Why is Risk Costly to Firms?

This lecture note is based primarily upon Chapter 7 from *Integrated Risk Management*, by Neil A. Doherty.

Risk Management and Firm Value

- Suppose we are interested in determining how risk management affects the value of the firm in a "frictionless" economy.
  - Assume that there are 10 firms facing various insurable hazards.
  - Suppose that after purchasing actuarially fair insurance contracts, the return distributions on the shares for all 10 firms are independent and identically distributed; $E(r_i)=10\%, \sigma_i = 10\%$, and $\rho_{ij} = 0$.

Risk Management and Firm Value

- An investor has \$1,000 in initial wealth and invests \$100 in each of 10 shares. Since return distributions are *iid*, the expected return on the investor's portfolio is 10%, and the standard deviation of her portfolio is

$$\sigma_p = \sqrt{\sum_i \sum_j w_i w_j \sigma_{ij}} = \sqrt{n(1/n)^2 \sigma^2}$$

$$= \sqrt{10(.1^2)(.1^2)} = 3.2\%.$$

Risk Management and Firm Value

- Now suppose firm 10 cancels its insurance, causing σ_{10} to increase from .1 to .3.
- Portfolio return=10%; portfolio risk increases to

$$\sigma_p = \sqrt{9\left(\frac{1}{10}\right)^2 (.1)^2 + \left(\frac{1}{10}\right)^2 (.3)^2} = 4.24\%$$

- However, by adding 5 more shares like the other 9 shares, we get

$$\sigma_p = \sqrt{14\left(\frac{1}{15}\right)^2 (.1)^2 + \left(\frac{1}{15}\right)^2 (.3)^2} = 3.2\%$$

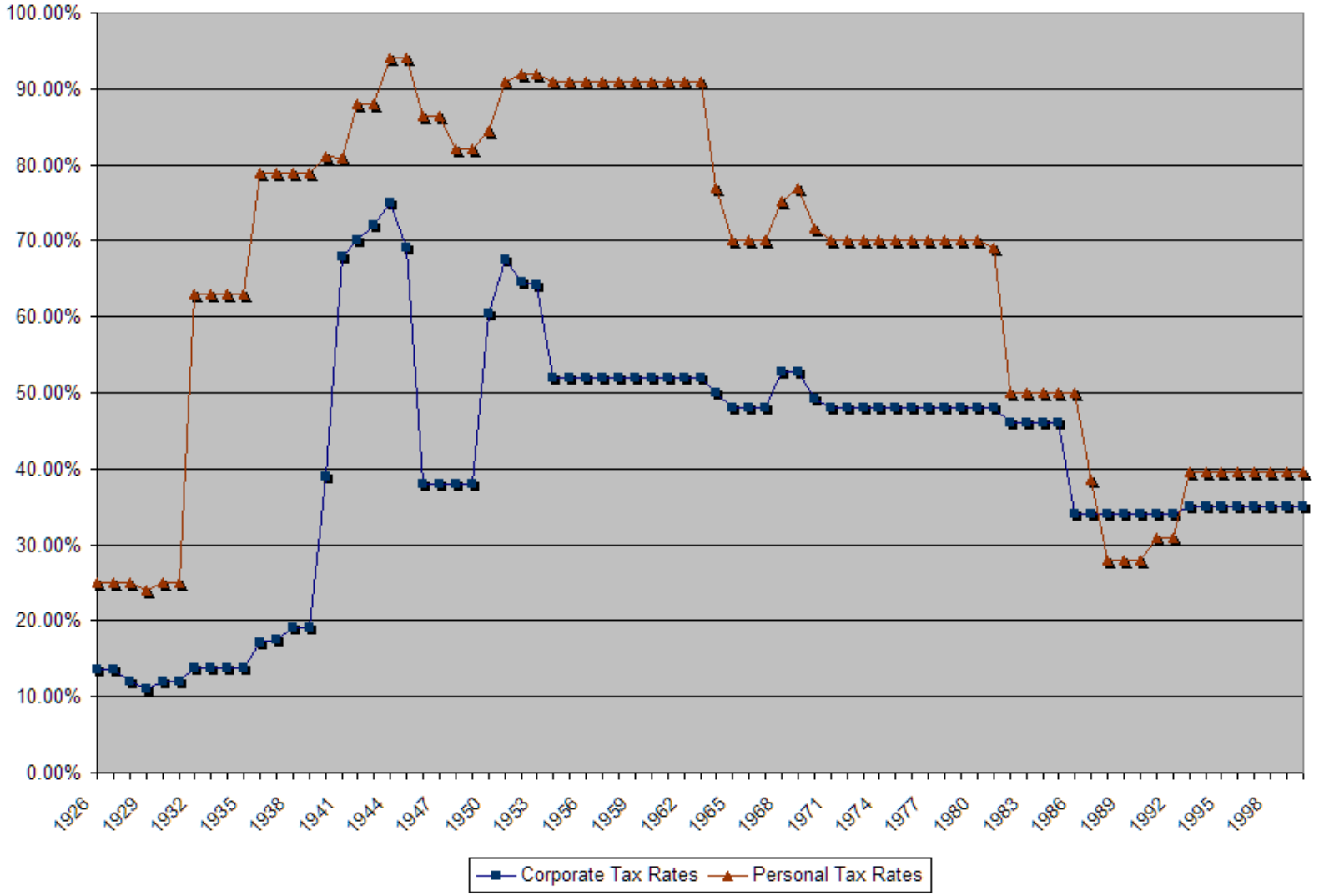
Risk Management and Firm Value

- Firms can alter their risk profiles by changing their corporate risk management policies.
- However, investors can effectively unwind such changes by simply altering the composition of their own portfolios.
- Therefore, corporate risk management is "irrelevant".

Tax Incentives for risk management

- Linear versus Asymmetric Taxes
  - Taxes are "linear" if the same tax rate applies to *all* levels of income.
  - Asymmetric (non-linear) taxes
    - Progressive tax rates
    - Incomplete tax-loss offsets

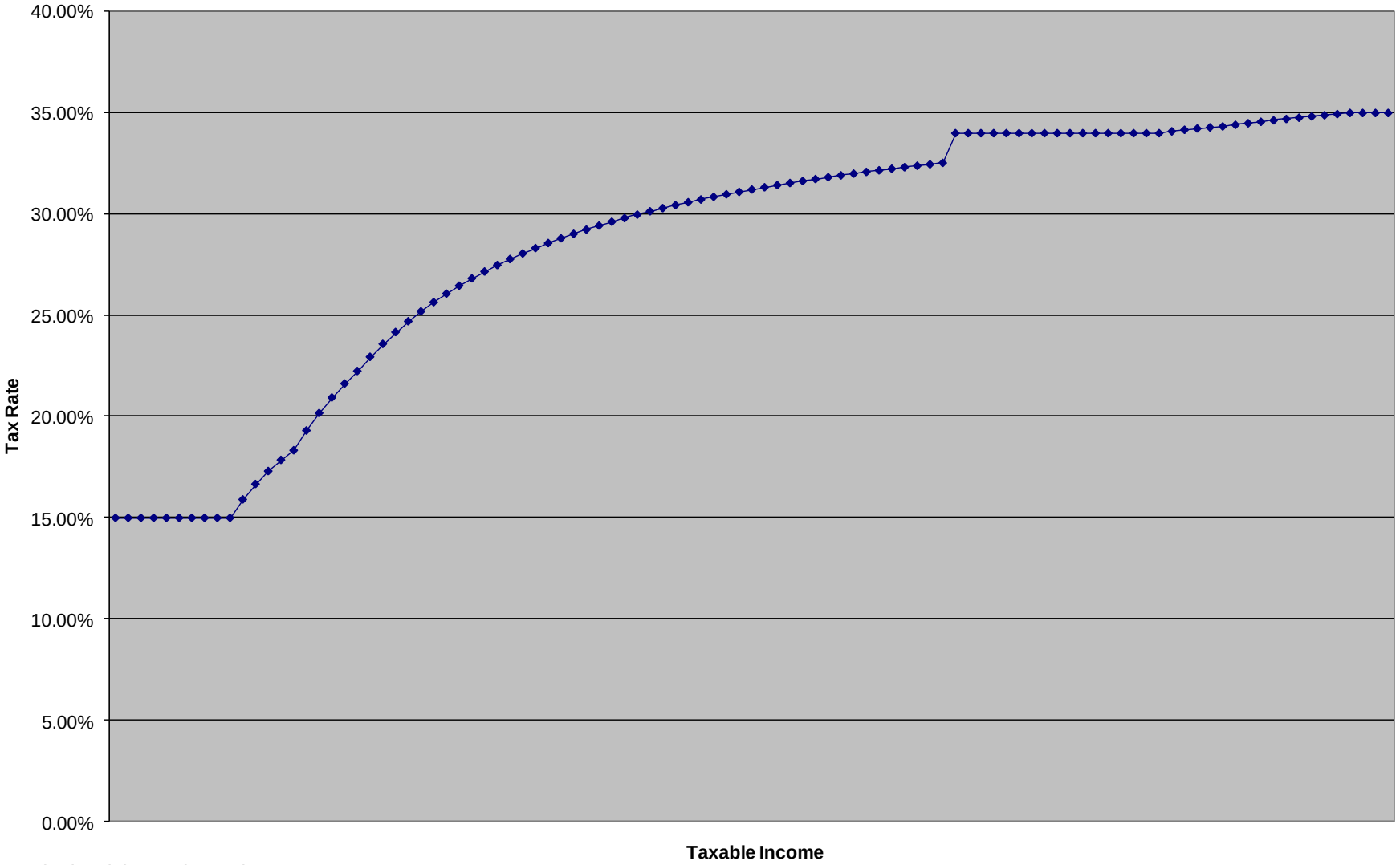
U.S. Income Tax Rates



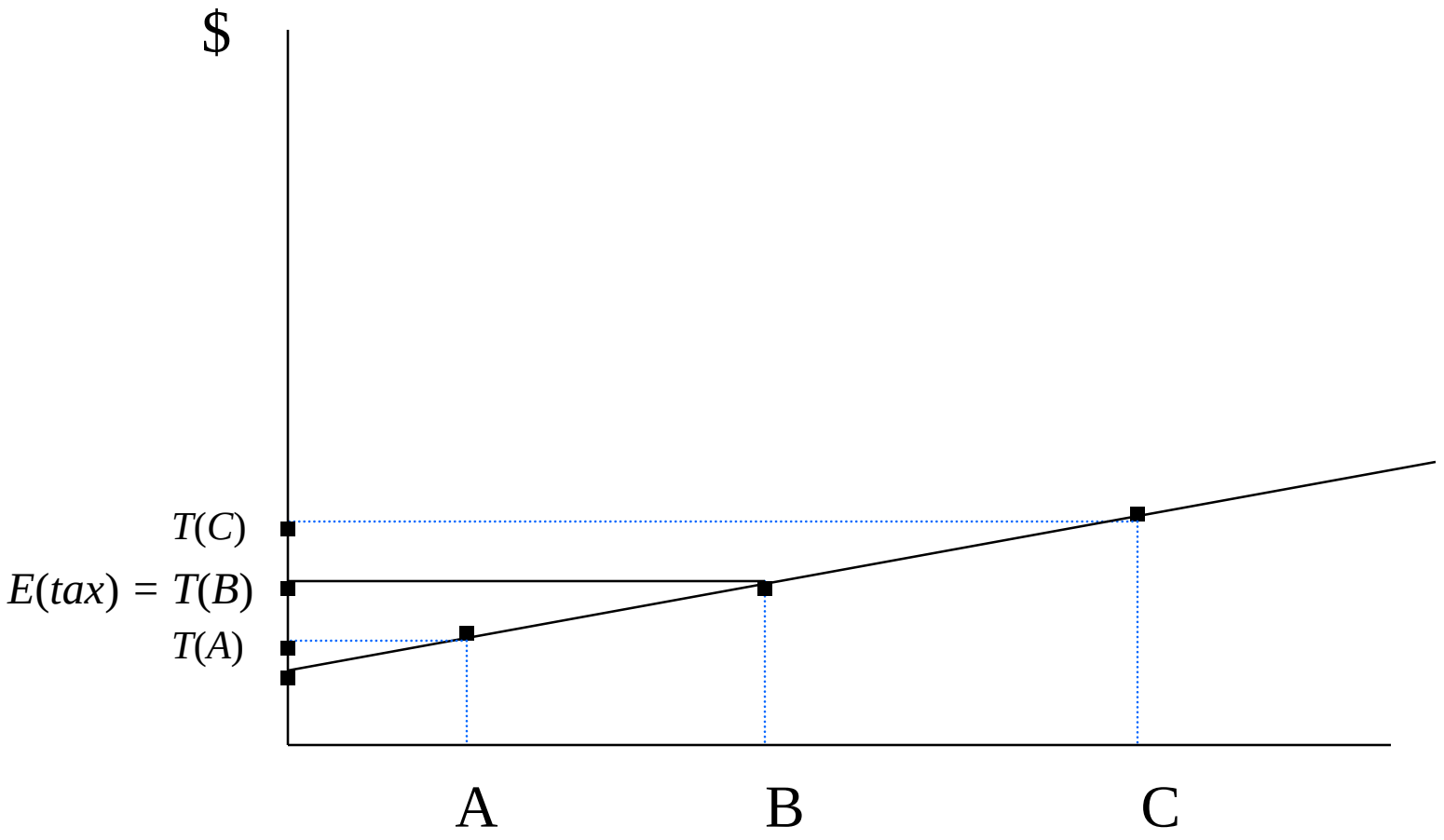
U.S. Corporate Income Tax Schedule

Taxable Income (Y)	Rate
$0	.15Y
$50,000	$7,500+.25(Y-$50,000)
$75,000	$13,750+.34(Y-75,000)
$100,000	$22,250+.37(Y-$100,000)
$335,000	$113,900+.34(Y-$335,000)
$10,000,000	$3,400,000+.35(Y-$10,000,000)
$15,000,000	$5,150,000+.38(Y-$15,000,000)
$18,333,333	.35(Y-$18,333,333)

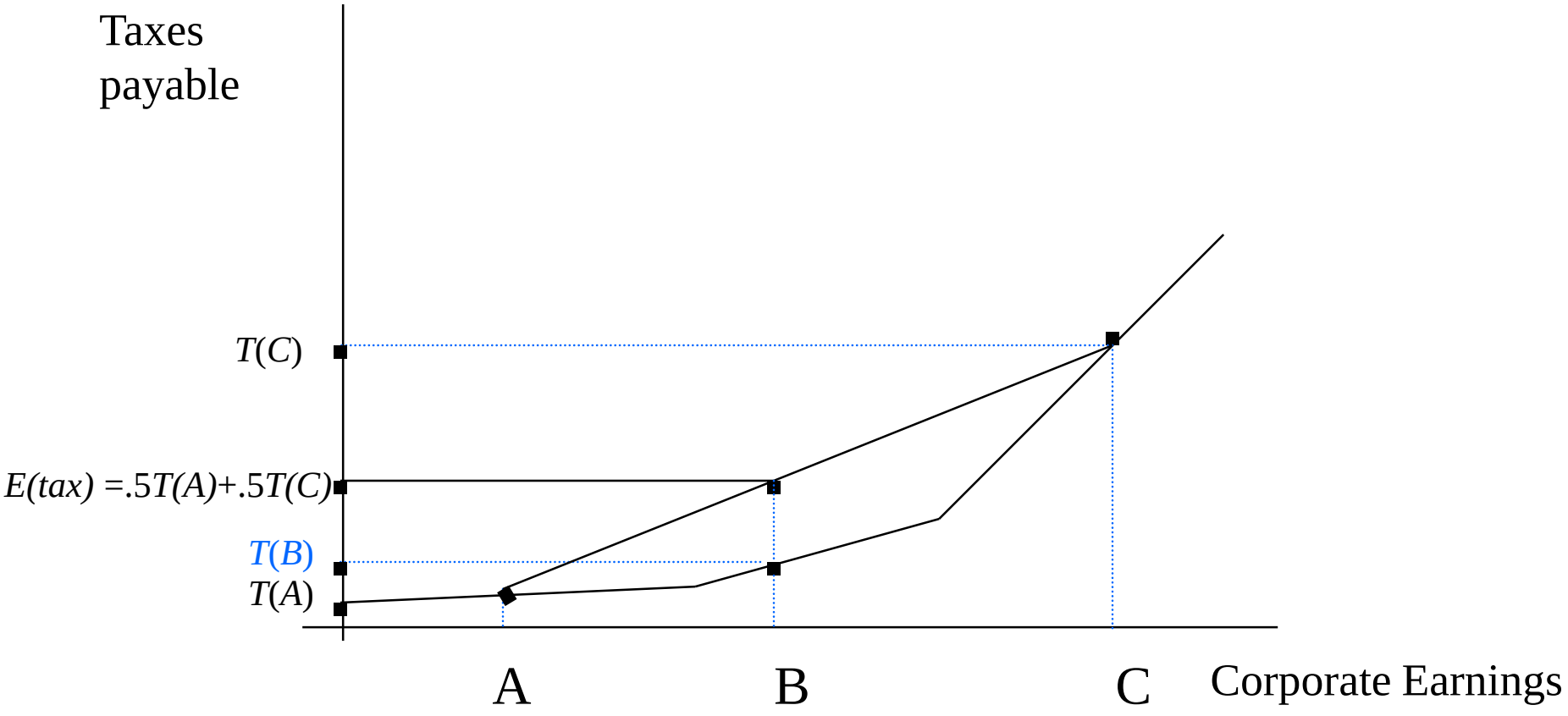
U.S. Corporate Income Tax Schedule



Linear Taxes and Risk



Non-linear Taxes and Risk



Incomplete Tax Loss Offset

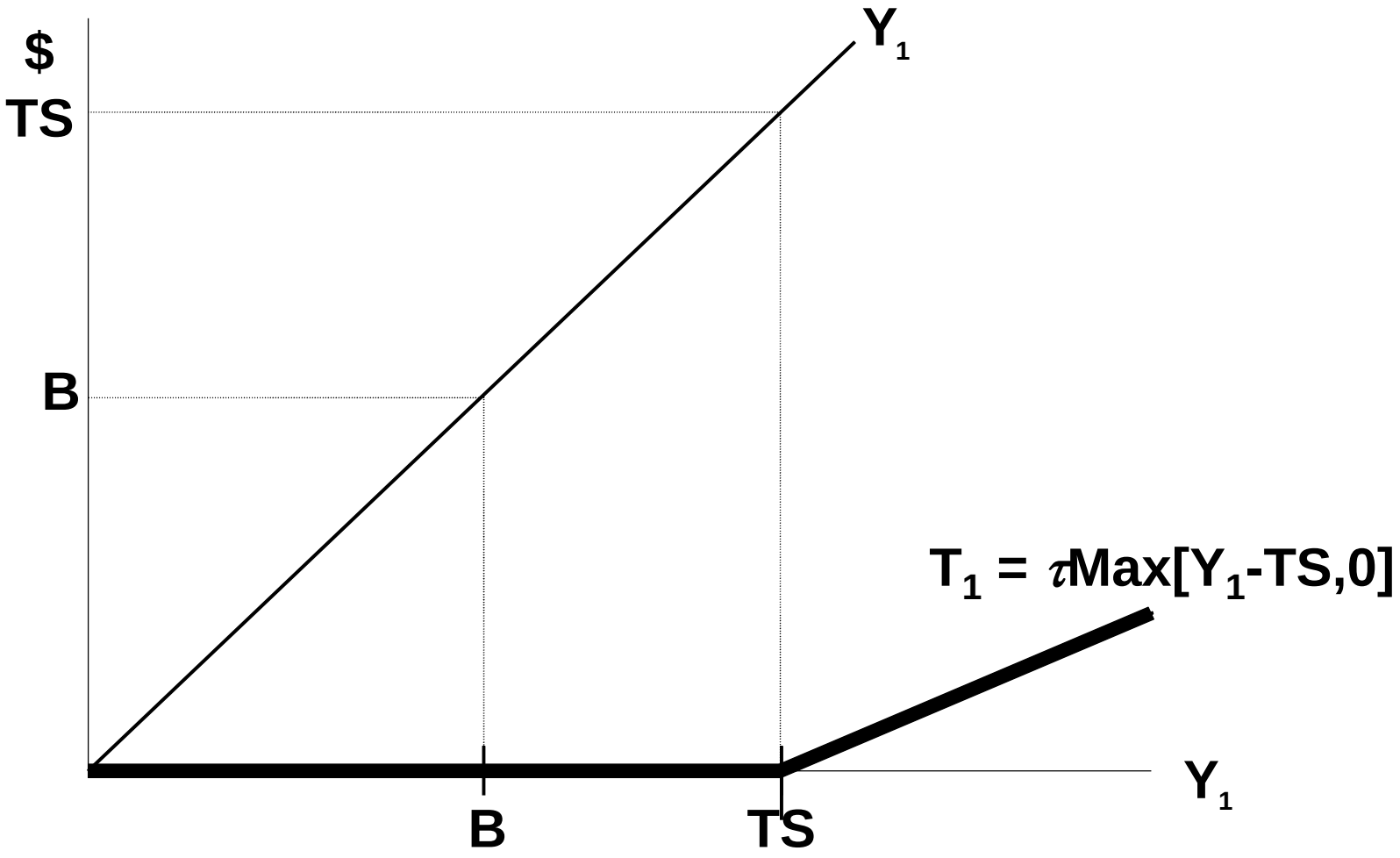
Table 1: The Levered, *Uninsured* Firm (B=\$200, τ = 35%)

State	p_s	V	L_s	$V - L_s$	D_s	Dep	T_s	S_s
no loss	50%	\$1000	\$0	\$1000	\$200	\$400	\$140	\$660
Loss	50%	\$1000	\$800	\$200	\$200	\$400	\$0	\$0
value		\$1000	\$400	\$600	\$200	\$400	\$70	\$330

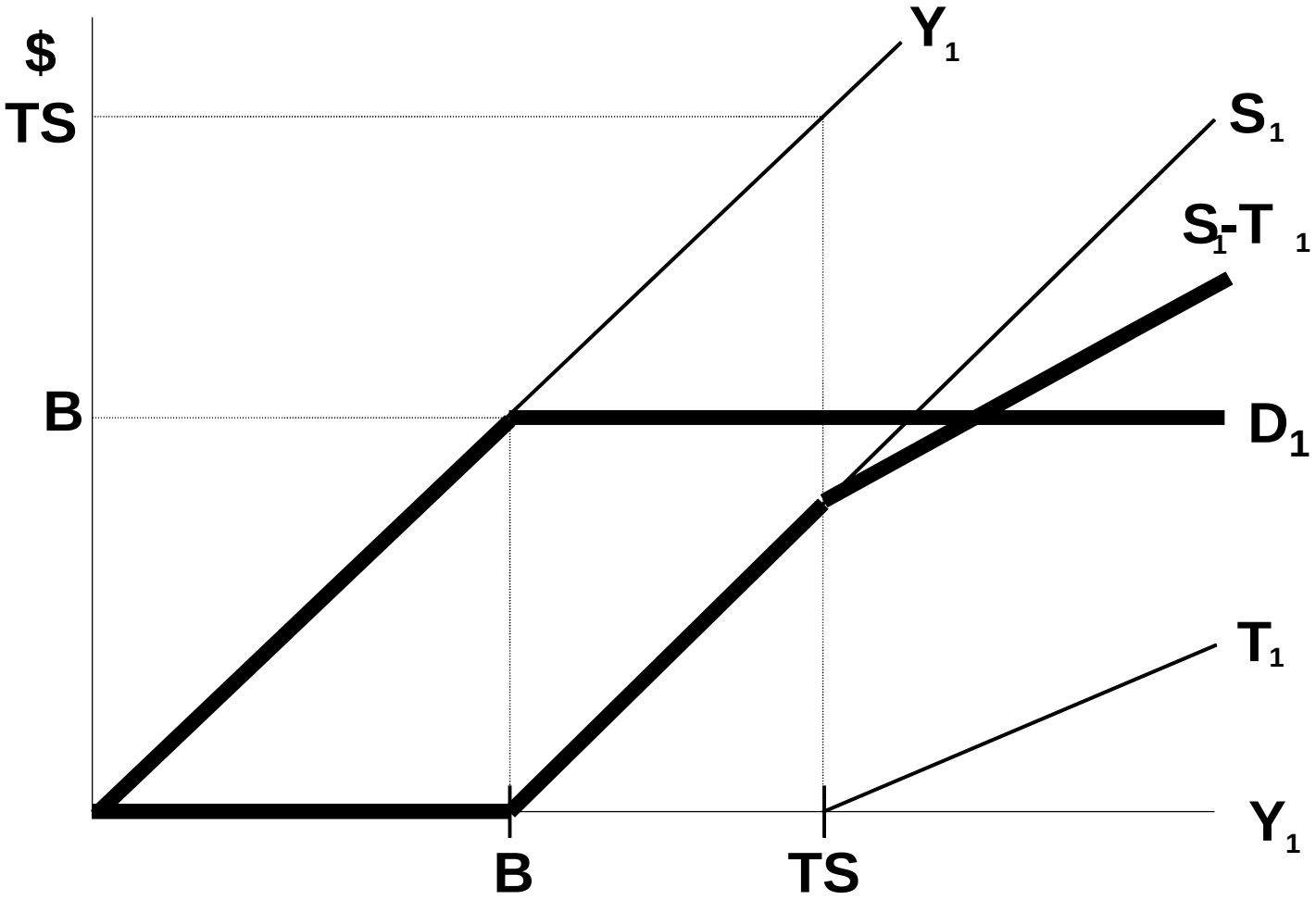
Table 2: The Levered, *Insured* Firm

State	p_s	V	L_s	$V - p$	D_s	Dep	T_s	S_s
no loss	50%	\$1000	\$0	\$600	\$200	\$400	\$0	\$400
loss	50%	\$1000	\$800	\$600	\$200	\$400	\$0	\$400
value		\$1000	\$400	\$600	\$200	\$400	\$0	\$400

Tax Options



Bondholders and Shareholder Payoffs



Valuing Taxes Using Option Theory

- Two step process
  1. Compute Black-Scholes values for the pre-tax value of equity and the value of the government's tax claim.
  2. The market value of equity is the difference in the value between these two options; i.e.,

$$V[Max(Y_1\text{-}B,0) - \tau Max(Y_1\text{-}TS,0)], \text{ where}$$

V = valuation operator (Black-Scholes method);

τ = corporate tax rate; and

$TS = B + dep$, where dep represents non-cash write-offs such as depreciation.

Tax Options – Firm 1

Time to Expiration		1	Depreciation	$250,000	
Interest Rate		5%	Tax Rate	35%	
Firm 1 Standard Deviation		40%			
Pre-Tax Asset Value	$1,000,000	d1	2.0579	Pre-Tax Stock Value	$527,733.09
Bonds Face Value	$500,000	d2	1.6579	Safe Bonds	$475,614.71
		N(d1)	98.02%	Put Price	$3,347.80
		N(d2)	95.13%	Risky Bonds	**$472,266.91**
Tax Shield	$750,000	d1	1.0442	PV Taxable Income	$323,673.46
		d2	0.6442	Value of tax option	**$113,285.71**
		N(d1)	85.18%	After-Tax Stock Value	**$414,447.38**
		N(d2)	74.03%		

Tax Options – Firm 2

Time to Expiration		1	Depreciation	$250,000	
Interest Rate		5%	Tax Rate	35%	
Firm 2 Standard Deviation		50%			
Pre-Tax Asset Value	$1,000,000	d1	1.7363	Pre-Tax Stock Value	$534,578.88
Bonds Face Value	$500,000	d2	1.2363	Safe Bonds	$475,614.71
		N(d1)	95.87%	Put Price	$10,193.59
		N(d2)	89.18%	Risky Bonds	**$465,421.12**
Tax Shield	$750,000	d1	0.9254	PV Taxable Income	$348,389.88
		d2	0.4254	Value of tax option	**$121,936.46**
		N(d1)	82.26%	After-Tax Stock Value	**$412,642.42**
		N(d2)	66.47%		

Interdependence of project and firm risk

- The classic capital budgeting model implicitly assumes that the firm has unlimited liability and faces linear taxes.
- When these assumptions hold, the NPV of a project is calculated by estimating the discounted expected values of future incremental after-tax cash flows without any reference to cash flows from existing assets.

Interdependence of project and firm risk

- Limited liability and nonlinear taxes imply that the NPV of a project depends upon the manner in which incremental project cash flows interact with cash flows from existing assets.
  - ∴ project NPV equals difference in after-tax value of equity (assuming the project is implemented), minus the after-tax value of equity (assuming the project is not implemented).
  - Important implication: Project value will differ from firm to firm.

Empirical Evidence: Risk Mgmt. &Taxes

- Dolde (1995) reports a statistically significant positive relationship between tax loss carry forwards and corporate hedging.
- Nance, Smith & Smithson (1993) and Mian (1994) find a statistically significant positive relationship between tax credits and corporate hedging.

Limited Liability: Creditor-Owner Relationship

- Limited liability implies risk sharing between creditors and owners of firm.
- Risk sharing implies (the possibility of) moral hazard.
- We'll consider two aspects of moral hazard: the so-called "underinvestment" and "asset substitution" problems.

The Underinvestment Problem

The Unlevered, Uninsured Firm

State	Pr(s)	Π	L(s)	$V^u(s)=\Pi-L(s)$	I(s)	$V^r(s)=\Pi-I(s)$
no loss	50%	$1000	$0	$1000	$0	$1000
loss	50%	$1000	$800	$200	$600	$400
value now		$1000	$400	$600	$300	$700

The Underinvestment Problem

The Levered, Uninsured Firm (B=$700)

State	Pr(s)	Π	L(s)	$D^u(s)$	$S^u(s)$	I(s)	$D^r(s)$	$S^r(s)$
no loss	50%	$1000	$0	$700	$300	$0	$700	$300
loss	50%	$1000	$800	$200	$0	$600	$400	$0
value now		$1000	$400	$450	$150	$300	$550	$150

The Underinvestment Problem

Levered, Insured Firm (B^c=\$500 & d=\$500)

State	Pr(s)	Π	L(s)	I(s)	$p^c(s)$ = max[I(s)-d,0]	Π*= Π -I(s)+$p^c(s)$	$D^c(s)$	$S^c(s)$
no loss	50%	\$1,000	\$0	\$0	\$0	\$1,000	\$500	\$500
loss	50%	\$1,000	\$800	\$600	\$100	\$500	\$500	\$0
value now		\$1,000	\$400	\$300	\$50	\$750	\$500	\$250

The Underinvestment Problem

Effect of Transaction Costs ($B^l = \$600$ & $d = \$400$)

State	Pr(s)	Π	L(s)	I(s)	$p^l(s) = \max[I(s)-d,0]$	$\Pi^* = \Pi - I(s) + p^l(s)$	$D^l(s)$	$S^l(s)$
no loss	50%	$1,000	$0	$0	$0	$1,000	$600	$400
Loss	50%	$1,000	$800	$600	$200	$600	$600	$0
value now		$1,000	$400	$300	$100	$800	$600	$200

The Asset Substitution Problem

- Future earnings have an expected present value (PV) of either 100 or 200 each with a 0.5 probability.
- The firm has existing senior debt with a face value of 100.
- Firm value is $150; debt value is $100, equity value is $50.

The firm now faces this choice; it can select one of the following new investments:

	Capital cost	Earnings	NPV
Project A	200	220	20
Project B	200	20; probability 0.5 or 310; probability 0.5	-35

The Asset Substitution Problem

NEW PROJECT → / ORIGINAL OPERATIONS ↓	A 220 (1.0)
100 (0.5)	320 (0.5)
200 (0.5)	420 (0.5)

← B →		
	20 (0.5)	310 (0.5)
100 (0.5)	120 (0.25)	410 (0.25)
200 (0.5)	220 (0.25)	510 (0.25)

The Asset Substitution Problem

Value of the firm if project A is chosen

Value of the firm	0.5(320 + 420)	= 370
Senior Debt	0.5(100 + 100)	= 100
Junior Debt	0.5(200 + 200)	= 200
Equity	0.5(20 + 120)	= 70

Value of the firm if project B is chosen

Value of the firm	0.25(120 + 220 + 410 + 510)	= 315
Senior Debt	0.25(100 + 100 + 100 + 100)	= 100
Junior Debt	0.25(20 + 120 + 200 + 200)	= 135
Equity	0.25(0 + 0 + 110 + 210)	= 80

The Asset Substitution Problem: Precommit to Hedge Project Risk

NEW PROJECT → **ORIGINAL** **OPERATIONS ↓**	**B*** **165** **(1.0)**
100 **(0.5)**	265 (0.5)
200 **(0.5)**	365 (0.5)

The Asset Substitution Problem: Precommit to Hedge Project Risk

- Since there is no risk in A, there is no need to hedge project risk; thus debt and equity values are exactly the same as previously shown.
- However, project B is risky and, with a costless hedge, the firm could replace a fair lottery of 20 and 310 with a certain payoff of 165.

Value of the firm if project A is chosen

Value of the firm	0.5(320 + 420)	= 370
Senior Debt	0.5(100 + 100)	= 100
Junior Debt	0.5(200 + 200)	= 200
Equity	0.5(20 + 120)	= 70

Value of the firm if project B is chosen

Value of the firm	0.5(265 + 365)	= 315
Senior Debt	0.5(100 + 100)	= 100
New Debt	0.5(165 + 200)	= 182.5
Equity	0.5(0 + 65)	= 32.5

The Asset Substitution Problem: Fund with equity

- If the new project were to be financed with equity, project A would be chosen. This follows since the total debt is now only 100 (old debt) and there is no chance that firm value would fall below 100 whatever project is chosen.
- Suppose that the firm chooses to raise 100 in new equity and 100 in new debt.

Value of the firm if project A is chosen

Value of the firm	0.5(320 + 420)	= 370
Senior Debt	0.5(100 + 100)	= 100
Junior Debt	0.5(100 + 100)	= 100
Equity	0.5(120 + 220)	= 170

Value of the firm if project B is chosen

Value of the firm	0.25(120 + 220 + 410 + 510)	= 315
Senior Debt	0.25(100 + 100 + 100 + 100)	= 100
Junior Debt	0.25(20 + 100 + 100 + 100)	= 80
Equity	0.25(0 + 20 + 210 + 310)	= 135

Investment, Risk and Managerial Incentives

- Let's look next at the role that compensation contract design might play in shaping the firm's investment and risk management decisions.
- Assumptions
  - Shareholders are risk neutral, but the manager is risk averse with utility $U = W^{.5}$.
  - The firm is 100% equity financed, interest rates are zero, and income is not taxed.

Investment, Risk and Managerial Incentives

- The firm must offer the manager a competitive compensation package; otherwise she will work elsewhere.
  - Suppose that the competitive certainty equivalent salary is $300,000 per year.
  - Thus the compensation contract must provide the manager with expected utility of at least $U(\$300{,}000) = \$300{,}000^{.5} = 547.72$.

Investment, Risk and Managerial Incentives

- Now suppose there are two equally probable states, one in which the firm's value is $500 million, and the other in which it is $1000 million.
  - Suppose there's an investment opportunity which increases firm value by $30 million and also reduces corporate risk to zero; will the manager find it in her self-interest to make this investment?

Investment, Risk and Managerial Incentives

- Consider three alternative managerial compensation contracts – a fixed salary, direct share ownership, and executive stock options.
  - Fixed salary of $300,000 causes the manager to be indifferent about making this investment her welfare remains unaffected.

Investment, Risk and Managerial Incentives

- Direct Share Ownership. Manager receives the proportion (x) of earnings and no salary. This incentive scheme must provide expected utility of at least U($300,000)=547.72. Solve for x:

$$547.72 \leq 0.5(500{,}000{,}000x)^{0.5}+.5(1{,}000{,}000{,}000x)^{0.5}$$

$$1095.45 \leq (500{,}000{,}000^{0.5} + 1{,}000{,}000{,}000^{0.5})\,(x)^{0.5}$$

$$1095.45 \leq 53983.46\,(x)^{0.5}$$

$$0.02029 \leq x^{0.5}$$

$$\therefore\ x \geq 0.000412.$$

Investment, Risk and Managerial Incentives

- Let's assume that the manager receives .0412% of the firm.
  - Expected income for the manager (without the investment): $E(income)$ =.5($500 mill(.0412%))+.5($1 bill(.0412%))= $309,000.
  - Since share ownership requires that the manager bear risk, she requires a $9,000 risk premium to compensate for risk bearing.
  - Expected income for the manager (with the investment) = ($780,000,000(.000412)) = $321,360.

Investment, Risk and Managerial Incentives

- Without the investment, $E(U) = .5(0.000412*500M)^{.5} + .5(0.000412*1000M)^{.5} = 547.72$.
- With the investment, $E(U) = (0.000412*\$780M)^{.5} = 566.89$.
- Thus, $E(U)$ is higher and shareholders are also better off w/investment.
- Consequently the direct share ownership scheme is preferred to the flat salary scheme, since it better aligns shareholder and managerial incentives.

Investment, Risk and Managerial Incentives

- Stock option grant:
  - Manager receives no salary nor shares of stock.
  - 10 million shares outstanding; thus, the value of a share is either $50 or $100.
  - Manager receives options to purchase 60,000 shares of stock at a price of $80 per share.
- Suppose there is no investment. Then the expected income and expected utility from holding options to purchase 60,000 shares are:

  $E(income) = (.5*(\text{Max}(50-80,0))+.5*\text{Max}(100-80,0))) \times 60{,}000 = \$600{,}000$, and

  $E(U) = .5(0 \times 60{,}000)^{.5} + .5(\$20 \times 60{,}000)^{.5} = 547.72.$

Investment, Risk and Managerial Incentives

- If the investment is implemented, then

  $E(income) = Max(78\text{-}80,0) \times 60{,}000 = \$0$, and

  $E(U) = Max(78\text{-}80,0)^{.5} = 0.$
- The optimal decision here is to not invest, because $E(U)$ is higher without the investment (547.72) than with it (0).

Investment, Risk and Managerial Incentives

Type of contract	Contract Design	Expected Utility	What to do?
Fixed Salary	Fixed Salary of $300,000	EU = 547.72 no matter what.	Indifferent between investing and not investing
Direct Share Ownership	Manager owns x = .00412% of the firm.	EU = 566.89 with investment; EU = 547.72 without investment.	Invest
Options	Manager owns option to purchase 60,000 shares of stock, exercise price of $80.	EU = 0 with investment; EU = 547.72 without investment.	Don't invest

Investment, Risk and Managerial Incentives

CEQ Income	$300,000					
U(Wceq)	547.7226					
# Shares	10,000,000					
U(W) = W^n, where n =	0.5					
Option 1 Exercise Price	$80					
Option 2 Exercise Price	$70					
Option 3 Exercise Price	$60					
		Fixed Salary	Share Ownership	Option 1	Option 2	Option 3
	Salary	$300,000	$0	$0	$0	$0
	Ownership fraction	0.0000%	0.0412%	0.0000%	0.0000%	0.0000%
	Options	0	0	60,000	40,000	30,000
Do not invest						
p(s)	V(s)	U(V(s))	U(V(s))	U(V(s))	U(V(s))	U(V(s))
50%	$500,000,000	547.7226	453.7482	0.0000	0.0000	0.0000
50%	$1,000,000,000	547.7226	641.6969	1095.4451	1095.4451	1095.4451
		547.7226	547.7226	547.7226	547.7226	547.7226
Invest						
NPV of investment	$30,000,000					
p(s)	V(s)	U(V(s))	U(V(s))	U(V(s))	U(V(s))	U(V(s))
50%	$780,000,000	547.7226	566.7313	0.0000	565.6854	734.8469
50%	$780,000,000	547.7226	566.7313	0.0000	565.6854	734.8469
		547.7226	566.7313	0.0000	565.6854	734.8469

Investment, Risk and Managerial Incentives

CEQ Income	$300,000					
U(Wceq)	547.7226					
# Shares	10,000,000					
U(W) = W^n, where n=	0.5					
Option 1 Exercise Price	$80					
Option 2 Exercise Price	$70					
Option 3 Exercise Price	$60					
		Fixed Salary	Share Ownership	Option 1	Option 2	Option 3
	Salary	$300,000	$0	$0	$0	$0
	Ownership fraction	0.0000%	0.0412%	0.0000%	0.0000%	0.0000%
	Options	0	0	60,000	40,000	30,000
Do not invest						
p(s)	V(s)	U(V(s))	U(V(s))	U(V(s))	U(V(s))	U(V(s))
50%	$500,000,000	547.7226	453.7482	0.0000	0.0000	0.0000
50%	$1,000,000,000	547.7226	641.6969	1095.4451	1095.4451	1095.4451
		547.7226	547.7226	547.7226	547.7226	547.7226
Invest						
NPV of investment	-$30,000,000					
p(s)	V(s)	U(V(s))	U(V(s))	U(V(s))	U(V(s))	U(V(s))
50%	$720,000,000	547.7226	544.4979	0.0000	282.8427	600.0000
50%	$720,000,000	547.7226	544.4979	0.0000	282.8427	600.0000

Investment, Risk and Managerial Incentives

- Tufano (1996) finds managerial equity positions positively correlated with risk management in gold firms, and negative relationship between risk management and larger managerial option positions.
- Geczy, Minton and Schrand (1997) find that managerial equity positions are positively correlated with FOREX management by nonfinancial firms; also, a negative relationship between risk management and larger managerial option positions.

Bankruptcy Costs

- If a firm goes bankrupt under U.S. Bankruptcy law, *ex post* costs of distributing assets are borne by firm's creditors.
- Direct costs include lawyers' and accountants' fees, other professional fees, court costs, and value of managerial time spent administering the bankruptcy.

Bankruptcy Costs

- Indirect costs of bankruptcy
  - Revenue losses may occur because customers prefer to do business with a solvent rather than bankrupt company.
  - Incentives for other stakeholders (e.g., vendors, managers, and employees) also undergo adverse changes; e.g., trade credit terms deteriorate, managers and employees leave the firm, etc.
- Direct and indirect *ex post* costs are reflected *ex ante* in the form of higher interest rates paid to creditors.

Empirical Evidence: Risk mgmt & bankruptcy risk

- Dolde and Samant (1996) find a statistically significant positive relationship between the use of interest rate swaps and leverage.
- Mayers and Smith (1990) show that demand for reinsurance is negatively related to credit standing (assigned by a rating agency); i.e., less credit-worthy insurers reinsure more.
- Garven and Lamm-Tennant (2003) show that demand for reinsurance is positively related to the insurer's financial leverage.

Pecking Order Theory

- Adverse selection in equity markets
  - Announcement of a secondary stock offering drives down the prices of currently outstanding shares because investors believe managers are more likely to issue equity when existing shares are overpriced.
  - This represents an adverse selection cost in the equity market!

Pecking Order Theory

- Firms prefer internal equity since funds can be raised without conveying adverse signals; internal equity is a *cheaper* source of financing than external equity.
- If external financing is required, firms issue debt first and equity as a last resort, thereby minimizing adverse selection costs.

Pecking Order Theory of Risk Mgmt.

- Suppose an unhedged firm suffers a loss of liquidity (e.g., a major manufacturing facility is destroyed).
- The loss in liquidity curtails the firm's internally financed investment projects, thereby resulting in a real economic loss to the firm.
- Hedging such a risk would ensure that the company has the cash available to fund value-enhancing investments which might otherwise be foregone.

Risk management and investment policy

- Froot, Scharfstein and Stein (1993) show that for each dollar of unhedged loss, project budgets are cut by about 30 cents.
- Minton and Schrand (1999) find that capital expenditure for firms with high (low) cash flow volatility is 19% (11%) below (above) average.

Conclusions

- Risk management adds value by reducing (the expected value of) taxes.
- The design of the managerial compensation contract is an important corporate risk management determinant.
- Risk management adds value by reducing the (the expected value of) financial distress costs.
- Risk management adds value by facilitating optimal investment.