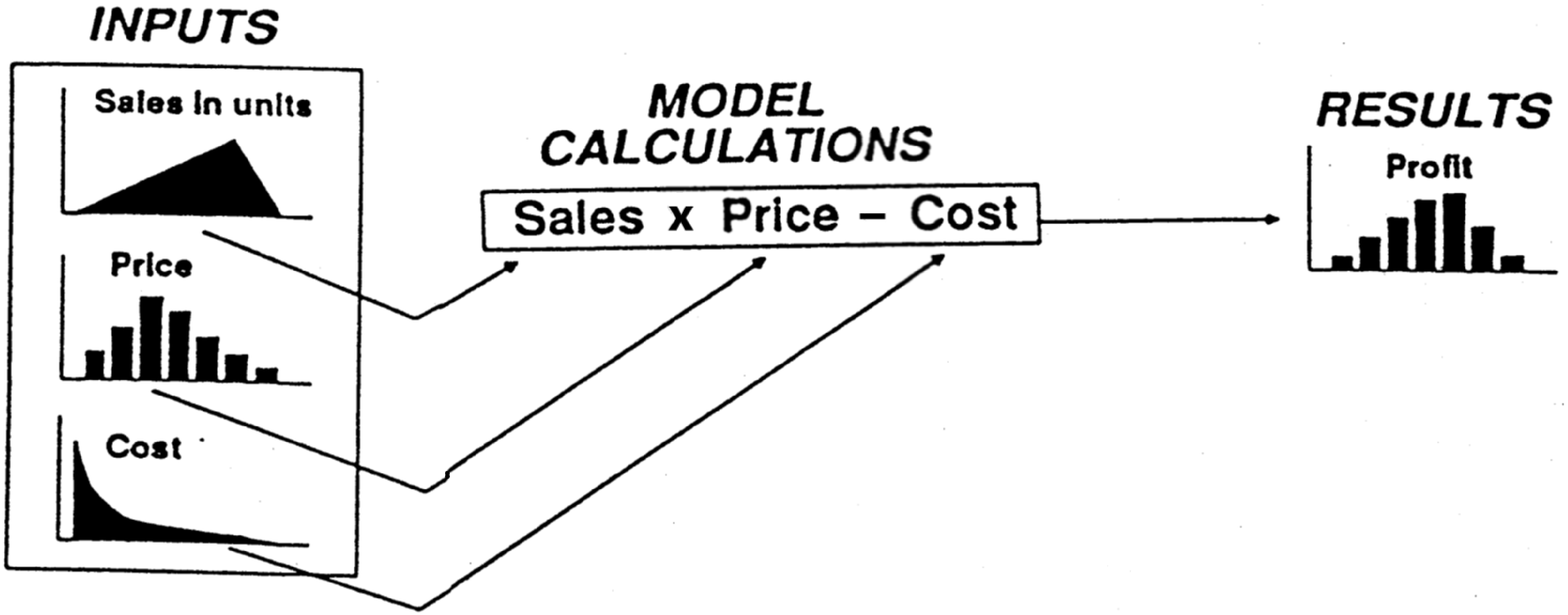
- **Sensitivity** analysis
  - Identify factors to which results are particularly sensitive and those to which they are relatively insensitive
  - Gain insight into risk exposure
  - What-if analysis
  - Data tables in Excel

- **Monte Carlo** simulation
  - Probabilistic approach
  - @Risk for Windows Excel or SimVoi for Mac Excel

Doubt is the beginning, not the end, of wisdom.
Anonymous

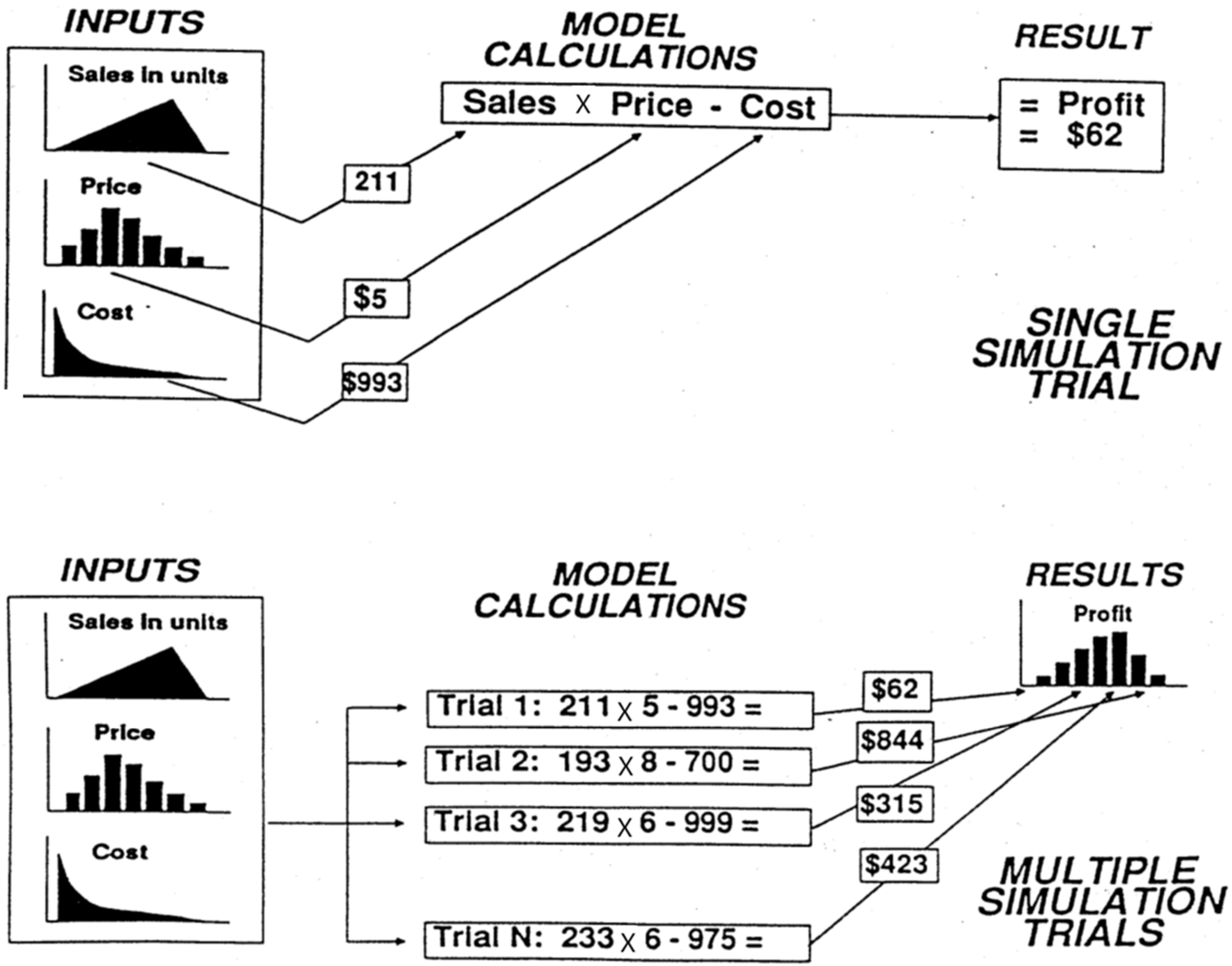
Monte Carlo Simulation

- Monte Carlo simulation is widely used for risk analysis. It estimates the probability distribution for a variable of interest, e.g. profit or NPV.



For the things we have to learn before we can do them, we learn by doing.
Aristotle

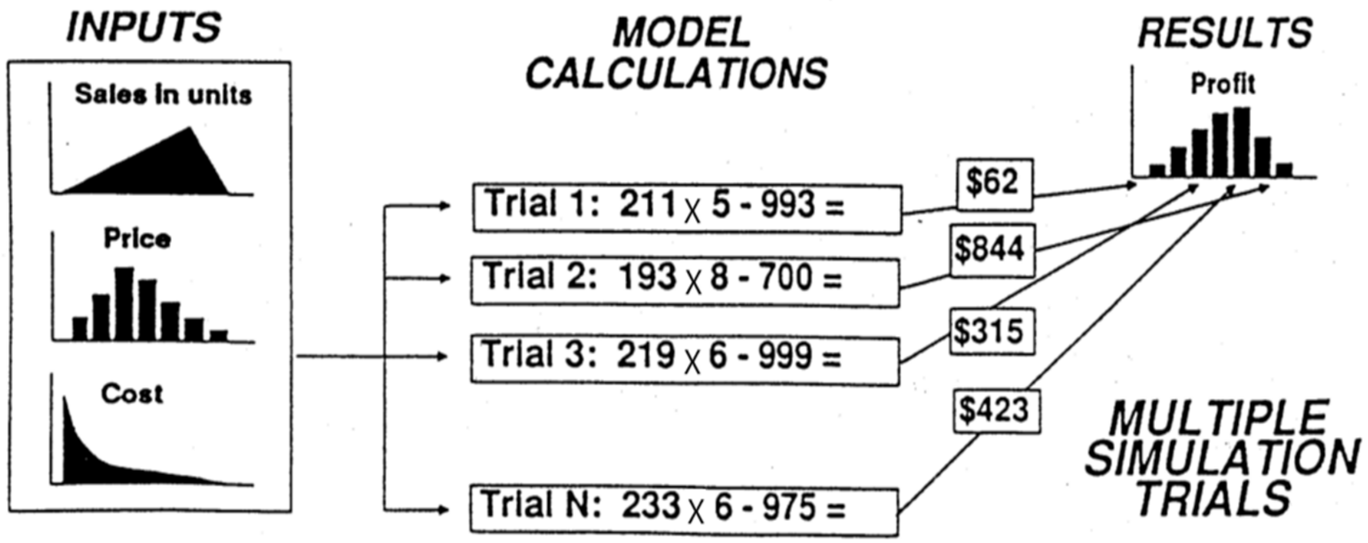
Monte Carlo Simulation - How it works



It is part of a probability that many improbable things will happen.

Aristotle

Monte Carlo Sampling



1. **Sample** from each of the input distributions.

2. **Substitute values** into spreadsheet cells.

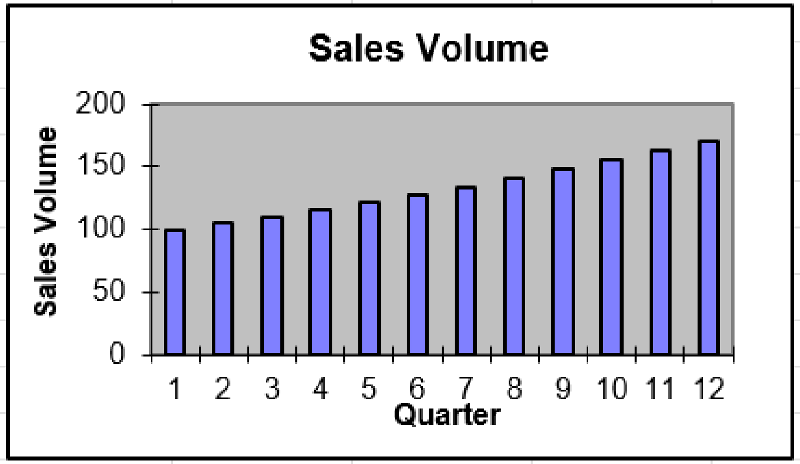
3. **Recalculate** entire spreadsheet and store values for the target cell of interest. This is a random scenario.

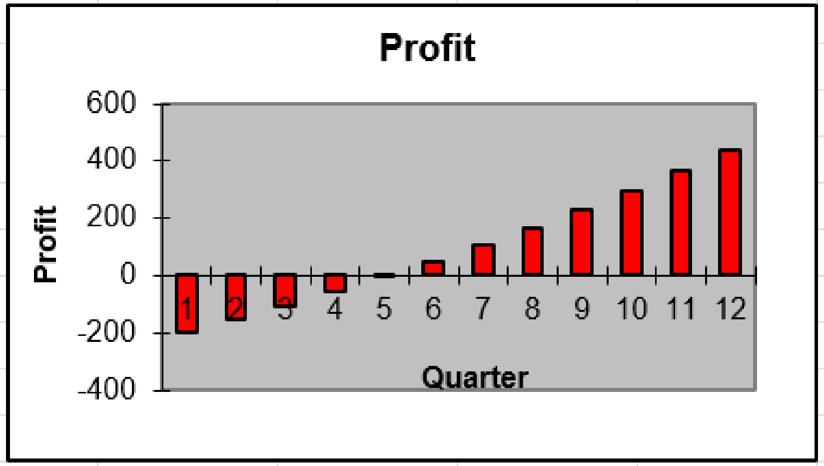
4. **Repeat** this many times. Each random scenario has probability of selection consistent with resultant probability distribution.

5. **Collect values** for target cell of interest, and plot frequency distribution.

Application of Monte Carlo to a Financial Model AAA.xlsx

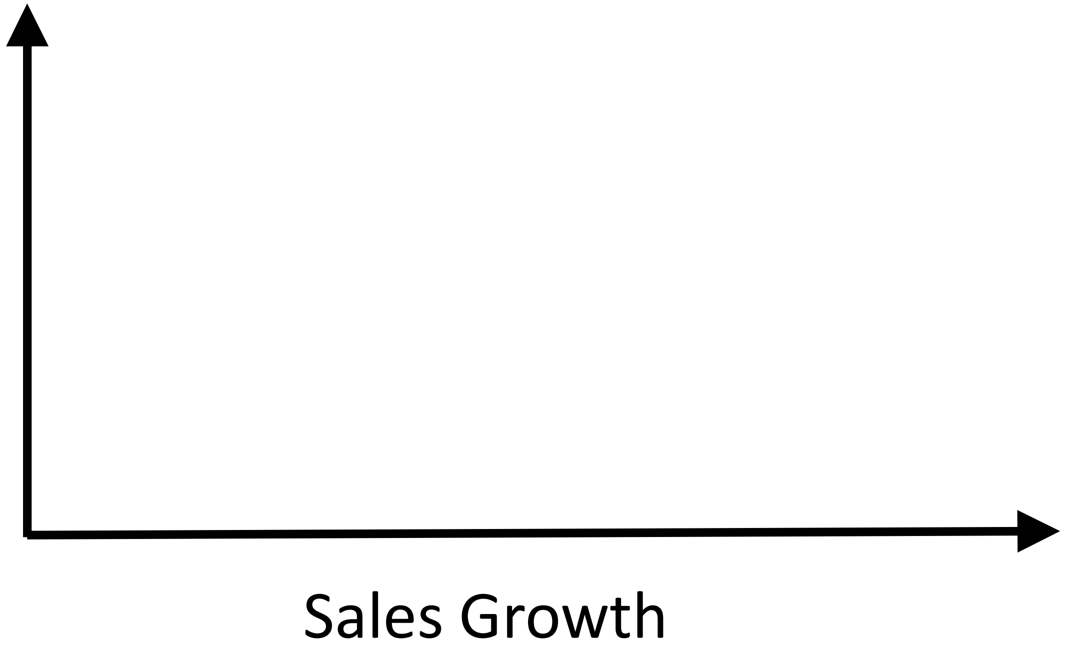
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Quarter	1	2	3	4	5	6	7	8	9	10	11	12	Total	Average
2															
3	Sales Volume	100	105	110	116	122	128	134	141	148	155	163	171	1,592	133
4	Sales Revenue	3,000	3,150	3,308	3,473	3,647	3,829	4,020	4,221	4,432	4,654	4,887	5,131	47,751	3,979
5	Variable Costs	2,100	2,205	2,315	2,431	2,553	2,680	2,814	2,955	3,103	3,258	3,421	3,592	33,426	2,785
6	Fixed Costs	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	13,200	1,100
7	Profits	-200	-155	-108	-58	-6	49	106	166	230	296	366	439	1,125	94
8															
9															
10	Planning	Values													
11															
12	Sales Growth	5%													
13	Price	30													
14	Cost of GS %	70%													
15	Fixed Costs	1,100													





Information Regarding Two Inputs

- "Sales Growth is equally likely to be any value between 0% and 10%."

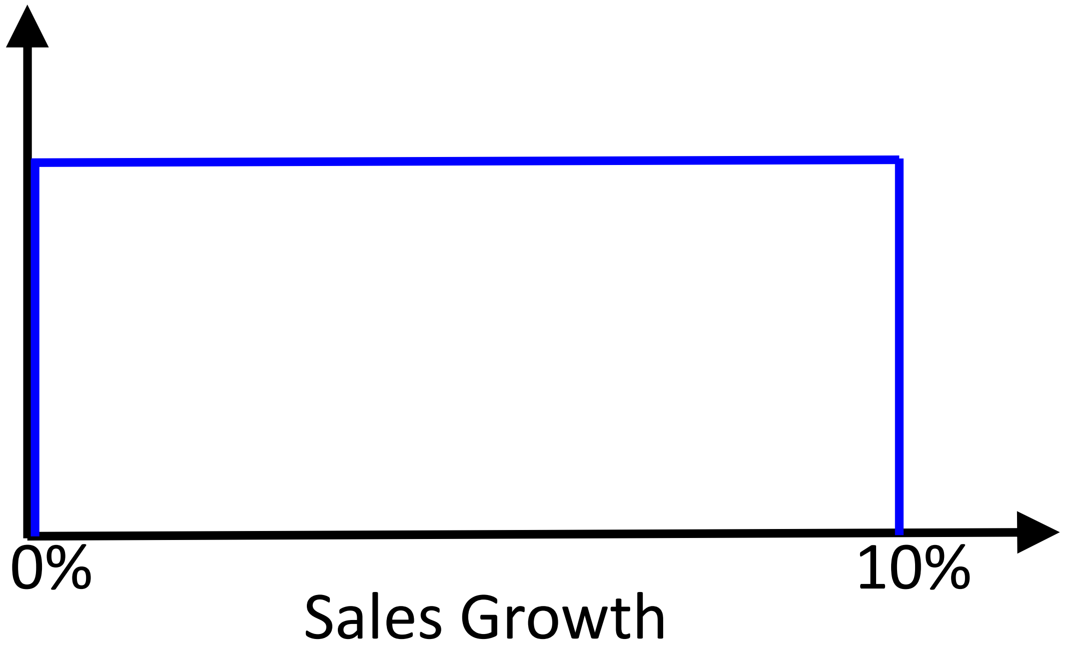


- "Price is most likely to be 30, but could range from 20 to 35."

If you are always trying to be normal, you will never know how amazing you can be.
Maya Angelou

Two Input Distributions

- “Sales Growth is equally likely to be any value between 0% and 10%.”



- “Price is most likely to be 30, but could range from 20 to 35.”

To expect the unexpected shows a thoroughly modern intellect.
Oscar Wilde

For Windows Excel: @RISK

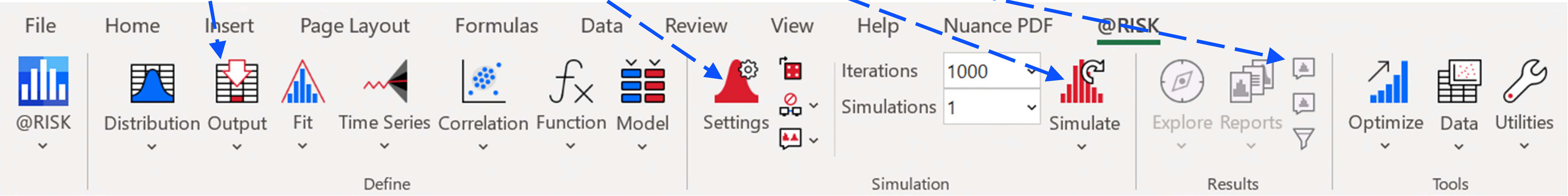
1. Introduce uncertainty into model
   =RiskUniform(0%,10%) for Sales Growth
   =RiskTriang(20,30,35) for Price

2. Select output cells (cells for which we want simulation results)

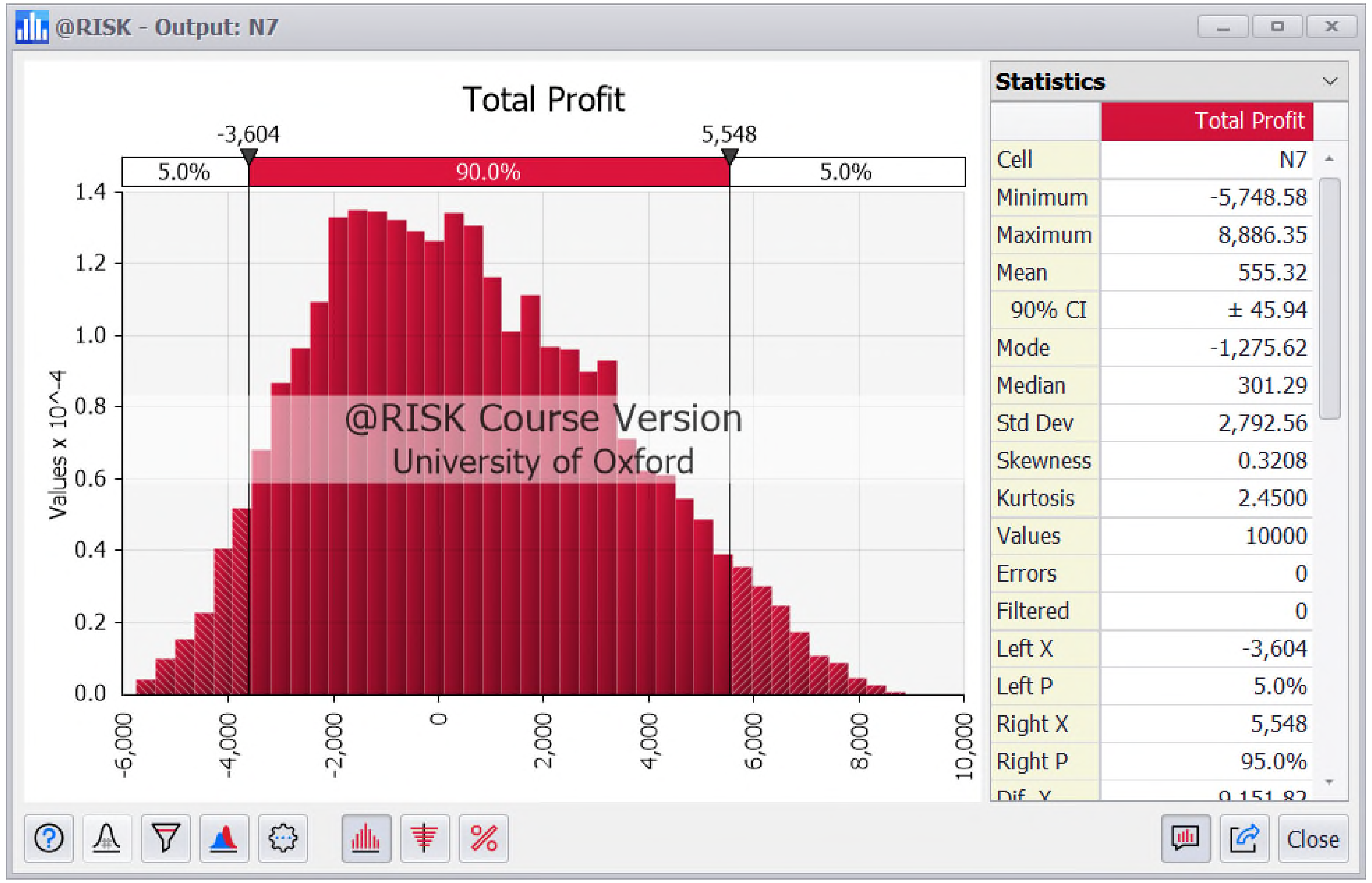
3. Select simulation settings - no. of iterations, etc.

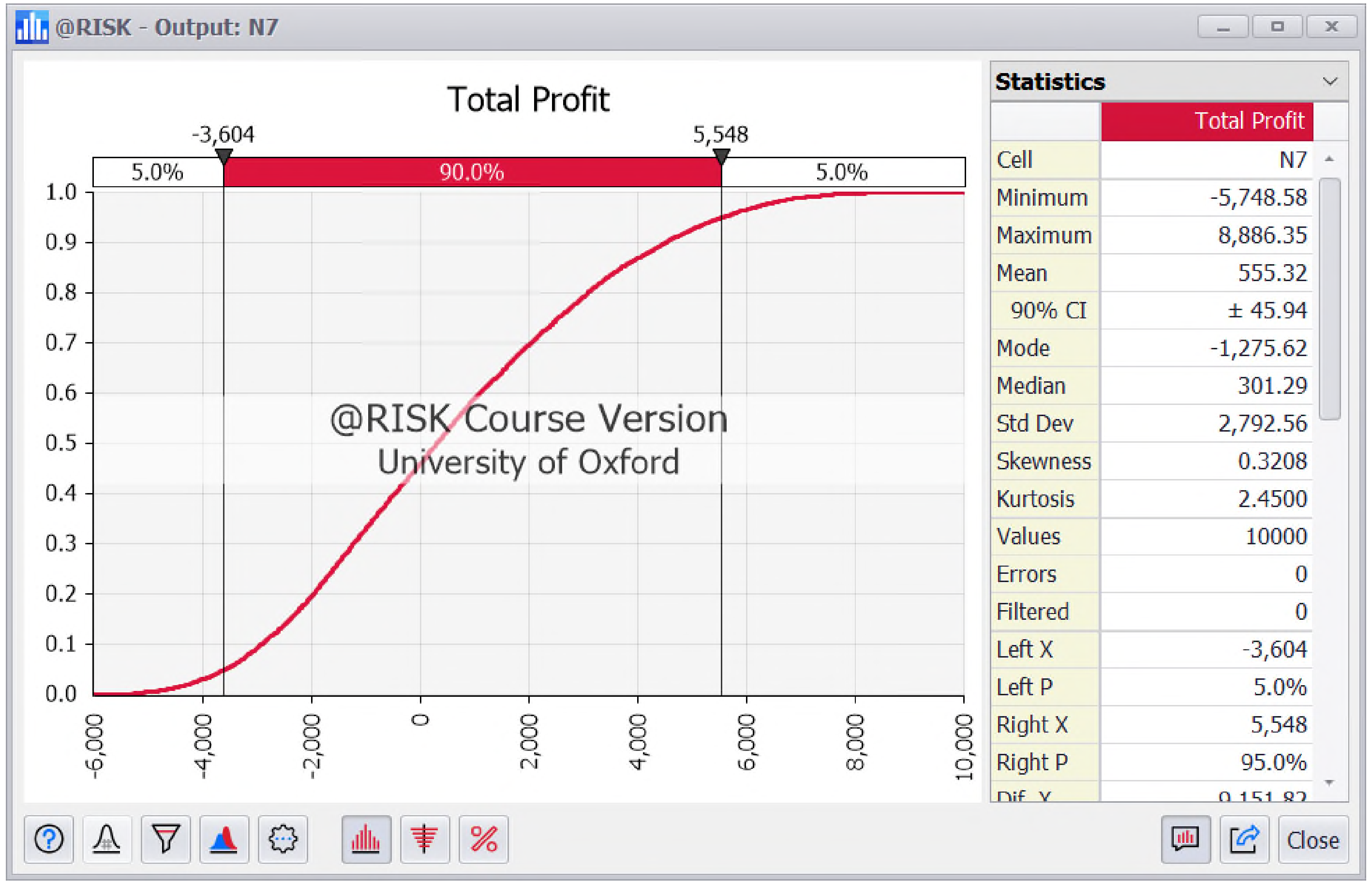
4. Execute simulation

5. View results - graphs, summary statistics



@RISK Output





Distribution for total profit:

Mean = 555

P(-3,604 < Total Profit < 5,548) = 90%

P(Total Profit < 0) = 46.0%

For Mac Excel: SimVoi

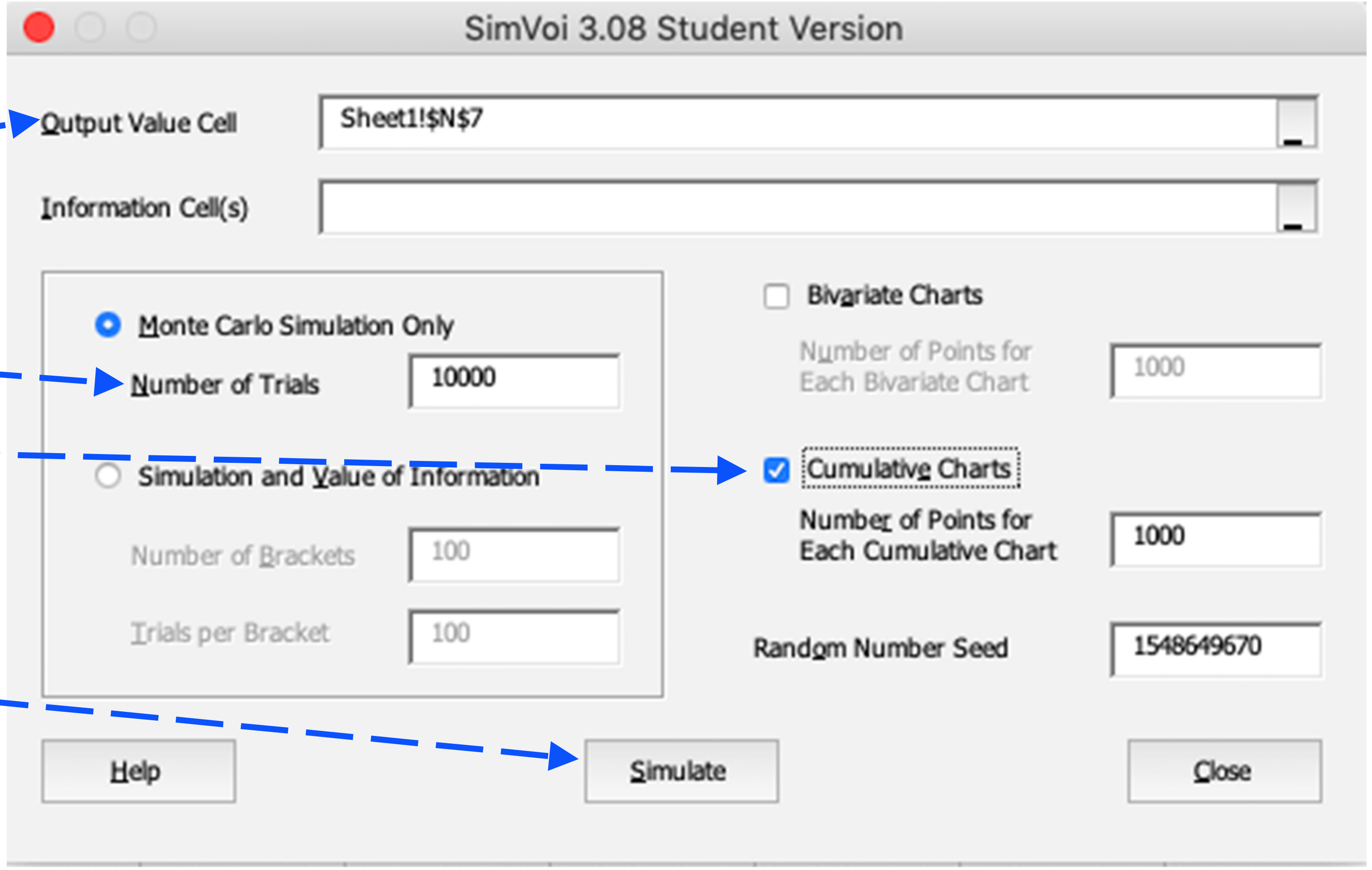
1. Introduce uncertainty into model
   =RandUniform(0%,10%) for Sales Growth
   =RandTriangular(20,30,35) for Price

2. From main menu, select Tools, then SimVoi (or alt+cmd+v).

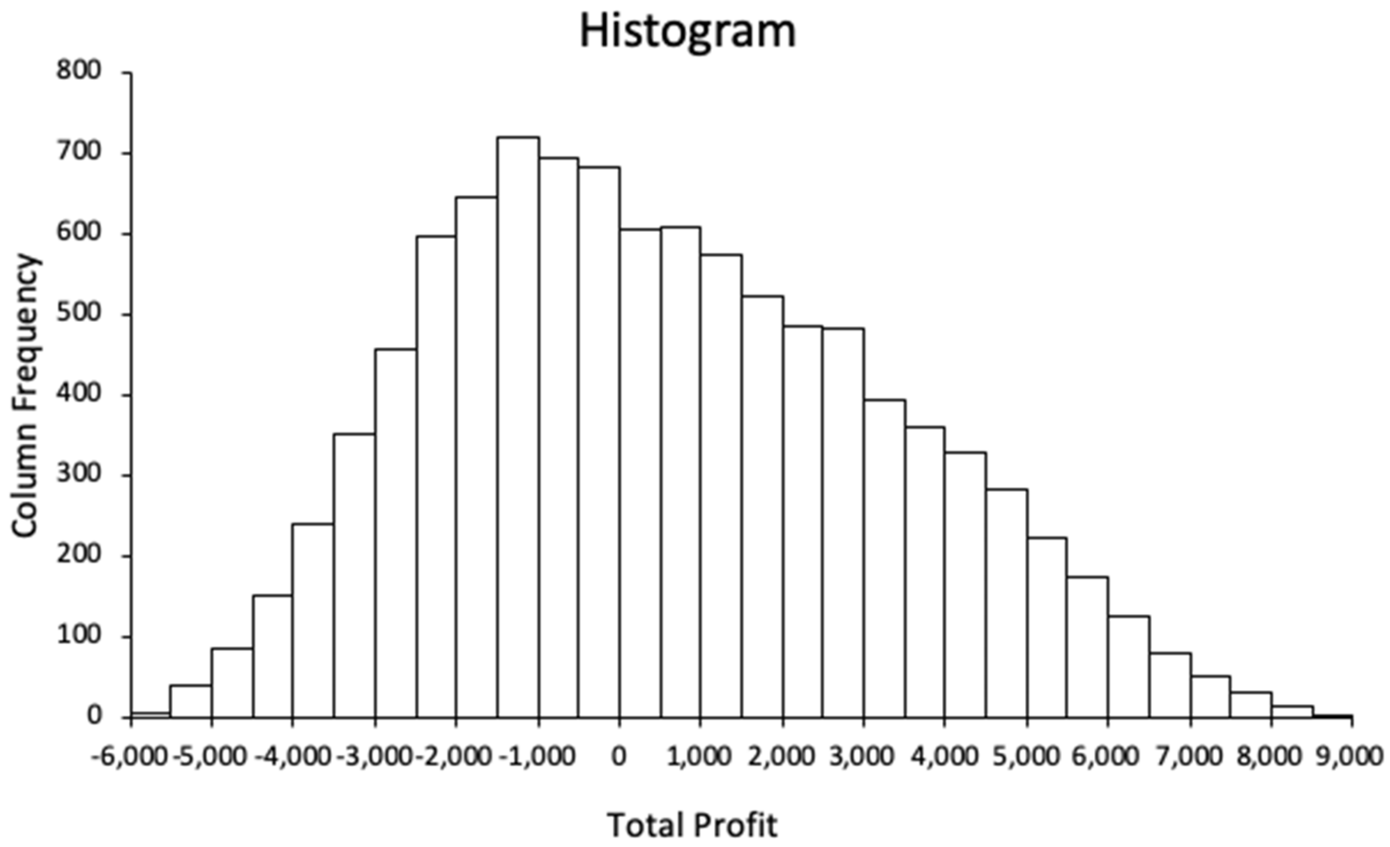
3. In dialog box, specify:
   - output cell of interest
   - number of iterations/trials
   - Cumulative Charts

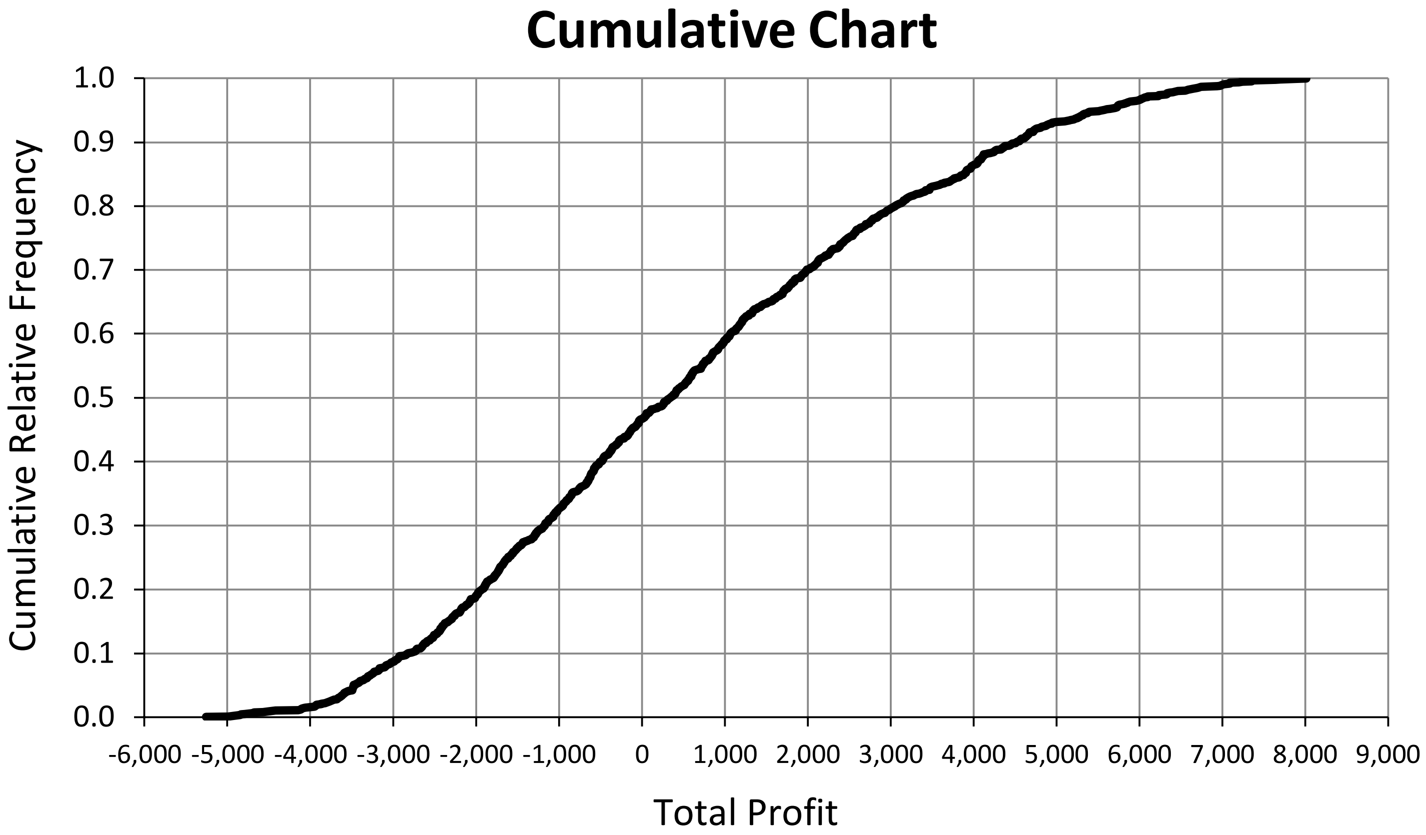
4. Execute simulation

5. View results - graphs, summary statistics



SimVoi Output





Distribution for total profit:

Mean = 583

P(-3,524 < Total Profit < 5,524) = 90%

P(Total Profit < 0) = 46.7%

Overview

- Risk analysis
- Monte Carlo simulation
- Application of Monte Carlo to:
  - Financial model
  - Order quantity decision

Someone figured out my password, now I have to rename my dog.
Anonymous

Deciding on Order Quantity at Carol Monet's Bookshop

- Order how many calendars?
- Each costs the bookshop £15 and will be sold for £20. After 1st January, any unsold will be returned to the publisher for refund of £5 each.
- Uncertain demand: N(200,50).
- Start by assuming demand will be 200, and order 200.

	A	B	C	D
1	**Carol Monet's Bookshop**			
2				
3	**Cost & price data (£)**			
4	Unit cost	15		
5	Unit price	20		
6	Unit refund	5		
7				
8	**Uncertain demand (units)**			
9	Demand	200		
10				
11	**Decision variable (units)**			
12	Order quantity	200		
13				
14	**Profit calculation**			
15	Sold units	200	<-------- =MIN(B9,B12)	
16	Revenue (£)	4000		
17	Cost (£)	3000		
18	Unsold units	0		
19	Refund (£)	0		
20	Profit (£)	1000		
21				

Flaw of Averages

- With order quantity as 200, and **assuming demand is its mean (200)**, we get sold units=200 and profit=1000.
- But don’t use these as forecasts because they are **actually the most** sales and profit could be.
- **Can be misleading to assume means of inputs when predicting the output** (Jensen’s inequality).

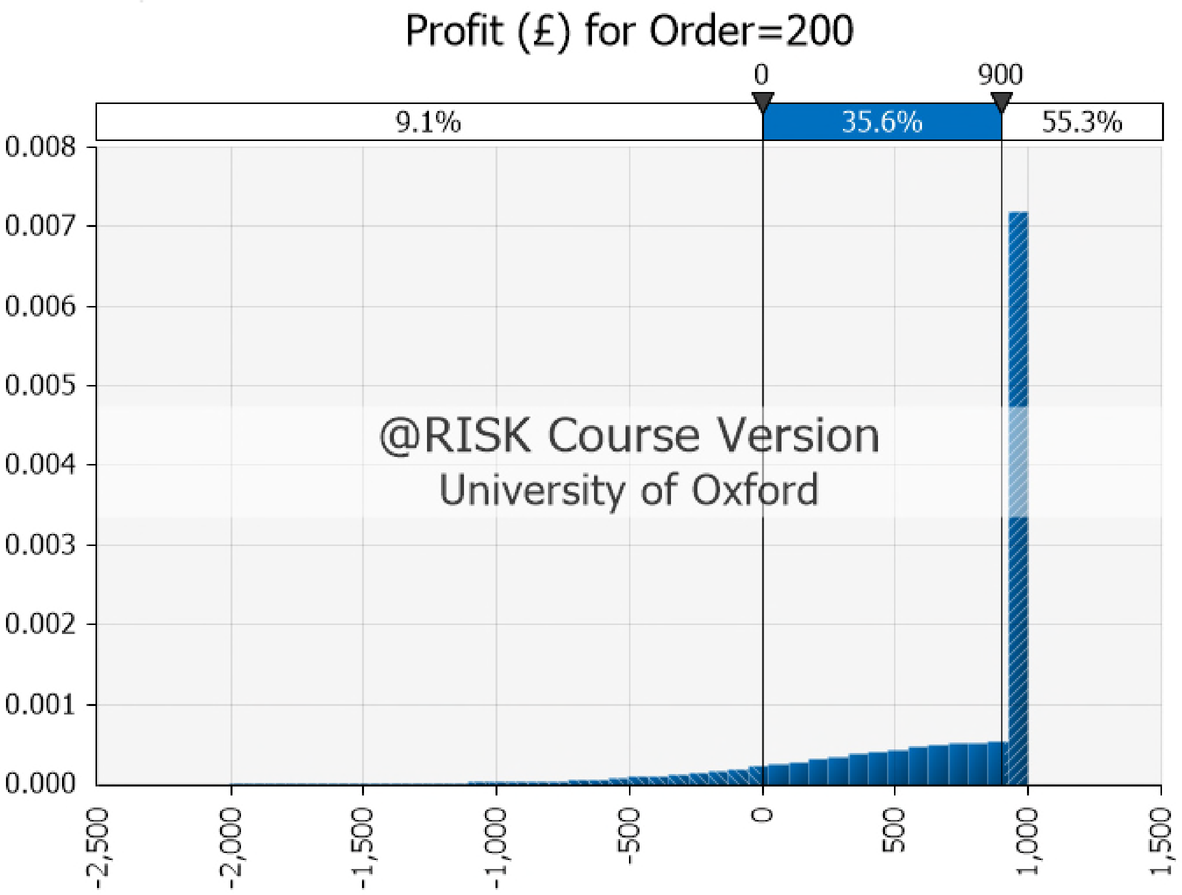
	A	B	C	D
1	**Carol Monet's Bookshop**			
2				
3	**Cost & price data (£)**			
4	Unit cost	15		
5	Unit price	20		
6	Unit refund	5		
7				
8	**Uncertain demand (units)**			
9	Demand	200		
10				
11	**Decision variable (units)**			
12	Order quantity	200		
13				
14	**Profit calculation**			
15	Sold units	200	<-------- =MIN(B9,B12)	
16	Revenue (£)	4000		
17	Cost (£)	3000		
18	Unsold units	0		
19	Refund (£)	0		
20	Profit (£)	1000		
21				

Monte Carlo Simulation with Demand ~ N(200,50)

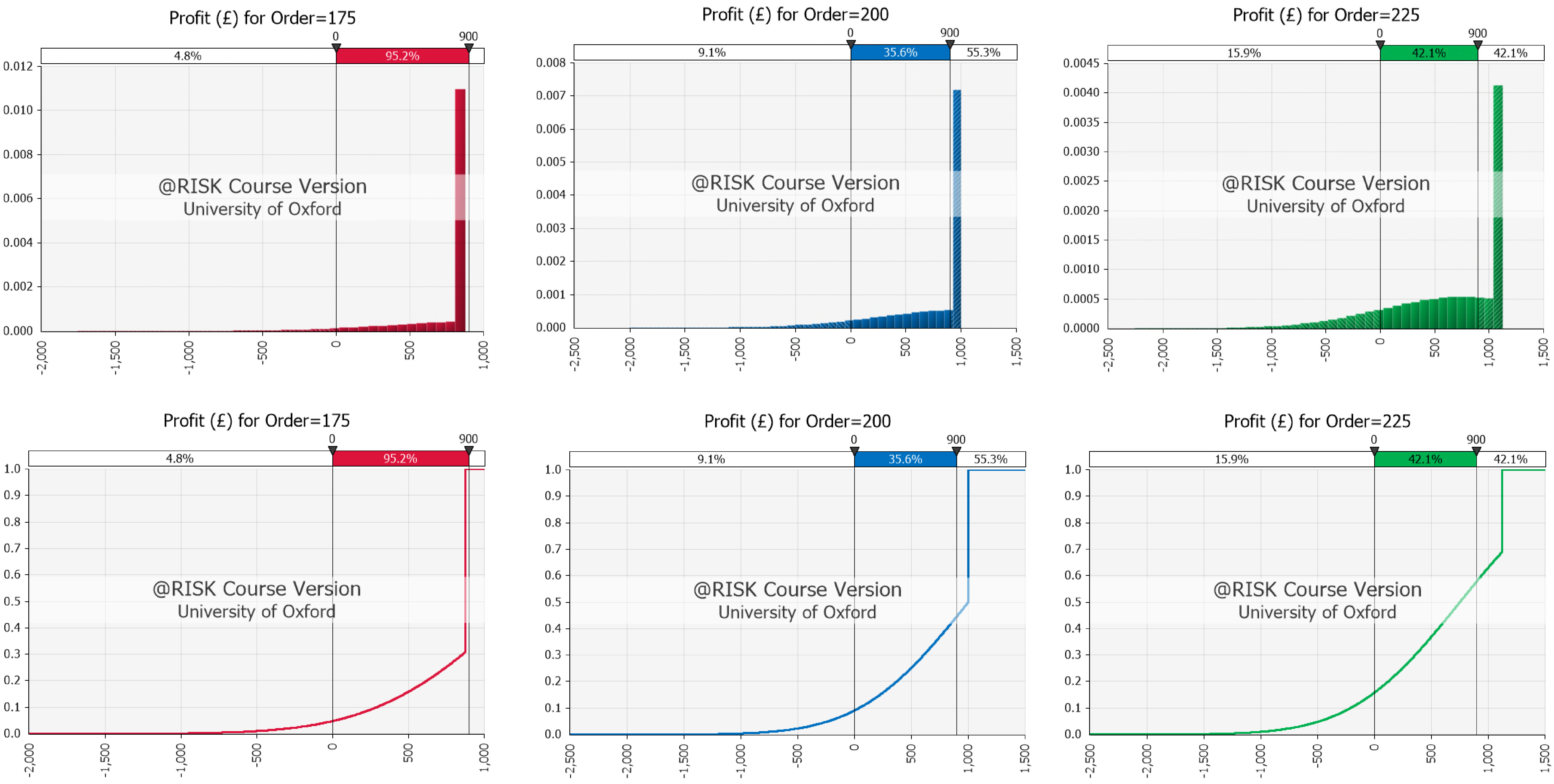
	A	B
1	**Carol Monet's Bookshop**	
2		
3	**Cost & price data (£)**	
4	Unit cost	15
5	Unit price	20
6	Unit refund	5
7		
8	**Uncertain demand (units)**	
9	Demand	200
10		
11	**Decision variable (units)**	
12	Order quantity	200
13		
14	**Profit calculation**	
15	Sold units	200
16	Revenue (£)	4000
17	Cost (£)	3000
18	Unsold units	0
19	Refund (£)	0
20	Profit (£)	1000
21		

<-------- For @Risk, use =RiskNormal(200,50).
For SimVoi, use =RandNormal(200,50).

- For order quantity = 200, sold units ≤ 200. Profit distribution has mean of 700.79, wide spread and interesting shape.



Order = 175, 200 or 225

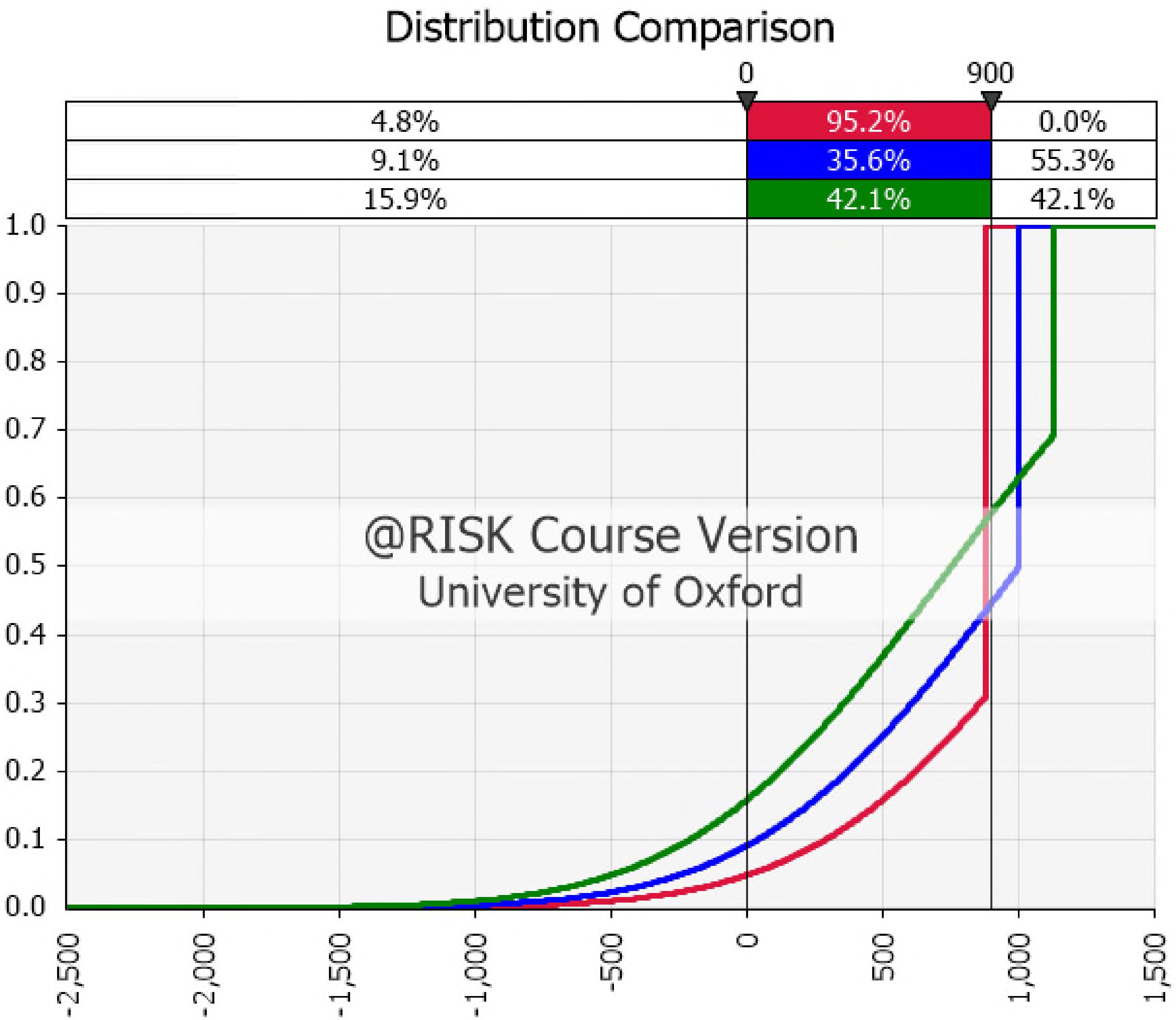


Comparison of Distributions for Order = 175, 200 or 225

	Profit for Order=175	Profit for Order=200	Profit for Order=225
Mean	726.65	700.79	601.65
Std Dev	309.75	437.91	558.00

There is no comparison between that which is lost by not succeeding and that which is lost by not trying. *Francis Bacon*

Comparison of Distributions for Order = 175, 200 or 225



Statistics	Profit (£) for Order=175	Profit (£) for Order=200	Profit (£) for Order=225
Cell	Ques3!B20	Ques3!C20	Ques3!D20
Minimum	-1,758.07	-2,008.07	-2,258.07
Maximum	875.00	1,000.00	1,125.00
Mean	726.65	700.79	601.65
90% CI	± 5.10	± 7.20	± 9.18
Mode	875.00	1,000.00	1,125.00
Median	875.00	999.96	749.96
Std Dev	309.75	437.91	558.00
Skewness	-2.5839	-1.6413	-1.0143
Kurtosis	10.2636	5.4124	3.4626
Values	10000	10000	10000
Errors	0	0	0
Filtered	0	0	0
Left X	0	0	0
Left P	4.8%	9.1%	15.9%
Right X	900	900	900
Right P	100.0%	44.7%	57.9%
Dif. X	900.00	900.00	900.00

Comparison of Distributions for Order = 175, 200 or 225

	Profit for Order=175	Profit for Order=200	Profit for Order=225
Mean	726.65	700.79	601.65
Std Dev	309.75	437.91	558.00
Prob(Profit<0)	4.8%	9.1%	15.9%
Prob(Profit>900)	0%	55.3%	42.1%

Summary

- If probability distributions can be proposed for uncertain input cells, Monte Carlo simulation enables a probability distribution to be generated for an output cell.
- Excel add-ins allow different types of probability distribution for inputs. But bear in mind, ‘rubbish in, rubbish out’.
- Correlation can be specified in more sophisticated add-ins.

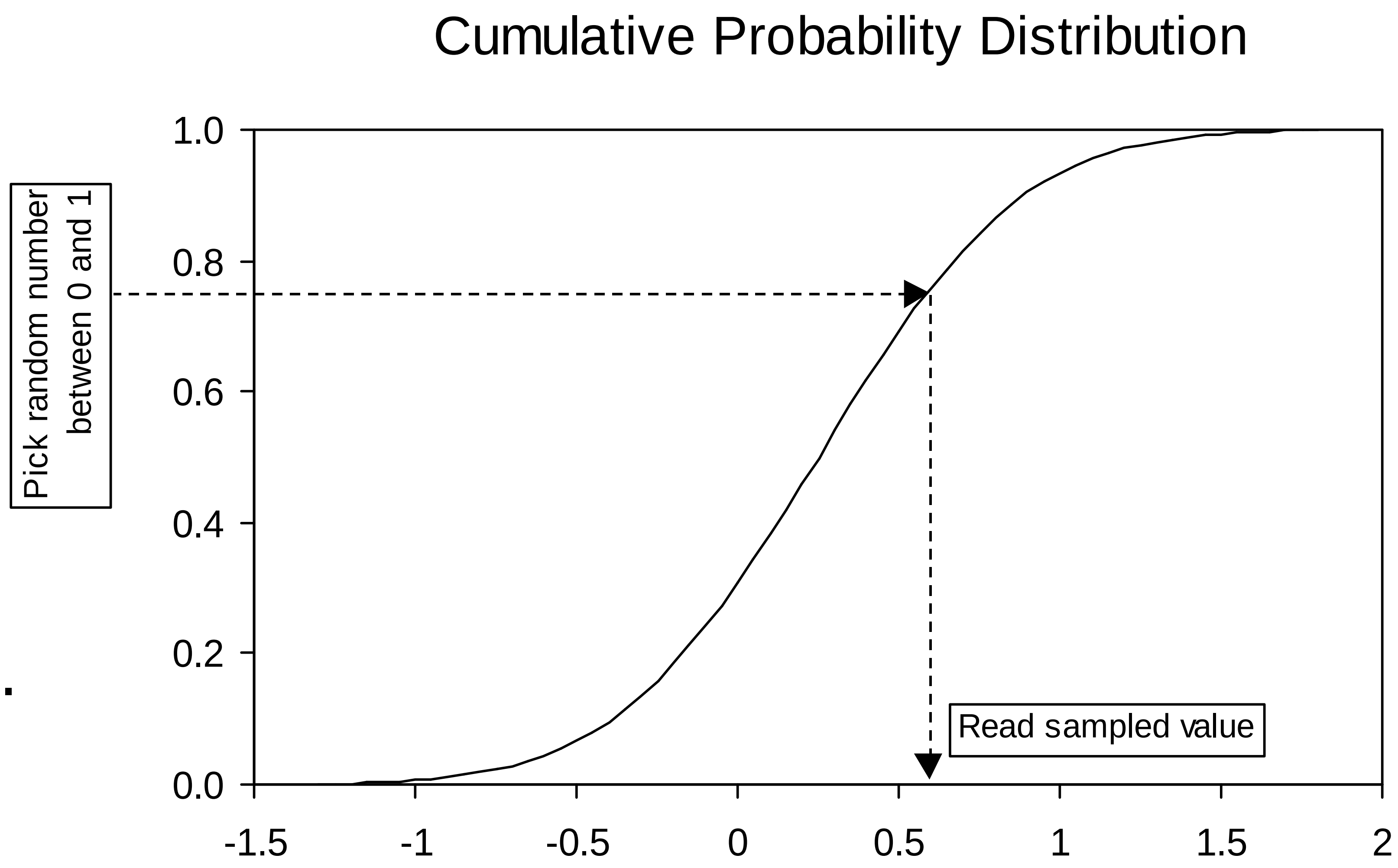
I'd rather regret the risks that didn't work out than the chances I didn't take at all.
Simone Biles

Appendix 1
Monte Carlo Sampling

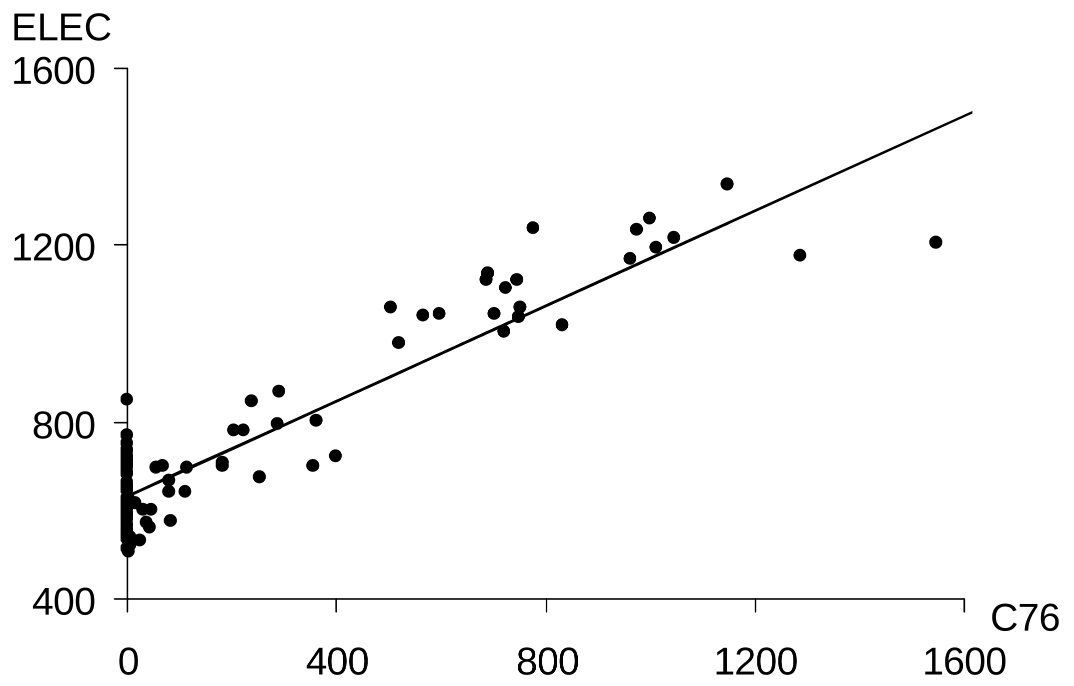
- Monte Carlo simulation involves sampling from a probability distribution.

- This is straightforward for a uniform distribution.

- To sample from other distributions, Monte Carlo sampling converts uniformly distributed random numbers using the cumulative probability distribution as shown here.



Appendix 2 - Application of Monte Carlo to a Regression Model



$$y = a + b\,\mathbf{x} + \mathbf{e}$$

- An approximate 95% confidence interval for a forecast:

$$\textit{forecast} \pm \mathbf{1.96}\,\boldsymbol{s}$$

where ***s* is standard deviation of *e***.

- Often get a similar interval using statistical software, which replaces *s* by a standard error summarising uncertainty due to *e* and uncertainty in estimating *a* and *b*.

- But if *x* needs predicting, we'll also have **uncertainty in *x***.

Appendix 2 - Applying Monte Carlo to a Regression Model

$$y = a + b\,x + e$$

- Input distributions for:
  - **uncertainty due to *e***
  - **uncertainty in *x***

- Use Monte Carlo to give output distribution for:
  - **uncertainty in *y***