CHAPTER 13: BOND PRICES AND YIELDS

1. a. Effective annual rate on 3-month T-bill:

   \[
   \left( \frac{100,000}{97,645} \right)^4 - 1 = 1.024124^4 - 1 = .10 \text{ or } 10\%
   \]

   b. Effective annual interest rate on coupon bond paying 5% semiannually:

   \[(1.05)^2 - 1 = .1025 \text{ or } 10.25\%
   \]

2. The effective annual yield on the semiannual coupon bonds is 8.16%. If the annual coupon bonds are to sell at par they must offer the same yield, which will require an annual coupon of 8.16%.

3. The bond callable at 105 should sell at a lower price because the call provision is more valuable to the firm. Therefore, its YTM should be higher.

4. Lower. As time passes, the bond price, which now must be above par value, will approach par.

5. We find the yield to maturity from our financial calculator using the following inputs:

   \[n = 3, \ FV = 1000, \ PV = 953.10, \ PMT = 80.\]

   This results in

   \[\text{YTM} = 9.88\%\]

   **Realized compound yield:** First find the future value, \(FV\), of reinvested coupons and principal:

   \[FV = (80 \times 1.10 \times 1.12) + (80 \times 1.12) + 1080 = $1268.16\]

   Then find the rate, \(y\), that makes the \(FV\) of the purchase price equal to $1268.16.

   \[953.10(1 + y)^3 = 1268.16\]

   \[y = 9.99\% \text{ or approximately } 10\%
   \]

13. a. Initial price, \(P_0 = 705.46 \[n = 20; \ PMT = 50; \ FV = 1000; \ i = 8]\]
Next year's price, \( P_1 = 793.29 \) \( [n = 19; \text{PMT} = 50; \text{FV} = 1000; i = 7] \)

\[
\text{HPR} = \frac{50 + (793.29 - 705.46)}{705.46} = .1954 = 19.54\%
\]

b. Using OID tax rules, the price path of the bond under the constant yield method is obtained by discounting at an 8% yield, simply reducing maturity by one year at a time:

**Constant yield prices**

\( P_0 = 705.46 \)
\( P_1 = 711.89 \) implies implicit interest over first year = $6.43
\( P_2 = 718.84 \) implies implicit interest over second year = $6.95

Tax on explicit plus implicit interest in first year = \(.40 \times (50 + 6.43) = 22.57\)

Capital gain in first year = Actual price – constant yield price

\( = 793.29 - 711.89 = 81.40 \)

Tax on capital gain = \(.30 \times 81.40 = 24.42 \)

Total taxes = $22.57 + $24.42 = $46.99

c. After tax HPR = \[
\frac{50 + (793.29 - 705.46) - 46.99}{705.46} = .1288 = 12.88\%
\]

d. Value of bond after 2 years equals $798.82 [using \( n = 18; i = 7\% \)]

Reinvested coupon income from the two coupons equals \( 50 \times 1.03 + 50 = 101.50 \)

Total funds after two years equals $798.82 + $101.50 = $900.32.

Therefore, the $705.46 investment grows to $900.32 after 2 years.

\( 705.46 (1 + r)^2 = 900.32 \) which implies that \( r = .1297 = 12.97\% \)

e. Coupon received in first year: \( 50.00 \)
Tax on coupon @ 40% \( - 20.00 \)
Tax on imputed interest (.40 \times 6.43) \( - 2.57 \)
Net cash flow in first year \( 27.43 \)

If you invest the year-1 CF at an after-tax rate of 3% \( \times (1 - .40) = 1.8\% \) it will grow by year 2 to \( 27.43 \times (1.018) = 27.92 \).

You sell the bond in the second year for \( 798.82 \) \( [n = 18; i = 7\%] \)
Tax on imputed interest in second year \( - 2.78 \) \( [.40 \times 6.95] \)
Coupon received in second year net of tax \( + 30.00 \) \( [.50 \times (1 - .40)] \)
Capital gains tax on sales price – constant yield value – 23.99 \[.30 \times (798.82 – 718.84)\]

CF from first year's coupon (reinvested) + 27.92 [from above]

TOTAL $829.97

705.46 (1 + r)^2 = 829.97
r = .0847 = 8.47%

Chapter 14

<table>
<thead>
<tr>
<th>Maturity</th>
<th>Price</th>
<th>YTM</th>
<th>Forward Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$943.40</td>
<td>6.00%</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>$898.47</td>
<td>5.50%</td>
<td>5.00% (1.055^2/1.06 – 1)</td>
</tr>
<tr>
<td>3</td>
<td>$847.62</td>
<td>5.67%</td>
<td>6.00% (1.0567^3/1.055^2 – 1)</td>
</tr>
<tr>
<td>4</td>
<td>$792.16</td>
<td>6.00%</td>
<td>7.00% (1.06^4/1.0567^3 – 1)</td>
</tr>
</tbody>
</table>

Chapter 15

1. The percentage bond price change will be:

\[-\frac{\text{Duration}}{1+y} \times \Delta y = -\frac{7.194}{1.10} \times .005 = -.0327 \text{ or a 3.27% decline.}\]

2. Computation of duration:

a. YTM = 6%

<table>
<thead>
<tr>
<th>Time until payment (years)</th>
<th>Payment discounted at 6%</th>
<th>Weight of each payment</th>
<th>Column (1) × Column (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60</td>
<td>56.60</td>
<td>.0566</td>
</tr>
<tr>
<td>2</td>
<td>60</td>
<td>53.40</td>
<td>.0534</td>
</tr>
<tr>
<td>3</td>
<td>1060</td>
<td>890.00</td>
<td>.8900</td>
</tr>
<tr>
<td>Column Sum</td>
<td>1000.00</td>
<td>1.0000</td>
<td>2.8334</td>
</tr>
</tbody>
</table>

Duration = 2.833 years

b. YTM = 10%
(1) Time until payment (years)  (2) Payment  (3) Payment discounted at 10%  (4) Weight of each payment  (5) Column (1) × Column (4)

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60</td>
<td>54.55</td>
<td>.0606</td>
<td>.0606</td>
</tr>
<tr>
<td>2</td>
<td>60</td>
<td>49.59</td>
<td>.0551</td>
<td>.1102</td>
</tr>
<tr>
<td>3</td>
<td>1060</td>
<td>796.39</td>
<td>.8844</td>
<td>2.6532</td>
</tr>
<tr>
<td>Column Sum</td>
<td>900.53</td>
<td>1.0000</td>
<td>2.8240</td>
<td></td>
</tr>
</tbody>
</table>

Duration = 2.824 years, which is less than the duration at the YTM of 6%.

**CHAPTER 6**

**RISK AVERSION AND CAPITAL ALLOCATION TO RISKY ASSETS**

1. a. The expected cash flow is: \((0.5 \times 70,000) + (0.5 \times 200,000) = 135,000\)

   With a risk premium of 8% over the risk-free rate of 6%, the required rate of return is 14%. Therefore, the present value of the portfolio is:

   \[
   \frac{135,000}{1.14} = 118,421
   \]

b. If the portfolio is purchased for $118,421, and provides an expected cash inflow of $135,000, then the expected rate of return \([E(r)]\) is derived as follows:

   \[
   118,421 \times [1 + E(r)] = 135,000
   \]

   Therefore, \(E(r) = 14\%\). The portfolio price is set to equate the expected rate or return with the required rate of return.

c. If the risk premium over T-bills is now 12%, then the required return is:

   \[6\% + 12\% = 18\%\]

   The present value of the portfolio is now:
$135,000/1.18 = $114,407

d. For a given expected cash flow, portfolios that command greater risk premia must sell at lower prices. The extra discount from expected value is a penalty for risk.

2. When we specify utility by $U = E(r) - .005A\sigma^2$, the utility from bills is 7%, while that from the risky portfolio is $U = 12 - .005A \times 18^2 = 12 - 1.62A$. For the portfolio to be preferred to bills, the following inequality must hold: $12 - 1.62A > 7$, or, $A < 5/1.62 = 3.09$. $A$ must be less than 3.09 for the risky portfolio to be preferred to bills.

Appendix 6A

1. Your $50,000 investment will grow to $50,000(1.06) = $53,000 by year end. Without insurance your wealth will then be:

<table>
<thead>
<tr>
<th>Probability</th>
<th>Wealth</th>
</tr>
</thead>
<tbody>
<tr>
<td>No fire:</td>
<td>.999</td>
</tr>
<tr>
<td>Fire:</td>
<td>.001</td>
</tr>
</tbody>
</table>

which gives expected utility

\[.001 \times \log_e(53,000) + .999 \times \log_e(253,000) = 12.439582\]
and a certainty equivalent wealth of

\[ \exp(12.439582) = 252,604.85 \]

*With fire insurance* at a cost of $P$, your investment in the risk-free asset will be only
$$(50,000 - P).$$ Your year-end wealth will be certain (since you are fully insured) and equal to

$$(50,000 - P) \times 1.06 + 200,000.$$

Setting this expression equal to $252,604.85$ (the certainty equivalent of the uninsured house) results in $P = 372.78$. This is the most you will be willing to pay for insurance. Note that the expected loss is "only" $200, meaning that you are willing to pay quite a risk premium over the expected value of losses. The main reason is that the value of the house is a large proportion of your wealth.

2. a. With 1/2 coverage, your premium is $100, your investment in the safe asset is $49,900 which grows by year end to $52,894. If there is a fire, your insurance proceeds are only $100,000. Your outcome will be:

<table>
<thead>
<tr>
<th>Probability</th>
<th>Wealth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire</td>
<td>.001</td>
</tr>
<tr>
<td>No fire</td>
<td>.999</td>
</tr>
</tbody>
</table>

Expected utility is

\[ .001 \times \log_e(152,894) + .999 \times \log_e(252,894) = 12.440222 \]
The minimum-variance portfolio is found by applying the formula:

\[ w_{\text{Min}}(S) = \frac{\sigma_B^2 - \text{Cov}(B,S)}{\sigma_S^2 + \sigma_B^2 - 2\text{Cov}(B,S)} \]

\[ = \frac{225 - 45}{900 + 225 - 2 \times 45} = .1739 \]

\[ w_{\text{Min}}(B) = .8261 \]

The minimum variance portfolio mean and standard deviation are:

\[ E(r_{\text{Min}}) = .1739 \times 20 + .8261 \times 12 = 13.39\% \]
\[ \sigma_{\text{min}} = \left[ W_S^2 \sigma_S^2 + W_B^2 \sigma_B^2 + 2 W_S W_B \text{Cov}(S, B) \right]^{1/2} \]

\[ = [0.1739^2 \times 900 + 0.8261^2 \times 225 + 2 \times 0.1739 \times 0.8261 \times 45]^{1/2} = 13.92\% \]
## 2.

<table>
<thead>
<tr>
<th>% in stocks</th>
<th>% in bonds</th>
<th>Exp. return</th>
<th>Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00%</td>
<td>100.00%</td>
<td>12.00</td>
<td>15.00</td>
</tr>
<tr>
<td>17.39%</td>
<td>82.61%</td>
<td>13.39</td>
<td>13.92</td>
</tr>
<tr>
<td>20.00%</td>
<td>80.00%</td>
<td>13.60</td>
<td>13.94</td>
</tr>
<tr>
<td>40.00%</td>
<td>60.00%</td>
<td>15.20</td>
<td>15.70</td>
</tr>
<tr>
<td>45.16%</td>
<td>54.84%</td>
<td>15.61</td>
<td>16.54</td>
</tr>
<tr>
<td>60.00%</td>
<td>40.00%</td>
<td>16.80</td>
<td>19.53</td>
</tr>
<tr>
<td>80.00%</td>
<td>20.00%</td>
<td>18.40</td>
<td>24.48</td>
</tr>
<tr>
<td>100.00%</td>
<td>0.00%</td>
<td>20.00</td>
<td>30.00</td>
</tr>
</tbody>
</table>

## 3.

![INVESTMENT OPPORTUNITY SET](image-url)

- **CML**
- **Min.Var.**
- **Tangency Pf**
- **Efficient frontier of risky assets**
The graph approximates the points: Min. Variance Portf. 13.4% 13.9%
Tangency Portfolio 15.6 16.5

4. The proportion of stocks in the optimal risky portfolio is given by:

\[ W_S = \frac{[E(r_S) - r_f]^2 \sigma_B - [E(r_B) - r_f]\text{Cov}(B,S)}{[E(r_S) - r_f]^2 \sigma_B^2 + [E(r_B) - r_f]^2 \sigma_S^2 - [E(r_S) - r_f + E(r_B) - r_f]\text{Cov}(B,S)} \]

\[ = \frac{(20 - 8)225 - (12 - 8)45}{(20 - 8)225 + (12 - 8)900 - [20 - 8 + 12 - 8]45} = .4516 \]

\[ W_B = .5484 \]

The mean and standard deviation of the optimal risky portfolio are:
\[ E(r_p) = .4516 \times 20 + .5484 \times 12 = 15.61\% \]
\[ \sigma_p = [.4516^2 \times 900 + .5484^2 \times 225 + 2 \times .4516 \times .5484 \times 45]^{1/2} = 16.54\% \]

5. The reward-to-variability ratio of the optimal CAL is:
\[ \frac{E(r_p) - r_f}{\sigma_p} = \frac{15.61 - 8}{16.54} = .4601 \]

6. a. If you require your portfolio to yield a mean return of 14% you can find the corresponding standard deviation from the optimal CAL. The formula for this CAL is:

\[ E(r_C) = rf + \frac{E(r_p) - r_f}{\sigma_p} \sigma_C = 8 + .4601 \sigma_C \]
Setting \( E(r_C) \) equal to 14% we find that the standard deviation of the optimal portfolio is 13.04%.

b. To find the proportion invested in T-bills we remember that the mean of the complete portfolio, 14%, is an average of the T-bill rate and the optimal combination of stocks and bonds, \( P \). Let \( y \) be the proportion in this portfolio. The mean of any portfolio along the optimal CAL is:

\[
E(r_C) = (1 - y) r_f + y E(r_P) = r_f + y [E(r_P) - r_f] = 8 + y (15.61 - 8)
\]

Setting \( E(r_C) = 14\% \) we find: \( y = .7884 \), and \( 1 - y = .2116 \), the proportion in T-bills.

To find the proportions invested in each of the funds we multiply .7884 by the proportions of the stocks and bonds in the optimal risky portfolio:

- Proportion of stocks in complete portfolio = \( .7884 \times .4516 = .3560 \)
- Proportion of bonds in complete portfolio = \( .7884 \times .5484 = .4324 \)

7. Using only the stock and bond funds to achieve a portfolio mean of 14% we must find the appropriate proportion in the stock fund, \( w_S \), and \( w_B = 1 - w_S \) in the bond fund. The portfolio mean will be:

\[
14 = 20w_S + 12(1 - w_S) = 12 + 8w_S \quad w_S = .25
\]

So the proportions will be 25% in stocks and 75% in bonds. The standard deviation of this portfolio will be:

\[
\sigma_p = (.25^2 \times 900 + .75^2 \times 225 + 2 \times .25 \times .75 \times 45)^{1/2} = 14.13%.
\]
This is considerably larger than the standard deviation of 13.04% achieved using T-bills and the optimal portfolio.

8. a. 

![Graph showing expected return vs. standard deviation for Gold, Stocks, and the Optimal CAL.]

Even though gold seems dominated by stocks, it still might be an attractive asset to hold as a *part* of a portfolio. If the correlation between gold and stocks is sufficiently low, it will be held as an element in a portfolio -- the optimal tangency portfolio.

b. If gold had a correlation coefficient with stocks of +1, it would not be held. The optimal CAL would be comprised of bills and stocks only. Since the set of risk/return combinations of stocks and gold would plot as a straight line with a negative slope (see the following graph), it would be dominated by the stocks portfolio. Of course, this
situation could not persist. If no one desired gold, its price would fall and its expected rate of return would increase until it became an attractive enough asset to hold.

9. Since A and B are perfectly negatively correlated, a risk-free portfolio can be created and its rate of return in equilibrium will be the risk-free rate. To find the proportions of this portfolio (with $w_A$ invested in A and $w_B = 1 - w_A$ in B), set the standard deviation equal to zero. With perfect negative correlation, the portfolio standard deviation reduces to

$$
\sigma_P = \text{Abs}[w_A \sigma_A - w_B \sigma_B]
$$

$$
0 = 5w_A - 10(1 - w_A)
$$

$$
w_A = .6667
$$

The expected rate of return on this risk-free portfolio is:
\[ E(r) = 0.6667 \times 10 + 0.3333 \times 15 = 11.67\% \]

Therefore, the risk-free rate must also be 11.67%.

10. False. If the borrowing and lending rates are not identical, then depending on the tastes of the individuals (that is, the shape of their indifference curves), borrowers and lenders could have different optimal risky portfolios.

11. False. The portfolio standard deviation equals the weighted average of the component-asset standard deviations only in the special case that all assets are perfectly positively correlated. Otherwise, as the formula for portfolio standard deviation shows, the portfolio standard deviation is less than the weighted average of the component-asset standard deviations. The portfolio variance will be a weighted sum of the elements in the covariance matrix, with the products of the portfolio proportions as weights.

12. The probability distribution is:

<table>
<thead>
<tr>
<th>Probability</th>
<th>Rate of Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7</td>
<td>100%</td>
</tr>
<tr>
<td>0.3</td>
<td>-50%</td>
</tr>
</tbody>
</table>

Mean = 0.7 \times 100 + 0.3 \times (-50) = 55\%

Variance = 0.7 \times (100 - 55)^2 + 0.3 \times (-50 - 55)^2 = 4725

Standard deviation = 4725^{1/2} = 68.74\%

13. \( \sigma_p = 30 = y \sigma = 40y \)

\( y = 0.75 \)

\( E(r_p) = 12 + 0.75(30 - 12) = 25.5\% \)
5. a. Call the aggressive stock A and the defensive stock D. Beta is the sensitivity of the stock’s return to the market return, i.e., the change in the stock return per unit change in the market return. Therefore, we compute each stock’s beta by calculating the difference in its return across the two scenarios divided by the difference in the market return:

\[
\beta_A = \frac{-2 - 38}{5 - 25} = 2.00
\]
\[
\beta_D = \frac{6 - 12}{5 - 25} = 0.30
\]

b. With the two scenarios equally likely, the expected return is an average of the two possible outcomes:

\[
E(r_A) = 0.5 \times (-2 + 38) = 18\%
\]
\[
E(r_D) = 0.5 \times (6 + 12) = 9\%
\]

c. The SML is determined by the market expected return of \([0.5(25 + 5)] = 15\%\), with a beta of 1, and the T-bill return of 6% with a beta of zero. See the following graph.
The equation for the security market line is:

\[ E(r) = 6 + \beta(15 - 6) \]

d. Based on its risk, the aggressive stock has a required expected return of:

\[ E(r_A) = 6 + 2.0(15 - 6) = 24\% \]

The analyst’s forecast of expected return is only 18%. Thus the stock’s alpha is:

\[ \alpha_A = \text{actually expected return – required return (given risk)} \]

\[ = 18\% - 24\% = -6\% \]

Similarly, the required return for the defensive stock is:
E(r_D) = 6 + 0.3(15 – 6) = 8.7%
The analyst’s forecast of expected return for D is 9%, and hence, the stock has a positive alpha:

\[ \alpha_D = \text{actually expected return} – \text{required return (given risk)} \]
\[ = 9 – 8.7 = +0.3\% \]

The points for each stock plot on the graph as indicated above.

e. The hurdle rate is determined by the project beta (0.3), not the firm’s beta. The correct discount rate is 8.7%, the fair rate of return for stock D.

6. Not possible. Portfolio A has a higher beta than B, but its expected return is lower. Thus, these two portfolios cannot exist in equilibrium.

7. Possible. If the CAPM is valid, the expected rate of return compensates only for systematic (market) risk represented by beta rather than for the standard deviation which includes nonsystematic risk. Thus, A's lower rate of return can be paired with a higher standard deviation, as long as A's beta is lower than B's.

8. Not possible. The SML for this situation is: \[ E(r) = 10 + \beta(18 – 10) \]
Portfolios with beta of 1.5 have an expected return of \[ E(r) = 10 + 1.5 \times (18 – 10) = 22\% \].
A's expected return is 16%; that is, A plots below the SML (\( \alpha_A = -6\% \)), and hence, is an overpriced portfolio. This is inconsistent with the CAPM.

9. Not possible. The SML is the same as in problem 10. Here, portfolio A's required
return is: 10 + .9 \times 8 = 17.2\%, \text{ which is still higher than } 16\%. \text{ A is overpriced with a negative alpha: } \alpha_A = -1.2\%.

10. Not possible. Portfolio A clearly dominates the market portfolio. It has a lower standard deviation with a higher expected return.

11. Since the stock's beta is equal to 1.2, its expected rate of return is \( 6 + 1.2(16 - 6) = 18\% \)

\[
E(r) = \frac{D_1 + P_1 - P_0}{P_0}
\]

\[
.18 = \frac{6 + P_1 - 50}{50}
\]

\[P_1 = $53\]

12. Assume that the $1,000 is a perpetuity. If beta is .5, the cash flow should be discounted at the rate
$6 + .5 \times (16 - 6) = 11\%$

$PV = 1000/.11 = $9,090.91$

If, however, beta is equal to 1, the investment should yield 16%, and the price paid for the firm should be:

$PV = 1000/.16 = $6,250$

The difference, $2,840.91, is the amount you will overpay if you erroneously assumed that beta is .5 rather than 1.

If the cash flow lasts only one year:

$PV(\text{beta}=0) = 1000/1.11 = 900.90$

$PV(\text{beta}=1) = 1000/1.16 = 862.07$

with a difference of $38.83.

For n-year cash flow the difference is $1000PA(11\%,n)-1000PA(16\%,n)$.

13. Using the SML: $4 = 6 + \beta(16 - 6)$

$\beta = -2/10 = -.2$
14. \( r_1 = 19\%; \quad r_2 = 16\%; \quad \beta_1 = 1.5; \quad \beta_2 = 1 \)

a. To tell which investor was a better selector of individual stocks we look at their abnormal return, which is the ex-post alpha, that is, the abnormal return is the difference between the actual return and that predicted by the SML. Without information about the parameters of this equation (risk-free rate and market rate of return) we cannot tell which investor was more accurate.

b. If \( r_f = 6\% \) and \( r_M = 14\% \), then (using the notation of alpha for the abnormal return)

\[
\alpha_1 = 19 - [6 + 1.5(14 - 6)] = 19 - 18 = 1\%
\]

\[
\alpha_2 = 16 - [6 + 1(14 - 6)] = 16 - 14 = 2\%
\]

Here, the second investor has the larger abnormal return and thus he appears to be the superior stock selector. By making better predictions the second investor appears to have tilted his portfolio toward underpriced stocks.

c. If \( r_f = 3\% \) and \( r_M = 15\% \), then

\[
\alpha_1 = 19 - [3 + 1.5(15 - 3)] = 19 - 21 = -2\%
\]

\[
\alpha_2 = 16 - [3 + 1(15 - 3)] = 16 - 15 = 1\%
\]

Here, not only does the second investor appear to be the superior stock selector, but the first investor's predictions appear valueless (or worse).
15. a. Since the market portfolio by definition has a beta of 1, its expected rate of return is 12%.

b. $\beta = 0$ means no systematic risk. Hence, the portfolio’s expected rate of return in market equilibrium is the risk-free rate, 5%.

c. Using the SML, the *fair* expected rate of return of a stock with $\beta = -0.5$ is:

$$E(r) = 5 + (-.5)(12 - 5) = 1.5\%$$

The *actually* expected rate of return, using the expected price and dividend for next year is:

$$E(r) = \frac{44}{40} - 1 = .10 \text{ or } 10\%$$

Because the actually expected return exceeds the fair return, the stock is underpriced.

is firm-specific risk, not related to market factors. Since it can be diversified away it should not affect the expected return.

28. a. According to the CAPM the equilibrium expected return on the fund should be $5 + .8x(15-5) = 13\%$. Hence, the excess return or alpha is 1%.

b. The passive portfolio would have 80% invested in the market portfolio with a beta of 1 and 20% in the riskless asset with a beta of 0. Its beta would then be $.8x1 = .8$. The return of the passive portfolio is $.8x15 + .2x6 = 13\%$, equal to the equilibrium expected return of the fund.
29. a. 

<table>
<thead>
<tr>
<th>Expected Return</th>
<th>Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>5% + 0.8(14% − 5%) = 12.2%</td>
</tr>
<tr>
<td>Y</td>
<td>5% + 1.5(14% − 5%) = 18.5%</td>
</tr>
</tbody>
</table>

i. Kay should recommend Stock X because of its positive alpha, compared to Stock Y, which has a negative alpha. In graphical terms, the expected return/risk profile for Stock X plots above the security market line (SML), while the profile for Stock Y plots below the SML. Also, depending on the individual risk preferences of Kay’s clients, the lower beta for Stock X may have a beneficial effect on overall portfolio risk.

ii. Kay should recommend Stock Y because it has higher forecasted return and lower standard deviation than Stock X. The respective Sharpe ratios for Stocks X and Y and the market index are:

- Stock X: \((17\% − 5\%)/25\% = 0.48\)
- Stock Y: \((14\% − 5\%)/36\% = 0.25\)
- Market index: \((14\% − 5\%)/15\% = 0.60\)

The market index has an even more attractive Sharpe ratio than either of the individual stocks, but, given the choice between Stock X and Stock Y, Stock Y is the superior alternative.

When a stock is held as a single stock portfolio, standard deviation is the relevant risk measure. For such a portfolio, beta as a risk measure is irrelevant. Although holding a single asset is not a typically recommended investment strategy, some investors may hold what is essentially a single-asset portfolio when they hold the stock of their
employer company. For such investors, the relevance of standard deviation versus beta is an important issue.

CHAPTER 9: INDEX MODELS AND THE ARBITRAGE PRICING THEORY

1. a. To optimize this portfolio one would need:

\[
\begin{align*}
    n & = 60 \text{ estimates of means} \\
    n & = 60 \text{ estimates of variances} \\
    \frac{n^2 - n}{2} & = 1770 \text{ estimates of covariances} \\
    \frac{n^2 + 3n}{2} & = 1890 \text{ estimates}
\end{align*}
\]

b. In a single index model: 

\[
    r_i - r_f = \alpha_i + \beta_i(r_M - r_f) + e_i
\]

the variance of the rate of return on each stock can be decomposed into the components:

1. \( \beta_i^2 \sigma_M^2 \) The variance due to the common market factor
2. \( \sigma^2(e_i) \) The variance due to firm specific unanticipated events

In this model \( \text{Cov}(r_i,r_j) = \beta_i \beta_j \sigma_M^2 \). The number of parameter estimates required would be:

\[
\begin{align*}
    n & = 60 \text{ estimates of the mean } E(r_i), \\
    n & = 60 \text{ estimates of the sensitivity coefficient } \beta_i, \\
    n & = 60 \text{ estimates of the firm-specific variance } \sigma^2(e_i), \text{ and}
\end{align*}
\]
1 estimate of the market mean $E(r_M)$
1 estimate for the market variance $\sigma_M^2$

182 estimates

Thus, the single index model reduces the total number of required parameter estimates from 1,890 to 182, and in general from $(n^2 + 3n)/2$ to $3n + 2$.

2. a. The standard deviation of each individual stock is given by:

$$\sigma_i = \left[ \beta_i^2 \sigma_M^2 + \sigma^2(e_i) \right]^{1/2}$$

Since $\beta_A = .8$, $\beta_B = 1.2$, $\sigma(e_A) = 30\%$, $\sigma(e_B) = 40\%$, and $\sigma_M = 22\%$ we get:

$$\sigma_A = (.8^2 \times 22^2 + 30^2)^{1/2} = 34.78\%$$
$$\sigma_B = (1.2^2 \times 22^2 + 40^2)^{1/2} = 47.93\%$$

b. The expected rate of return on a portfolio is the weighted average of the expected returns of the individual securities:

$$E(r_p) = w_A E(r_A) + w_B E(r_B) + w_f r_f$$

where $w_A$, $w_B$, and $w_f$ are the portfolio weights of stock A, stock B, and T-bills, respectively.

Substituting in the formula we get:
\[ E(r_p) = 0.30 \times 13 + 0.45 \times 18 + 0.25 \times 8 = 14\% \]

The beta of a portfolio is similarly a weighted average of the betas of the individual securities:

\[ \beta_P = w_A \beta_A + w_B \beta_B + w_f \beta_f \]

The beta of T-bills (\( \beta_f \)) is zero. The beta of the portfolio is therefore:

\[ \beta_P = 0.30 \times 0.8 + 0.45 \times 1.2 + 0 = 0.78 \]

The variance of this portfolio is:

\[ \sigma^2_P = \beta_P^2 \sigma^2_M + \sigma^2(e_P) \]

where \( \beta_P^2 \sigma^2_M \) is the systematic component and \( \sigma^2(e_P) \) is the nonsystematic component. Since the residuals, \( e_i \) are uncorrelated, the non-systematic variance is:

\[ \sigma^2(e_P) = w_A^2 \sigma^2(e_A) + w_B^2 \sigma^2(e_B) + w_f^2 \sigma^2(e_f) \]

\[ = 0.30^2 \times 30^2 + 0.45^2 \times 40^2 + 0.25^2 \times 0 = 405 \]

where \( \sigma^2(e_A) \) and \( \sigma^2(e_B) \) are the firm-specific (nonsystematic) variances of stocks A and B, and \( \sigma^2(e_f) \), the nonsystematic variance of T-bills, is zero. The residual standard deviation of the portfolio is thus:

\[ \sigma(e_P) = (405)^{1/2} = 20.12\% \]
The total variance of the portfolio is then:

\[ \sigma_p^2 = .78^2 \times 22^2 + 405 = 699.47 \]

and the standard deviation is 26.45%.

5. The standard deviation of each stock can be derived from the following equation for \( R^2 \):

\[ R_i^2 = \frac{\beta_i^2 \sigma_M^2}{\sigma_i^2} = \frac{\text{Explained variance}}{\text{Total variance}} \]

Therefore,

\[ \sigma_A^2 = \frac{\beta_A^2 \sigma_M^2}{R_A^2} = \frac{.7^2 \times 20^2}{.20} = 980 \]

\[ \sigma_A = 31.30\% \]

For stock B

\[ \sigma_B^2 = \frac{1.2^2 \times 20^2}{.12} = 4800 \]

\[ \sigma_B = 69.28\% \]

6. The systematic risk for A is

\[ \beta_A^2 \sigma_M^2 = .70^2 \times 20^2 = 196 \]
and the firm-specific risk of A (the residual variance) is the difference between A's total risk and its systematic risk,

\[ 980 - 196 = 784 \]

B's systematic risk is:

\[ \beta_B^2 \sigma_M^2 = 1.2^2 \times 20^2 = 576 \]

and B's firm-specific risk (residual variance) is:

\[ 4800 - 576 = 4224 \]

7. The covariance between the returns of A and B is (since the residuals are assumed to be uncorrelated):

\[ \text{Cov}(r_A,r_B) = \beta_A \beta_B^2 \sigma_M^2 = .70 \times 1.2 \times 400 = 336 \]

The correlation coefficient between the returns of A and B is:

\[ \rho_{AB} = \frac{\text{Cov}(r_A,r_B)}{\sigma_A \sigma_B} = \frac{336}{31.30 \times 69.28} = .155 \]

8. Note that the correlation coefficient is the square root of $R^2$: $\rho = \sqrt{R^2}$
\[ \text{Cov}(r_A, r_M) = \rho \sigma_A \sigma_M = 0.20^{1/2} \times 31.30 \times 20 = 280 \]

\[ \text{Cov}(r_B, r_M) = \rho \sigma_B \sigma_M = 0.12^{1/2} \times 69.28 \times 20 = 480 \]

9. The non-zero alphas from the regressions are inconsistent with the CAPM. The question is whether the alpha estimates reflect sampling errors or real mispricing. To test the hypothesis of whether the intercepts (3% for A, and –2% for B) are significantly different from zero, we would need to compute t-values for each intercept.

17. As a first step, convert the scenario rates of return to dollar payoffs per share, as shown in the following table:

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Price</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$10</td>
<td>$8.50</td>
<td>$12.00</td>
<td>$13.00</td>
</tr>
<tr>
<td>B</td>
<td>$15</td>
<td>$18.75</td>
<td>$16.50</td>
<td>$13.50</td>
</tr>
<tr>
<td>C</td>
<td>$50</td>
<td>$56.00</td>
<td>$57.50</td>
<td>$56.00</td>
</tr>
</tbody>
</table>

Identifying an arbitrage opportunity always involves constructing a zero investment portfolio. This portfolio must show non-negative payoffs in all scenarios.

For example, the proceeds from selling short two shares of A and two shares of B will be sufficient to buy one share of C.

\[ (-2)10 + (-2)15 + 50 = 0 \]

The payoff table for this zero investment portfolio in each scenario is:
<table>
<thead>
<tr>
<th></th>
<th># of Price</th>
<th>shares</th>
<th>Investment</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$10</td>
<td>−2</td>
<td>−20</td>
<td>−17</td>
<td>−24</td>
<td>−26</td>
</tr>
<tr>
<td>B</td>
<td>$15</td>
<td>−2</td>
<td>−30</td>
<td>−37.5</td>
<td>−33</td>
<td>−27</td>
</tr>
<tr>
<td>C</td>
<td>$50</td>
<td>+1</td>
<td>50</td>
<td>56</td>
<td>57.5</td>
<td>56</td>
</tr>
</tbody>
</table>

This portfolio qualifies as an arbitrage portfolio because it is both a zero investment portfolio and has positive returns in all scenarios.

18. Substituting the portfolio return and the betas in the expected return-beta relationship, we obtain two equations in the unknowns, the risk-free rate and the factor risk premium, RP.

\[
12 = r_f + 1.2 \times RP \\
9 = r_f + 0.8 \times RP
\]

Solving these equations, we obtain

\[
r_f = 3\% \text{ and } RP = 7.5\%\]

19. a. Shorting equally the 10 negative-alpha stocks and investing the proceeds equally in the 10 positive-alpha stocks eliminates the market exposure and creates a zero-investment portfolio. Denoting the systematic market factor as \( R_M \), the expected dollar return is
(noting that the expectation of non-systematic risk, $e$, is zero):

$$1,000,000 \times [.03 + 1.0 \times R_M] - 1,000,000 \times [-.03 + 1.0 \times R_M]$$

$$= 1,000,000 \times .06 = \$60,000$$

The sensitivity of the payoff of this portfolio to the market factor is zero because the exposures of the positive alpha and negative alpha stocks cancel out. (Notice that the terms involving $R_M$ sum to zero.) Thus, the systematic component of total risk also is zero. The variance of the analyst's profit is not zero, however, since this portfolio is not well diversified.

For $n = 20$ stocks (i.e., long 10 stocks and short 10 stocks) the investor will have a $100,000 position (either long or short) in each stock. Net market exposure is zero, but firm-specific risk has not been fully diversified. The variance of dollar returns from the positions in the 20 firms is

$$20 \times [(100,000 \times .30)^2] = 18,000,000,000$$

and the standard deviation of dollar returns is $134,164.

b. If $n = 50$ stocks (25 long and 25 short), $40,000 is placed in each position, and the variance of dollar returns is

$$50 \times [(40,000 \times .30)^2] = 7,200,000,000$$

The standard deviation of dollar returns is $84,853.
Similarly, if \( n = 100 \) stocks (50 long and 50 short), $20,000 is placed in each position, and the variance of dollar returns is

\[
100 \times [(20,000 \times 0.30)^2] = 3,600,000,000
\]

The standard deviation of dollar returns is $60,000.

Notice that when the number of stocks increased by a factor of 5, from 20 to 100, standard deviation fell by a factor of \( \sqrt{5} \approx 2.236 \), from $134,164 to $60,000.

20 a. \( \sigma^2 = \beta^2 \sigma_M^2 + \sigma^2(e) \)

The standard deviations are:

<table>
<thead>
<tr>
<th></th>
<th>( \sigma(e) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>25</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>20</td>
</tr>
</tbody>
</table>

and \( \sigma_M = 20 \). Thus,

\[
\begin{align*}
\sigma_A^2 &= .8^2 \times 20^2 + 25^2 = 881 \\
\sigma_B^2 &= 1.0^2 \times 20^2 + 10^2 = 500 \\
\sigma_C^2 &= 1.2^2 \times 20^2 + 20^2 = 976 \\
\end{align*}
\]

b. If there are an infinite number of assets with identical characteristics, a well-diversified portfolio of each type will have only systematic risk since the non-systematic risk will approach zero with large \( n \). The mean will equal that of the individual (identical) stocks.

c. There is no arbitrage opportunity because the well-diversified portfolios all plot on the security market line (SML). Because they are fairly priced, there is no arbitrage.
Note: In Chapter 12's end-of-chapter-problems the focus is on the estimation procedure. To keep the exercise feasible the sample was limited to returns on 9 stocks plus a market index and a second factor over 12 years. The data was generated to conform to a two-factor CAPM so that actual rates of return equal CAPM expectations plus random noise and the true intercept of the SCL is zero for all stocks. The exercise will give you a feel for the pitfalls of verifying social-science models. However, due to the small size of the sample, results are not always consistent with the findings of other studies that are reported in the chapter itself.

1. Using the regression feature of Excel with the data presented in the text, the first-pass (SCL) estimation results are:

<table>
<thead>
<tr>
<th>Stock:</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>R Square</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.37</td>
<td>0.17</td>
<td>0.59</td>
<td>0.06</td>
<td>0.67</td>
<td>0.70</td>
</tr>
<tr>
<td>Observations</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Alpha</td>
<td>9.00</td>
<td>-0.63</td>
<td>-0.64</td>
<td>-5.05</td>
<td>0.73</td>
<td>-4.53</td>
<td>5.94</td>
<td>-2.41</td>
<td>5.92</td>
</tr>
<tr>
<td>Beta</td>
<td>-0.47</td>
<td>0.59</td>
<td>0.42</td>
<td>1.38</td>
<td>0.90</td>
<td>1.78</td>
<td>0.66</td>
<td>1.91</td>
<td>2.08</td>
</tr>
</tbody>
</table>
2. The hypotheses for the second-pass regression for the SML are that the intercept is zero and the slope is equal to the average excess return on the index portfolio.

3. The second-pass data from first-pass (SCL) estimates are:

<table>
<thead>
<tr>
<th>Average Excess Return</th>
<th>Beta</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5.18</td>
</tr>
<tr>
<td>B</td>
<td>4.19</td>
</tr>
<tr>
<td>C</td>
<td>2.75</td>
</tr>
<tr>
<td>D</td>
<td>6.15</td>
</tr>
<tr>
<td>E</td>
<td>8.05</td>
</tr>
<tr>
<td>F</td>
<td>9.90</td>
</tr>
<tr>
<td>G</td>
<td>11.32</td>
</tr>
<tr>
<td>H</td>
<td>13.11</td>
</tr>
<tr>
<td>I</td>
<td>22.83</td>
</tr>
<tr>
<td>M</td>
<td>8.12</td>
</tr>
</tbody>
</table>

The second-pass regression yields:
Regression Statistics

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple R</td>
<td>0.7074</td>
</tr>
<tr>
<td>R Square</td>
<td>0.5004</td>
</tr>
<tr>
<td>Adjusted R Square</td>
<td>0.4291</td>
</tr>
<tr>
<td>Standard Error</td>
<td>4.6234</td>
</tr>
<tr>
<td>Observations</td>
<td>9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Coefficients</th>
<th>Standard Error</th>
<th>t Stat for =0</th>
<th>t Stat for =8.12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>3.92</td>
<td>2.54</td>
<td>1.54</td>
<td></td>
</tr>
<tr>
<td>Slope</td>
<td>5.21</td>
<td>1.97</td>
<td>2.65</td>
<td>-1.48</td>
</tr>
</tbody>
</table>

The results are reflected in the regression equation above intercept, slope coefficients, standard errors and t-statistics as shown.

4. As we saw in the chapter, the intercept is too high (3.92%/year instead of zero), and the slope is too flat (5.21% instead of a predicted value equal to the sample-average risk premium, \( r_M - r_f = 8.12\% \)). While the intercept is not significantly greater than zero (the t-statistic is less than 2) and the slope is not significantly different from its theoretical value (the t-statistic for this hypothesis is only -1.48), the lack of statistical significance is probably due to the small size of the sample.
5. Arranging the securities in three portfolios based on betas from the SCL estimates, the first pass input data are:

<table>
<thead>
<tr>
<th>Year</th>
<th>ABC</th>
<th>DEG</th>
<th>FHI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15.05</td>
<td>25.86</td>
<td>56.69</td>
</tr>
<tr>
<td>2</td>
<td>-16.76</td>
<td>-29.74</td>
<td>-50.85</td>
</tr>
<tr>
<td>3</td>
<td>19.67</td>
<td>-5.68</td>
<td>8.98</td>
</tr>
<tr>
<td>4</td>
<td>-15.83</td>
<td>-2.58</td>
<td>35.41</td>
</tr>
<tr>
<td>5</td>
<td>47.18</td>
<td>37.70</td>
<td>-3.25</td>
</tr>
<tr>
<td>6</td>
<td>-2.26</td>
<td>53.86</td>
<td>75.44</td>
</tr>
<tr>
<td>7</td>
<td>-18.67</td>
<td>15.32</td>
<td>12.50</td>
</tr>
<tr>
<td>8</td>
<td>-6.35</td>
<td>36.33</td>
<td>32.12</td>
</tr>
<tr>
<td>9</td>
<td>7.85</td>
<td>14.08</td>
<td>50.42</td>
</tr>
<tr>
<td>10</td>
<td>21.41</td>
<td>12.66</td>
<td>52.14</td>
</tr>
<tr>
<td>11</td>
<td>-2.53</td>
<td>-50.71</td>
<td>-66.12</td>
</tr>
<tr>
<td>12</td>
<td>-0.30</td>
<td>-4.99</td>
<td>-20.10</td>
</tr>
</tbody>
</table>

Average   4.04  8.51  15.28
Std Dev.  19.30 29.47 43.96

which result in first-pass (SCL) estimates:

<table>
<thead>
<tr>
<th></th>
<th>ABC</th>
<th>DEG</th>
<th>FHI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple R</td>
<td>0.19</td>
<td>0.69</td>
<td>0.91</td>
</tr>
<tr>
<td>R Square</td>
<td>0.04</td>
<td>0.48</td>
<td>0.82</td>
</tr>
<tr>
<td>Adjusted R Square</td>
<td>-0.06</td>
<td>0.42</td>
<td>0.81</td>
</tr>
<tr>
<td>Standard Error</td>
<td>19.86</td>
<td>22.36</td>
<td>19.38</td>
</tr>
</tbody>
</table>
Grouping into portfolios has improved the SCL estimates as is evident from the higher R-square. This means that the beta (slope) is measured with greater precision, reducing the error-in-measurement problem at the expense of leaving fewer observations for the second pass.

The inputs for the second pass regression are:

<table>
<thead>
<tr>
<th></th>
<th>Avg. Excess Return</th>
<th>Beta</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABC</td>
<td>4.04</td>
<td>0.18</td>
</tr>
<tr>
<td>DEH</td>
<td>8.51</td>
<td>0.98</td>
</tr>
<tr>
<td>FGI</td>
<td>15.28</td>
<td>1.92</td>
</tr>
<tr>
<td>M</td>
<td>8.12</td>
<td></td>
</tr>
</tbody>
</table>

which results in second-pass estimates:

<table>
<thead>
<tr>
<th>Regression Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple R</td>
</tr>
<tr>
<td>R Square</td>
</tr>
<tr>
<td>Adjusted R Square</td>
</tr>
<tr>
<td>Standard Error</td>
</tr>
</tbody>
</table>
### Observations

<table>
<thead>
<tr>
<th></th>
<th>Coefficients</th>
<th>Standard Error</th>
<th>t Stat for ( \beta = 0 )</th>
<th>t Stat for ( \beta = 8.12 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>2.62</td>
<td>0.58</td>
<td>4.55</td>
<td></td>
</tr>
<tr>
<td>Slope</td>
<td>6.47</td>
<td>0.46</td>
<td>14.03</td>
<td>-3.58</td>
</tr>
</tbody>
</table>

Despite the decrease in the intercept and increase in slope, the intercept is now significantly positive and the slope is significantly less than the hypothesized value by more than twice the standard error.

6. Roll’s critique suggests that the problem begins with the market index, which isn’t the theoretical portfolio against which the second pass regression is supposed to hold. Hence, even if the relationship is valid with respect to the true (unknown) index, we may not find it. As a result, the second pass relationship may be meaningless.
Except for Stock I, which realized an extremely positive surprise, the CML shows that the index dominates all other securities, and the three portfolios dominate all individual stocks. The power of diversification is evident despite the use of a very small sample.

**Chapter 19**

5. a. When $S_T$ is 130, $P$ will be 0.

When $S_T$ is 80, $P$ will be 30.

The hedge ratio is $\frac{P^+ - P^-}{(S^+ - S^-)} = \frac{(0 - 30)}{(130 - 80)} = -3/5$.

b. Riskless Portfolio

<table>
<thead>
<tr>
<th></th>
<th>$S = 80$</th>
<th>$S = 130$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 shares</td>
<td>240</td>
<td>390</td>
</tr>
<tr>
<td>5 puts</td>
<td>150</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>390</td>
<td>390</td>
</tr>
</tbody>
</table>
Present value  =  \frac{390}{1.10} = 354.545

c. The portfolio cost is $3S + 5P = 300 + 5P$, and it is worth $354.545. Therefore, P must be $\frac{354.545}{5} = 10.91$.

6. The hedge ratio for the call is \( \frac{(C^+ - C^-)/(S^+ - S^-)}{= \frac{(20 - 0)/(130 - 80)}{2/5} \).

<table>
<thead>
<tr>
<th>Riskless Portfolio</th>
<th>S = 80</th>
<th>S = 130</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 shares</td>
<td>160</td>
<td>260</td>
</tr>
<tr>
<td>5 calls written</td>
<td>0</td>
<td>-100</td>
</tr>
<tr>
<td>Total</td>
<td>160</td>
<td>160</td>
</tr>
</tbody>
</table>

\(-5C + 200 = \frac{160}{1.10}. Therefore, C = 10.91.\)

Does P = C + PV(X) − S?

10.91 = 10.91 + \frac{110}{1.10} − 100
10.91 = 10.91

7. \(d_1 = .3182 \quad N(d_1) = .6248\)
\(d_2 = -.0354 \quad N(d_2) = .4859\)
\(Xe^{-rT} = 47.56\)
\(C = 8.13\)

8. a. C falls to 5.5541
b. C falls to 4.7911
c. C falls to 6.0778
d. C rises to 11.5066
e. C rises to 8.7187

9. According to the Black-Scholes model, the call option should be priced at
\(55 \times N(d_1) - 50 \times N(d_2) = 55 \times .6 - 50 \times .5 = 8\)

Because the option actually sells for more than $8, implied volatility is higher than .30.