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HARVARD Kennedy School ASH CENTER for Democratic Governance and Innovation

FULBRIGHT Economics Teaching Program

LMPPI Lower Mekong Public Policy Initiative

Technical Training in Project Appraisal for the Lower Mekong Basin

RISK ANALYSIS AND RISK MANAGEMENT

Ho Chi Minh City

Nov 28 - Dec 09, 2016

DECISION-MAKING UNDER UNCERTAINTY

1. RISK ANALYSIS

- TO IDENTIFY, ANALYZE, AND INTERPRET THE EXPECTED VARIABILITY IN PROJECT OUTCOMES.

2. RISK DIVERSIFICATION AND MANAGEMENT

- HOW TO DIVERSIFY RISK
- HOW TO REDESIGN AND REORGANIZE PROJECTS IN ORDER TO REALLOCATE RISK

RISK ANALYSIS

1. WHY?

- **PROJECT RETURNS ARE SPREAD OVER TIME**
- **EACH VARIABLE AFFECTING NPV IS SUBJECT TO HIGH LEVEL OF UNCERTAINTY**
- **INFORMATION AND DATA NEEDED FOR MORE ACCURATE FORECASTS ARE COSTLY TO ACQUIRE**
- **NEED TO REDUCE THE LIKELIHOOD TO UNDERTAKE A "BAD" PROJECT WHILE NOT FAILING TO ACCEPT A "GOOD" PROJECT**

2. ALTERNATIVE METHODS FOR ANALYSIS OF RISK

2.1 SENSITIVITY ANALYSIS

2.2 SCENARIO ANALYSIS

2.3 MONTE CARLO RISK ANALYSIS

(SIMULATION ANALYSIS)

2.1 SENSITIVITY ANALYSIS

- **TEST THE SENSITIVITY OF A PROJECT'S OUTCOME (NPV) TO CHANGES IN ONE PARAMETER VALUE AT A TIME**
- **"WHAT IF" ANALYSIS**
- **ALLOWS YOU TO TEST WHICH VARIABLES ARE IMPORTANT (I.E., AS A SOURCE OF RISK)**
- **A VARIABLE IS IMPORTANT DEPENDING ON:**

A) ITS SHARE OF TOTAL BENEFITS OR COSTS

B) LIKELY RANGE OF VALUES

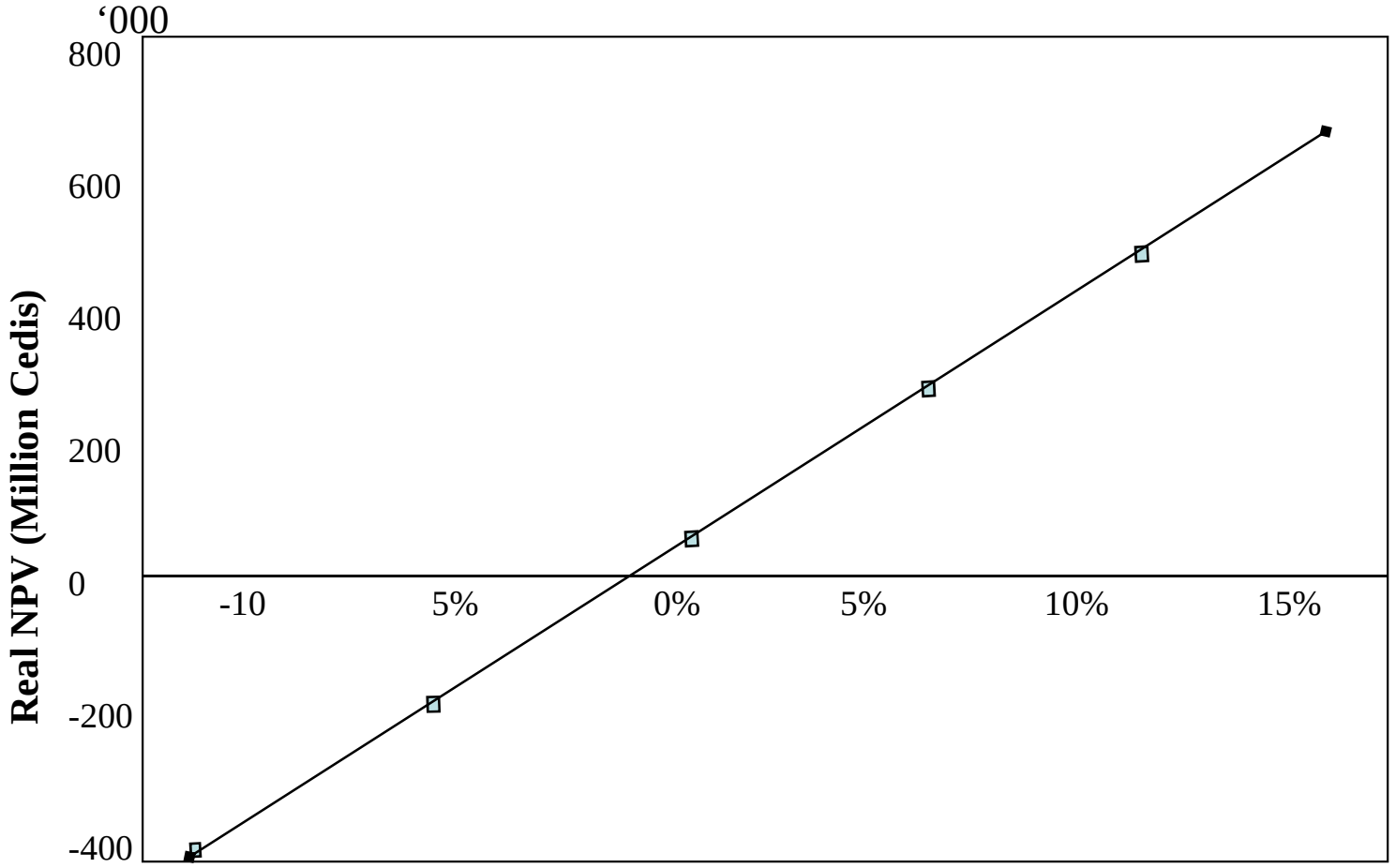
- **SENSITIVITY ANALYSIS ALLOWS YOU TO DETERMINE THE DIRECTION OF CHANGE OF THE NPV**
- **BREAK-EVEN ANALYSIS ALLOWS YOU TO DETERMINE HOW MUCH A VARIABLE MUST CHANGE BEFORE THE NPV TURNS NEGATIVE**

SENSITIVITY ANALYSIS FOR ONE CASE

Domestic Inflation Rate	Real Financial NPV (Million Cedis)	Tariff Escalation Factor	Real Financial NPV (Million Cedis)
15%	8078	-10%	-38314
20%	5106	-5%	-17971
25%	**2371**	**0%**	**2371**
30%	-153	5%	22714
35%	-2490	10%	43057
40%	-4660	15%	63400
Production Factor	Real Financial NPV (Million Cedis)	Divergence form Original Investment Cost Estimate	Real Financial NPV (Million Cedis)
60%	-160372	-5%	24074
70%	-119686	**0%**	**2371**
80%	-79000	5%	-19331
90%	-38314	10%	-41033
100%	**2371**	15%	-62736
110%	43057	20%	-84438

Hydro Electric Power Project

Sensitivity Analysis with Tariff Escalation Factor and Real NPV Financial NPV



LIMITATIONS OF SENSITIVITY ANALYSIS

- Sensitivity analysis doesn't cover all the range of values of inputs and outputs
- For most variables, the direction is obvious but not enough
  - If price increases, the quantity of electricity sold may decrease
  - If fuel price changes, sales price may change
  - If exchange rate changes, all tradable goods' prices and foreign liabilities change.
- One-at-a-time testing is not realistic because of correlation among variables
- One method of partially dealing with these combined or correlated effects is scenario analysis

2.2 Scenario Analysis

Scenario analysis recognizes that certain variables are interrelated. Thus a small number of variables can be altered in a consistent manner at the same time.

What is the set of circumstances that are likely to combine to produce different "cases" or "scenarios"?

A. Worst case / Pessimistic case

B. Expected case / Best estimate case

C. Best case / Optimistic case

Note: Scenario analysis does not take into account the **Probability** of cases arising

- **Interpretation is easy when results are robust:**

A. Accept project if NPV > 0 even in the worst case

B. Reject project if NPV < 0 even in the best case

C. If NPV is sometimes positive, sometimes negative, then results are not conclusive.

2.3 Risk Analysis and Monte Carlo Simulation

Risk Analysis:

- Knowing that a coal plant is a better investment than gas-fired combined cycles plant if gas prices triple is of little help without assessing the likelihood that such gas price increases might occur.
- In risk analysis, the picture of uncertainty is explicitly specified and likelihood of occurrence and range of the input variables are specified
- The likelihood of occurrence of the output values are generated by the risk analysis
- Monte Carlo Risk analysis can accommodate large number of variable combinations, specifications and runs

2.3 Monte Carlo Method of Risk Analysis

- **A natural extension of sensitivity analysis**
- **Simultaneously takes into account different probability distributions and different ranges of possible values for key project variables**
- **Allows for correlation (covariation) between variables**
- **Generates a probability distribution of project outcomes (npv, ncf) instead of just a single value estimate**
- **The probability distribution of project outcomes may assist decision-makers in making choices, but there can be problems of interpretation and use.**

Steps in Building a Monte Carlo Simulation

1. **Develop a mathematical model: project evaluation spreadsheet**
2. **Identify variables which are sensitive and uncertain**
3. **Define uncertainty**

- **Establish a range of options (minimum and maximum)**
- **Allocate probability distribution**
  - **Normal distribution**
  - **Triangular distribution**
  - **Uniform distribution**
  - **Step distribution**

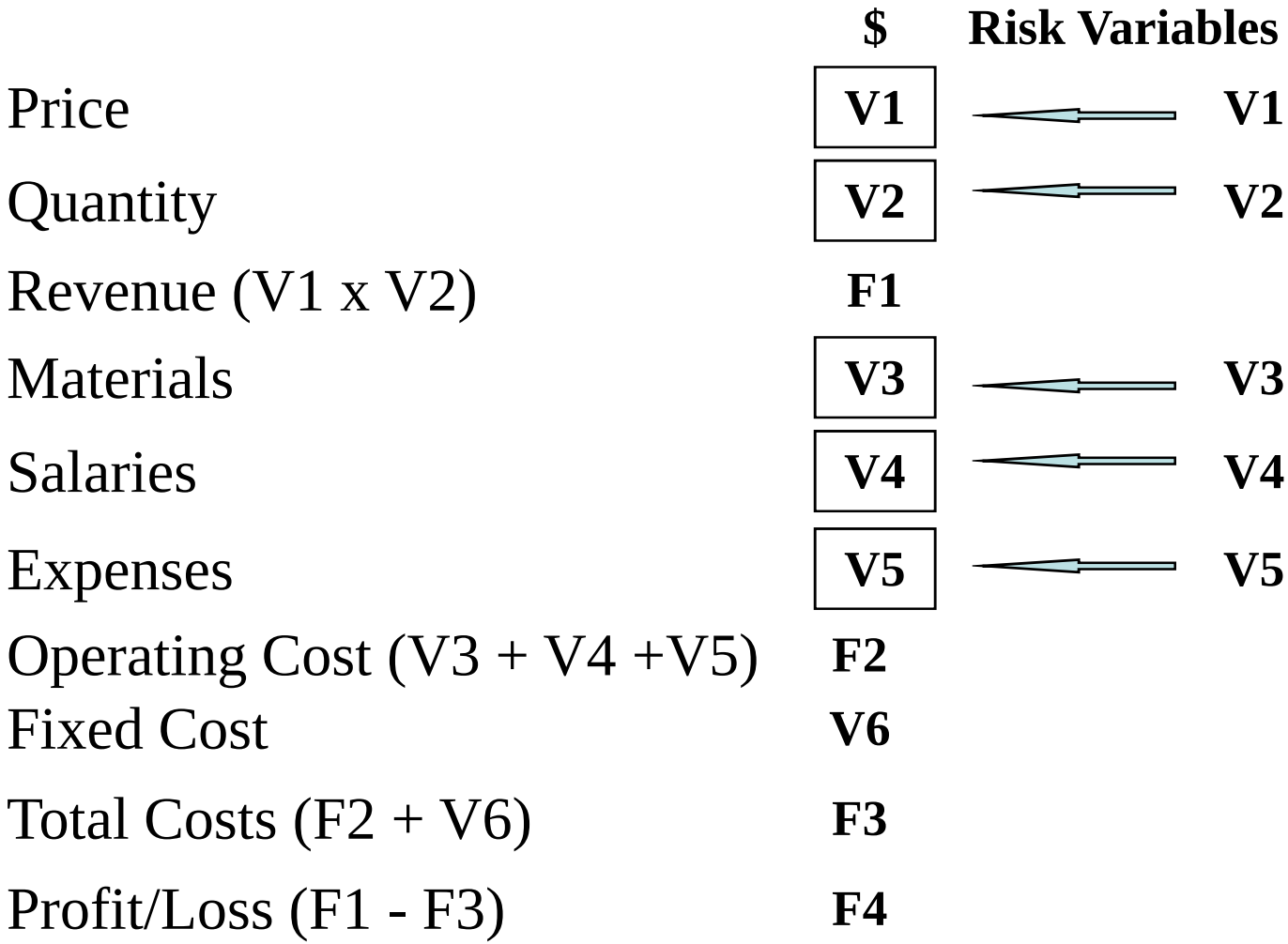
4. **Identify and define correlated variables**

- **Positive or negative correlation**
- **Strength of correlation**

5. **Run Simulation model**
6. **Analyze results**

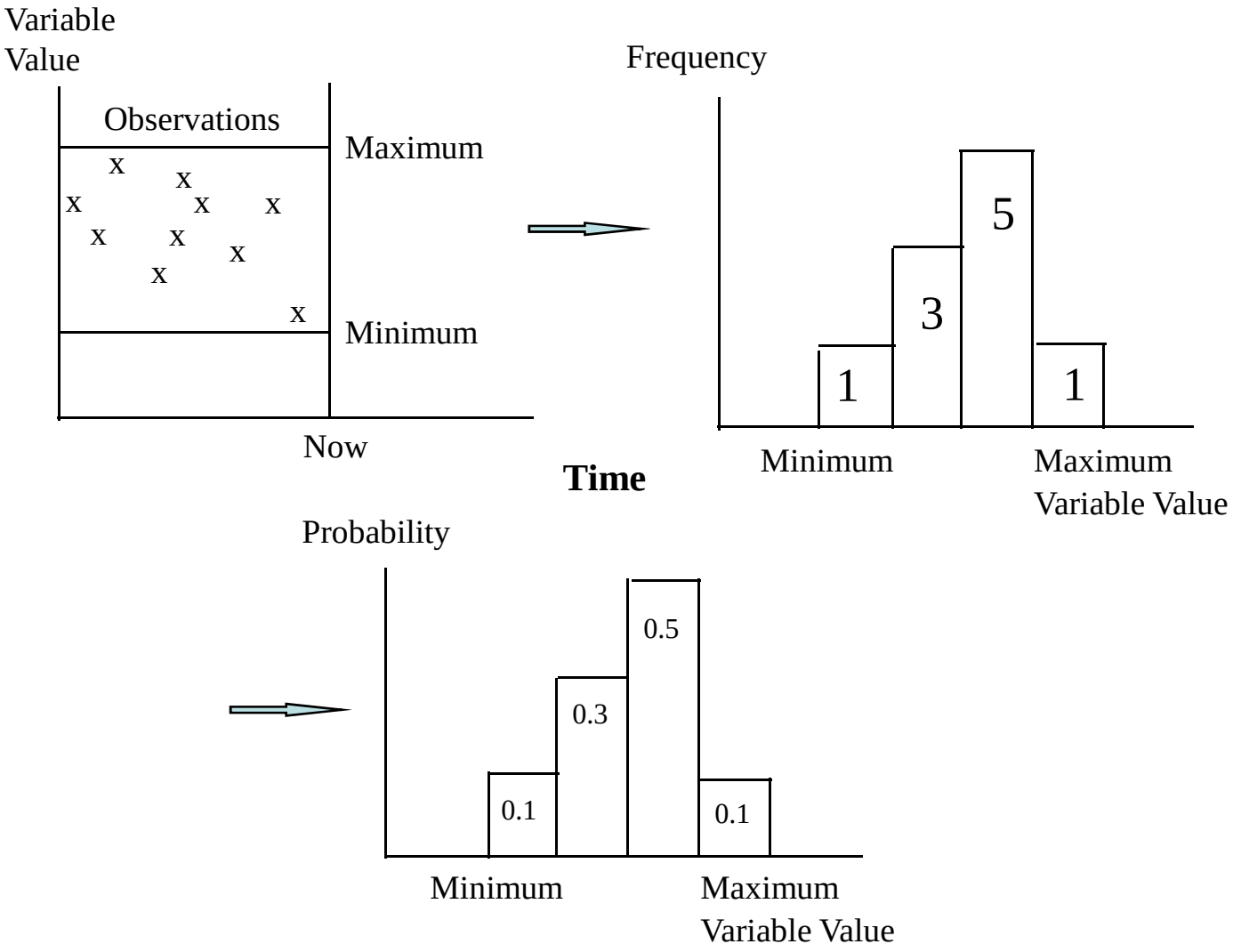
- **Statistics**
- **Distributions**

Sensitivity Analysis



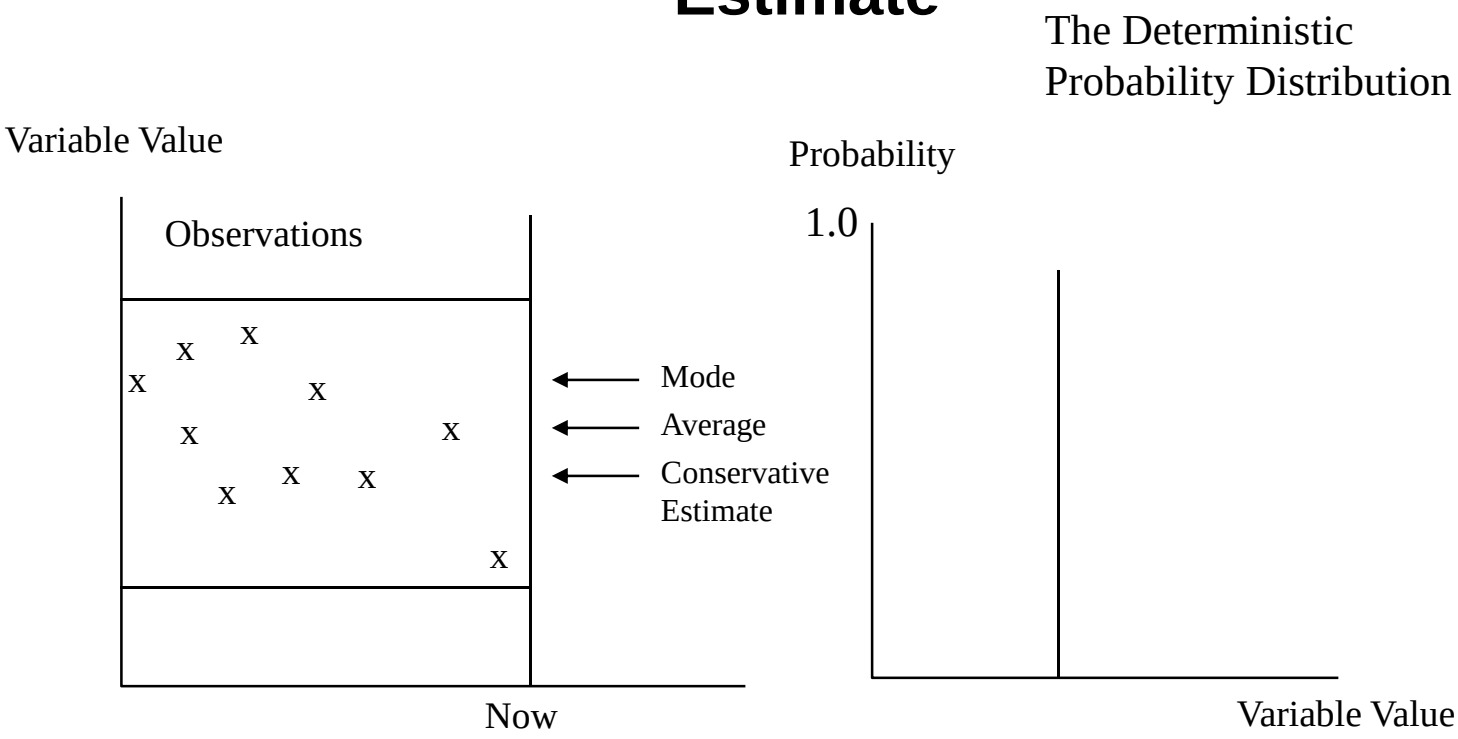
Forecasting the Outcome of a Future Event

From a Frequency to a Probability Distribution



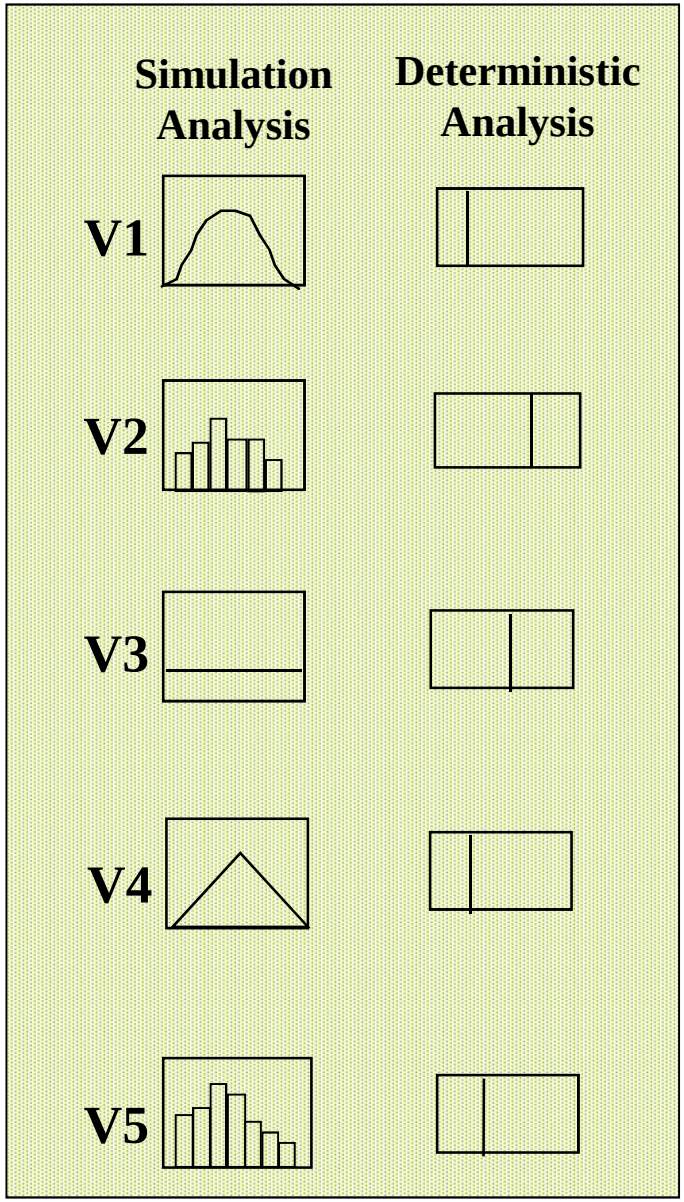
Forecasting the Outcome of a Future Event

The Single -Value Estimate



Deterministic vs. Simulation Analysis

	$
Price	V1
Quantity	V2
Revenue (V1 x V2)	F1
Materials	V3
Salaries	V4
Expenses	V5
Operating Cost (V3+V4+V5)	F2
Fixed Cost	V6
Total Costs (F2 + V6)	F3
Profit/Loss (F1 - F3)	F4

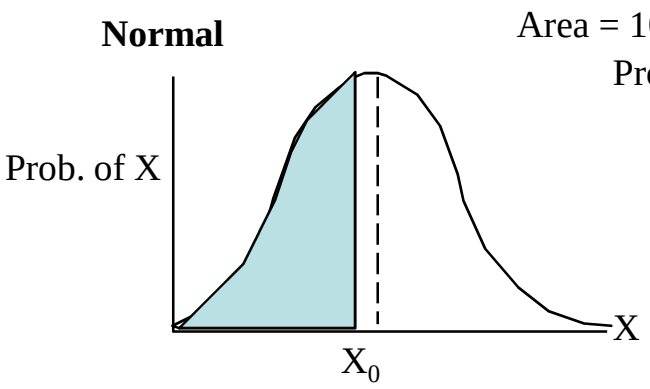


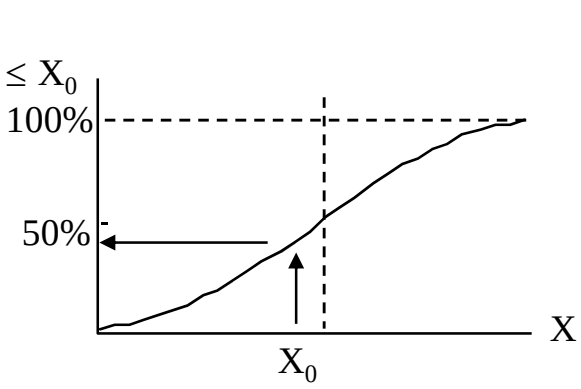
Foundations of Risk Analysis: Probability Distributions
3. Symmetrical Distributions

Relative Prob. or Density Function

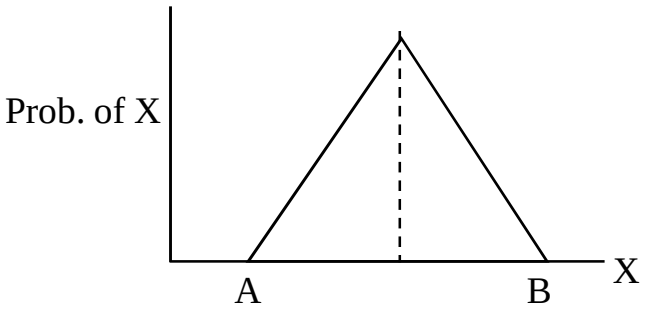
Cumulative Probability

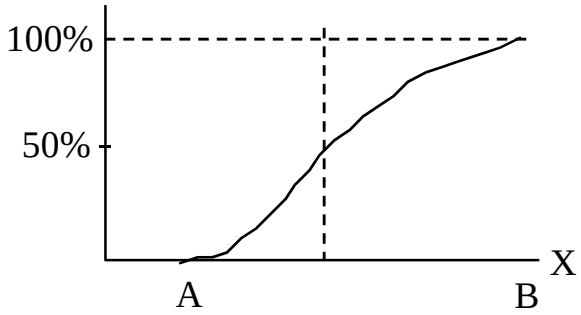
Normal



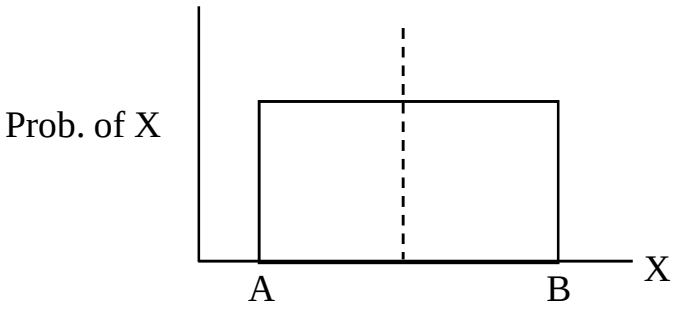


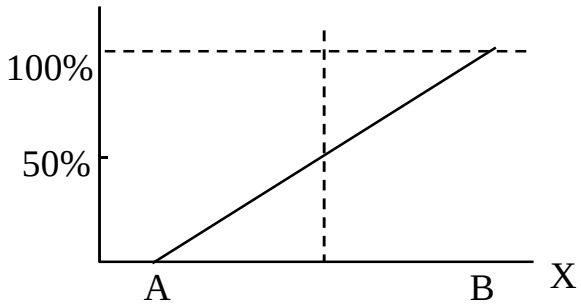
Triangular





Uniform

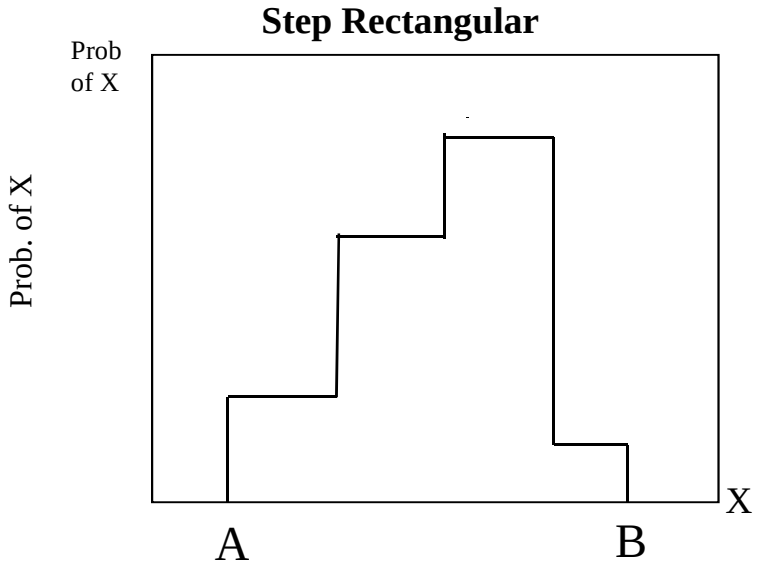




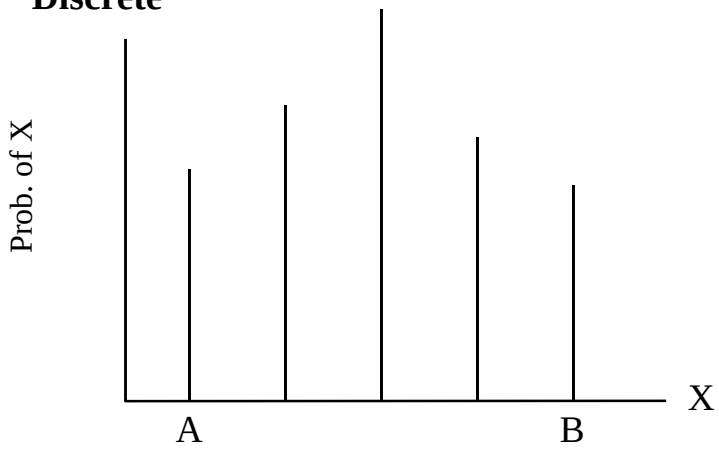
2. Non-Standard Flexible Distributions

Relative Prob./ Density Function

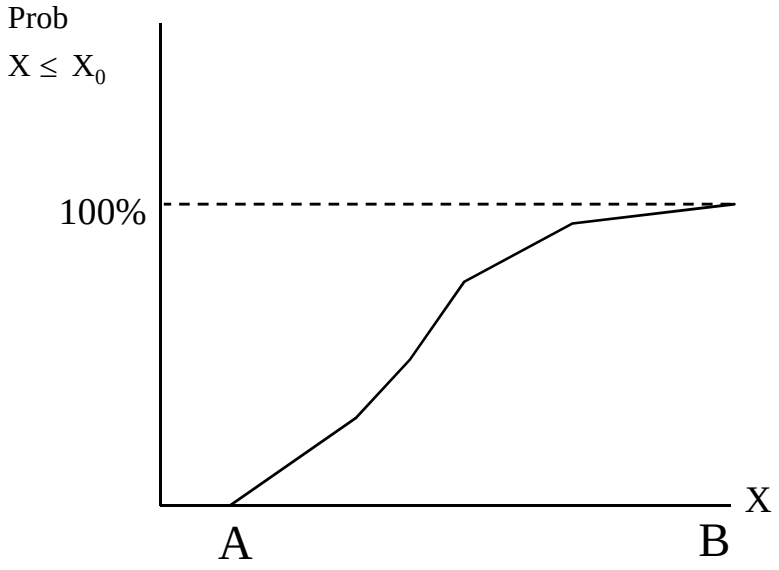
Step Rectangular

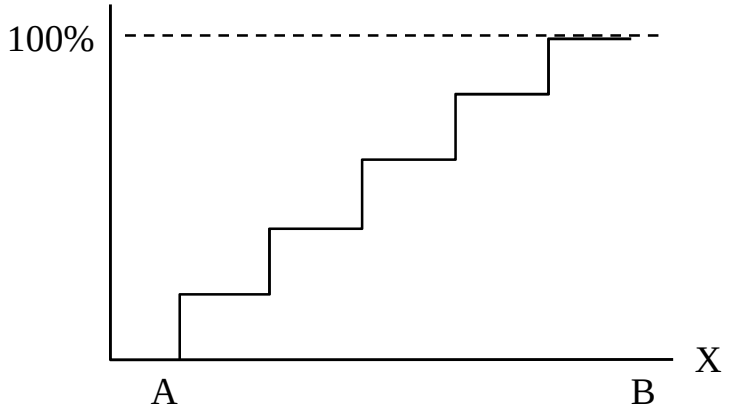


Discrete

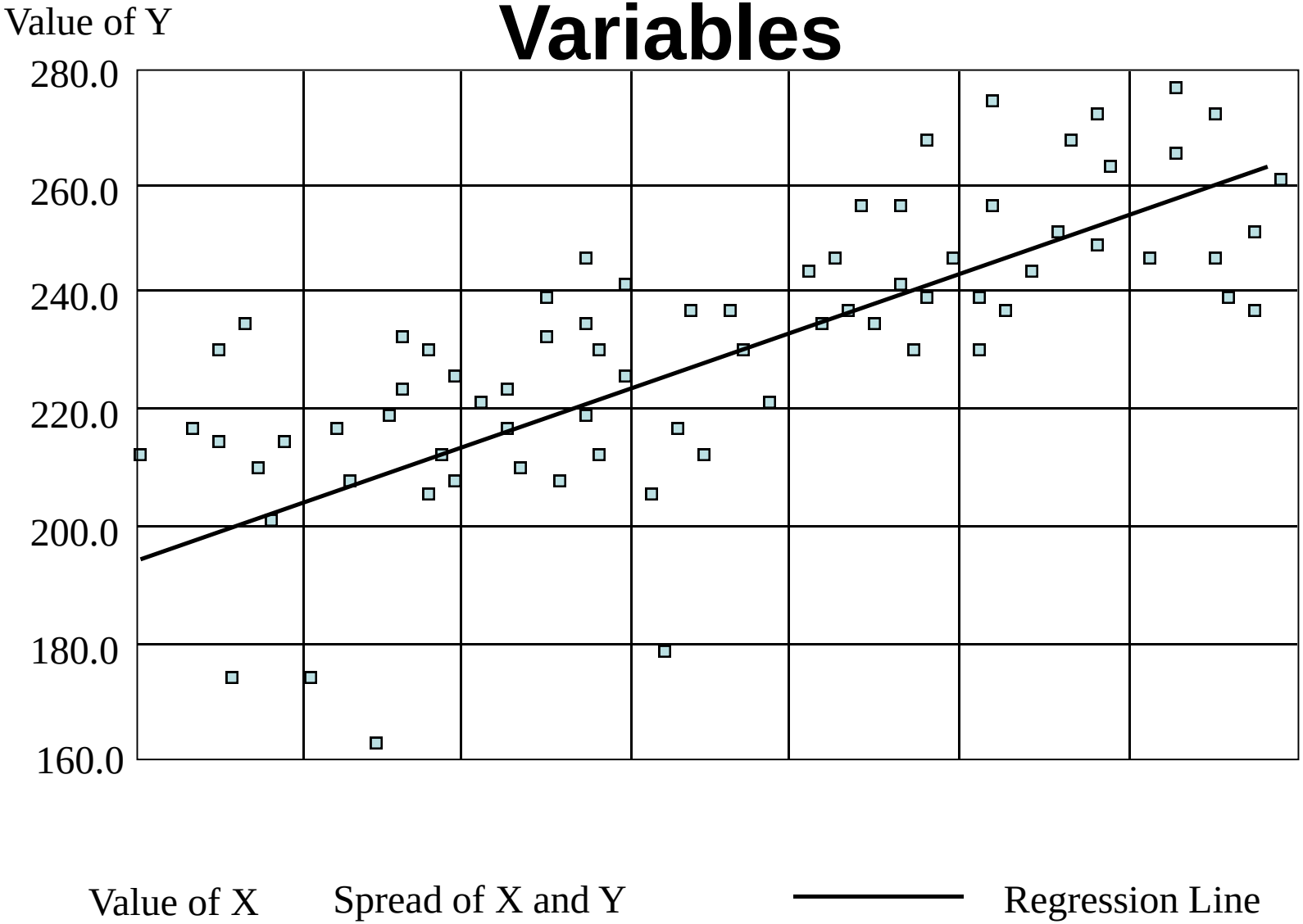


Cumulative Probability



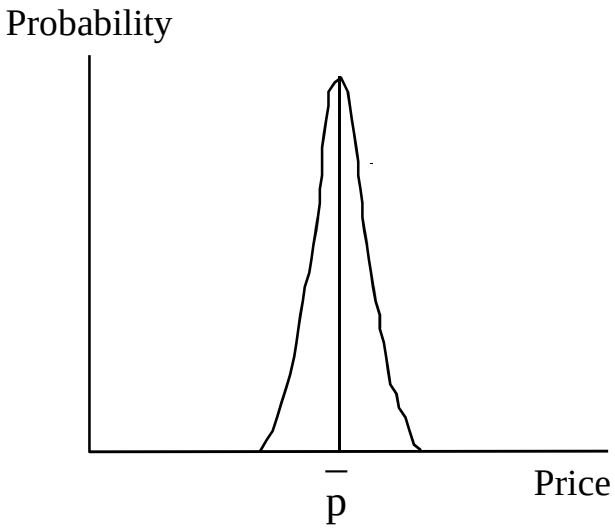


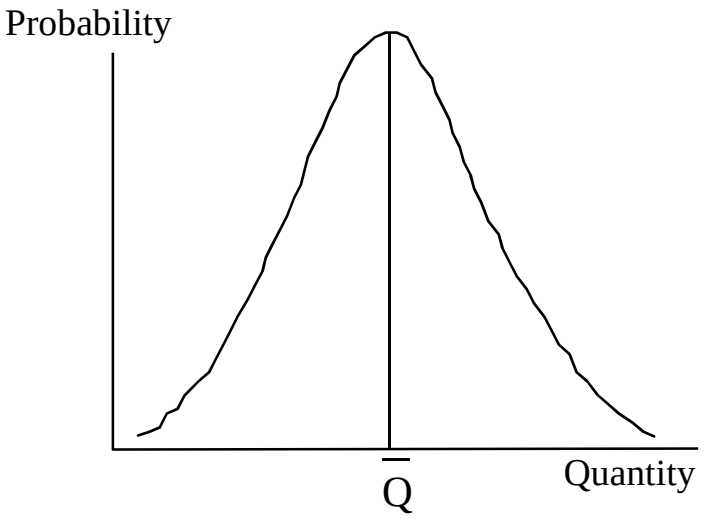
Correlated Variables



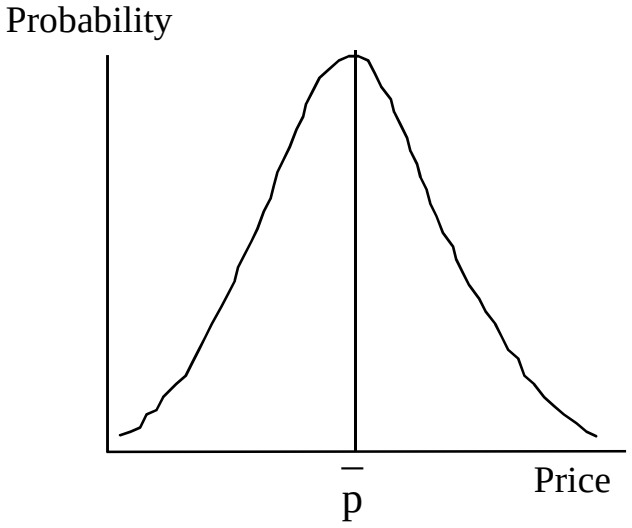
Relationship Between Quantity and Price

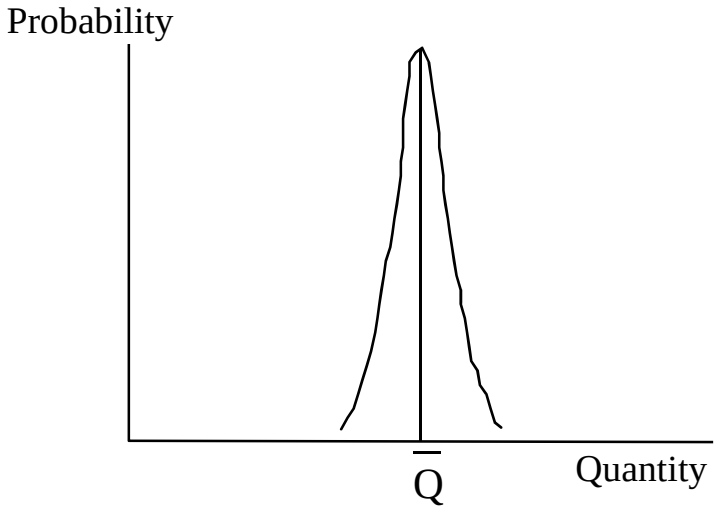
Example 1: High Price Elasticity of Demand





Example 2: Low Price Elasticity of Demand





Correlated Variables

Price

Quantity

Revenue (V1 x V2)

Materials

Salaries

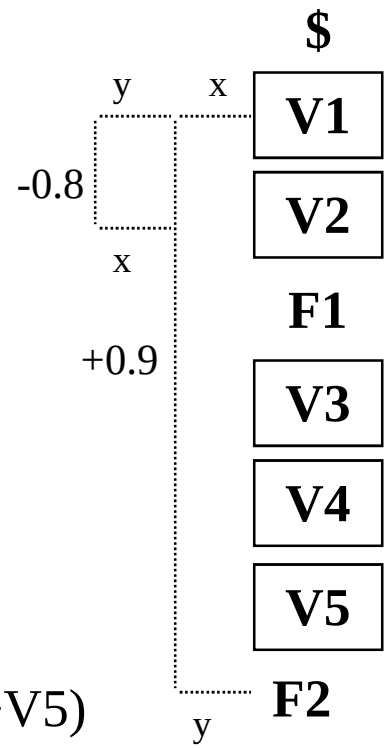
Expenses

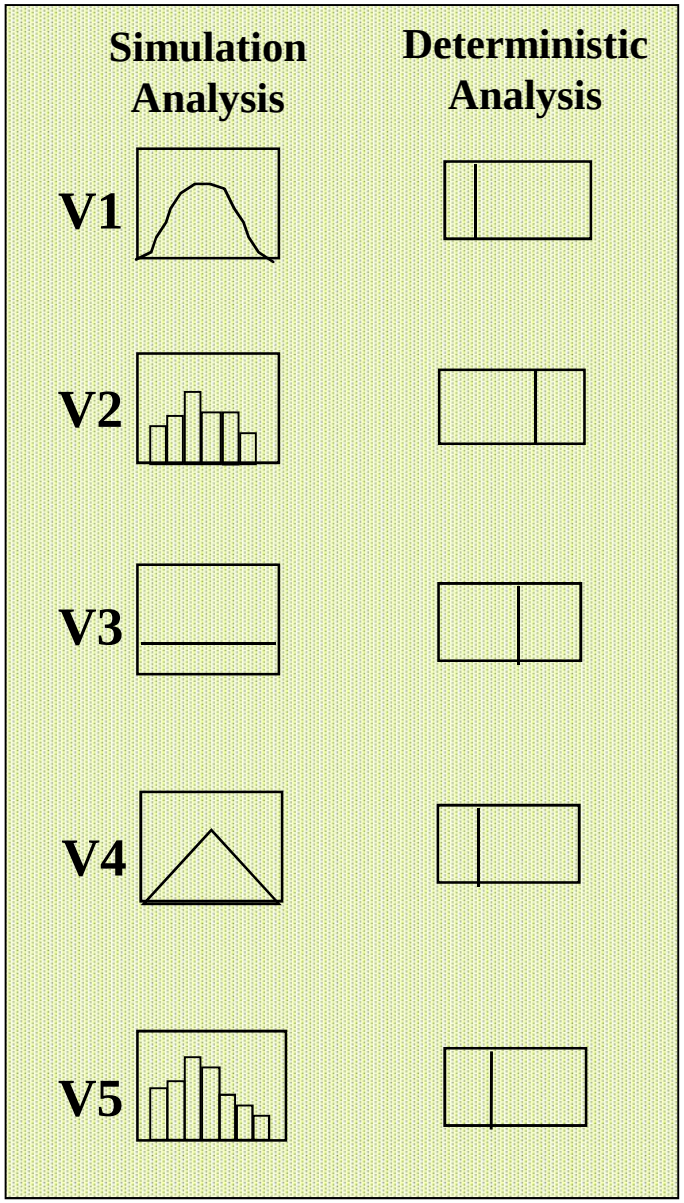
Operating Cost (V3+V4+V5)

Fixed Cost

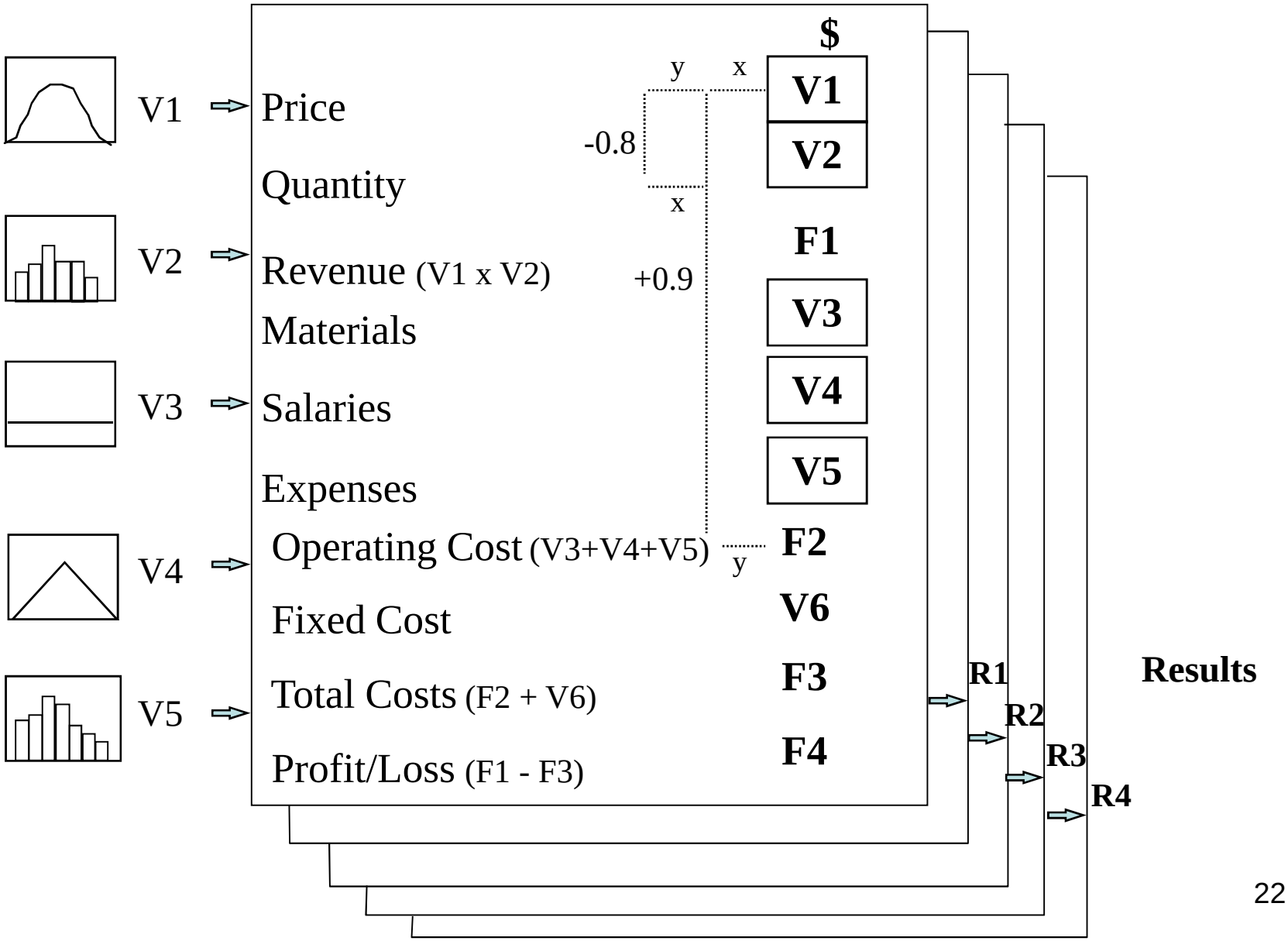
Total Costs (F2 + V6)

Profit/Loss (F1 - F3)



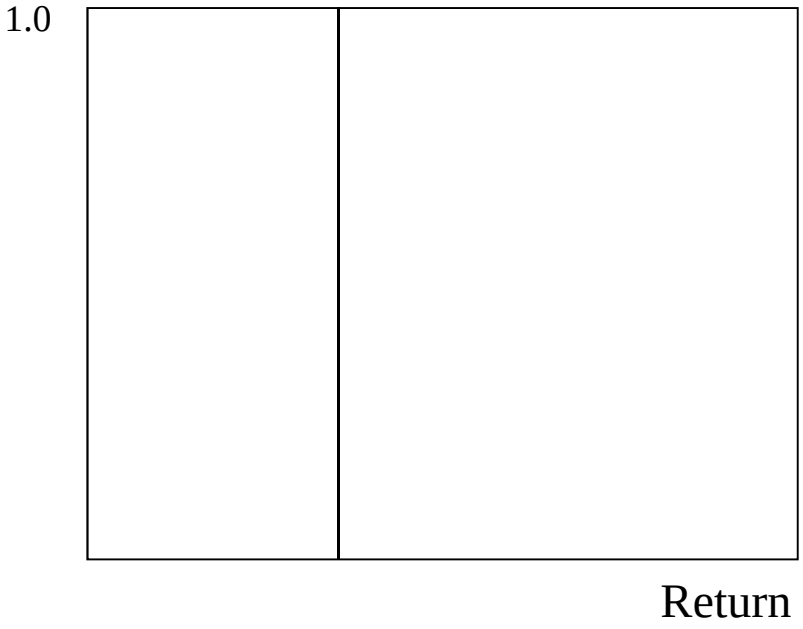


Simulation Runs

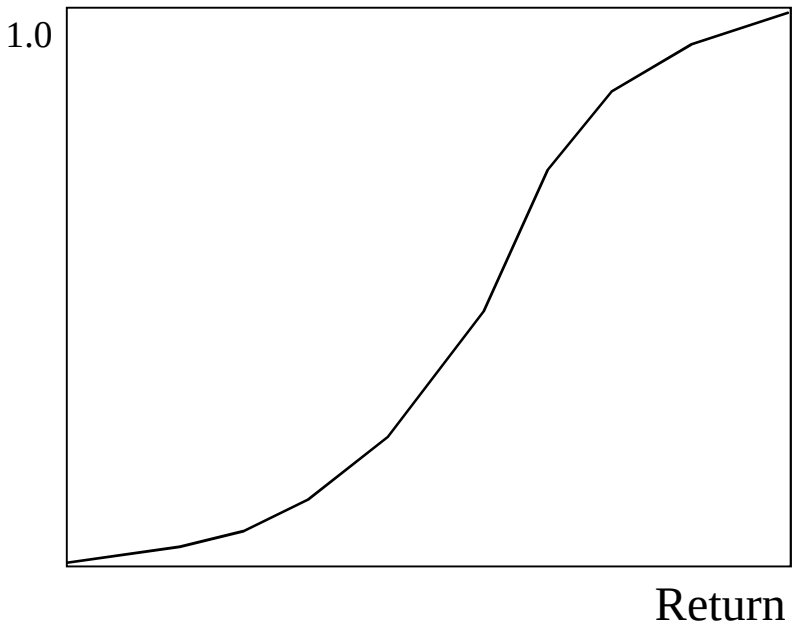


Results

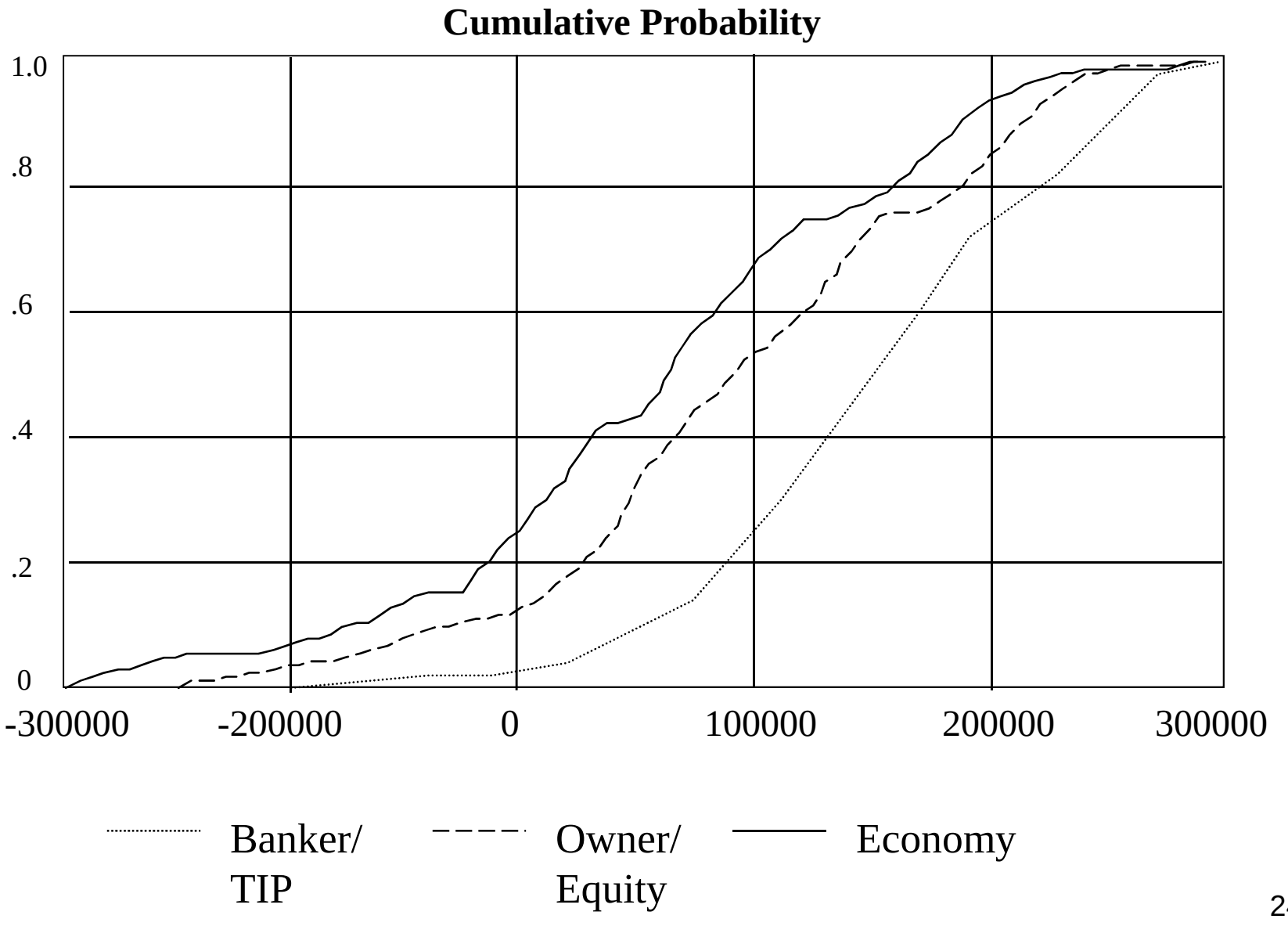
Deterministic Analysis



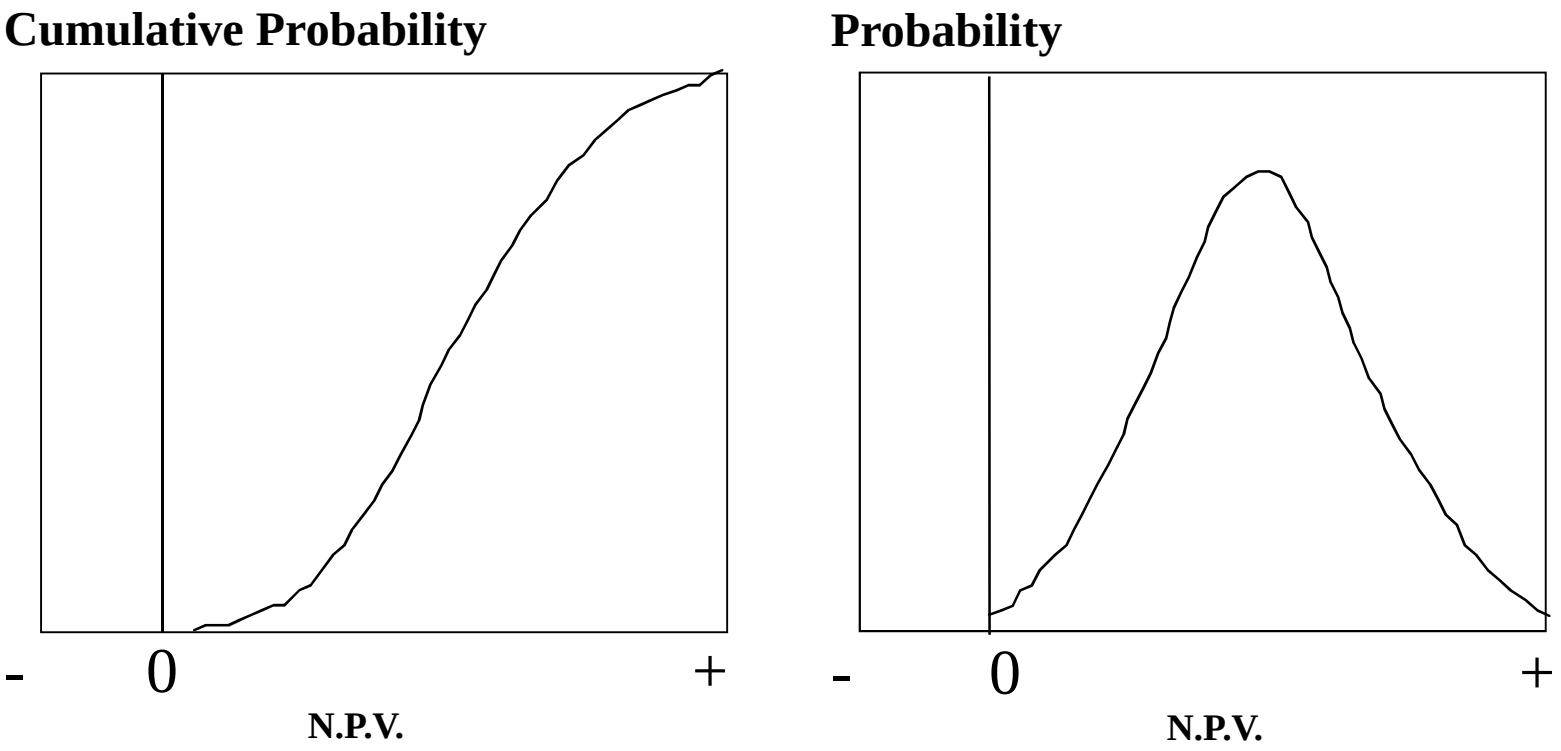
Simulation Analysis



Net Present Value Distribution



Case 1: Probability for Negative N.P.V = 0

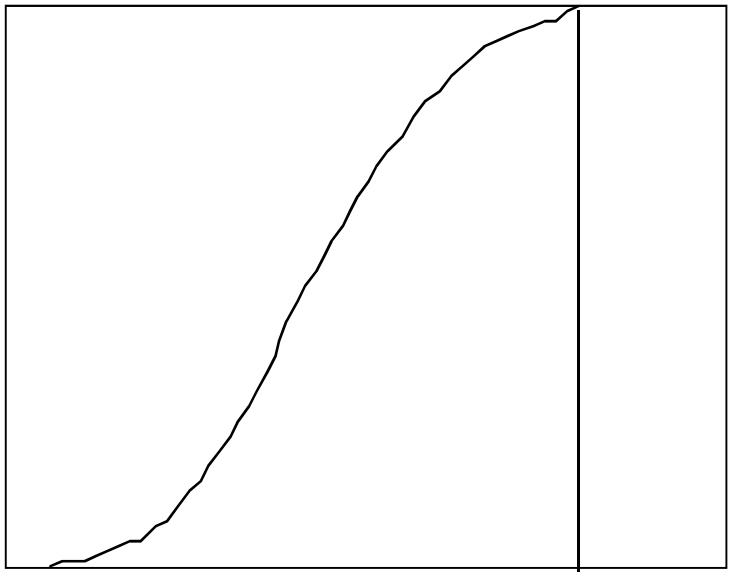


DECISION: ACCEPT

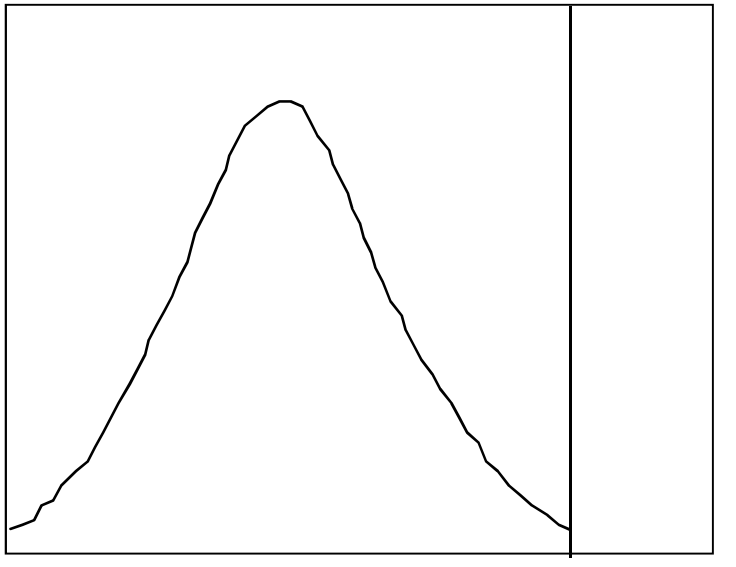
Note: Lower end of cumulative probability distribution is to the right of zero N.P.V. point

Case 2: Probability for Positive N.P.V = 0

Cumulative Probability



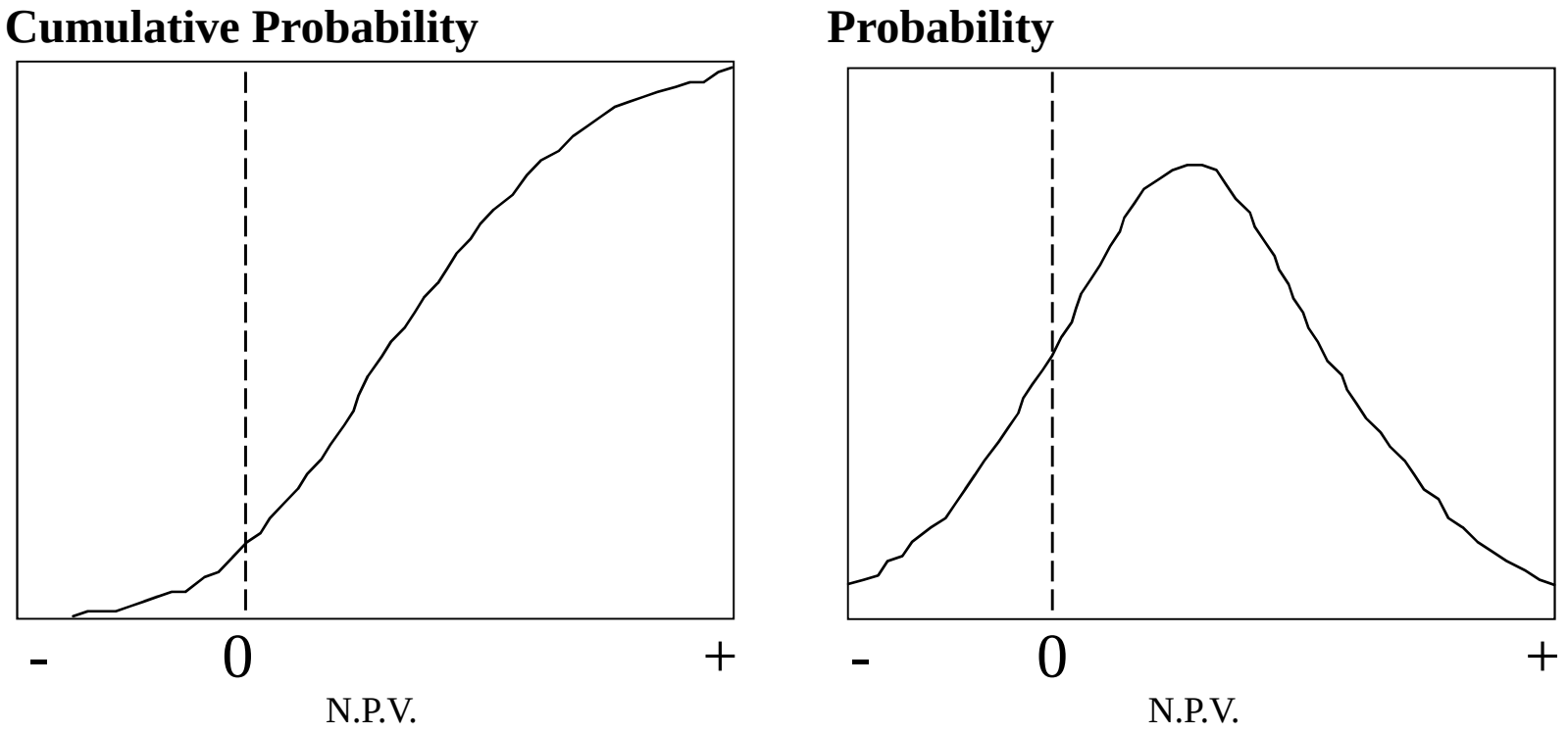
Probability



DECISION: REJECT

Note: Higher end of cumulative probability distribution is to the left of zero N.P.V. point

Case 3: The Probability for Zero N.P.V Is Greater Than 0 but Less Than 1

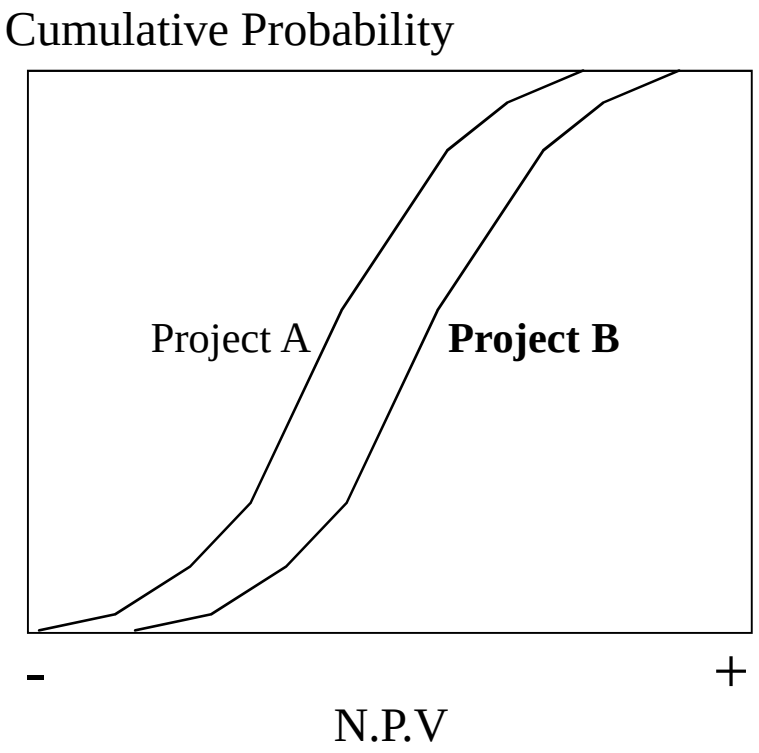


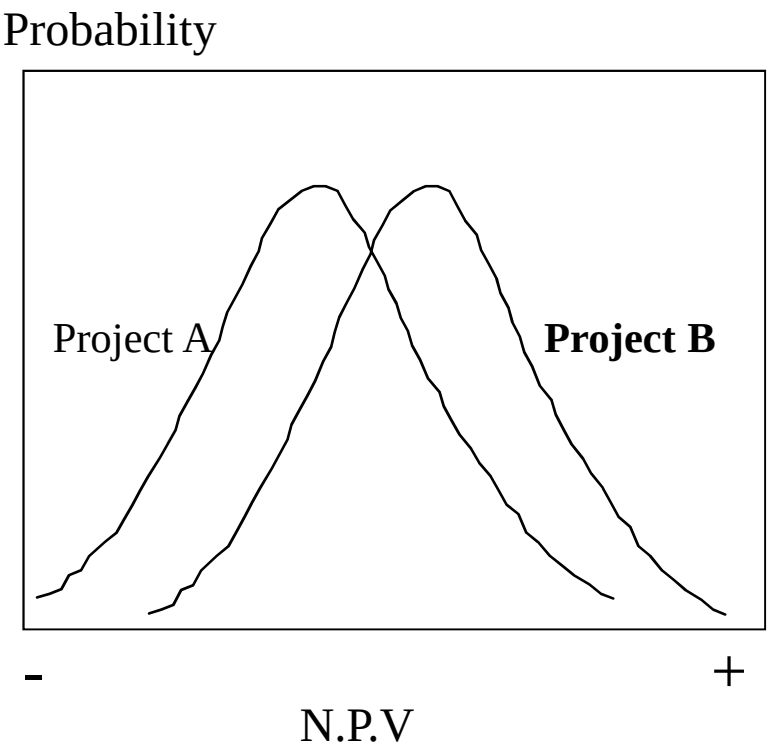
DECISION: INDETERMINATE

Note: Zero N.P.V. line cuts across the relevant range of the cumulative probability distribution

Case 4: Mutually Exclusive Projects

Given the Same Probability, One Project Always Shows a Higher Return

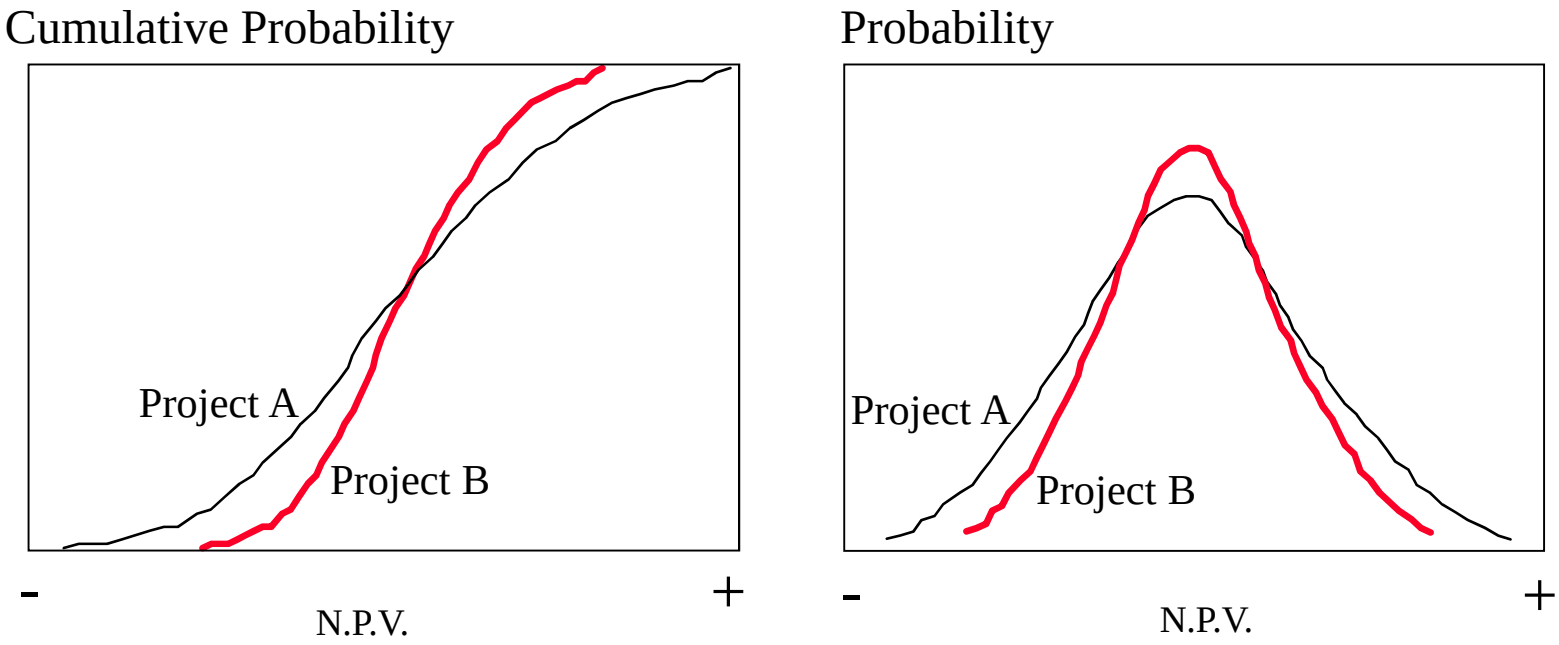




DECISION: CHOOSE PROJECT B

Note: The cumulative probability distributions do not intersect at any point

Case 5: Mutually Exclusive Projects High Return versus Low Loss



DECISION: INDETERMINATE

Note: The cumulative probability distributions are intersecting

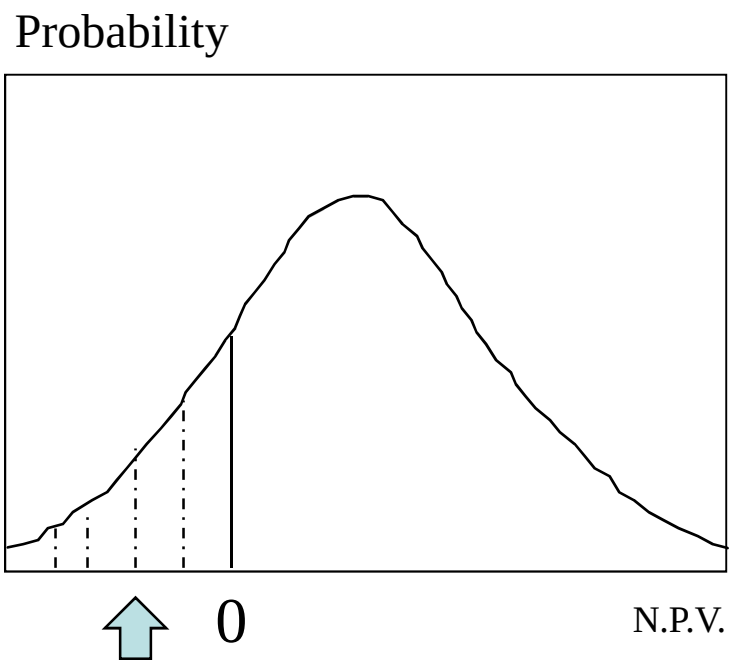
Need to know attitude toward risk:

A. If risk neutral, then uncertain which is best.

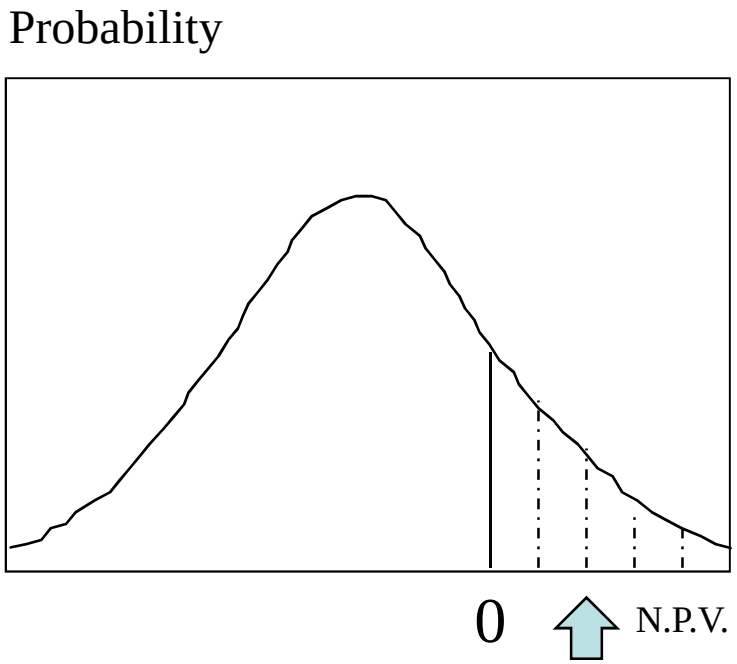
B. If risk averse, then B preferred to A.

C. If risk lover, then A may be preferred to B.

Cost of Uncertainty

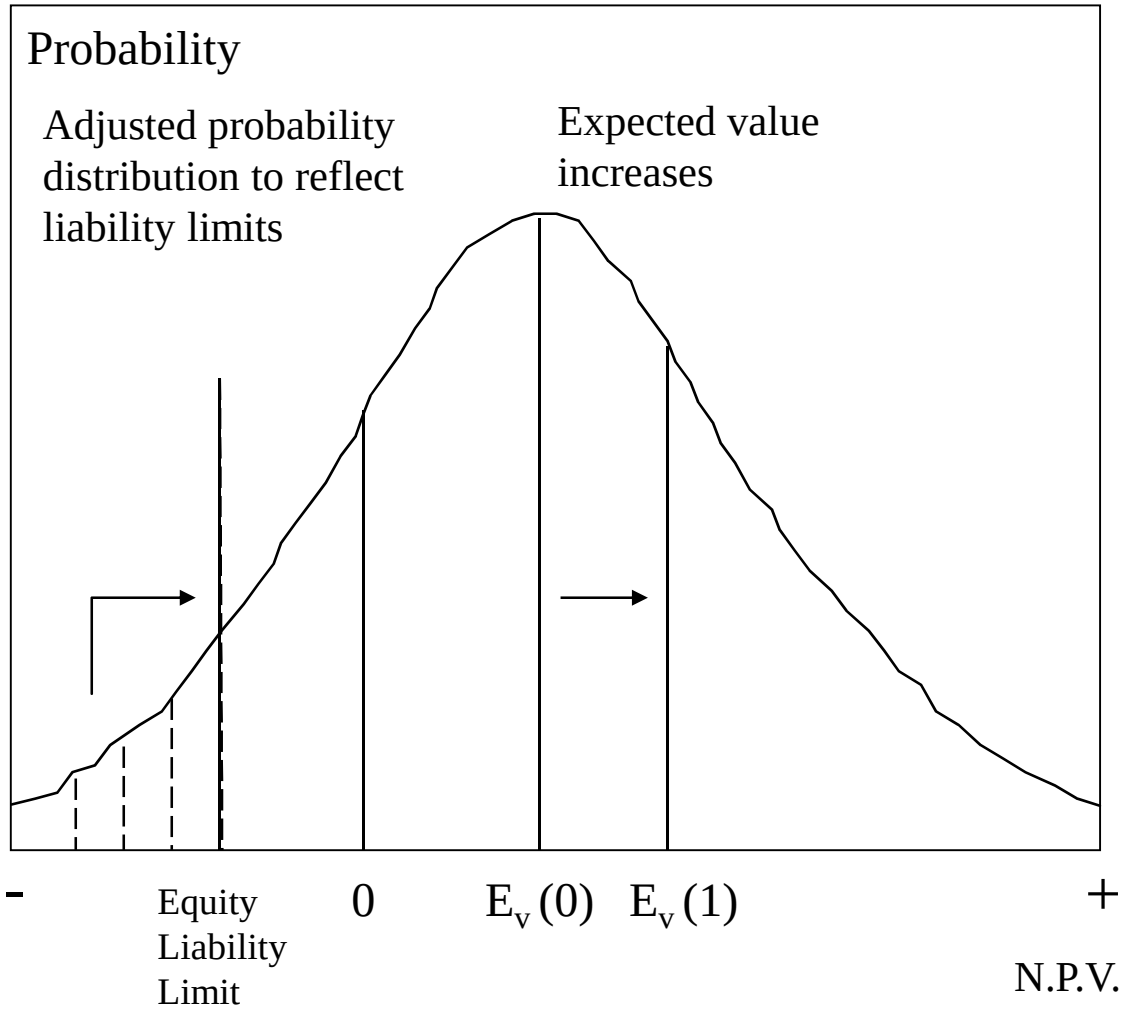


Expected value of possible loss From ACCEPTING a project



Expected value of gain forgone From REJECTING a project

Risk Under Conditions of Limited Liability



Simple Example
Project: Silver Commodities Speculation

- Buy an ounce of silver today (or multiples) and sell it in a year's time
- Today's price (P_0) is certain $20
- Next Year's price (P_1) is uncertain

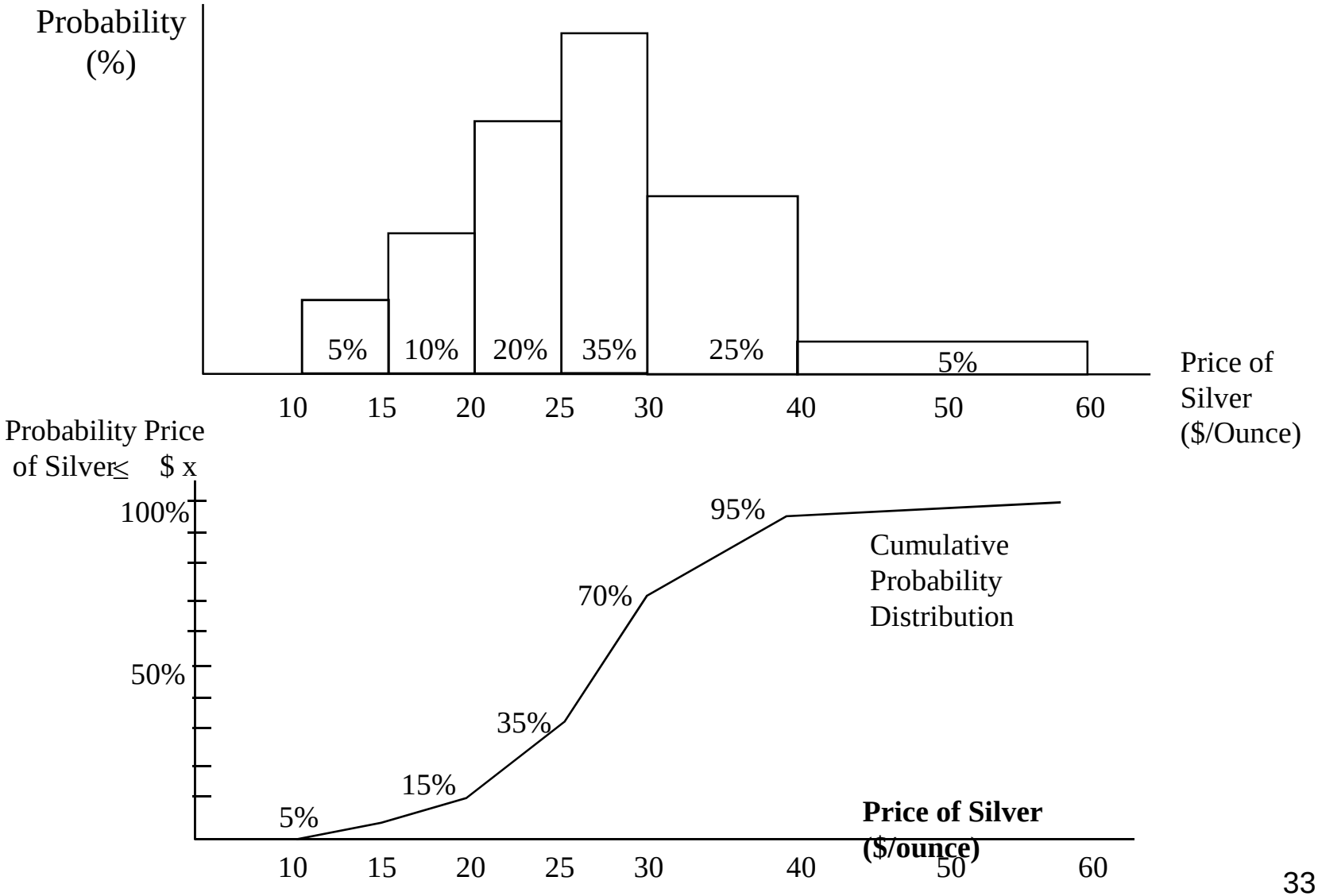
Steps:

1) What is the RANGE of possible values?

- Minimum value: Zero probability of being below $10
- Maximum value: Zero probability of being higher than $60

2) What is the PROBABILITY of finding values between these extremes?

Relative Probability Distribution for Price of Silver/Ounce Next Year



Single - Valued or Deterministic Model

Based on **BEST** estimate or expected values

Model:

NPV = $-p_0 + p_1/(1+r)$

p_0 = \$20

r = 10%

p_1 = expected value of silver next year

=	5% * \$12.50	=	0.625
+	10% * \$17.50	=	1.75
+	20% * \$22.50	=	4.5
+	35% * \$27.50	=	9.625
+	25% * \$35.00	=	8.75
+	5% * \$50. 00	=	2.5
			\$27.75

NPV = -20 + 27.75/1.1 = **5.23**

Result: Therefore, undertake the project

Monte Carlo Simulation of Model

Model:

NPV = -20 + RV/1.1

RV = risk variable

= price of silver next year defined by step distribution

SIMULATION:

Repeatedly (500 times, for example) pick price values from distribution at random. This is done by picking a random number between 0 and 100% and looking up the corresponding price value from the cumulative probability distribution. For each simulation, calculate value of NPV. After 500 simulation runs, 500 values of NPV are obtained for which expected NPV and other characteristics of NPV distribution can be found.

Silver Speculation Project: Base Case

Assumptions: $-P_0 = \$20$
$-r = 0.10$

- Step Rectangular Distribution
- Range for next year's Silver Price \$10 to \$60
- 500 Model Runs

Summary of Results:

Model: NPV = -20 + RV/1.1
Simulation results from 500 runs
Expected NPV = 5.29
Standard deviation of NPV = 9.24
Probability NPV ≤ 0 = 27%
Range: -9.69 to 34.18

Single-Valued Best Estimate

NPV = -20 + 27.75/1.1 = 5.23

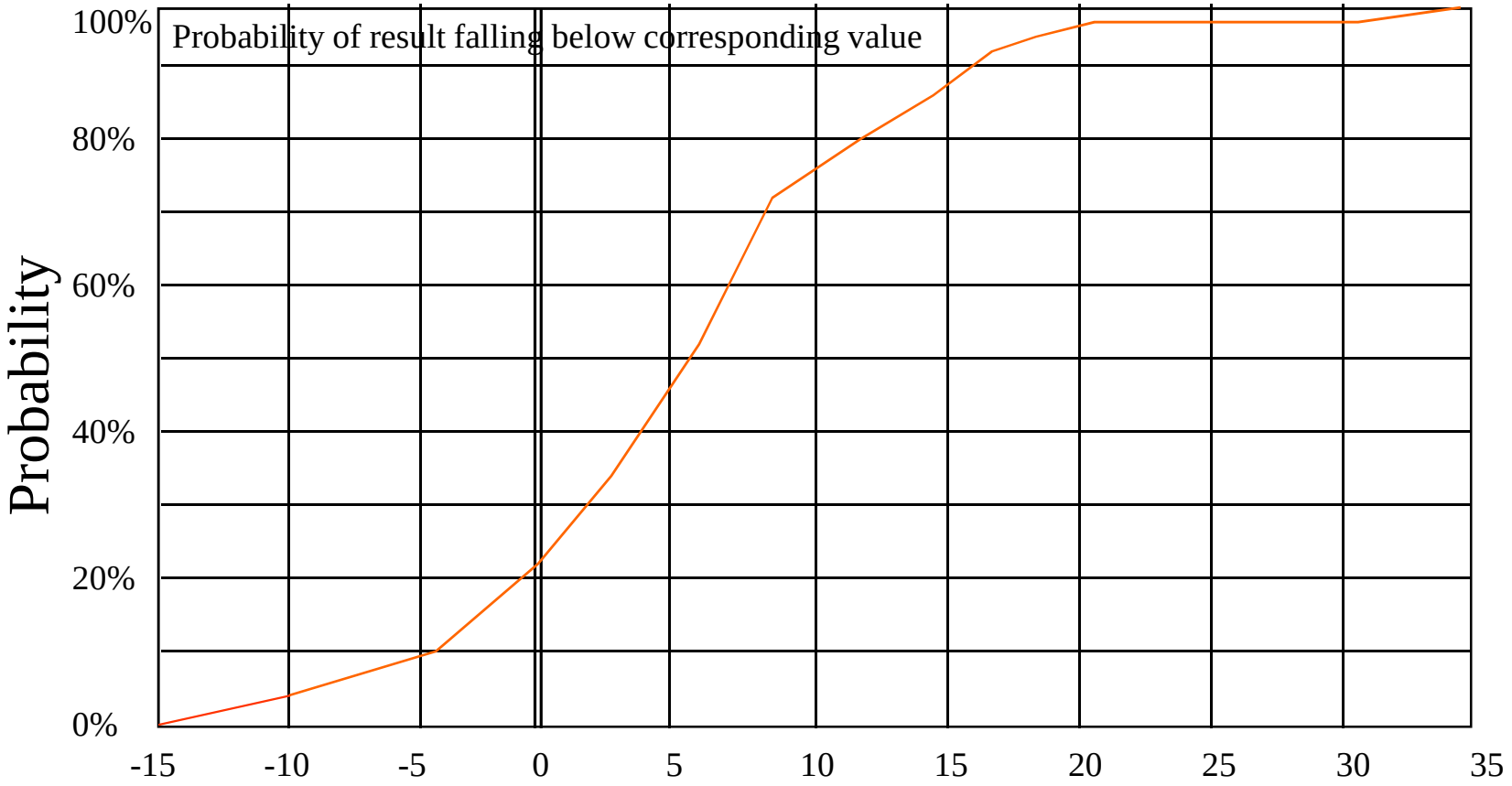
Result: Acceptance or rejection of project depends on risk attitudes/policies

Assumptions: -P_0 = $20
-r = 0.10

- Step Rectangular Distribution
- Range for Next Year's Silver Price $10 to $60
- 500 Model Runs

Cumulative NPV Distribution

Silver Speculation Project: Base Case



Expected Value (NPV) = 5.29 Standard Deviation = 9.24

•Eliminate Prospect of Prices Being in $30 to $60 Range

Let next year's silver price range be as follows:

$10 to $15 15% Expected Value

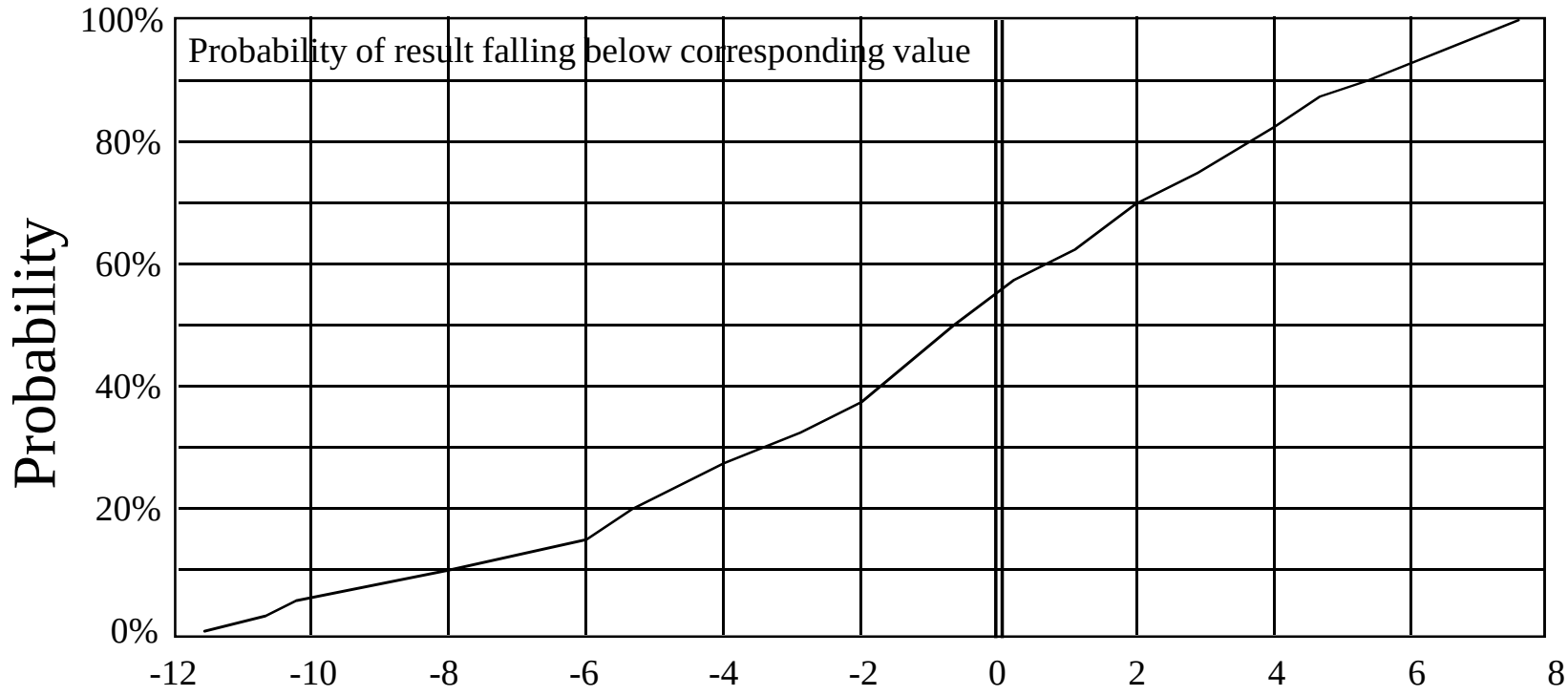
$15 to $20 20%

$20 to $25 35% $\overline{P}_1$ = $21.5

$25 to $30 30%

Cumulative NPV Distribution

Base case with Narrower Price Range



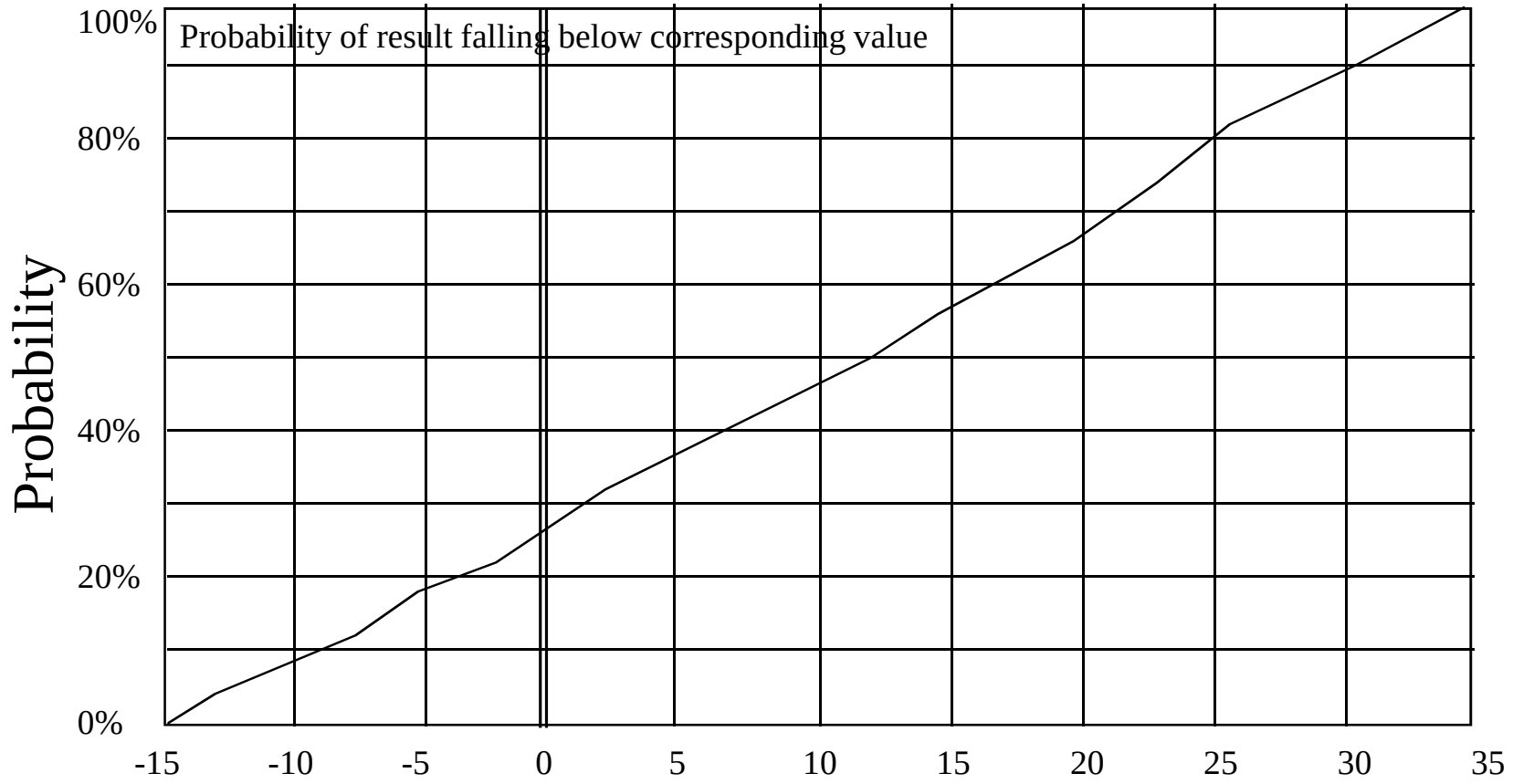
Expected Value (NPV) = -0.38 Standard Deviation = 5.13

Assumptions: -P_0 = $20
-r = 0.10

•Uniform Distribution
• Range for Next Year's Silver Price $10 to $60
•500 Model Runs

Cumulative NPV Distribution

Base Case with Uniform Distribution



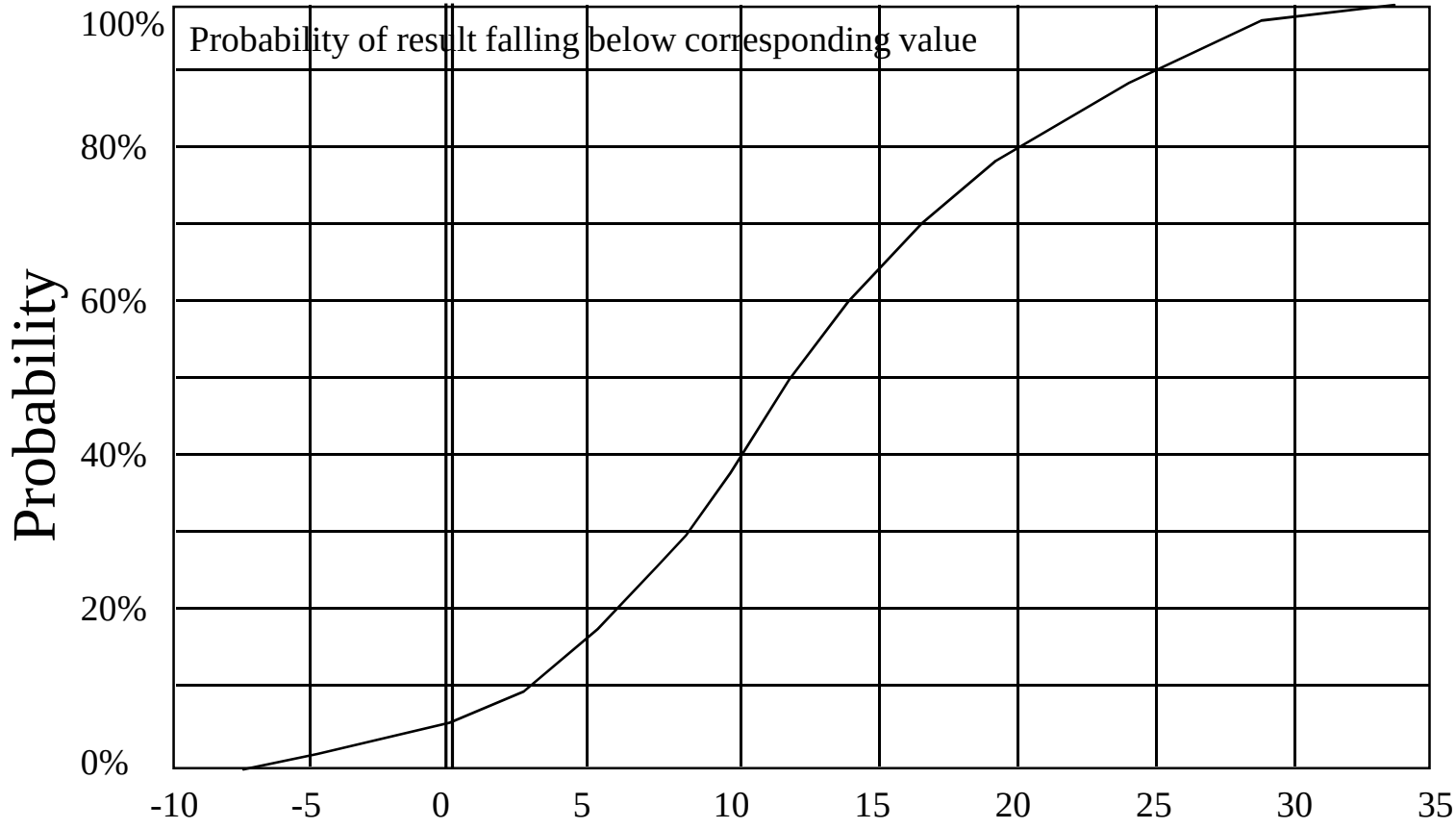
Expected Value (NPV) = 11.38 Standard Deviation = 13.08

Assumptions: -P_0 = $20
-r = 0.10

- Normal Distribution
- Range for Next Year's Silver Price $10 to $60
- 500 Model Runs

Cumulative NPV Distribution

Base Case with Normal Distribution



Expected Value (NPV) = 12.68 Standard Deviation = 6.31

Assumptions: -P_0 = $20

-r = 0.10

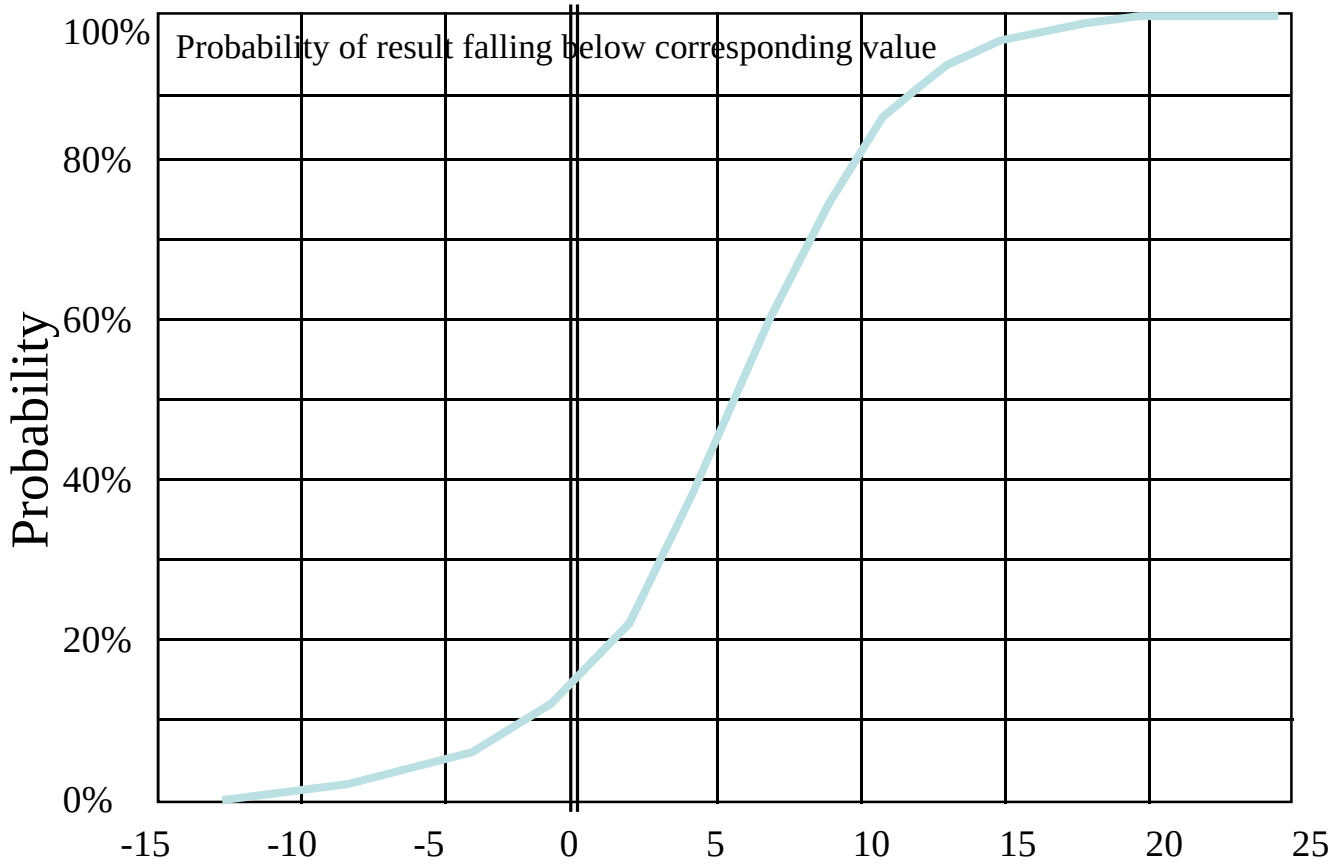
•Normal Distribution

• Range for Next Year's Silver Price $10 to $45.50 (Mean P_1 = 27.75, which is the same as base case)

•500 Model Runs

Cumulative NPV Distribution

Normal Distribution with Range ($10, $45.50)



Expected Value (NPV) = 5.71 Standard Deviation = 5.02

Summary of Results for Silver Speculation Project

	Net Present Value Distribution	
	Expected Value	Standard Deviation
A. Base Case	$5.29	$9.24
B. Base Case with Narrower Oil Price Range ($10 to $30)	-0.38	5.13
C. Base Case with Uniform Distribution	11.38	13.08
D. Base Case with Normal Distribution	12.68	6.31
E. Base Case with Normal Distribution and Range ($10 to $45.50)	5.71	5.02

Add Positive Correlation between Discount Rate and the Future Price of Silver

Shift Mean of Discount Rate

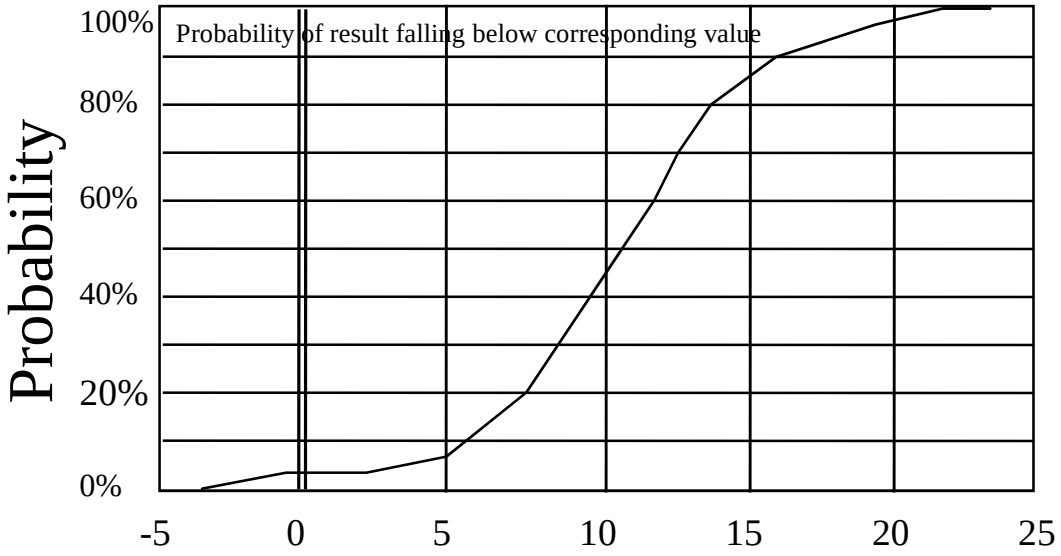
$\rho_{r,p1} = 0.7$

P_1 has a normal distribution with a range of $10 to $60

Let r = required rate of return with a range of 0.09 to 0.14

Cumulative NPV Distribution

Correlated Silver Prices & Req. Rate of Return



	With Correlation Between the Price of Silver and the Req. Rate of Return = 0.7	Without Correlation
Expected NPV	10.14	12.68
Standard Deviation	5.78	6.31

Testing Rules (Contracts) to Determine if they Reflect Historical Correlations

For Example: **Let $r = 0.1 + 0.001 (P_1 - 20)$**

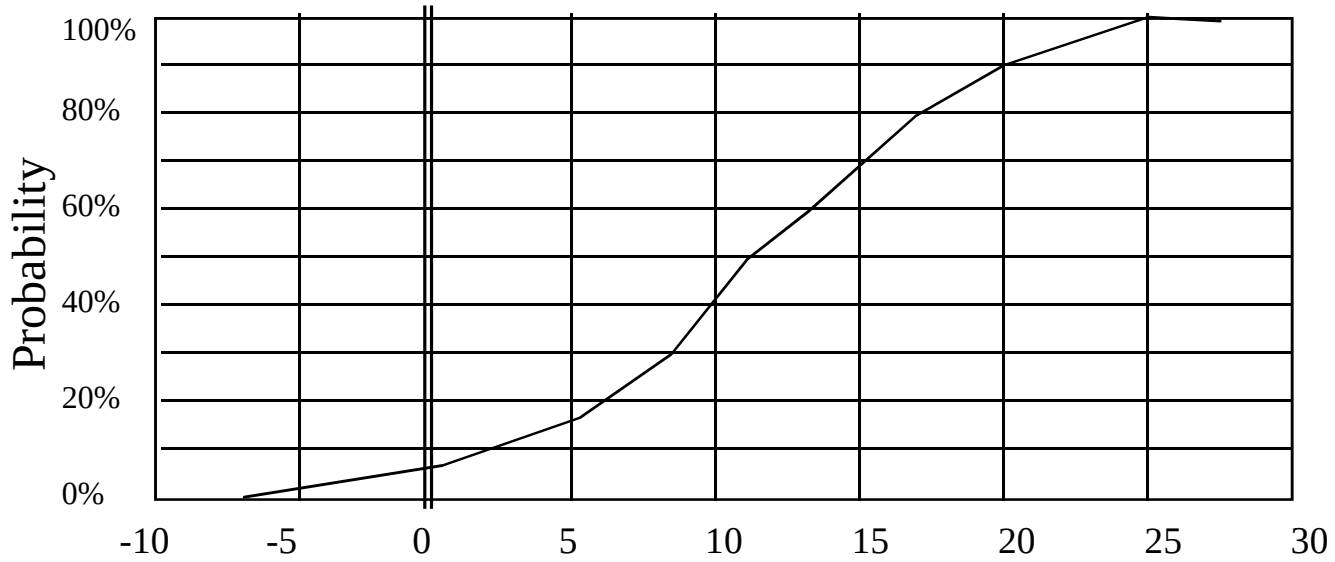
Thus,

P_1	r
$10	0.09
20	0.10
30	0.11
.	.
60	0.14

P_1 has a normal distribution with a range of $10 to $60

Cumulative NPV Distribution

Silver Price and Discount Rate Formula



Expected Value (NPV) = 11.63 Standard Deviation = 6.23

Silver Speculation Project with Relationship between Silver Price and Required Rate of Return

Results with 500 Model Runs	Correlated r and P_1 ($\rho_{r, p1} = 0.7$)	r and P_1 Formula
Expected Value	$10.14	$11.63
Standard Deviation	5.78	6.23
Cost of Accepting A "Bad" Project	0.03	0.13
Cost of Rejecting A "Good Project	10.18	11.76
Probability NPV $\leq$ 0	4.0%	5.0%
Minimum Value	$-2.36	$-6.83
Maximum Value	23.66	25.86

RISK ANALYSIS

EVALUATION OF A CEMENT ADDITIVES PLANT SUBJECT TO RISK

Existing Information

You are supplied with 9 tables of information describing the existing financial evaluation of the project over a 12-year time horizon. These tables give

1. Basic Parameters
2. Formulas for estimating revenues, unit costs and taxes
3. Revenues
4. Costs
5. Investment Costs and Depreciation
6. Loan Schedule for Long-Term Debt
7. Income Tax Schedule
8. Cash Flows - Total Investment perspective
9. Cash Flows - Equity Holders Perspective

(The model of the project has been simplified to allow you to focus on the risk analysis procedures)

Table 1: Basic Parameters

Inflation Rate		5.50%
Expected Inflation Rate		5.50%
Price of Quickfix in Year 0	Po=	18 $/bottle
Growth Rate of Real Price	rp=	2.00% per year
Quantity of Quickfix in Year 0	Qo=	5 million bottles
Growth Rate in Q	g=	4.00% per year
Unit Cost in Year 0	co=	9 $/bottle
Growth Rate of Real Unit Cost	rc=	3.00% per year
Capital Assets Purchased	Ao=	300 $million
Economic Depreciation Rate	de=1/20 or	5.00% per year
Tax Depreciation Rate (Straight Line Depreciation)	dtax=1/12 or	8.33% per year
Loan		
Initial Investment Loan	Do=	160 $million
Real Interest Rate	ir=	6.00% per year
Risk Premium on Debt	R=	2.00% per year
Real Supply Price of Equity	re=	10.00% per year
Corporate Tax Rate	Tc=	25.00% per year

Tables 2: Formulas

Revenues

R[t]= $Po*Qo*(1+rp)^t*(1+gpe)^t$

Q[t]= $Qo*(1+g)^t$

Costs

C[t]= $co*Q[t]*(1+rc)^t*(1+gpe)^t$

Corporate Income Taxes

Tax[t]= {R[t] - C[t] - Ao*dtax - LCF[t-1]}*Tc

Tax[11]= (Ae,n - Atax,n)*Tc

Table 3: Revenues

Year	0	1	2	3	4	5	6	7	8	9	10	11
Inflation Index	1.000	1.055	1.113	1.174	1.239	1.307	1.379	1.455	1.535	1.619	1.708	1.802
Sales Price	18.00	19.37	20.84	22.43	24.14	25.97	27.95	30.08	32.37	34.83	37.48	
Quantity (millions)		5.20	5.41	5.62	5.85	6.08	6.33	6.58	6.84	7.12	7.40	
Revenue ($millions)		100.72	112.72	126.15	141.18	158.01	176.83	197.90	221.48	247.87	277.40	

Table 4: Costs

Year	0	1	2	3	4	5	6	7	8	9	10	11
Inflation Index	1.000	1.055	1.113	1.174	1.239	1.307	1.379	1.455	1.535	1.619	1.708	1.802
Operating Costs Per Unit	9.00	9.78	10.63	11.55	12.55	13.64	14.82	16.10	17.50	19.01	20.66	
Quantity Produced	0.00	5.20	5.41	5.62	5.85	6.08	6.33	6.58	6.84	7.12	7.40	
Total Cost ($million)	0.00	50.86	57.47	64.95	73.40	82.95	93.75	105.94	119.73	135.31	152.91	

Table 5: Investment Costs and Depreciation

Year	0	1	2	3	4	5	6	7	8	9	10	11
Inflation Index												
Investment Costs (Assets)	1.000	1.055	1.113	1.174	1.239	1.307	1.379	1.455	1.535	1.619	1.708	1.802
Total Investment	300											
Real Economic Depreciation		15	15	15	15	15	15	15	15	15	15	
Real Remaining Value of Assets		285	270	255	240	225	210	195	180	165	150	150
Nominal Economic Terminal Value												270.31
Nominal Tax Depreciation Allowance		25	25	25	25	25	25	25	25	25	25	
Real Tax Depreciation Allowance		24	22	21	20	19	18	17	16	15	15	
Nominal Book Value		275	250	225	200	175	150	125	100	75	50	50

Table 6: Loan Schedule for Long-Term Debt

Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Inflation Index	1.000	1.055	1.113	1.174	1.239	1.307	1.379	1.455	1.535	1.619	1.708	1.802
Loan	160											
Interest Rate	13.94%											
Disbursement	160											
Debt Beginning Balance	160	160.00	182.30	154.69	123.23	87.38	46.54					
Interest	0	22.30	25.41	21.56	17.18	12.18	6.49					
Interest Payment			25.41	21.56	17.18	12.18	6.49					
Principal			27.61	31.46	35.85	40.84	46.54					
Installment			53.03	53.03	53.03	53.03	53.03					
Debt End	160	182.30	154.69	123.23	87.38	46.54	0.00					

Table 7: Corporate Tax Schedule

Year	0	1	2	3	4	5	6	7	8	9	10	11
Inflation Index	1	1.055	1.113	1.174	1.239	1.307	1.379	1.455	1.535	1.619	1.708	1.802
Revenues R[t]t		100.72	112.72	126.15	141.18	158.01	176.83	197.90	221.48	247.87	277.40	0.00
Operating Costs		50.86	57.47	64.95	73.40	82.95	93.75	105.95	119.73	135.31	152.91	
Interest Payment			25.41	21.56	17.18	12.18	6.49					
Depreciation Allowance		25	25	25	25	25	25	25	25	25	25	50
Total Allowances	0.00	75.86	107.89	111.51	115.58	120.13	125.23	130.94	144.73	160.31	177.91	50.10
Income	0.00	24.87	4.84	14.64	25.60	37.87	51.60	66.96	76.75	87.56	99.48	-50.10
Loss Carry Forward	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-50.10
Taxable Income after LCF	0.00	24.87	4.84	14.64	25.60	37.87	51.60	66.96	76.75	87.56	99.48	0.00
Tax Payment	0.00	6.22	1.21	3.66	6.40	9.47	12.90	16.74	19.19	21.89	24.87	0.00

Table 8: Cash Flows: Total Investment Perspectives

Year	0	1	2	3	4	5	6	7	8	9	10	11
Inflation Index	1.000	1.055	1.113	1.174	1.239	1.307	1.379	1.455	1.535	1.619	1.708	1.802
Revenues	0.00	100.72	112.72	126.15	141.18	158.01	176.83	197.90	221.48	247.87	277.40	
Liquidation Values												270.31
Expenses												
Investment	300											
Operating Expenses		50.86	57.47	64.95	73.40	82.95	93.75	105.94	119.73	135.31	152.91	
Before Tax Net Cash Flow	-300.00	49.87	55.25	61.20	67.78	75.05	83.09	91.96	101.75	112.56	124.48	270.31
Tax Payments	0.00	6.22	1.21	3.66	6.40	9.47	12.90	16.74	19.19	21.89	24.87	0.00
After Tax net Cash Flow Nominal	-300.00	43.65	54.04	57.54	61.38	65.59	70.19	75.22	82.56	90.67	99.61	270.31
After Tsx Net Cash Flow Real	-300.00	41.38	48.55	49.00	49.55	50.18	50.90	51.71	53.80	56.00	58.32	150.00
Net Present Value at D.R. (See Below)	69.24											

Table 9: Cash Flows: Equity Holders' Perspective

Year	0	1	2	3	4	5	6	7	8	9	10	11
Inflation Index	1.000	1.055	1.113	1.174	1.239	1.307	1.379	1.455	1.535	1.619	1.708	1.802
Net Cash Flow After Taxes	-300.00	43.65	54.04	57.54	61.38	65.59	70.19	75.22	82.56	90.67	99.61	270.31
Loan	160		-53.03	-53.03	-53.03	-53.03	-53.03					
			-47.641	-45.1573	-42.8	-40.57	-38.46					
PV of Loan	0.00											
Equity Net Cash Flow Nominal	-140.00	43.65	1.02	4.52	8.36	12.56	17.16	75.22	82.56	90.67	99.61	270.31
Equity Net Cash Flow Real	-140.00	41.38	0.91	3.85	6.75	9.61	12.45	51.71	53.80	56.00	58.32	150.00
Net Present Value at 10% D.R.	69.30											

SENSITIVITY ANALYSIS FOR CEMENT ADDITIVES PLANT (QUICKFIX)

Sensitivity Case (10% Change in Varible)	**NPV to Equity (Owner's Perspective)**	**Percentage Change from Base Case**
Base Case	$69.30	0.0%
Inflation = 6.05%	$69.03	-0.4%
P_o = $19.80	$124.88	80.2%
r_p = 2.2%	$75.00	8.2%
Q_o = 5.5 M	$95.63	38.0%
g = 4.4%	$74.53	7.5%
c_o = $9.90	$40.02	-42.0%
r_c = 3.3%	$64.76	-6.6%
A_o = $330.00	$47.57	-31.4%
d_e = 5.5%	$64.04	-7.6%
d_{tax} = 9.163%	$72.31	4.3%
D_o = $176.00	$71.62	3.3%
i_r = 6.6%	$66.86	-3.5%
R = 2.2%	$68.49	-1.2%
r_e = 11.0%	$55.90	-19.3%
T_c = 27.5%	$64.80	-6.5%

Risk Analysis

Evaluation of a Cement Additives Plant Subject to Risk

Risk Variables, Probability Distribution, and Correlation

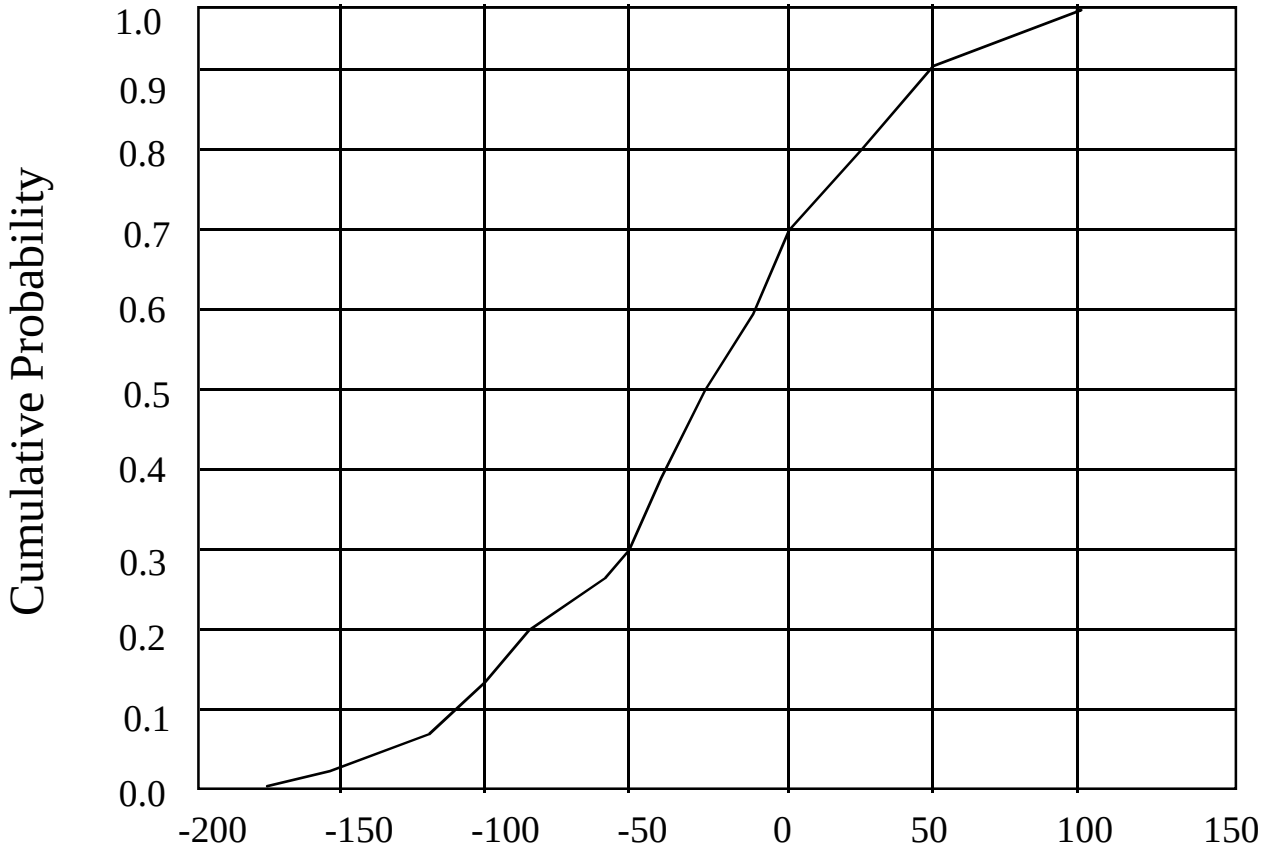
Risk Variables	Type of Distribution	Value		Probability
	Step			
Inflation Rate	Rectangular		<3%	0%
	From:	3%	4%	10%
		4%	5%	20%
		5%	6%	40%
		6%	7%	25%
		7%	8%	5%

Risk Variables	Type of Distribution	Minimim	Maximum
Growth Rate in Real Price of Quickfix			
rp	Normal	-1.5%	3.0%
Growth Rate in Sales of Quickfix			
g	Rectangular	2.5%	5.0%
unit Costs in Year 0 co ($/unit)	Rectangular	7	16
Growth Rate in Real Unit Cost			
rc	Normal	2.0%	5.0%

Expected Value of NPV = -27.83
Standard Deviation = 60.83
Expected Loss from accepting = 40.59
Expected loss from rejecting = 12.76

Cumulative NPV Distribution

Total Capital: Banker's View

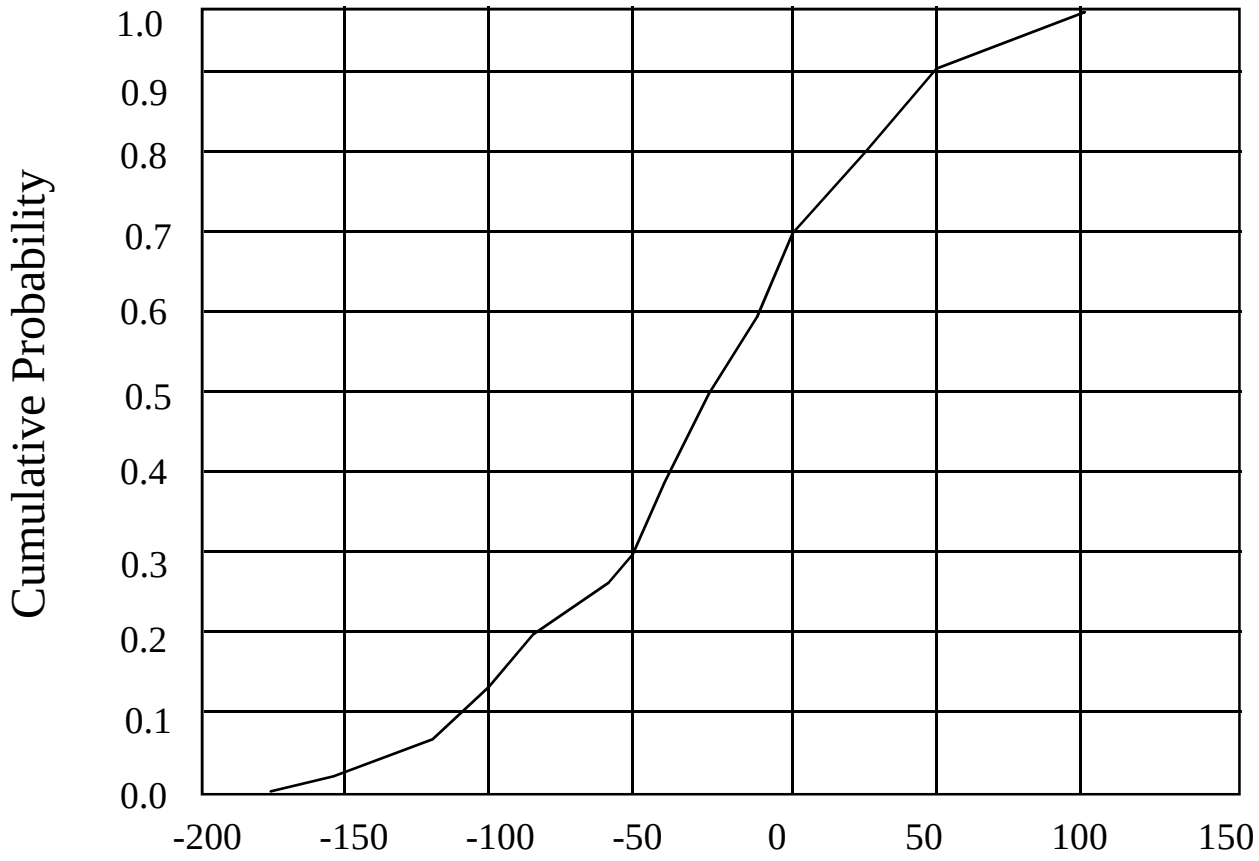


P(NPV<0) = 71.00%

Expected Value of NPV = -28.19
Standard Deviation = 61.26
Expected loss from accepting = 40.96
Expected loss from rejecting = 12.77

Cumulative NPV Distribution

Equity Capital: Owner's View



P(NPV<0) = 71.00%

Overview Principles of Risk Management

RISK MANAGEMENT

- **Costs of risk?** Reduction in value of asset or cash flow because of actual (objective) or perceived (subjective) variability in value. Risk premium is price charged to bear risk
- **Risk analysis?** Analysis of sources and sizes of risk in a project individually on particular cash flows and collectively on the net cash flow, and thus NPV, of project – sensitivity, scenario and Monte Carlo analysis
- **Risk management?** Ways to structure internal and external relationships of projects to reduce costs of risk and improve incentives through contracts and other arrangements to share and reallocate risks

Sources of risk

- **External or exogenous**
  - Markets: prices and quantities of products, material and service inputs,
  - Financial and foreign exchange (forex) markets
  - Government policy – taxes, licensing, regulation
  - Natural resource quality and quantity
  - Natural disasters, politics, personal/physical security
- **Internal or endogenous**
  - Relationships between prices and quantities within project to exogenously determined market values. Example: To what extent is product price correlated with input price?
  - Real choices or options in project design – degree of flexibility to expand or to change product lines, markets, raw materials, etc. in response to exogenous market situations
  - Incentive relationships in construction and operating phases
  - Endogenous behavioral or contractual relationships involving owners, debt holders, labor, suppliers and/or government

Who bears risk?

- Generally, focus of risk analysis and management is **return to owners of business or project**: owners bear **residual gains and losses**, and make key investment decisions
- **Return to equity**: (*or* ROE*Equity) results from:

  = Revenues – Material & service costs – Labor cost – Depreciation – Interest expenses – Taxes
- Risks are also borne by and can be shared with or shifted to
  - Government
  - Labor
  - Customers/buyers
  - Suppliers
  - Contractors

How are costs of risk reduced?

- Some risks can be virtually eliminated by **spreading** burden across many persons; some risks cannot be spread, only **shifted or reallocated**
- Different players in market place have different preferences, willingness and capacity to bear risk: cost of risk is lower to those with greater capacity and willingness to bear risk – gains from trading in risk – risk-return trade-offs
- Capacity to bear risk has two dimensions
  - Income or wealth
  - Degree of influence or control over performance (for endogenous risks)
- Economic efficiency gains by shifting and reallocating risk are achieved if overall cost of risk declines: ***same risk will have a lower cost if is borne by persons more capable and willing to bear risk.***

Mechanisms for reducing costs of risk

1. Capital, financial and futures markets

- Financial structure (mix of debt and equity) and probabilities of default and bankruptcy
- Risk spreading and pooling: **unsystematic** risk
- Insurance markets
- Risk diversification and portfolio structures for **systematic** risk
- Derivative financial instruments: futures, options, swaps, etc
- Futures markets

Mechanisms for reducing costs of risk

2. **Contracting: reallocating or sharing risks to reduce cost of risk**
   - Contracts that change internal relationships to deal with exogenous market variability
     - Forex (foreign exchange) risk, product price formulas
   - Contracts to limit exogenous market variability in price and/or quantities of product or raw materials
   - Internal relationships to change endogenous incentives
     - Profit sharing, stock options and other flexible wage agreements
     - Profit participation by construction contractor and/or operator
3. **Real options: design flexibility into project (at a cost) to allow for responses to new information or market changes**
4. **Project finance: complex contractual arrangements to deal with risk in large investments involving all mechanisms of risk allocation and reduction**