Queens College, CUNY, Department of Computer Science

Computational Finance
CSCI 365 / 765
Spring 2018

Instructor: Dr. Sateesh Mane

Final Spring 2018

due Wednesday May 23, 2018 11:59 pm

- NOTE: **It is the policy of the Computer Science Department to issue a failing grade to any student who either gives or receives help on any test.**
- This is an **open-book** test.
- **Any problem to which you give two or more (different) answers receives the grade of zero automatically.**
- This is a **take home exam.**
  Please submit your solution via email, as a file attachment, to `Sateesh.Mane@qc.cuny.edu`.
  The file name should have either of the formats:

  `StudentId_first_last_CS365_midterm2_Apr2018`

  `StudentId_first_last_CS765_midterm2_Apr2018`

  Acceptable file types are txt, doc/docx, pdf (also cpp, with text in comment blocks).
- **In all questions where you are asked to submit programming code, programs which display any of the following behaviors will receive an automatic F:**
  1. Programs which do not compile successfully (compiler warnings which are not fatal are excluded, e.g. use of deprecated features).
  2. Array out of bounds.
  3. Dereferencing of uninitialized variables (including null pointers).
  4. Operations which yield NAN or infinity, e.g. divide by zero, square root of negative number, etc. *Infinite loops.*
  5. Programs which do NOT implement the public interface stated in the question.
- **In addition, note the following:**
  1. Programs which compile and run successfully but have memory leaks will receive a poor grade (but not F).
  2. All debugging and/or output statements (e.g. `cout` or `printf`) will be commented out.
  3. Program performance will be tested solely on function return values and the values of output variable(s) in the function arguments.
  4. In other words, program performance will be tested solely via the public interface presented to the calling application. (I will write the calling application.)

1 Question 1

- **You do NOT need to submit programming code for this question.**
- The time today is $t_0 = 0$.
- The par yields and bootstrapped spot rates of the yield curve are tabulated below.

t	y (%)	r (%)
0.5	1	0.99751
1	1.62383	1.61980
1.5	1.98875	1.98461
2	2.24766	2.24432

- You are given a newly issued bond with a maturity of $T = 2$ years and face value $F = 100$.
- The bond pays 8 coupons, with a **quarterly frequency** at times $t_i = 0.25$, 0.5, 0.75, 1.0, 1.25, 1.5, 1.75 and 2.0, where $i = 1, \dots, 8$.
- The amounts of the annualized coupon rates are as follows:
  1. **The (annualized) coupon rates are the 8 digits of your student id.**
  2. For example if your student id is 23054617, the coupons are $(2, 3, 0, 5, 4, 6, 1, 7)$.
  3. It is possible for some coupon amounts to be zero.
  4. Recall there is a factor of 4 for quarterly coupons.
  5. Hence in this case the bond fair value B is, with discount factors d_{t_i},

$$B = \frac{2}{4}\,d_{0.25} + \frac{3}{4}\,d_{0.5} + \frac{0}{4}\,d_{0.75} + \frac{5}{4}d_{1.0} + \frac{4}{4}\,d_{1.25} + \frac{6}{4}\,d_{1.5} + \frac{1}{4}\,d_{1.75} + \left(F + \frac{7}{4}\right) d_{2.0}\,. \tag{1.1}$$

- The discount factors d_{t_i} are obtained via **cfr (constant forward rate) interpolation of the yield curve.**
- **Calculate the fair value of the bond in eq. (1.1).**
  Call the answer B_{FV}. State your answer to 2 decimal places.
- **Calculate the yield y of the bond in eq. (1.1), if the bond market price is B_{FV}.**
  Call the answer y_1. State the value of y_1 (in percent) to 2 decimal places.
- Recall for quarterly coupons the bond fair value is given by

$$B_{FV} = \left[\sum_i \frac{c_i/4}{(1+\frac{1}{4}y)^{4t_i}}\right] + \frac{F}{(1+\frac{1}{4}y)^8}\,. \tag{1.2}$$

- Define a constant coupon, say c.
- **Find the value of c such that**

$$B_{FV} = \frac{c}{4}\,d_{0.25} + \frac{c}{4}\,d_{0.5} + \frac{c}{4}\,d_{0.75} + \frac{c}{4}\,d_{1.0} + \frac{c}{4}\,d_{1.25} + \frac{c}{4}\,d_{1.5} + \frac{c}{4}\,d_{1.75} + \left(F + \frac{c}{4}\right) d_{2.0}\,. \tag{1.3}$$

- State the value of c to 2 decimal places.

2 Question 2

2.1 Case 1

- In this question, the stock does not pay dividends.
- The prices of an American call C and American put P with the same strike K and expiration T (and on the same stock S) satisfy the following arbitrage bounds

$$C - P \geq S - K\,, \qquad C - P \leq S - \mathrm{PV}(K)\,. \tag{2.1}$$

- Suppose that at time t_0 (today), $S_0 = 100.5$, $K = 100$ and $e^{-r(T-t_0)} = 0.99$.
- All symbols have their usual meanings.
- An American call and put both trade today at $C = P = 100$.
- **Formulate an arbitrage strategy to take advantage of the above mispricing.**

2.2 Case 2

- In this question, the stock does not pay dividends.
- The prices of two American calls C_1 and C_2 with strikes K_1 and K_2, respectively (and $K_1 < K_2$), with the same expiration T (and on the same stock S) satisfy the following arbitrage inequality

$$C_1 - C_2 \leq K_2 - K_1\,. \tag{2.2}$$

- Suppose that at time t_0 (today), $S_0 = 100.5$, $K_1 = 100$, $K_2 = 105$ and $e^{-r(T-t_0)} = 0.99$.
- All symbols have their usual meanings.
- The American calls have prices today of $C_1 = 11$ and $C_2 = 5$.
- **Formulate an arbitrage strategy to take advantage of the above mispricing.**

2.3 Case 3

- In this question, the stock does not pay dividends.
- The prices of two American puts P_1 and P_2 with strikes K_1 and K_2, respectively (and $K_1 < K_2$), with the same expiration T (and on the same stock S) satisfy the following arbitrage inequality

$$P_2 - P_1 \leq K_2 - K_1\,. \tag{2.3}$$

- Suppose that at time t_0 (today), $S_0 = 100.5$, $K_1 = 100$, $K_2 = 105$ and $e^{-r(T-t_0)} = 0.99$.
- All symbols have their usual meanings.
- The American puts have prices today of $P_1 = 5$ and $P_2 = 11$.
- **Formulate an arbitrage strategy to take advantage of the above mispricing.**

3 Question 3

- A **butterfly spread** consists of three options on the same stock.
- All three options have the same expiration time T.
- The options have strike prices K_1, K_2 and K_3, which are are equally spaced.
- Hence K_2 is located at the midpoint of K_1 and K_3, so $K_2 = (K_1 + K_3)/2$.
- A butterfly spread can be created using three call options or three put options.
- The spread consists of long one option at K_1, short two options at K_2, long one option at K_3.

3.1 European option butterfly spreads

- Suppose the market price of a stock is S at the current time t. The stock does not pay dividends. The interest rate is $r > 0$ (a constant).
- For a European call and put c and p with the same strike K and expiration T, the put-call parity relation in this case is
$$c - p = S - Ke^{-r(T-t)}\,. \tag{3.1}$$
- Let c_i and p_i, $i = 1, 2, 3$, be the values of European calls and puts with strikes K_1, K_2 and K_3, where $K_2 = (K_1 + K_3)/2$.
- Use eq. (3.1) to prove the following relation:
$$c_1 - 2c_2 + c_3 = p_1 - 2p_2 + p_3\,. \tag{3.2}$$
- The values of a European call butterfly spread and a European put butterfly spread are equal.
- The corresponding relation is not necessarily true for American options.

3.2 American calls

- A butterfly spread consists of three American calls C_1, C_2 and C_3, with strikes K_1, K_2 and K_3, as described above.
- The butterfly spread consists long C_1, short $2 \times C_2$, long C_3:

$$B_{\text{call}}(S,t) = C_1 - 2C_2 + C_3\,. \tag{3.3}$$

- **Draw a graph of the intrinsic value of the butterfly spread $B_{\text{call}}(S,t)$.**
- **Show that $B_{\text{call}}(S,t) < 0$ if**

$$C_2(S,t) > \frac{C_1(S,t) + C_3(S,t)}{2}\,. \tag{3.4}$$

- **Formulate an arbitrage trade if $C_2(S,t) > (C_1(S,t) + C_3(S,t))/2$.**
- **Therefore deduce the following inequality must be true at any time $t \le T$:**

$$C_2(S,t) \le \frac{C_1(S,t) + C_3(S,t)}{2}\,. \tag{3.5}$$

- The mathematical expression is that the value of a call option is a **convex function** of the strike.

3.3 American puts

- A butterfly spread consists of three American puts P_1, P_2 and P_3, with strikes K_1, K_2 and K_3, as described above.
- The butterfly spread consists long P_1, short $2 \times P_2$, long P_3:

$$B_{\text{put}}(S,t) = P_1 - 2P_2 + P_3\,. \tag{3.6}$$

- **Draw a graph of the intrinsic value of the butterfly spread $B_{\text{put}}(S,t)$.**
- **Show that $B_{\text{put}}(S,t) < 0$ if**

$$P_2(S,t) > \frac{P_1(S,t) + P_3(P,t)}{2}\,. \tag{3.7}$$

- **Formulate an arbitrage trade if $P_2(S,t) > (P_1(S,t) + P_3(S,t))/2$.**
- **Therefore deduce the following inequality must be true at any time $t \le T$:**

$$P_2(S,t) \le \frac{P_1(S,t) + P_3(S,t)}{2}\,. \tag{3.8}$$

- The mathematical expression is that the value of a put option is a **convex function** of the strike.

4 Question 4

- In this question we shall employ the classes `BinomialTree` and `Derivative`, etc. introduced in Homework 9.
- **Write a class `Option` which inherits from `Derivative`.**
  1. The option has a strike K and expiration T.
  2. The option can be a put/call (`bool isCall`).
  3. The option can be American/European (`bool isAmerican`).
  4. Make all the data members public so I can set them in my calling application.
- **Submit your code for all of the above classes (including the `Database` class, etc.**
- Denote the fair values of a European call and put option by c and p, respectively.
- Denote the fair values of an American call and put option by C and P, respectively.
- **Your code will be tested by a calling application with random input values for $(S_0, K, r, q, \sigma, T, t_0)$.**
  1. **The option fair values will be calculated using the `BinomialTree` class.**
  2. Your code will be tested to see if it satisfies put–call parity for European options (with a tolerance of 10^{-6}):

$$\left|(c-p) - (Se^{-q(T-t_0)} - Ke^{-r(T-t_0)})\right| \le 10^{-6} \,. \tag{4.1}$$

  3. Your code will be tested to see if it satisfies the following inequalities for American options (with a tolerance of 10^{-6}):

$$\begin{aligned} C - P &\ge (Se^{-q(T-t_0)} - K) - 10^{-6} \,, \\ C - P &\le (S - Ke^{-r(T-t_0)}) + 10^{-6} \,. \end{aligned} \tag{4.2}$$

  4. Other inequalities will also be checked:

$$\begin{aligned} 0 \le c &\le Se^{-q(T-t_0)} + 10^{-6} \,, \\ 0 \le C &\le S + 10^{-6} \,, \\ 0 \le p &\le Ke^{-r(T-t_0)} + 10^{-6} \,, \\ 0 \le P &\le K + 10^{-6} \,. \end{aligned} \tag{4.3}$$

  5. ***I may perform other tests. Your code must pass all the rational option pricing inequalities in Lecture 7 (for a stock with a continuous dividend yield).***
  6. There will be no tests with discrete dividends.

5 Question 5

- A **straddle** is an option spread with expiration time T and strike price K and a terminal payoff of $|S_T - K|$.
- A European straddle is therefore equal to a long European call plus a long European put, both with the same expiration T and the same strike K.
- An American straddle can be exercised at any time $t_0 \le t \le T$, and pays $|S_t - K|$ if exercised.
- An American straddle is therefore **cheaper** than a long American call plus a long American put, both with the same expiration T and the same strike K. This is because the American options can be exercised individually, whereas when the straddle is exercised, the entire package terminates.
- **Write a class `Straddle` which inherits from `Derivative`.**
  1. The straddle has a strike K and expiration T.
  2. The straddle can be American/European (`bool isAmerican`).
  3. Make all the data members public so I can set them in my calling application.
- **Your code will be tested by a calling application with random input values for $(S_0, K, r, q, \sigma, T, t_0)$.**
  1. **The fair value of a straddle will be calculated using the `BinomialTree` class.**
  2. Denote the fair value of a straddle by Z.
  3. Your code for the fair value of a European straddle will be tested to see if it satisfies the following equality (with a tolerance of 10^{-6}):

$$|Z_{\text{Eur}} - (c + p)| \le 10^{-6}\,. \tag{5.1}$$

  4. Your code for the fair value of an American straddle will be tested to see if it satisfies the following inequalities (with a tolerance of 10^{-6}):

$$\begin{aligned} Z_{\text{Am}} &\ge |S_0 - K| - 10^{-6}\,, \\ Z_{\text{Am}} &\le (C + P) + 10^{-6}\,. \end{aligned} \tag{5.2}$$

6 Question 6

- A **binary option** (also known as a **digital option**) is an option with expiration time T and strike price K and the following terminal payoff:
  1. A binary call option pays \$1 if $S_T \geq K$ and zero otherwise.
  2. A binary put option pays \$1 if $S_T < K$ and zero otherwise.
- **Write a class `BinaryOption` which inherits from `Derivative`.**
- We shall consider only European binary call options below so we can ignore the early exercise valuation tests.
- You are given the following input values:
  $\boldsymbol{S_0 = 90}$, $K = 100$, $q = 0.02$, $T = 1$, $t_0 = 0$.
- **Set the risk free rate to the value of y_1 from Question 1.**
  (Note that r is a decimal value, so for example if $y_1 = 5.12\%$ then set $r = 0.0512$.)

$$r = y_1 \qquad \text{(decimal)}\,. \tag{6.1}$$

- There are also Black–Scholes–Merton formulas for the fair values of binary options

$$c_{\text{bin}} = e^{-r(T-t_0)}\,N(d_2)\,, \qquad p_{\text{bin}} = e^{-r(T-t_0)}\,N(-d_2)\,. \tag{6.2}$$

- **Write functions to compute the formulas in eq. (6.2).**
- **Submit you code as part of your solution to this question.**
- Use $\boldsymbol{n = 1000}$ steps in the binomial model.
- **Fill the following table.**

σ	$c^{\text{binomial}}_{\text{binary}}$	$p^{\text{binomial}}_{\text{binary}}$	$c^{\text{BSM}}_{\text{binary}}$	$p^{\text{BSM}}_{\text{binary}}$
0.1	3 d.p.	3 d.p.	3 d.p.	3 d.p.
0.2	3 d.p.	3 d.p.	3 d.p.	3 d.p.
0.3	3 d.p.	3 d.p.	3 d.p.	3 d.p.
0.4	3 d.p.	3 d.p.	3 d.p.	3 d.p.
0.5	3 d.p.	3 d.p.	3 d.p.	3 d.p.
0.6	3 d.p.	3 d.p.	3 d.p.	3 d.p.
0.7	3 d.p.	3 d.p.	3 d.p.	3 d.p.
0.8	3 d.p.	3 d.p.	3 d.p.	3 d.p.
0.9	3 d.p.	3 d.p.	3 d.p.	3 d.p.
1.0	3 d.p.	3 d.p.	3 d.p.	3 d.p.

- **Plot a graph of the binary call option fair value as a function of the volatility, using (i) the binomial model and (ii) the Black–Scholes–Merton formulas in eq. (6.2), for $0.01 \leq \sigma \leq 1.0$ in steps of 0.01.**

- **Plot a graph of the binary put option fair value as a function of the volatility, using (i) the binomial model and (ii) the Black–Scholes–Merton formulas in eq. (6.2), for $0.01 \le \sigma \le 1.0$ in steps of 0.01.**
- *Do not be concerned if the graphs look choppy (not smooth curves) for the binomial model.*
- If you have done your work correctly, the binary option fair values will NOT be monotonic functions of the volatility. The fair value of the binary call will exhibit a peak and the fair value of the binary put will exhibit a dip.
- Because of the peak/dip, implied volatility is not a useful concept for binary options. For a given market price, there can be two solutions for the implied volatility, i.e. not a unique value.

7 Question 7

- **This question will carry more weight than the others, maybe double weight.**
- A **convertible bond** is an equity derivative with the following characteristics.
  1. It has a strike K and expiration T and can be American or European.
  2. The terminal payoff is
  $$\text{terminal payoff} = \max(S_T, K)\,. \tag{7.1}$$
  3. This is similar to the payoff in Midterm 2 Question 6(a).
  4. What this means is that if $S_T \geq K$ at expiration, the holder receives one share of stock and if $S_T < K$ at expiration, the holder receives cash in the amount K.
  5. Prior to expiration, if a convertible bond is exercised, the intrisic value at time t is S_t:
  $$\text{intrinsic value at time } t = S_t\,. \tag{7.2}$$
  6. We shall add one more feature, essentially a knockout barrier.
  7. Many convertible bonds are **callable.**
  8. This means that there is a threshold B and if $S \geq B$ at any time, the convertible bond terminates. The value of the convertible bond if called in this way is $V = S$.
  9. Hence in addition to early exercise, we add one more feature to the valuation tests, which is $V = S_t$ if $S_t \geq B$ for $t_0 \leq t < T$.
- In more detail, a convertible bond is intermediate between a bond and an option.
  1. A convertible bond also pays coupons.
  2. We shall ignore coupons and consider only a zero coupon convertible bond.
  3. Zero coupon convertible bonds do exist.
- **Prove that $V \geq \text{PV}(K)$ for a zero coupon convertible bond.**
- Convertible bonds are issued by companies, and when an investor exercises a convertible bond, the company prints new shares of stock and delivers them to the investor.
- In that sense, convertible bonds are different from exchange listed options and are more similar to warrants.
- Convertible bonds usually have much longer expiration times than exchange listed options, extending many years (30 years is not uncommon).
- One reason investors buy convertible bonds is because they can perform gamma trading with a longer time horizon than is possible with exchange listed options.
- In this question, we shall perform **gamma trading** with a convertible bond.
- **See next page.**

- **Write a class `ConvertibleBond` which inherits from `Derivative`.**
- In this question, we shall employ a callable American convertible bond.
- Denote the fair value of the convertible bond by U.
- Denote the market price of the convertible bond by M.
- You are given the following inputs: $K = 100$, $B = 130$, $T = 5.0$, $r = 0.05$ and $q = 0$.
- A graph of the fair value of a convertible bond with the above parameters in displayed in Fig. 1. The fair value was calculated with a volatility of $\sigma = 0.35$.
- **Plot a graph of the fair value of a convertible bond with the above parameters using a volatility of $\sigma = 0.5$.**
- If you have done your work correctly, the fair value will be higher than that displayed in Fig. 1. (Except $V = S$ when $S \geq B$ and also at $S = 0$.)
- **(Bonus) Explain why the fair value at $S \to 0$ is the same in both graphs, independent of the value of the volatility.**

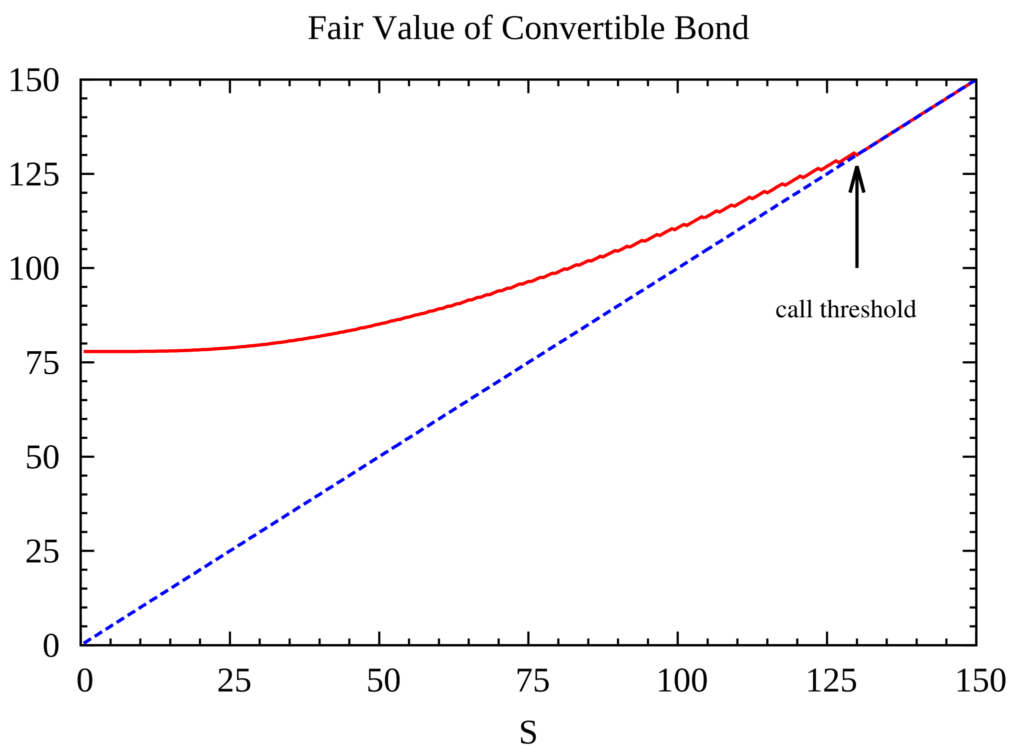

Figure 1: Graph of the fair value of a convertible bond. The intrinsic value is shown as a dashed line. The call threshold is also indicated.

- We require two more values.
  1. **Take the first 4 digits of your student id. Define:**
  $$\delta S_1 = \frac{\text{first 4 digits of your student id}}{10^4}\,. \tag{7.3}$$
  2. **Take the last 4 digits of your student id. Define (note the minus sign):**
  $$\delta S_2 = -\frac{\text{last 4 digits of your student id}}{10^4}\,. \tag{7.4}$$
  3. For example if your student id is 23054617, then
  $$\delta S_1 = 0.2305\,, \qquad \delta S_2 = -0.4617\,. \tag{7.5}$$
  4. Note that δS_2 is **negative.**
- **See next page.**

- We shall perform **gamma trading** using a convertible bond.

1. **Day 0:**
   (a) The time is $t_0 = 0$.
   (b) The stock price is $S_0 = 60$.
   (c) The convertible bond market price is $M_0 = 90$.
   (d) **Calculate the implied volatility of the convertible bond (4 decimal places).**
   (e) Denote the answer by σ_0.
   (f) **Calculate the Delta of the convertible bond (4 decimal places) using a finite difference numerical derivative as follows. The volatility is $\sigma = \sigma_0$.**

$$\Delta_0 = \frac{U(S_0+1) - U(S_0-1)}{2} \qquad (t_0 = 0,\ \sigma = \sigma_0)\,. \tag{7.6}$$

   (g) We start trading with zero cash and zero stock and options.
   (h) We create a portfolio of **long one convertible bond U and short sale of Δ_0 shares of stock.**
   (i) The money in the bank on day 0 is therefore

$$\text{Money}_0 = \Delta_0 S_0 - M_0\,. \tag{7.7}$$

   (j) **Calculate the value of Money_0 to 2 decimal places.** (It may be negative.)
   (k) **See next page.**

2. **Day 1:**
   (a) The time is $\boldsymbol{t_0 = 0.01}$.
   (b) **The stock price has changed to:**
   $$S_1 = S_0 + \delta S_1 \,. \tag{7.8}$$
   (c) **The convertible bond market price has changed to:**
   $$M_1 = 90.2 \,. \tag{7.9}$$
   (d) **Calculate the implied volatility of the convertible bond (4 decimal places).**
   (e) Denote the answer by σ_1.
   (f) **Calculate the Delta of the convertible bond (4 decimal places) using a finite difference numerical derivative as follows. The volatility is $\sigma = \sigma_1$.**
   $$\Delta_1 = \frac{U(S_1+1) - U(S_1-1)}{2} \qquad (t_0 = 0.01,\ \sigma = \sigma_1) \,. \tag{7.10}$$
   (g) **We rebalance the hedge to short Δ_1 shares of stock.**
   (h) Hence we sell $\Delta_1 - \Delta_0$ shares of stock, at the new stock price S_1.
   (i) The money in the bank on day 1 is therefore:
   $$\text{Money}_1 = \text{Money}_0 + (\Delta_1 - \Delta_0) S_1 \,. \tag{7.11}$$
   (j) **Calculate the value of Money_1 to 2 decimal places.**
   (k) The value of Money_1 may be greater or less that Money_0, it will be different for each of you.
   (l) **See next page.**

3. **Day 2:**
   (a) The time is $\boldsymbol{t_0 = 0.02}$.
   (b) **The stock price has changed to:**
   $$S_2 = S_1 + \delta S_2 \,. \tag{7.12}$$
   (c) Note that this is a negative change in the stock price.
   (d) **The convertible bond market price has changed to:**
   $$M_2 = 90.15 \,. \tag{7.13}$$
   (e) **Calculate the implied volatility of the convertible bond (4 decimal places).**
   (f) Denote the answer by σ_2.
   (g) **Calculate the Delta of the convertible bond (4 decimal places) using a finite difference numerical derivative as follows. The volatility is $\sigma = \sigma_2$.**
   $$\Delta_2 = \frac{U(S_2+1) - U(S_2-1)}{2} \qquad (t_0 = 0.02,\ \sigma = \sigma_2) \,. \tag{7.14}$$
   (h) **We rebalance the hedge to short Δ_2 shares of stock.**
   (i) Hence we sell $\Delta_2 - \Delta_1$ shares of stock, at the new stock price S_2.
   (j) (Note that $\Delta_2 - \Delta_1$ is a negative number, so we are really buying stock at the new stock price S_2. We let the mathematics take care of the minus signs.)
   (k) **The money in the bank on day 2 is therefore:**
   $$\text{Money}_2 = \text{Money}_1 + (\Delta_2 - \Delta_1) S_2 \,. \tag{7.15}$$
   (l) **Calculate the value of Money_2 to 2 decimal places.**
   (m) Once again, the value of Money_2 may be greater or less than Money_1.
   (n) **See next page.**

- **We close out our gamma trading portfolio at the end of day 2.**

  1. We sell our convertible bond at the price M_2.
  2. We buy Δ_2 shares of stock at the stock price S_2 to close out our short stock position.
  3. Hence there is only cash in the bank. The convertible bond and the stock are gone.
  4. **Your total profit is therefore:**

$$\text{Profit} = \text{Money}_2 + M_2 - \Delta_2 S_2 \,. \tag{7.16}$$

  5. **Calculate the value of the profit to 2 decimal places.**
  6. This is your profit from gamma trading.
  7. If you have done your work correctly, you should obtain a positive profit.
  8. **Note that I neglected interest rate compounding to calculate the profit/loss.** For an expiration time of 5 years and a trading interval of two days, the effects of interest rate compounding are negligible and merely make the calculations complicated.
  9. **Notice that the stock price was always $S < K$, yet the gamma trading strategy yielded a profit.**
  10. This is what options traders do.
  11. Options traders buy and sell volatility.
  12. Options traders do not care if an option (or convertible bond) is out of the money its whole life.