Chapter 3: Essential Microeconomic and Financial Theory for Banking

A. Introduction

The purpose of this chapter is to examine some of the important financial mathematics and microeconomics issues that concern banking. Among the most important are the issues that arise from limited shareholder liability, which, as we will discuss, can have profound influences on the motives of bank shareholders and managers. We will continue to discuss such models, theories and issues, including interest rates and risk as we proceed through subsequent chapters of this book. We will also provide illustrations of each of these theoretical constructs as appropriate later in the text.

The *economics of information* is concerned with how information affects an economy and economic decisions along with the quality, value and distribution of this information. Information is normally inexpensively created, may or may not be reliable and, when reliable, can be valuable. Some economists have suggested that more than half of the U.S. economy is currently engaged in activities that are producing and analyzing information products. However, markets for information are quite different from those of most other goods. First, the consumption of information by one agent does not preclude its consumption by another. Second, information production has a high fixed cost component and a very low variable cost component. While information is costly to produce, the marginal cost of reproducing information of a specific type (e.g., a particular book, music recording, stock analyst reports, cola recipe) is typically almost zero. That is, duplicating information is practically costless. The cost of duplicating information may be as small as the cost of producing its medium, paper, CD, etc. Information is normally sold as a package with the medium that contains it. Because the marginal cost of producing information is so low, cost-based pricing does not work, and pricing is normally related to consumer demand.

Many of the simplest microeconomics models assume that information is costless and all agents have equal access to relevant information. This chapter is concerned primarily with problems that arise when agents have asymmetric and/or costly access to information. For example, agents in an economy may well have different access to quality information, a situation known as *asymmetric information availability*. Information asymmetries occur when some agents have more timely or better information than others. For example, an investment bank may have better information concerning an IPO than any prospective investors in that IPO. In this chapter, we will discuss information, information asymmetries, the principal agent problem, adverse selection, the moral hazard problem, contracts and signaling, all of which impose significant problems on banking and investment banking markets.

B. The Principal-Agent Problem

The principal-agent or *agency problem* arises in environments exhibiting incomplete information availability or information asymmetries. Generally, agency theory is concerned with the efforts of a *principal* attempting to induce an *agent* to undertake some costly action on behalf of the principal. That is, how can an agent be motivated to act on behalf of a principal? The principal's problem is to design an incentive scheme to induce the agent to make the best and most productive effort on *his* behalf. This often means that the principal seeks to make the self-interested rational choices of the agent coincide with the desires of the principal.

The relationship between a bank's manager and other stakeholders, including shareholders is a classic example of the principal-agent problem. Bank managers act as agents on behalf of bank shareholders with the bank's board of directors monitoring managerial activities on behalf of shareholders. Jensen and Smith [1985] suggest that there are three primary potential sources of conflict between managers and shareholders:

1. *Managerial effort and actions*: Broadly defined, effort includes direct pecuniary compensation, non-pecuniary benefits (e.g., the corporate jet), shirking (e.g., not undertaking the unpleasant task of firing unproductive or redundant employees), empire-building (e.g., taking over companies to increase the span of control and compensation), etc.
2. *Human capital*: Risk associated with firm-specific human capital cannot be diversified away as can sources of risk to shareholders.[1] For example, bank shareholders might be able to diversify their holdings and absorb more risk while bank managers may prefer to act conservatively in order to preserve their careers.
3. *Time horizons*: Shareholders are perpetual stakeholders in the firm; managers' tenures are limited.

These potential sources of conflict mean that managers can direct efforts to their own interests, managers' risk preferences will differ from those of shareholders and managerial actions will tend to be focus more on the more short-run. The shareholder problem is to induce the management team to act in shareholder interests. In a bank, we will argue that shareholders are likely to benefit from increased risk-taking, particularly in the presence of deposit insurance. However, shareholders have the opportunity to diversify, whereas bank managers might prefer not to take on larger risks because they cannot diversify against the job loss risk associated with bank failure. Hence, managerial risk aversion and associated job loss might offset the shareholding benefits of excessive risk-taking.

Many other types of agency problems occur in a bank, with most of which being exacerbated by limited shareholder liability and the very high levels of leverage maintained by most banks. Banks draw capital from depositors, creditors and a variety of other sources and bank managers make decisions affecting the wealth of all of these stakeholders as well as insurers and the economy as a whole. Investment banks take their clients public in an IPO, and might prefer to keep their client share prices low in order to more easily market the shares. The principal-agent problem concerns these relationships, as we will discuss in the following sections, first concerning the moral hazard problem.

C. Moral Hazard

Moral hazard originally referred to the tendency of insured individuals to reduce their efforts to avoid or mitigate insured losses. For example, once insured, policyholders might increase their risk-taking, enabling them to benefit from potential gains but force the insurer to take on potential losses from the risk-taking. More generally, moral hazard is post-contractual opportunism where the incentives or actions of one contracting party are not freely observable. Moral hazard is a problem of hidden action. For example, after purchasing insurance, the insured party can change her behavior at the expense of the insurer. This is a clear example of moral hazard, the term originally concerning the character of the purchaser of insurance. For example, the moral hazard problem arises when one buys life insurance and then takes up sky diving.

[1] Note that certain compensation schemes including option-based payments serve as a reaction to this problem, but can reflect an overreaction to this problem.

Here, the insured's behavior changes upon taking an insurance policy. In the bank, moral hazard arises when the bank borrows money from depositors then increases its risk-taking, to the advantage of shareholders and to the detriment of depositors who are unlikely to share in the potential gains from risk-taking. Moral hazard also occurs when the bank's deposits are insured, worsening the moral hazard problem by leading to indifference to risk-taking on the part of depositors, which in turn, leads to an increase in risk-taking activity by managers at the expense of the insurer. When depositors, shareholders stand to benefit from risk-taking, but insured depositors are protected by their insurance. The increased risk-taking is at the cost of the insurer.

Here, we discuss two types of agency problems related to the capital structure decision. First, managers presumably acting on behalf of shareholders might be motivated to transfer wealth away from creditors and other stakeholders to shareholders. In banks, depositors and deposit insurers are particularly vulnerable to the moral hazard problem. The moral hazard problem is one type of agency problem, where *the firm changes its behavior* (e.g., taking on additional risk) *after making a transaction* (after borrowing money or obtaining deposit insurance).

A second type of agency problem arises where corporate managers engage in capital structure activities to enrich themselves at the expense of shareholders. For example, managers can sell additional shares of stock to outside shareholders to reduce their personal costs of perquisites (e.g., the corporate jet, avoiding unpleasant actions such as downsizing, etc.) consumption. In this type of scenario as affecting banks, managers selling additional shares might reduce the risk of the bank while increasing their own job safety. Shareholders might want to exploit the option feature associated with limited shareholder liability; managers might prefer the opposite, and take steps to reduce institutional risk. Thus, managers can use capital structure devises to transfer wealth to shareholders at the expense of other stakeholders (depositors, insurers) in the firm or use capital structure to transfer wealth to themselves at the expense of shareholders. Shareholders can take measures to protect themselves from manager self-serving behavior, frequently by designing compensation schemes that align shareholder and managerial interests, though as we will discuss later, these schemes can go awry. Nevertheless, the problem of moral hazard is not new; it has been a central feature of banking systems and banking regulation for centuries.

Asymmetric information between lenders and borrowers is key to this agency problem. Leland and Pyle [1977] note that "Lenders would benefit from knowing the true characteristics of borrowers. But moral hazard hampers the direct transfer of information between market participants. Borrowers cannot be expected to be entirely straightforward about their characteristics, nor entrepreneurs about their projects, since there may be substantial rewards for exaggerating positive qualities. And verification of true characteristics by outside parties may be costly or impossible." Nevertheless, banks enjoy scale economies that enable them to more efficiently obtain information and share that information among members of lending coalitions (loan syndicates), perhaps mitigating moral hazard problems. Furthermore, banks, particularly those benefiting from scale economies can more effectively benefit from asset diversification. We will discuss the moral hazard problem in the next section and in later chapters, especially as they apply to banks.

D. Limited Shareholder Liability and Moral Hazard

<u>Limited Shareholder Liability</u>

A widespread and interesting feature of the American corporation is the limited liability enjoyed by shareholders. Why is this feature so popular? Manne [1965] suggests that the existence of this feature owes merely to shareholder preference, though also suggests that limited liability will tend to draw more diverse groups of investors. However, as Jensen and Meckling [1976] point out, limiting shareholder liability does not eliminate liability, it merely shifts it to other corporate stakeholders. Shareholders must pay a price for this limited liability when selling other corporate securities, for example, through higher interest rates on bonds or premiums on government deposit insurance.

Woodward [1985] argued that limited liability exists so that it is not necessary for shareholders to know personal wealth levels and other characteristics concerning other shareholders with whom they trade and make joint decisions. In the event of corporate failure, unlimited shareholder liability as in a partnership exposes different shareholders to different levels of risk. Wealthier shareholders are exposed to more risk because they have more assets to attach. Shareholders would rather partner with or invest in the presence of more wealthy shareholders who can assume a larger share of the failure costs. Limited shareholder liability removes this need to seek wealthier investors to share with whom to share the burden of failure. Not requiring information about other shareholders saves on transactions costs and increases liquidity. Hence, firm stakeholders make decisions affecting the corporation based only on the assets and obligations that are revealed and maintained by the corporation and need not know whether certain shareholders will provide additional funding to fulfill failed firm obligations.

This limited liability feature of equity enhances the liquidity of shares because the wealth level of any other potential shareholder is irrelevant to existing shareholders. This enhanced liquidity enables firms to access larger pools of capital, facilitating shareholder diversification opportunities, which enable businesses to benefit from economies of scale unavailable to closely held and family businesses, all serving to improve production and the real economy. In banking parlance, the value of limited liability along with the license to engage in banking activities is referred to as *charter value*. But, the cost of this improved liquidity and improved capital access are a variety of incentive problems such as the moral hazard problem, as we will discuss shortly. Briefly, though, charter value helps offset the incentive for firms to increase risk because firms with the ability to generate monopoly rents or profits will seek to protect their valuable charters.

Corporate Securities as Options

As we have discussed, corporate law provides for limited liability for shareholders. This limits the obligation of shareholders to creditors to the amount that shareholders have invested in the equity of the firm. Limited shareholder liability is valuable to shareholders and is costly to creditors. This limited liability feature of the typical corporation provides opportunity for increased risk-taking by managers on behalf of shareholders. Increased risk-taking by managers increases shareholder wealth by enabling shareholders to benefit from highly successful ventures. While creditors do not share proportionately in the gains of the successful venture, they do stand to lose if the risky ventures are unsuccessful. Hence, shareholders are the primary beneficiaries of a successful venture; creditors lose disproportionately in unsuccessful ventures. This increases shareholder wealth at the expense of creditors.

Key to this analysis, as we discussed earlier, is the notion that shareholders can be thought to have a call option on the firm's assets. If the firm does well, shareholders exercise their right to purchase the firm's assets by paying off creditors. The face value of debt (along with accrued interest) can be regarded as the exercise price of the shareholder call option on the firm's assets. The shareholder call option to purchase the firm's assets is exercised when it is realized that the firm has performed well enough such that the value of those assets exceeds the face value of debt along with accrued interest representing the exercise price of the call option. If the firm performs poorly enough such that the value of assets is exceeded by the value of the creditor obligation, shareholders default and leave the assets to creditors. In effect, they decline their right to purchase the firm's assets. Hence, shareholders can be thought to have a call option on the firm's assets which is exercised only if the firm performs well and shareholders opt to assume control of the firm's assets by settling obligations to creditors.

Now, let us consider the creditor's position. Creditors expect to receive a fixed payment. This is analogous to riskless debt. However, creditors understand that if the firm performs poorly, they must accept control of the firm's assets in exchange for indemnifying shareholder obligations. Hence, they agree to accept the firm's assets if shareholders wish to put the firm's assets to them. This position is analogous to a short position in a put. Creditors must take control of the firm's assets if shareholders do not want them; otherwise, creditors have no obligation. The exercise price associated with this put is the value (face value plus accrued interest) of the shareholder obligation to them.

Corporate Security Payoff Functions

Limited shareholder liability alters the payoff structures of corporate securities. Here, we introduce the corporate capital structure problem from the Black and Scholes [1973] and Merton [1973] frameworks, using the put-call parity concept offered by Stoll [1969].[2] In a limited shareholder liability context, Black, Scholes and Merton viewed corporate equity as a call option on the issuing firm's assets. That is, shareholders have the right to take complete control of the firm’s assets by satisfying creditor claims on the firm. Black, Scholes and Merton viewed debt as combining the features of riskless debt and a short position in a put on the firm's assets. Thus, should shareholders fail to satisfy their obligations to creditors, creditors can take over the firm’s assets through a bankruptcy process. However, shareholders are no longer obliged to make the contracted payments towards debt resolution.

Option Payoffs

Based on the methodology of Stoll, terminal (expiration date T) payoff structures of calls (c_T) and puts (p_T) are functions of their exercise prices X and underlying asset prices (S_T) as follows:

$$c_T = MAX[0, S_T - X]$$
$$p_T = MAX[0, X - S_T]$$

Thus, for example, the owner of a call has the right to purchase the underlying asset with value S_T at time T by paying the call striking price X, and will do so as long as $S_T - X > 0$. Similarly, on any date ($0 < t < T$) prior to option expiration, American calls and puts must be worth at least as much as the difference between the stock price and the call exercise price:

$$c_t \geq MAX[0, S_t - X]$$
$$p_t \geq MAX[0, X - S_t]$$

[2] Readers unfamiliar with option pricing should see Appendix A to this chapter for a simple introduction to options and the Black-Scholes option pricing model.

Options in the Limited Liability Corporate Context

Now, redefine the underlying instrument to be the sum of assets of a leveraged corporation that provides for limited liability for shareholders. The face value of debt, or, in the case of banks, deposits, is X, and we will ignore coupon payments by assuming zero coupon debt. The shareholder claim on those assets can be regarded to be a call option that shareholders exercise if the underlying asset value exceeds X; otherwise they abandon their residual claims. This means that the shareholder can exercise his option to take control of the bank's assets by paying off depositors and other creditors; otherwise, the shareholder abandons his claim. Thus, the terminal payoff function for shareholders is $c_T = MAX[0, S_T - X]$ and initial stock value equals c_0.

The creditor claim on the firm's assets is modeled as a combination of riskless debt with initial value Xe^{-r_fT} (r_f is the riskless discount or interest rate) and a short position in a put in which creditors take possession of the firm's assets and abandon their claim on X should shareholders abandon their residual claims. In effect, p_0 is the market value of the insurance provided by the creditors, enabling shareholders to avoid their liability for all claims. The fair market value of this risk premium is p_0, which is deducted from the market value of the riskless component of deposits to obtain the overall value of debt, including the creditor's short position on the put. Thus, the total current value of the firm's assets and securities, based on the Stoll put-call parity framework are as follows:

$$S_0 \quad = \quad c_0 \quad + \quad \left[Xe^{-r_fT} - p_0\right]$$

$$Assets \; = Equity \;\; + \qquad Debt$$

In the case of the commercial bank with deposit insurance, this equality is rewritten:

$$S_0 \quad = \quad c_0 \quad + \quad Xe^{-r_fT} \; - \qquad p_0$$

$$Assets \; = Equity \;\; + Deposits - \underset{Insurance}{Deposit}$$

When the firm's debt or the bank's deposits mature, and if $S_T > X$, stock value equals S_T - X, debt value equals X, and the total asset value equals S_T. No claim is filed against deposit insurance. This means that creditors (or depositors) receive their claims X and shareholders receive the residual S_T-X. Alternatively, if $S_T \leq X$, stock value equals 0, debt value equals S_T for the uninsured firm as shareholders abandon their claim on the assets of the firm, turning assets over to creditors (or the government insurer) and the total asset value equals S_T. In the case of the insured bank, if $S_T \leq X$, stock value equals 0 as shareholders abandon their residual claims, deposit value equals X and the insurer takes control of the bank's assets, while paying the difference $X - S_T$ to insured depositors. The initial value of the deposit insurance to the bank equals p_0 while the government insurer maintains a short position on that put.

Illustration: The Asset Substitution Problem

Let us consider an example involving a bank that has \$100 in assets, financed by \$94 in deposits at an interest rate of 5% and \$6 in equity. If the bank were to invest \$100 by extending a loan on a very safe residential real estate mortgage, surely to earn a 6% return in one year, the depositors would receive $94 · 1.05 = $98.70 and shareholders would receive the remaining $MAX[0, S_T - X]$ = MAX [0, ($100 · 1.06) - $98.70] = $7.30. Thus, assuming that the residential real estate mortgages are quite safe and ignoring administrative costs, shareholders earn an expected profit of $1.30 on their $6 investment and depositors receive $4.70 in interest on their $94 investment:

Expected depositor profit = ($94 · 1.05) - $94 = $4.70

Expected shareholder profit = ($106 - $98.70) - $6 = $1.30

Expected total profit = $106 - $100 = $6

Now, consider an alternative strategy in which the bank can invest $100 into a much riskier commercial real estate loan such that its return might be as high as 15%. Suppose that the probability of the loan being repaid is assumed to equal 80%, while the probability of default equals 20%, in which case none of the balance of the loan is paid. Depositors receive $98.70 with a probability of 80% and zero (there are no assets with which to pay creditors) with a probability of 20%. In the case of bank failure, shareholders facing limited liability would simply abandon their claims on the bank and default on depositor obligations. On the other hand, in the more successful scenario, shareholders receive $MAX[0, S_T - X]$= MAX[0, $115-$98.70] = $16.30 with a probability of 80%, while facing a 20% percent probability of receiving zero = $MAX[0, S_T - X]$ = MAX[0, (0 - $98.70)] = 0. The potential profits to shareholders based on their initial $6 investment are $10.30 with probability equal to .80 and -$6 with probability equal to 20%. Thus, the expected profits to depositors and shareholders from the higher risk commercial real estate loan strategy are determined:

Expected depositor profit = [.8 · ($94 · 1.05)] + (.2 · 0) - $94 = -$15.04

Expected shareholder profit = [.8 · ($115-$98.70)] + [.2 · 0] - $6 = $7.04

Expected total profit = (.8 · $115) + (.2 · 0) - $100 = -$8

The expected profit to shareholders from the higher risk investment in commercial real estate loans ($7.04) is significantly higher than the expected profit ($1.30) associated with the safe residential real estate mortgage strategy. Hence, a bank managed on behalf of shareholder interests would pursue the riskier loan strategy despite its overall expected loss. The value of the firm's equity can be compared to that of a call option; the riskier the firm's investment strategy, the more valuable will be the firm's equity. The depositor position is analogous to that of a short position in a put; the riskier the firm's investment strategy, the less valuable will be the deposits.

E. Black-Scholes Valuation of Corporate Securities

Capital Structure in a Black Scholes Framework

In the Black-Scholes framework (See Appendix A to this chapter if an introduction to Black-Scholes is needed), corporate equity in the limited liability firm with total asset value S_0 can be regarded as an option to purchase the firm's assets by paying off at debt maturity date T

debt with face value X. In this scenario, shares can be valued as c_0 from the Black-Scholes model as follows:

(I)

$$c_0 = S_0 N(d_1) - \frac{X}{e^{r_f T}} N(d_2)$$

(II)

$$d_1 = \frac{ln\left(\frac{S_0}{X}\right) + \left(r_f + \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}}$$

(III)

$$d_2 = d_1 - \sigma\sqrt{T}$$

Riskless debt with face value X and maturity date T is valued at $Xe^{-r_f T}$. Following from our discussion of put-call parity in the previous section, the limited shareholder liability premium on risky debt is valued at p_0, such that the firm's risky debt is valued as the difference between the risk-free debt value less the value premium on risky debt:

$$D = Xe^{-r_f T} - p_0$$

Illustration 1:

Suppose that a bank with \$200 market value in assets is obliged to repay \$190 face value in deposits in two years. The current riskless rate of return is 4% per annum and the standard deviation of annual returns on the bank's assets is 0.6904. What is the value of the bank's equity? What is the value of the bank's deposits? Our first step is to obtain equity value, based on the reasoning that the equity is a call option to purchase the bank's assets:

$$d_1 = \frac{ln\left(\frac{200}{190}\right) + \left(0.04 + \frac{1}{2}.6904^2\right) \times 2}{0.6904 \times \sqrt{2}} = 0.623;\ N(d_1) = 0.733$$

$$d_2 = 0.623 - 0.6904 \times \sqrt{2}; N(d_2) = 0.362$$

$$Equity\ Value = c_0 = 200 \times 0.733 - \frac{190}{e^{.04 \times 2}} \times 0.362 = 83.196$$

While the face value of bank deposits (190) comprise 95% of bank assets (200), suggesting that the book value of equity should be 10, the market value of equity is 83.196. This extreme difference is due to the high risk associated with the bank's assets (indicated by the standard deviation of .6904) and the protection provided by limited shareholder liability.

Next, we begin the process of valuing the bank's debt. We first value the risk premium associated with bank default, assuming that the bank's shareholders might put the bank's assets to depositors by refusing to pay deposit obligations:

$$p_0 = c_0 + Xe^{-r_f T} - S_0 = 83.196 + 190 \times 0.9231 - 200 = 58.588$$

If this bank were FDIC insured, the 58.588 value of this obligation would be assumed by FDIC. This insurance would enhance the value of deposits and share value by an equivalent amount. Independently of the risk component of deposits, the bank has an outstanding obligation of 190, payable in two years in an environment with a riskless discount rate equal to 4%:

$$Xe^{-r_f T} = 190 \times e^{-.04 \times 2} = 190 \times 0.9231 = 175.392$$

If deposits are insured, their present value is simply their face value (190) discounted at the riskless rate, or 175.392. Without the deposit insurance, the value of deposits, net of the default risk premium declines as follows:

$$\textit{Deposit Value} = 175.389 - 58.588 = 116.804$$

Notice that the sum of the deposit value and the equity value is 200, the total value of assets. If the leveraged firm were a bank, and a federal insurer (e.g., FDIC) were to assume responsibility for insuring deposits, the value of the insurance to the bank would be p_0 = \$58.588.

Illustration 2:

Now, suppose that the bank with \$200 market value in assets and obliged to repay \$190 face value in debt in two years were to increase its risk-taking. The current riskless rate of return is still 4% per annum but the standard deviation of annual returns on the bank’s assets will now be 1.2. What is the value of the bank's equity? What is the value of the bank's debt? Our first step is to obtain equity value, based on the assumption that the equity is a call option to purchase the bank's assets:

$$d_1 = \frac{\ln\left(\frac{200}{190}\right) + \left(.04 + \frac{1}{2} \times 1.2^2\right) \times 2}{1.2\sqrt{2}} = 0.925893; N(d_1) = .822749$$

$$d_2 = 0.682 - 1.2\sqrt{2} = -.77116; N(d_2) = .220305$$

$$\textit{Equity Value} = c_0 = 200 \times .822749 - \frac{190}{e^{.04 \times 2}} \times .220305 = 125.91$$

Notice that the increase in the standard deviation associated with the bank's assets significantly increased the value of the bank's equity. Because of the substantial increase in the risk associated with the bank's assets, the value the risk premium associated with bank default will increase significantly:

$$p_0 = 125.91 + 190 \times .9231 - 200 = 101.3022$$

Independently of the risk component of debt, the bank still has an outstanding obligation of 190, payable in two years in an environment with a riskless discount rate equal to 4%:

$$Xe^{-r_f T} = 190 \times e^{-.04\times 2} = 190 \times .9231 = 175.392$$

Thus, the value of deposits, net of the default risk premium declines as follows:

$$\textit{Deposit Value} = 175.389 - 101.3022 = 74.08993$$

Notice that the sum of the deposit value and the equity value is still 200, the total value of assets. If the leveraged firm were a bank, and a federal insurer (e.g., FDIC) were to assume responsibility for insuring deposits, the value of the insurance to the bank would be p_0 = \$101.30, substantially higher than before the increase in asset risk.

The increase in bank asset risk in the illustrations above results in a transfer of wealth from the bank deposit insurer to shareholders. This illustrates the essential bank moral hazard problem, the primary principal-agent problem in banking.

F. Contracting

Contract theory is concerned with how agents design construct contracts. Typically, contracting occurs in environments with asymmetric information availability, with contracting parties who do not have perfect knowledge of one another and with different access to other types of information. Contracting would be more simple with perfect or at least symmetric information availability, as contracting parties would be less concerned about being exploited.

A *complete contract* fully specifies all parties' rights, payoffs and responsibilities under every contingency for every point in time. Of course, complete contracts are not likely to be commonplace in reality. Motivation problems arise because most contracts cannot be fully specified or enforced and contingencies cannot be fully delineated in advance. Incomplete contracts frequently provide for default rules to deal with unanticipated circumstances, perhaps leading to contract renegotiations or arbitration. *Bounded rationality* exists where contingencies cannot all be accounted for, when individuals cannot properly analyze all their potential strategies and actions or when communication is imperfect.

There are a number of mechanisms to deal with bounded rationality. For example, *implicit contracts* are unarticulated shared expectations shared among contracting parties. For example, suppose that an employee elects to work beyond her shift to meet an unanticipated increase in production demand. If the employer pays this employee for working beyond the end of her shift, an implicit contract may arise even though there was no explicit agreement to do this. That is, after the employee first works beyond her shift to satisfy unanticipated production quotas, the implicit contract might well oblige the employer to pay for this overtime. Courts might well find that that the employer must pay for continued working after shifts end unless the employer explicitly forbids work to continue at the end of shifts. In a somewhat different type of example, although Coca Cola does not explicitly contract with consumers to maintain its formula for Coke everywhere all the time, it does so to maintain its reputation. Implicit contracts are normally self-enforcing, where reputation is a common mechanism for contributing to self-enforcement.

Relationship Lending and Relational Contracting

Relationship lending or relationship banking arises from close and continued contact between a bank and its client. Relationship lending mitigates information asymmetries between borrowers and lenders, and due to difficulties that arise from such information asymmetries, can be particularly useful in relationships involving small borrowers, firms with high R&D intensities, and firms without extensive histories or without extensive media and analyst coverage. Relationship lending facilitates the passage of costly and confidential information from borrowers to lenders because borrowers are often more willing to pass proprietary information on to lenders when credit extension is facilitated by a close relationship. Relational contracts improve information flows between parties and allows lenders to obtain specific knowledge about borrowers. Relationship lending also allows for flexibility in responses when unforeseen events occur.

In addition to the long-term nature of relationship lending and sharing of proprietary information, relationship banking also implies that the borrower will also purchase other financial services from the lender and allows for enhanced flexibility in the event of unanticipated events. For example, should the borrower experience financial distress, the long-term relationship might facilitate renegotiation of loans. While relationship lending exists all over the world, it is especially prevalent in Germany (evidenced by interlocking directorships and cross shareholdings between banks and borrowers) and Japan (e.g., the keiretsu and "main bank" system).

Incomplete contracting can also give rise to *relational contracting*, which frames the relationship among contracting parties, focusing on goals, objectives and procedures for dealing with unforeseen contingencies rather than attempting to fully pre-specify all rights and responsibilities under all circumstances. Even though it does not involve an explicit contract, corporate culture might be viewed as a form of relational contracting. Contract law can be enacted to facilitate the efforts of contracting parties to maximize the joint gains (the "contractual surplus" or profits) from their transactions.

Transactional Banking

Perhaps the opposite of relationship lending is transactional or contract banking. In this scenario, banks compete with one another for each transaction with a client. Banks compete for each contract or transaction for each customer. While neither the relationship banking or transactional banking models hold anywhere in their strictest senses, most banking relationships are probably some combination to these two extreme models.

The Hold-up Problem

Klein, Crawford and Alchian (1978) characterize a scenario involving post-contractual opportunism where a transaction requires one agent to make a relationship-specific investment. Since complete contracts are not possible in this scenario, the second agent might be able to use the first agent's relationship-specific investment as leverage to renegotiate the contract or otherwise exploit the first's investment to extract gains. The result, when one party faces a potential hold-up exploitation, is the failure to contract, leading to underinvestment in potentially profitable projects.

Consider, for example, a company that makes specific parts for a specific automobile manufacturer. The parts maker and auto manufacturer agree to a contract for the assembly, in which the auto manufacturer agrees to build a plant for the parts maker. Obviously, this represents a significant investment for the auto manufacturer. After the auto manufacturer has made the investment (sunk costs), the parts maker might seek to renegotiate (perhaps after some event unanticipated at the time of the original transaction) terms of the contract. This sort of post-contractual opportunism is known as the hold-up problem. Such possibilities can prevent firms from entering into otherwise profitable contracts or expend resources to prevent such post-contractual exploitation; they under-invest.

The threat of this scenario actually did arise between General Motors (auto manufacturer) and Fisher Body (parts maker) in the 1920s. The problem was resolved by Fisher Body's vertical integration into General Motors. Mergers between potentially competing firms at different stages of the production process can align incentives and prevent the hold-up problem. In effect, the merger can remove the partnership from the market where conflicting partner objectives can lead to significant transactions costs or underinvestment.

In relationship banking, the hold-up problem can arise when, after a prospective lender has invested significant resources in analyzing the creditworthiness of the borrower threatens to seek a better interest rate from another potential lender. In effect, the borrower seeks to negotiate better lending terms from the bank after the bank has made considerable investment in its relationship with the borrower. Similarly, the lender could present the hold-up problem to the borrower after the borrower has invested resources into organizing and providing costly information to the lender. Regardless, relationship lending can facilitate creating a hold-up problem.

G. Adverse Selection and Lemons Markets

Adverse selection originally referred to the tendency of higher risk individuals to seek insurance coverage. More generally, adverse selection refers to pre-contractual opportunism where one contracting party uses her private information to the other counterparty's disadvantage. That is, adverse selection is a problem of hidden information. For example, the adverse selection problem can arise when a woman planning a pregnancy purchases health insurance, when a car rental customer planning a trip through a Golan Heights minefield buys comprehensive insurance on the car or when a pyromaniac purchases fire insurance. In all three cases, the agent (insured agent or customer) has private information with respect to the higher anticipated costs of the insurance coverage or lease, but pays a "pooling" premium for the coverage or lease. Note the similarity of and difference between the post-contractual moral hazard behavior discussed earlier to this pre-contractual adverse selection problem.

Adverse Selection and Information Collection

The adverse selection problem manifests regularly in banking and financial markets. For example, a corporation selling its securities faces the following problem: *Who should be willing to buy the securities of a business whose managers want to sell those securities?* Buyers of securities often lack quality information; selling managers should sell securities only if the price that they receive for those securities based on their inside information exceeds the true worth of those securities, which managers with superior information know. Clearly, less informed buyers should be cautious about transacting with more informed buyers.

Bank managers maintain close ties in the communities in which they conduct business in order to collect information on lending and borrowing opportunities. In effect, one might argue that the primary business of banks is to collect, store and act on information, essentially dealing with the adverse selection problem in lending by focusing resources on collecting and maintaining relevant information. Successful information collection and interpretation provides banks a substantial advantage over purchasers of bank products.

The Lemons Problem

Akerlof [1970] discussed a similar information-based agency problem focusing on differences in information available to buyers and sellers of used cars (asymmetric information availability). Suppose that sellers are recognized as having superior information about the cars that they sell than prospective buyers. In fact, suppose that sellers know whether their cars are good or bad, but buyers cannot distinguish good used cars from bad used cars. But, all sellers will claim that they are selling good used cars. Obviously, good used cars should be worth more than bad used cars (lemons). Essentially, Akerlof argues that if used car buyers cannot distinguish lemons from good used cars, then they will not pay the value of a good used for any car. Buyers of used cars will set a purchase price based on the probability that the car in question is actually a lemon. Thus, they will offer a price for a used car that accounts for the probability that the car is, in fact, a lemon. Prospective buyers simply are unwilling to risk purchasing a lemon for the value of a good used car. However, sellers are not willing to sell a good used car for the price of a lemon. Hence, owners of good used cars will never be willing to sell their good used cars because they cannot receive full value for them; prospective buyers discount all cars based on the possibility that they are lemons. Therefore, all used cars will be priced as though they are lemons, or at least not priced at the value of good used cars. Since owners of good used cars will never sell their good used cars at a price that prospective buyers are willing to pay, there will be no market for good used cars. Only a market for lemons will exist. All cars will be priced as lemons and good used cars will never be sold at such prices. This agency problem (conflict between the interests between buyers and sellers) breaks down the market for good used cars; only lemons can be sold in this market. The literature focuses on two primary solutions to this lemons problem: screening and signaling.

In the market for securities, for example, shares of stock, we often think of the investor as evaluating good and bad potential outcomes for the stock, then being willing to pay the stock's expected value for shares. However, what if the seller of the shares, such as in an IPO has better information, and knows whether the stock is or is not a good buy? First, the seller would never accept a price for a good stock based on an expected value since part of its expected value reflects the stock's value to the buyer as though it might be a bad stock. So, the good shares will never be sold when the seller has better information than the buyer. There is only a market for "lemon" shares.

Adverse Selection and Credit Rationing

Earlier, we characterized adverse selection as pre-contractual opportunism where one contracting party uses her private information to the other counterparty's disadvantage. Stiglitz and Weiss [1981] describe the adverse selection problem in a banking scenario. Their paradigm shows how interest rate levels might affect the pool of prospective borrowers as a result of adverse selection and why banks might ration credit when interest rates rise.

Let us consider an example involving a bank that can make \$100 loans, all at an interest rate of 5%, to both high-risk and low-risk borrowers, between which the bank cannot distinguish. The bank's "safe" customers will invest the loan proceeds in projects that will pay \$106 with certainty. If the bank were to invest \$100 by extending a very safe 5% loan to be repaid in one year, the expected future value of the loan would be \$105.

Now, consider an alternative strategy, in which the bank extends a loan of \$100 to a "risky" company at the same interest rate of 5%. The risky loan repayment is uncertain. Suppose that the probability of the risky loan being repaid is assumed to equal 80%, where the loan customer receives a project payoff equal to \$120. On the other hand, the probability of default equals 20%, in which case none of the balance of the loan is paid because the project payoff is zero. Thus, the potential profit levels to the loan customer equal \$120.00 - \$105.00 = \$15.00 with probability equal to .80 and \$0 with probability equal to 20%. Thus, the expected profit to the loan customer equals (.8×\$15) + (.2×0) = \$12.00. The expected profit to the bank is (.8×\$5) + (.2×-100) = -\$16. The bank earns a profit of \$15 on its performing loans and loses \$100 on its defaulted loans.

Suppose that the bank's market contains some proportion of low-risk borrowers and the remaining borrowers are high-risk. If the proportion of performing (low-risk) loans were to be sufficiently high, the bank would continue to make loans at an interest rate of 5%. Thus, in the low (5%) interest rate environment, the bank will continue to make loans as long as the pool of borrowers contains a sufficient number of lower risk companies to borrow.

Now suppose that the bank's cost of funds increases such that it needs to charge 10% on its loans. The bank's "safe" customers will not want to borrow at 10% because their investments will never cover the 10% required interest payment. Now, consider the bank's alternative strategy where the bank can extend a loan of \$100 at 10% to the risky company. Suppose that the probability of the loan being repaid are assumed to equal 80%, where the loan customer receives a project payoff equal to \$120 if the project is successful. On the other hand, the probability of default equal 20%, in which case none of the balance of the loan is paid because the project payoff is zero. The potential profits to the loan customer equals \$120.00 - \$110.00 = \$10.00 with probability equal to .80 and \$0 with probability equal to 20%. Thus, the expected profit to the loan customer equals \$8.00, still a profitable arrangement for the loan customer. The expected profit to the bank is (.8×10) + (.2×-100) = -\$12, a situation in which the bank still will not lend. Banks will not to lend when interest rates rise because their higher interest rates will force low-risk borrowers out of the market.

Now, what if the bank were to increase its rate to risky customers even more to cover potential losses? For example, if the bank were to increase its lending rate to 35%, increasing its expected profits to 0 = .8(135 - 110) + (.2×-100). While this rate enables the bank to break even on its loans, the expected profit to the borrower is certainly negative: .8(120-135) + (.2×0). The bank will never be able to lend at a rate that borrowers will be able to pay. Obviously, raising the interest rate to cover a higher cost of capital to the bank does not result in profitable loans; the higher interest rate simply forces away the safer and profitable loan customers. In this scenario, only the high-risk customers are willing to take loans, but only if there are low risk customers willing to pay at higher pooling rates.

How does the bank respond to this adverse selection problem in this higher interest rate environment? Rather than raise interest rates to cover the higher cost of borrowing, the bank will simply refuse to make loans (ration credit). Thus, when interest rates rise, banks will tend to ration credit rather than make low-risk loans. The adverse selection problem in an environment of rising interest rates, at least in the less dramatic scenario, causes banks to ration credit rather than necessarily cause the market for lending to break down. Increased screening and monitoring expenditures might mitigate this adverse selection problem.

Consider this problem in a labor market context. Suppose that a firm's per-unit sales revenues were to decline. Should the firm reduce wages paid to employees? If it attempted to do so, more productive employees would simply quit because their services would be more highly valued elsewhere. Alternatively, the firm can respond by firing employees, cutting expenses without losing a disproportionate number of more productive employees. The employer otherwise would never agree to pay a wage that employees would be willing to accept.

H. Mitigating Information Problems

An important mechanism to facilitate markets subject to moral hazard, adverse selection and other information asymmetries is improve the production, flow and symmetry of information. Methods by which to accomplish this include screening, signaling, monitoring and bonding, restrictive covenants, government regulation, collateral and appropriate securities and incentives structures. In addition, there are a few mechanisms to mitigate information asymmetry problems once they occur.

Screening

Screening can be accomplished by a principal observing choices made by an agent in the design of a contract. Screening is a contracting activity undertaken by principals without private information in an effort to discern qualities of prospective agents. For example, if a borrower were to insist on no limitations on risk-taking, the lender can infer that the borrower might be interested in taking excess risks. Of course, this might lead the lender to price the loan as a risky loan. Normally, uninformed principals offer contracts through which informed agents reveal their qualities through their choices on how the contracts are written. Since principals can easily observe and discern the information provided in contracts, they can infer agent qualities from the contract terms that they prefer.

Suppose, for example, that firms invest significant resources into the training of new employees and lose significant portions of that investment should employees resign. Firms will seek employees that will remain under their employ for long periods of time. When workers' willingness to commit is otherwise unobservable, firms can seek to induce workers to reveal their "stability" through the choices employees select in the contracting process. A prospective employer can offer a prospective employee an employment contract where workers receive below market wages for short periods of time followed by above market wages in the longer term. Should a prospective employee select this type of contract, the firm can infer that the employee is likely to remain with the firm for an extended period of time in order to enjoy higher future wages. Thus, successful screening is characterized by the uninformed agent designing a contract that is attractive only to the counterparty with the desired characteristics.

Screening can also take the form of recommendations or references from trustworthy sources. For example, a firm may wish to hire MBAs from a prestigious university not because of the training provided by that university but because the university is known for screening in its admissions processes. A university produces strong graduates because it accepts strong students. Similarly, recommendation letters from references are useful screening devises because they serve to diminish the reputation or prestige of the recommender should his recommendation advice ultimately become false. Thus, a professor who writes a strong letter for a weak student diminishes his own reputation. Similarly, a bank uses a screening process to refuse to lend to a client because its lending officer learns from a CEO's colleague that the borrowing CEO has a serious drinking problem.

Signaling

Signaling might be an even more effective device when the seller of a commodity or service has superior information than the buyer. Signaling can take the form of guarantees, investment in brand names or reputation, or other costly investment. Essentially, the signaling action imposes a cost on the signaling agent that would be prohibitively costly for the agent without the desired characteristic. A prospective MBA might seek a degree from a rigorous institution to signal that she has the aptitude to obtain a degree that is not prohibitively costly, whereas a low-aptitude MBA candidate might prefer a less rigorous institution because the likelihood of succeeding is simply too low at a more rigorous institution. The high-aptitude MBA attends the rigorous institution to distinguish herself from the low-aptitude MBA. Similarly, a strong corporation might pay a particularly high dividend to distinguish itself from a weaker corporation that simply cannot sustain a high dividend payment.

An informational equilibrium requires that the observed actions of better-informed agents yield valuable information to lesser-informed agents. In the Spence Paradigm, workers' observed actions, education, yields information regarding their productivity. Thus, workers obtain educations (degrees) to signal their initially unobservable attribute: productivity. If more productive workers can obtain degrees from rigorous programs of study at lower costs than less productive workers, then employers can distinguish between potential productivity levels of workers by observing their education levels.

A successful signal will have the following characteristics: It must transmit a non-ambiguous message to the desired audience, it must not be falsely duplicated by other agents, and it must be cost effective and the audience must react appropriately to the signal. Thus, the signaling, activity is directed towards two ends - advertising and authentication.

The lemons problem is easily extended to other markets, including those for financial securities. Consider, for example, a situation where owners of a private company wish to introduce their stock to the general public. If these managers are more knowledgeable about their companies' prospects than prospective investors, prospective investors may be reluctant to buy, believing that managers will only sell stock in their firms if the shares are not a good investment. How do corporations deal with this problem? The capital-seeking firm might seek to establish a long-term relationship with a bank that will regularly extend loans. In this scenario, which might result from *relationship banking*, the bank screens its clients and regularly monitors them. This screening and monitoring can mitigate the principal-agent and adverse-selection problems. Another possibility is for the corporation to engage a high-reputation investment bank or venture capital firm to, in effect, certify the relative strength of the firm seeking to raise money by issuing securities. Here, the firm issuing securities to the general public obtains at significant expense the services of a high-reputation investment bank to signal to the public that the investment bank is willing to stake its reputation on its client's newly issued securities.

Pooling and Signaling Equilibriums: An Illustration

Suppose that there are two types of prospective employees in the market, more capable and less capable, and assume that employees know whether they are more or less capable. More capable employees are more productive than less capable employees, hence, employers prefer to hire the more capable employees. However, employers are unable to distinguish between more and less capable employee applicants without some sort of credible signal from prospective employees. This leads to a pooling equilibrium.

Now, suppose that some proportion q of prospective employees is more productive, and that each of these more productive employees are twice as productive as the less productive employees, which make up proportion $(1-q)$ of the labor force. Thus, in this illustration, each less productive employee produces value equal to 1 and each more productive employee produces value equal to 2. But, the employer cannot distinguish more from less productive employees, so the *pooling* wage paid each employee equals $w' = 2q + (1-q)$, where proportion q of prospective employees are twice as productive as the remaining proportion (1-q) of employees. Thus, for example, if half of prospective employees are more productive, the pooling wage is w' = 2×(.5) + (1-.5) = 1.5.

Now, suppose that the more productive employees can obtain a university degree at half the cost $y/2$ (say, taking half the time) of the less productive employee who incurs cost y. For example, the more capable employee spends only half as much time learning essential material for the degree. A more productive employee can obtain a degree by incurring the cost of $y/2$; this action could serve as a credible signal to distinguish himself from a less productive employee if the less productive employee cannot replicate this action in a cost-effective manner. Since the maximum wage that a firm could pay to a more productive employee is 2 and the minimum wage payable to a less productive employee is 1, the signal is credible if the cost of the degree to the less productive employee exceeds 1. That is, the less productive employee will never attempt to obtain a degree at a cost exceeding 1 if the benefit of doing so is to raise his wage from 1 to 2. The more productive employee will be better off by incurring the cost of the degree if $2-y/2 > 2q + (1-q)$; that is, $y < 2-2q$, meaning that the cost of obtaining the degree is less than wage increase if he is recognized as being more productive than his counterpart without the degree. Thus, a signaling or *separating equilibrium* wage can be obtained when more productive employees obtain a degree at a cost of $y/2 > y^*/2$ with bounds on the separating wage y^* being $1 < y^* < 2 - 2q$. The lower bound ensures that less productive employees cannot replicate the action of the more productive employee while the upper bound ensures that the cost is worthwhile for the more productive employee to incur.

Monitoring and Bonding

Banks can engage in costly monitoring and bonding activities to ensure that borrowers do not impair their abilities to fulfill their borrowing obligations. For example, bank monitoring activities might include regular examinations of financial statements and management reports, site visits, interviews of customers and suppliers, etc. *Bonding*, the process of certifying or guaranteeing that borrowers fulfill their responsibilities to lenders, can take the form of having an outside auditor or CPA firm stake its reputation on the claims of the borrower. The actual expenditures can be costly, and can be reimbursed or even paid by borrowers themselves. Regardless, both activities can serve to reduce the costs information asymmetry in banking relationships.

Restrictive Covenants

Lending agreements regularly provide for *restrictive covenants*, which are intended to either prevent the borrower from engaging in activities that might impair its ability to fulfill the terms of the contract, or to engage in activities so as to enhance its ability to fulfill terms of the loan agreement. Restrictive covenants can include requirements to maintain certain financial ratios, prohibitions on selling fixed assets, making dividend payments, paying off other loans before they are due, and restrictions on managerial compensation. Violations of such covenants can result in the loan being declared in default, accelerated or called, as well as result in other financial penalties. When lenders cannot know the motives of borrowers or fully monitor their activities, restrictive covenants can enable lenders to make loans in environments characterized by asymmetric information. Collateral (securing a loan with an asset or assets) and sinking fund provisions (having the borrower set aside funds for eventual loan repayment) can also help the lender deal with information asymmetries.

Government Regulation, Insurance and Intervention

We will discuss government regulation of financial institutions in more detail later, but such regulation is generally used to improve transparency in environments with asymmetric information and to mitigation the ill effects of information asymmetries. Such regulation tends to apply to large numbers of financial institutions, or to institutions whose markets might be particularly affected by asymmetric information. The overriding purpose of such regulation is to avoid broader market failures that arise from asymmetric information.

Governments can also mitigate market problems when they arise from information asymmetries by offering deposit insurance (e.g., FDIC) to banks. When accompanied by various regulations and various restrictions on activities to protect themselves, governments can use deposit insurance to protect markets from the effects of information asymmetries. Of course, governments need to facilitate sound banking practices to ensure that their insurers are protected from bank failures.

To contend with the most egregious bank crises and market failure, governments can intervene in a number of ways in financial markets. For example, we will discuss later "too big to fail" policies, government assisted takeovers, bank closures and a variety of other intervention mechanisms.

Exercises

1. Members of tribal fishing societies generally undertake efforts to share information on where the fish are biting. Modern fishermen often purchase information identifying locations of schools of fish obtained from remote sensing satellite data. However, this information is often kept secret. Why do members of tribal societies share this information and modern fishermen opt not to share?

2. If the marginal production costs are the same, why do providers of stock prices charge less for delayed transactions data than for real time price data?

3. Suppose that a limited shareholder liability bank that has $1,000 in assets, financed by $950 in deposits at an interest rate of 3% and $50 in equity.

a. Suppose that the bank invests its $1,000 in ultra-safe 1-year government bonds paying interest at a rate of 4%. There is no risk of default. What would be the value of the bank in one year? Of this total value, what will be the cash flow received by depositors? What will be the cash flow received by shareholders?

b. Suppose instead that the bank invests its $1,000 in a consumer loans portfolio, which has a 90% chance of paying off $1,100 and a 10% chance of paying off $500. In the first and better scenario, what would be the value of the bank in one year? Of this total value, what will be the cash flow received by depositors? What will be the cash flow received by shareholders?

c. Continuing part b, in the second and weaker scenario, what would be the value of the bank in one year? Of this total value, what will be the cash flow received by depositors? What will be the cash flow received by shareholders?

d. Continuing parts b and c, what would be the total expected value of the bank in one year? Of this total value, what will be the expected value of the cash flow received by depositors? What will be the expected value of the cash flow received by shareholders?

e. Continuing parts a through d, which of the investment schemes should be preferred by shareholders? Which of the investment schemes should be preferred by depositors?

4. Suppose that a bank with $5,000,000 market value in assets is obliged to repay $4,500,000 face value to depositors in two years. There are no other interest payments due to depositors. The current riskless rate of return is 5% per annum and the standard deviation of annual returns on the bank's loans is .2. Assume that all Black-Scholes assumptions hold for this bank.

a. What is the initial value of the bank's equity?
b. Suppose that the bank is insured by FDIC. What is the initial value of the FDIC insurance policy to the bank?
c. What is the initial value of the bank's deposits?
d. Suppose that this bank maintains deposit insurance, and, in two years, the value of the bank's assets is $5,500,000. What will be the value of deposits at that time? What will be the value of bank equity at that time? What will be the value of the deposit insurer claim on the bank at that time?
e. Suppose that instead, in two years, the value of the bank's assets declines to $3,500,000. What will be the value of deposits at that time? What will be the value of bank equity at that time? What will be the value of the deposit insurer claim on the bank at that time?

5. Four of the 5 inputs required to implement the Black-Scholes model are very easily obtained. The option exercise price and term to expiry are defined by the option contract. The riskless return and underlying stock price are based on current quotes. Only the underlying stock return volatility is an issue. The traditional sample estimating procedure (historical return variance) requires the assumption of stable variance estimates over time; more specifically, that future variances equal or can be estimated from historical variances. A procedure first suggested by Latane and Rendleman [1976] is based on market prices of options that might be used to imply variance estimates. For example, the Black-Scholes Option Pricing Model and its extensions provide an excellent means to estimate underlying stock variances if market prices of calls are known. Essentially, this procedure determines market estimates for underlying stock variance based on known market prices for options on the underlying securities. Consider the following example pertaining to a six-month call currently trading for $8.20 and its underlying stock currently trading for $75:

$T = .5 \quad r_f = .10 \quad c_0 = 8.20$

$X = 80 \quad S_0 = 75$

What volatility (standard deviation) does the market imply for the stock on this company?

6. Emu Company stock currently trades for $50 per share. The current riskless return rate is .06. Under the Black-Scholes framework, what would be the standard deviations implied by six-month (.5 year) European calls with current market values based on each of the following striking prices? That is, with market prices of calls taken as given and equal to Black-Scholes estimates, what standard deviation estimates in Black-Scholes models would yield call values equal to market values in each of the following scenarios?

a. $X = 40;\ c_0 = 11.50$
b. $X = 45;\ c_0 = 8.25$
c. $X = 50;\ c_0 = 4.75$
d. $X = 55;\ c_0 = 2.50$
e. $X = 60;\ c_0 = 1.25$

7. As of 2019, FDIC deposit insurance guarantees depositor accounts for up to $250,000. How might increasing this insurance limit worsen the moral hazard problem for banks?

8. Consider a borrower that obtains all of its credit and funding from a single bank as opposed to many different banks (transactional or contract banking). This relationship between the bank and the borrower has been maintained for many years, and requires that the borrower regularly submit financial statements and management operating data to the bank.

a. Might this relationship between the bank and the borrower seem to typify relationship lending?

b. While the sharing of proprietary information by the borrower with its bank facilitates the extension of credit, under what circumstances might it actually increase the likelihood of default relative to a market-based or contract-based lending relationships with many banks?

9. Suppose that you seek to buy a used car from a local dealer. You are attracted to a particular car with a dealer price of $25,000, which you estimate to be fair only if the car is in perfect condition, and displays none of the characteristics associated with a "lemon." On the other hand, you believe that the car is worth only $15,000 if it is an unmitigated lemon. Since you know

nothing about populations of good and bad used cars, you assume that either scenario is equally likely. Furthermore, both you and the dealer seek to maximize expected payoffs; you seek to maximize the expected value of the difference between the value of the car and what you pay for it and the dealer seeks to maximize the difference between the sales price of the car and its value, based on his own expectations.

a. Suppose that the dealer knows as little about the value of the car as you do. What is the maximum price you should offer for the car, what is the minimum price that the dealer will accept and what, if it exists, should be the transaction price for the car?
b. Suppose that the dealer has the car's service records, can precisely determine its mechanical condition, fully understands the market for used cars, and knows the car's previous owner. Hence, the dealer knows exactly what the car is worth. What is the maximum price you should offer for the car, what is the minimum price that the dealer will accept and what, if it exists, should be the transaction price for the car?
c. Suppose that a reliable certification (bonding) agency exists for used cars, and will certify if a car can be expected to be perfectly reliable. How might this certification agency be used to mitigate the market for lemons (actually, for good used cars)? Might a 30-day "money-back" guarantee serve the same purpose?

10. There may be significant information content in a firm's (or bank's) dividend policy. Numerous studies, including Asquith and Mullins (1983), who studied the market's reaction to dividend announcements have found a significant positive relationship between dividends and announcement date abnormal returns. Corporate managers tend to be very reluctant to cut dividends. Thus when management increases its dividends, it may be "signaling" to the market that it anticipates being able to maintain higher earnings over an extended period of time sufficient to sustain dividend payments at this increased level. If shareholders believe that an increased dividend is indicative of higher future earnings, they will bid up that price of the company's stock. What are the qualities of a dividend payment that would enable it to be a successful signal of firm quality?

11.a. How are the adverse selection and moral hazard problems similar?
b. How are the adverse selection and moral hazard problems different?

12. Moral hazard occurs when a bank's management has an incentive to increase risk levels to socially sub-optimal levels. Some economists argue that when such banks approach failure, the government should at least consider bailing them out because the economic and social costs of bank failure and bank crises are simply too high. Other economists argue that such bailouts tend to encourage more undesirable risk-taking by banks, and that such banks should simply be allowed to fail. Furthermore, allowing such banks to fail will encourage more productive screening, monitoring and research activities among clients and lenders who wish to avoid problems associated with doing business with a failed bank. Consider an unrelated scenario. When the R.M.S. Titanic sank in 1912, it did not have onboard enough safety equipment such as lifeboats, search lights and life preservers. Should such obvious deficiencies result in limited efforts to rescue passengers on the doomed vessel?

13. Describe how relationship banking can improve information asymmetries that exist in banking transactions.

Exercise Responses

1. Perhaps there are many reasons for this, but the most relevant to this chapter is that members of the tribal society share in the catch of fish whereas modern fishermen compete against one another to harvest the catch.

2. Marginal production costs for stock price data is practically zero, so pricing is based on consumer value. Providers of data engage in price discrimination, and assume that those who want real time data value data more than those who would purchase delayed data.

3. a. By investing \$1,000 in government bonds, the bank will be worth \$1,040 in one year. Depositors will be entitled to \$950 · 1.03 = \$978.50 and shareholders would receive the remaining $MAX[0, S_T - X]$ = MAX [0, (\$1,000 · 1.05) - \$978.50] = \$71.50.

b. By investing \$1,000 in consumer loans, the bank will be worth \$1,100 in one year, contingent of the strong outcome. Depositors will be entitled to \$950 · 1.03 = \$978.50 and shareholders would receive the remaining $MAX[0, S_T - X]$ = MAX [0, \$1,100 - \$978.50] = \$121.50.

c. By investing \$1,000 in consumer loans, the bank will be worth \$500 in one year, contingent of the weak outcome. Depositors will be entitled to the entire \$500 and shareholders would receive nothing: $MAX[0, S_T - X]$ = MAX [0, \$500 - \$978.50] = \$0.

d. The expected value of total bank cash flows is (.9 · \$1,100) + (.1 · \$500) = \$1,040. The expected value of cash flows to depositors is (.9 · \$978.50) + (.1 · \$500) = \$930.65. The expected value of cash flows to shareholders is (.9 · \$121.50) + (.1 · \$0) = \$109. 35.

e. Depositors prefer the government bond investment scheme to the consumer loan scheme. Despite the fact that the bank is worth less under the consumer loan investment scheme, shareholders will prefer it to the government bond investment scheme.

4.a. Our first step is to obtain the bank's equity value, based on the assumption that the equity is a call option to purchase the bank's assets:

$$d_1 = \frac{\ln\left(\frac{5{,}000{,}000}{4{,}500{,}000}\right) + \left(.05 + \frac{1}{2}\times .2^2\right)\times 2}{.2\sqrt{2}} = 0.86748; N(d_1) = .807161$$

$$d_2 = 0.867161 - .2\sqrt{2} = 0.584638\,; N(d_2) = .720604$$

$$Equity\ Value = c_0 = 5{,}000{,}000 \times .807161 - \frac{4{,}500{,}000}{e^{.05\times 2}} \times .720604 = 1{,}101{,}669$$

b. Next, we begin the process of valuing the firm's debt. We first value the risk premium associated with firm default, assuming that the firm's shareholders might put the firm's assets to creditors by refusing to pay debt obligations:

$$p_0 = 1{,}101{,}669 + 4{,}500{,}000 \times .904837 - 5{,}000{,}000 = 173{,}437.4$$

c. Independently of the risk component of debt, the firm has an outstanding obligation of 4,500,000, payable in two years in an environment with a riskless discount rate equal to 5%:

$$Xe^{-r_f T} = 4{,}500{,}000 \times e^{-.05\times 2} = 4{,}500{,}000 \times .904837 = 4{,}071{,}768$$

d. Depositors receive face value X = \$4,500,000. Shareholders receive the residual value c_2 = \$5,500,000-\$4,500,000 = \$1,000,000. The insurer stake in the firm is p_2 = 0.

e. Depositors receive face value X = \$4,500,000. Shareholders receive the larger of zero or residual value c_2 = MAX[$3,500,000-$4,500,000, 0] = 0. The insurer stake in the firm, the short position on a put on assets, is p_2 = MIN[0, $3,500,000-$4,500,000] = -$1,000,000. Hence, the insurer is obliged to fulfill shareholder obligations to depositors.

5. We find that this system of equations holds when σ = .411. That is, if investors use the Black-Scholes Options Pricing Model to value calls, the following must hold:

$$8.20 = 75 \cdot N(d_1) - 80e^{-.1\times.5} \cdot N(d_2)$$

$$d_1 = \frac{\ln\left(\frac{75}{80}\right) + \left(.1 + .5 \times \sigma^2\right) \cdot .5}{\sigma\sqrt{.5}}$$

$$d_2 = d_1 - \sigma\sqrt{.5}$$

Thus, the market prices this call as though it expects that the standard deviation of anticipated returns for the underlying stock is .411. Unfortunately, the system of equations required to obtain an implied variance has no closed form solution. That is, we will be unable to solve this equation set explicitly for standard deviation; we must search, iterate and substitute for a solution. Each trial solution for σ will produce a different c_0; higher trial σ's will produce higher values for c0 and lower trial values for will produce lower values. Thus, we will increase and decrease our trial value for σ until our resulting call value equals c_0. One can substitute trial values for σ until she finds one that solves the system. A significant amount of time can be saved by using one of several well-known numerical search procedures such as the Method of Bisection or the Newton-Raphson Method discussed elsewhere.

6. Implied volatilities are given as follows:

a. X = 40; σ = .2579
b. X = 45; σ = .3312
c. X = 50; σ = .2851
d. X = 55; σ = .2715
e. X = 60; σ = .2704

These values are obtained through a process of substitution (guess) and iteration (guess again and again as necessary).

7. The moral hazard problem is somewhat mitigated by the deposit insurance limit in that large depositors have an incentive to monitor the operations of the bank to ensure the safety of their deposits. Increasing the insurance limit reduces the monitoring incentive and worsens the moral hazard problem.

8.a. Yes

b. Relationship lending facilitates loan contract renegotiation relative to market-based relationships because with a single lender, renegotiations are easier and more flexibility. Hence, borrowers might use this ease and flexibility to renegotiate terms of loans even when they are not experiencing extreme financial distress.

9.a. The scenario here involves symmetric information availability, therefore, the transaction price will result from a pooling equilibrium. Since each condition outcome has an associated probability of 50%, you are willing to offer up to $20,000 ($25,000*.5+14,000*.5) for the car. The dealer should be willing to accept as little as $20,000 for the car. Therefore, the transaction price is $20,000.

b. The scenario here involves asymmetric information availability, resulting in a lemons problem. You first assess what conditions at which the dealer will sell the car. If it is a good used car, the dealer will know this and will view the car as being worth $25,000 and will not accept less. If the car is a lemon, again, the dealer will know this and will view the car as being worth $15,000 and will accept any offer above this value. Thus, you know that if the dealer will accept any price under $25,000, it is a lemon; in fact, it might well be a lemon even if the dealer won't accept less than $25,000. Thus, you will never pay more than $15,000 for the car. The dealer will sell the car to you only if it is a lemon. Thus, in the event of information asymmetry, a market for the car exists only if it is a lemon, in which case, its transaction price is $15,000.

c. If a certification agency can certify the reliability of a car, then the dealer (or buyer) could pay the agency to evaluate it, and certify it as being good as might be warranted. Of course, this certification might well drive up the price and value of a good used car, so the cost of the certification must justify its expense. A 30-day "money-back" guarantee might well serve the same purpose as the certification. However, the agency offering the certification or the dealer offering the warranty must have strong reputations or otherwise be considered to be reliable.

10. A successful signal will have the following characteristics: It must transmit a non-ambiguous message to the desired audience (i.e., high dividend imply high firm cash flows), it must not be falsely duplicated by other agents (a weak firm cannot pay high dividends), it must be cost effective (the dividend does not impair the strong firm's operations) and the audience must react appropriately to the signal (shareholders bid up the price of the stock). Thus, the signaling, activity is directed towards two ends - advertising and authentication.

11.a. Both problems arise from information asymmetries, when actions cannot be costlessly observed. The problem originates when one party to a transaction uses his unique or superior information to exploit or transfer wealth away from his transaction counterpart. When potential market participants expect to be exploited by either moral hazard or adverse selection, market frictions result, potentially eliminating the possibility for welfare-increasing transactions. That is, moral hazard problems can cause markets to fail or cease to function.

b. The adverse selection problem arises from hidden attributes of the good, service or instrument to be exchanged, resulting from information asymmetries *before* the transaction is executed. Moral hazard results from hidden, unanticipated or unpreventable *actions* that occur *after* the transaction is executed.

12. Rather than answer this rhetorical question here, we ask that the reader consider the analogies between the scenarios, including consideration for uninformed customers, moral hazard and risk-taking incentives, bail-outs, etc.

13. Relationship banking is often able to diminish the problem of asymmetric information and sharing of proprietary information by establishing a relationship of trust between businesses and banks. Such long-term relationships improve information gathering efficiencies by using information previously gathered and by expanding the range of services offered by banks to their

clients.

References

Akerlof, G. A. (1970): “The Market for ‘Lemons’: Quality Uncertainty and the Market Mechanism," *Quarterly Journal of Economics* 84: pp. 488–500.

Asquith, Paul, and David W. Mullins, Jr. (1983): "The impact of Initiating Dividend Payments on Shareholders' Wealth," *Journal of Business* 56, pp. 77-96.

Berle, Adolph A. and Gardiner C. Means (1932): *The Modern Corporation and Private Property* (New York: Harcourt, Brace & World, reprinted 1968.

Black, Fischer and Myron Scholes (1972): "The Valuation of Options Contracts and a Test of Market Efficiency," *Journal of Finance*, 27, pp. 399-417.

Black, Fischer and Myron Scholes (1973): "The Pricing of Options and Corporate Liabilities, *Journal of Political Economy*, vol. 81, pp. 637-654.

Gorton, Gary B. (2008). “The Panic of 2007,” in Federal Reserve Bank of Kansas City, Proceedings of Jackson Hole Conference, Maintaining Stability in a Changing Financial System.

Jensen, M.C., and Meckling, W. (1976): “Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure”, in J. Michael Brennan, ed., *The Theory of Corporate Finance*. Vol. 1, Cheltenham, UK: Elgar, 1996, pp.35–90.

Klein, Benjamin, Robert Crawford, and Armen Alchian (1978): ‘‘Vertical Integration, Appropriable Rents, and the Competitive Contracting Process,’’ *Journal of Law and Economics* 21, pp. 297–326.

Latane, Henry and Richard Rendleman (1976): “Standard Deviations of Stock Price Ratios Implied by Option Prices,” *Journal of Finance* 31: pp. 369-381.

Leland, H. and D. Pyle (1977): "Information Asymmetries, Financial Structure, and Financial Intermediation," *Journal of Finance*, pp. 371-387.

Manne, H. (1965): "Mergers and the Market for Corporate Control," *Journal of Political Economy*, 73, pp. 110-120.

Merton, Robert C. (1973): "Theory of Rational Option Pricing," Bell Journal of Economics and *Management Science*, 4 (1), pp. 141-183.

Spence, Michael (1974): *Market Signaling*. Cambridge, Mass.: Harvard University Press.

Spence, Michael. Job Market Signaling", *Quarterly Journal of Economics*, August 1973: pp. 355–379.

Stiglitz, Joseph E. and Andrew Weiss (1981). "Credit Rationing in Markets with Imperfect Information." *The American Economic Review* 71(3), pp. 393-410.

Stoll, Hans (1969): "The Relationship Between Put and Call Option Prices," *Journal of Finance* 24, 801-824.

Teall. John L. (2018): *Financial Trading and Investing*, 2nd ed. San Diego, California: Academic Press.

Williamson, Oliver, *The Economic Institutions of Capitalism*. New York: The Free Press, 1985.

Woodward, S. (1985): "The Economics of Limited Liability," *Journal of Economic Theory and Institutions*, 141-1, pp.187-195.

Appendix 3.A: A Primer on Black-Scholes Option Pricing

Calls and Puts

First, we will introduce a few option basics. A *stock option* is a legal contract that grants its owner the right (though, not obligation) to either buy or sell a given stock. There are two types of stock options: puts and calls. A *call* grants its owner to purchase stock (called underlying shares) for a specified exercise price (also known as a striking price or exercise price) on or before the expiration date of the contract. In a sense, a call is similar to a coupon that one might find in a newspaper enabling its owner to, for example, purchase a roll of paper towels for one dollar. If the coupon represents a bargain, it will be exercised and the consumer will purchase the paper towels. If the coupon is not worth exercising, it will simply be allowed to expire. The value of the coupon when exercised would be the amount by which value of the paper towels exceeds one dollar (or zero if the paper towels are worth less than one dollar). Similarly, the value of a call option at exercise equals the difference between the underlying market price of the stock and the exercise price of the call.

An investor can take any combination of positions in an underlying security and/or calls and puts that trade on the security. Long positions reflect purchases while short positions reflect sales. Table A.1 describes a single long and short position in each of the six individual securities. Future (time *T*, expiration date) payoffs are given in the table. Long positions require time zero purchase payments of S_0, c_0 and p_0 to invest, while short positions resulting from sales result in time zero cash flows of S_0, c_0 and p_0 to the sellers.

Your Position	Payoff if $S_T \leq X$	Payoff if $S_T > X$	Notes on your Position
Long Underlying	S_T	S_T	You own the underlying asset
Short Underlying	$- S_T$	$- S_T$	You short sold the underlying asset
Long Call	0	S_T-X	You dispose of or exercise the call
Short Call	0	-(S_T-X)	You are obliged to allow exercise
Long Put	(X-S_T)	0	You exercise or dispose of the put
Short Put	-(X-S_T)	0	You are obliged to allow exercise

Table A.1: Stock and Plain Vanilla Option Position Payoffs

Illustration

Suppose, for example, that there is a call option with an exercise price of $90 on one share of stock. The option expires in one year. This share of stock is expected to be worth either $80 or $120 in one year, but we do not know which at the present time. If the stock were to be worth $80 when the call expires, its owner should decline to exercise the call. It would simply not be practical to use the call to purchase stock for $90 (the exercise price) when it can be purchased in the market for $80. The call would expire worthless in this case. If, instead, the stock were to be worth $120 when the call expires, its owner should exercise the call. Its owner would then be able to pay $90 for a share that has a market value of $120, representing a $30 profit. In this case, the call would be worth $30 when it expires. Let T designate the options term to expiry, S_T the stock value at option expiry and c_T be the value of the call option at expiry determined as follows:

(1) $$c_T = MAX[0, S_T - X]$$

$$\text{When } S_T = 80,\ c_T = \text{MAX}[0, 80 - 90] = 0$$
$$\text{When } S_T=120,\ c_T = \text{MAX}[0, 120 - 90] = 30$$

A put grants its owner the right to sell the underlying stock at a specified exercise price on or before its expiration date. A put contract is similar to an insurance contract. For example, an owner of stock may purchase a put contract ensuring that he can sell his stock for the exercise price given by the put contract. The value of the put when exercised is equal to the amount by which the put exercise price exceeds the underlying stock price (or zero if the put is never exercised).

To continue the above example, suppose that there is a put option with an exercise price of $90 on one share of stock. The put option expires in one year. Again, this share of stock is expected to be worth either $80 or $120 in one year, but we do not know which yet. If the stock were to be worth $80 when the put expires, its owner should exercise the put. In this case, its owner could use the put to sell stock for $90 (the exercise price) when it can be purchased in the market for $80. The put would be worth $10 in this case. If, instead, the stock were to be worth $120 when the put expires, its owner should not exercise the put. Its owner should not accept $90 for a share that has a market value of $120. In this case, the call would be worth nothing when it expires. Let p_T be the value of the put option at expiry, determined as follows:

(2) $$p_T = \text{MAX}[0, X - S_T]$$

$$\text{When } S_T=80,\ p_T = \text{MAX}[0, 90 - 80] = 10$$
$$\text{When } S_T=120,\ p_T = \text{MAX}[0, 90 - 120] = 0$$

Thus, Table A.1 can be rewritten for our example as Table A.2. In Table A.2, the total Time 1 payoff from purchasing and selling the underlying asset is either 80 or 120. The total Time 1 payoff from short selling and then repurchasing is either -80 or -120. The short seller sells to the buyer at Time 0; the buyer sells to the short seller at Time 1. The short-seller must repurchase the stock.

The Time 1 profit from purchasing the call, ignoring the Time 0 premium paid at purchase, is either 0=MAX[0, 80-90] or 30=MAX[0,120-90]; in the first instance, the call is disposed of, in the second, the call is exercised. The Time 1 profit from selling (writing) the call, ignoring the Time 0 premium, is either 0 = -MAX[0, 80-90] or -30 = -MAX[0,120-90].

The Time 1 profit from purchasing the put, ignoring the Time 0 premium at its sale, is either 10= MAX[0, 90-80] or 0 = MAX[0,90-120]; in the first instance, the put is exercised, in the second, the put is disposed of. The Time 1 profit from selling (writing) the put, ignoring the Time 0 premium, is either -10 = -MAX[0, 90-80] or 0 = -MAX[0,90-120].

Your Position	Payoff if $S_1 \leq 90$	Payoff if $S_1 > 90$	Notes on your Position
Long Underlying	80	120	You own the underlying asset
Short Underlying	- 80	- 120	You short sold the underlying asset
Long Call	0	30	You dispose of or exercise the call
Short Call	0	- 30	You are obliged to allow exercise
Long Put	10	0	You exercise or dispose of the put
Short Put	- 10	0	You are obliged to allow exercise

Table A.2: Stock and Plain Vanilla Option Position Payoffs Example

Long for Option; Short for Obligation

The owner of the option contract may exercise his right to buy or sell; however, he is not obligated to do so. Stock options are simply contracts between two investors issued with the aid of a clearing corporation, exchange and broker, which ensure that investors honor their obligations to each other. The corporation whose stock options are traded will probably not issue and does not necessarily trade these options. Investors, typically through a clearing corporation, exchange and brokerage firm, create and trade option contracts amongst themselves.

For each owner of an option contract, there is a seller or "writer" who creates the contract, sells it to a buyer and must satisfy an obligation to the owner of the option contract. The option writer sells (in the case of a call exercise) or buys (in the case of a put exercise) the stock when the option owner exercises. The owner of a call is likely to profit if the stock underlying the option increases in value sufficiently over the exercise price of the option (he can buy the stock for less than its market value); the owner of a put is likely to profit if the underlying stock declines in value sufficiently below the exercise price (he can sell stock for more than its market value). Since the option owner's right to exercise represents an obligation to the option writer, the option owner's profits are equal to the option writer's losses. Therefore, an option must be purchased from the option writer; the option writer receives a "premium" from the option purchaser for assuming the risk of loss associated with enabling the option owner to exercise. Next, we begin the process of determining the call and put values at time zero.

<u>The Black Scholes Model</u>

The Black-Scholes Options Pricing Model provides a simple mechanism for valuing calls under certain assumptions. If circumstances are appropriate to apply the Black-Scholes model, call options can be valued with the following:

(3)

$$c_0 = S_0 N(d_1) - \frac{X}{e^{r_f T}} N(d_2)$$

(4)

$$d_1 = \frac{ln\left(\frac{S_0}{X}\right) + \left(r_f + \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}}$$

(5)

$$d_2 = d_1 - \sigma\sqrt{T}$$

where N(d*) is the cumulative normal distribution function for (d*). This function might be referred to in a statistics setting as the "z" value for (d*). From a computational perspective, one would first work through Equation (4), then Equation (5) before valuing the call with Equation (3). $N(d_1)$ and $N(d_2)$ are areas under the standard normal distribution curves (z-values). Simply locate the z-value on an appropriate table (see the z-table in chapter Appendix B) corresponding to the $N(d_1)$ and $N(d_2)$ values.

Consider the following simple illustration of a Black-Scholes Model application: An investor has the opportunity to purchase a six month call option for $7.00 on a stock which is currently selling for \$75. The exercise price of the call is \$80 and the current riskless rate of return is 10% per annum. The variance of annual returns on the underlying stock is 16%. At its current price of \$7.00, does this option represent a good investment? First, we note the model inputs in symbolic form:

$T = .5 \qquad r_f = .10 \qquad \sigma = .4 \qquad S_0 = 75$

$X = 80 \qquad \sigma^2 = .16$

Our first steps are to find d_1 and d_2 from Equations 4 and 5:

$$d_1 = \frac{ln\left(\frac{75}{80}\right) + \left(0.10 + \frac{1}{2}.4^2\right) \times 0.5}{0.4 \times \sqrt{.5}} = \frac{ln(0.9375) + 0.09}{0.2828} = 0.09$$

$$d_2 = 0.09 - 0.4 \times \sqrt{.5} = 0.0909 - .2828 = -0.1928$$

Next, by either using a z-table (see Table A.4.a in the text Appendix) or by using an appropriate estimation function from a statistics manual, we find normal density functions for d_1 and d_2:

$$N(d_1) = N(0.09) = 0.536; \quad N(d_2) = N(-0.1928) = 0.424$$

Finally, we use $N(d_1)$ and $N(d_1)$ in Equation (3) to value the call:

$$c_0 = 75 \times 0.536 - \frac{80}{e^{.10 \times .5}} \times 0.42 = 7.96$$

Since the 7.96 estimated value of the call exceeds its 7.00 market price, the call should be purchased.

Put-Call Parity

If we subtract Equation 2 from Equation 1 from we obtain the terminal value *put-call relation*:

(6) $c_T - p_T = MAX[0, S_T - X] - MAX[0, X - S_T] = S_T - X$

A slight rewrite of this terminal put-call relation allows us to write the terminal or exercise value a put given the terminal value of a call with identical exercise terms:

(4) $p_T = c_T + X - S_T$

Since the terminal value of a put is always given by Equation 4, the time zero value of a put must be given by Equation 5:

(5) $p_0 = c_0 + X \times e^{-r_f T} - S_0$

$p_0 = 7.96 + 80(0.9512) - 75 = 9.06$

Appendix Exercises

1. Call and put options with an exercise price of \$30 are traded on one share of Company X stock.

a. What is the value of the call and the put if the stock is worth \$33 when the options expire?

b. What is the value of the call and the put if the stock is worth \$22 when the options expire?

c. What is the value of the call writer's obligation stock is worth \$33 when the options expire? What is the value of the put writer's obligation stock is worth \$33 when the options expire?

d. What is the value of the call writer's obligation stock is worth \$22 when the options expire? What is the value of the put writer's obligation stock is worth \$22 when the options expire?

e. Suppose that the purchaser of a call in part a paid \$1.75 for his option. What was the profit on his investment?

f. Suppose that the purchaser of a call in part b paid \$1.75 for his option. What was the profit on his investment?

2. An investor has the opportunity to purchase a three-year call option on a stock that is currently selling for \$150. The exercise price of the call is \$140 and the current riskless rate of return is 2% per annum. The variance of annual returns on the underlying stock is 16%. What is the value of this call?

3. Evaluate calls for each of the following European stock option series:

Option 1	Option 2	Option 3	Option 4
$T = 1$	$T = 1$	$T = 1$	$T = 2$
$S = 30$	$S = 30$	$S = 30$	$S = 30$
$\sigma = .3$	$\sigma = .3$	$\sigma = .5$	$\sigma = .3$
$r_f = .06$	$r_f = .06$	$r_f = .06$	$r_f = .06$
$X = 25$	$X = 35$	$X = 35$	$X = 35$

Appendix Exercise Solutions

1. a. $c_T = \$33 - \$30 = \$3$; $p_T = 0$

   b. $c_T = 0$; $p_T = \$30 - \$22 = \$8$

   c. $c_T = -\$3$; $p_T = 0$

   d. $c_T = 0$; $p_T = -\$8$

   e. \$3 - \$1.75 = \$1.25

   f. \$0 - \$1.75 = -\$1.75

2. First, we note the model inputs in symbolic form:

$T = 3 \quad r_f = .02 \quad \sigma = .4 \quad S_0 = 150 \quad X = 140 \quad \sigma^2 = .16$

Our first steps are to find d_1 and d_2:

$$d_1 = \frac{ln\left(\frac{150}{140}\right) + \left(0.02 + \frac{1}{2} \times .16\right) \times 3}{0.4 \times \sqrt{3}} = \frac{ln(1.07) + 0.3}{0{,}4 \times 1.736} = 0.5326$$

$$d_2 = 0.5326 - 0.4 \times \sqrt{3} = 0.5326 - .0.693 = -0.16$$

Next, by either using a z-table (see Table in the text Appendix) or by using an appropriate estimation function from a statistics manual or spreadsheet, we find normal density functions for d_1 and d_2:

$$N(d_1) = N(0.5326) = 0.7; \quad N(d_2) = N(-0.16) = 0.436$$

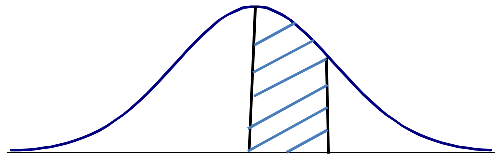
Finally, we use $N(d_1)$ and $N(d_1)$ to value the call:

$$c_0 = 150 \times 0.7 - \frac{140}{e^{.02 \times 3}} \times 0.436 = 48$$

3. The options are valued with the Black-Scholes Model in a step-by-step format in the following table:

	OPTION 1	OPTION 2	OPTION 3	OPTION 4
d(1)	.957739	-.163836	.061699	.131638
d(2)	.657739	-.463836	-.438301	-.292626
N[d(1)]	.830903	.434930	.524599	.552365
N[d(2)]	.744647	.321383	.330584	.384904
Call	7.395	2.455	4.841	4.623

Appendix 3.B: z-table



The Normal Density Function
The z-Table

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	.0000	.0040	.0080	.0120	.0159	.0199	.0239	.0279	.0319	.0358
0.1	.0398	.0438	.0478	.0517	.0557	.0596	.0636	.0675	.0714	.0753
0.2	.0793	.0832	.0871	.0909	.0948	.0987	.1026	.1064	.1103	.1141
0.3	.1179	.1217	.1255	.1293	.1331	.1368	.1406	.1443	.1480	.1517
0.4	.1554	.1591	.1628	.1664	.1700	.1736	.1772	.1808	.1844	.1879
0.5	.1915	.1950	.1985	.2019	.2054	.2088	.2123	.2157	.2190	.2224
0.6	.2257	.2291	.2324	.2356	.2389	.2421	.2454	.2486	.2517	.2549
0.7	.2580	.2611	.2642	.2673	.2703	.2734	.2764	.2793	.2823	.2852
0.8	.2881	.2910	.2939	.2967	.2995	.3023	.3051	.3078	.3106	.3133
0.9	.3159	.3186	.3212	.3238	.3264	.3289	.3315	.3340	.3365	.3389
1.0	.3413	.3437	.3461	.3485	.3508	.3531	.3554	.3577	.3599	.3621
1.1	.3643	.3665	.3686	.3708	.3729	.3749	.3770	.3790	.3810	.3830
1.2	.3849	.3869	.3888	.3906	.3925	.3943	.3962	.3980	.3997	.4015
1.3	.4032	.4049	.4066	.4082	.4099	.4115	.4131	.4147	.4162	.4177
1.4	.4192	.4207	.4222	.4236	.4251	.4265	.4279	.4292	.4306	.4319
1.5	.4332	.4345	.4357	.4370	.4382	.4394	.4406	.4418	.4429	.4441
1.6	.4452	.4463	.4474	.4484	.4495	.4505	.4515	.4525	.4535	.4545
1.7	.4554	.4564	.4573	.4582	.4591	.4599	.4608	.4616	.4625	.4633
1.8	.4641	.4649	.4656	.4664	.4671	.4678	.4686	.4693	.4699	.4706
1.9	.4713	.4719	.4726	.4732	.4738	.4744	.4750	.4756	.4761	.4767
2.0	.4772	.4778	.4783	.4788	.4793	.4798	.4803	.4808	.4812	.4817
2.1	.4821	.4826	.4830	.4834	.4838	.4842	.4846	.4850	.4854	.4857
2.2	.4861	.4864	.4868	.4871	.4875	.4878	.4881	.4884	.4887	.4890
2.3	.4893	.4896	.4898	.4901	.4904	.4906	.4909	.4911	.4913	.4916
2.4	.4918	.4920	.4922	.4925	.4927	.4929	.4931	.4932	.4934	.4936
2.5	.4938	.4940	.4941	.4943	.4945	.4946	.4948	.4949	.4951	.4952
2.6	.4953	.4955	.4956	.4957	.4959	.4960	.4961	.4962	.4963	.4964
2.7	.4965	.4966	.4967	.4968	.4969	.4970	.4971	.4972	.4973	.4974
2.8	.4974	.4975	.4976	.4977	.4977	.4978	.4979	.4979	.4980	.4981
2.9	.4981	.4982	.4982	.4983	.4984	.4984	.4985	.4985	.4986	.4986
3.0	.4986	.4987	.4987	.4988	.4988	.4989	.4989	.4989	.4990	.4990

The areas given here are from the mean (zero) to z standard deviations to the right of the mean. To get the area to the left of z, simply add .5 to the value given on the table.

Appendix 3.C: Black-Scholes Implied Volatility

Four of the 5 inputs required to implement the Black-Scholes model are easily observed. The option exercise price and term to expiry are defined by the option contract. The riskless return and underlying stock price are based on current quotes. Only the underlying stock return volatility during the life of the option cannot be observed. Instead, we often employ a traditional sample estimating procedure for return variance:

$$\sigma^2 = Var[r_t] = Var[lnS_t - lnS_{t-1}]$$

The difficulty with this procedure is that it requires that we assume that underlying security return variance is stable over time; more specifically, that future variances equal or can be estimated from historical variances. An alternative procedure first suggested by Latane and Rendleman [1976] is based on market prices of options that might be used to imply variance estimates. For example, the Black-Scholes Option Pricing Model might provide an excellent means to estimate underlying stock variances if the market prices of one or more relevant calls and puts are known. Essentially, this procedure determines market estimates for underlying stock variance based on known market prices for options on the underlying securities. When we use this procedure, we assume that the market reveals its estimate of volatility through the market prices of options.

Consider the following example pertaining to a six-month call currently trading for $8.20 and its underlying stock currently trading for $75:

$$T = .5 \qquad r = .10 \qquad c_0 = 8.20$$
$$X = 80 \qquad S_0 = 75$$

If investors use the Black-Scholes Options Pricing Model to value calls, the following should be expected:

$$8.20 = 75N(d_1) - 80e^{-.1\times.5}N(d_2)$$

$$d_1 = \frac{\ln\left(\frac{75}{80}\right) + \left(.1 + .5\times\sigma^2\right)\cdot .5}{\sigma\sqrt{.5}}$$

$$d_2 = d_1 - \sigma\sqrt{.5}$$

Through a process of substitution and iteration, we find that this system of equations holds when σ = .41147. Thus, the market prices this call as though it expects that the standard deviation of anticipated returns for the underlying stock is .41147.

Unfortunately, the system of equations required to obtain an implied variance has no closed form solution. That is, we will be unable to solve this equation set explicitly for standard deviation; we must search, iterate and substitute for a solution. One can substitute trial values for σ until she finds one that solves the system. A significant amount of time can be saved by using one of several well-known numerical search procedures such as the Method of Bisection or the Newton-Raphson Method.

Appendix 3.D: Vega

Sources of sensitivity of the Black-Scholes model (See Black and Scholes [1972]) to each of its 5 inputs are known as the *Greeks*. For example, option prices are very sensitive to the risk σ of the underlying security. *Vega*, which actually is not a Greek letter, measures the sensitivity of the option price to the underlying stock's standard deviation of returns (vega is sometimes known as either *kappa* or *zeta*). Vega is calculated by finding the partial derivative of c_0 with respect to σ in the Black Scholes option pricing model. One might expect the call option price to be directly related to the underlying stock's standard deviation:

$$\frac{\partial c}{\partial \sigma} = \frac{S_0\sqrt{T}}{\sqrt{2\pi}} e^{\left(-\frac{d_1^2}{2}\right)} > 0 \qquad \textit{Vega } \nu$$

Although the Black-Scholes model assumes that the underlying stock volatility is constant over time, in reality, volatility can and does shift. Vega provides an estimate for the impact of a small volatility shift on a particular option's value. For example, in our illustration in Section E, we can calculate the option vega as follows:

$$\frac{\partial c}{\partial \sigma} = \frac{200 \times \sqrt{2}}{\sqrt{2\pi}} e^{\left(-\frac{d_1^2}{2}\right)} = 92.958$$

This vega implies that a small increase in σ (e.g., .01, from .6904 to .7004) would result in an approximate change 92.958% as large in option value (e.g., from 83.196 to 83.97):

$$c_1 = c_0 + \nu\,\Delta\sigma = 83.196 + 92.958 \times .01 = 83.97$$

Vega can be used in a banking context to calculate the impact of a change in asset volatility on equity value. Vega-based calculations are more accurate for smaller changes in volatility.