MMA 707 Analytical Finance I

Curran model for pricing Asian options

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Abstract

We try Curran model to price an Asian option. The first section gives general outlook of Curran model and computational algorithm. In second section we proceed to application developed for Curran model implementation. In the last section we use our application to present real-life example of pricing an Asian call.

Contents

1. Introduction

An Asian option (or average value option) is a special type of option contract. For Asian options the payoff is determined by the average underlying price over some pre-set period of time. Asian options are thus one of the basic forms of exotic options. Asian options are so called because they were introduced in Tokyo, Japan, in 1987, at a branch of an American bank [1].

The pricing of Asian options in a "Black - Scholes" environment has given researchers trouble. The difficulty with these problems is that the probability distribution of the variable which determines the option payoff at expiration, a sum of correlated lognormal random variables, has no closed-form representation [2].

This paper is dedicated to one of the methods of pricing Asian options developed by Curran, so called “Curran’s Approximation”. Curran claims that this method is more accurate then other closed-form approximations presented earlier [3].

The main goal of our research is to develop a general application for pricing of Asian options according to Curran model. VBA code of application can be found in appendix.

2. Problem description

2.1 Curran model.

In Curran model expected payoff of Asian option is computed conditioning on the geometric mean of underlying asset prices and integrated with respect to the (known) distribution of the geometric mean price [2].

Thus, price of an Asian option can be expressed as:

$$C = \exp(-rT)\tilde{E}\left\{\tilde{E}\left[Max(A-k,0) \mid G\right]\right\}, \qquad (1)$$

where *C* is the price of the call option, *r* is the risk-free interest rate, *T* is the time to expiration, $\tilde{E}$ denotes a risk- adjusted expectation, *A* is the arithmetic mean of the relevant prices,

$$A = (1/W)\sum_{i=1}^{n} \omega_i S_i,$$

K is the strike price, and *G* is the geometric mean price given by

$$G = \left\{\prod_{i=1}^{n} S_i^{\omega_i}\right\}^{1/W}$$

where, $\omega_i > 0$ is the weighting of the *i*th relevant price, S_i is the *i*th relevant price, *n* is the number of prices to be averaged, and

$$W = \sum_{i=1}^{n} w_i$$

The expression for the price of an Asian option given in (1) can be expanded to

$$C = \exp(-rT)\left\{\int_0^K \tilde{E}\left[Max(A-K,0) \mid G\right] g(G)dG + \int_K^{\infty} \tilde{E}\left[Max(A-K,0) \mid G\right] g(G)dG\right\}, \quad (2)$$

where *g* is the density function of *G*. Let the terms inside the braces on the right-hand side of (2) be denoted by C_1 and C_2 so that

$$C = \exp(-rT)\left[C_1 + C_2\right]$$

The complete description of solution and derivation of the following results is rather complicated and is beyond the scope of this paper. Complete proof and derivation of following results can be found in [2]

We present now the final result.

$$C_1 \approx \int_0^K Max\left[\tilde{E}(A \mid G) - K, 0\right] g(G) dG.$$

$$C_2 = \left(1/W\right) \sum_{i=1}^{n} \omega_i \exp\left(\mu_i + \sigma_i^2/2\right) \times \Phi\left(\left(\mu - \ln K\right)/\sigma + \sigma_{X_i}/\sigma\right) - K\Phi\left(\left(\mu/\ln K\right)/\sigma\right)$$

2.2 Computational algorithm

Before jumping to the application overview we need to state formulas on which our calculations are based. For our research we will use formulas for calculating the price of an Asian option presented in [3].

The price of an Asian option *C* is given by the formula:

$$c \approx e^{-rT}\left[\frac{1}{n}\sum_{i=1}^{n} e^{\mu_i + \sigma_i^2/2} N\left(\frac{\mu - \ln\left(\hat{X}\right)}{\sigma_X} + \frac{\sigma_{xi}}{\sigma_x}\right) - XN\left(\frac{\mu - \ln\left(\tilde{X}\right)}{\sigma_x}\right)\right],$$

Where

S = Initial asset price

X = Strike price of an option.

r = Risk-free interest rate.

B = Cost-of-carry.

T = Time to maturity in years

Δt = Time between averaging points

N = Number of averaging points

σ = Volatility of asset.

N(x) = The cumulative normal distribution function.

$$\mu_i = \ln(S) + (b - \sigma^2/2)t_i$$
$$\sigma_i = \sqrt{\sigma^2[t_1 + (i-1)\Delta t]}$$
$$\sigma_{xi} = \sigma^2\{t_1 + \Delta t[(i-1) - i(i-1)/2n]\}$$
$$\mu = \ln(S) + (b - \sigma^2/2)[t_1 + (n-1)\Delta t/2]$$
$$\sigma_x = \sqrt{\sigma^2[t_1 + \Delta t(n-1)(2n-1)/6n]}$$

and

$$\tilde{X} = 2X - \frac{1}{n}\sum_{i=1}^{n} \exp\left\{\mu_i + \frac{\sigma_{xi}[\ln(X) - \mu]}{\sigma_x^2} + \frac{\sigma_i^2 - \sigma_{xi}^2/\sigma_x^2}{2}\right\}$$

If we are inside the averaging period, $m > 0$, then the strike price should be replaced by

$$X = \frac{nX - mS_A}{n-m} n - \frac{m}{n-m}$$

Further, if $S_A > (n/m)X$, then exercise is certain for a call, and in the case of a put, it must end up out of the money. So the value of a put must be zero, while the value of a call must be

$$c_A = e^{-rT}(\tilde{S}_A - X)$$

where

$$\hat{S}_A = S_A \frac{m}{n} + E[A]\frac{n-m}{n}$$

If there is only one fixing left to maturity, then the value can be calculated using the generalized Black- Scholes formula (For details please see [2]) weighted with time left to maturity and an adjusted strike price. The value of an Asian call option is then

$$c_A = c_{BSM}(S, \hat{X}, T, r, b, \sigma)\frac{1}{n},$$

where c_{BSM} is the generalized Black- Scholes call formula.

$$\hat{X} = nX - (n-1)S_A,$$

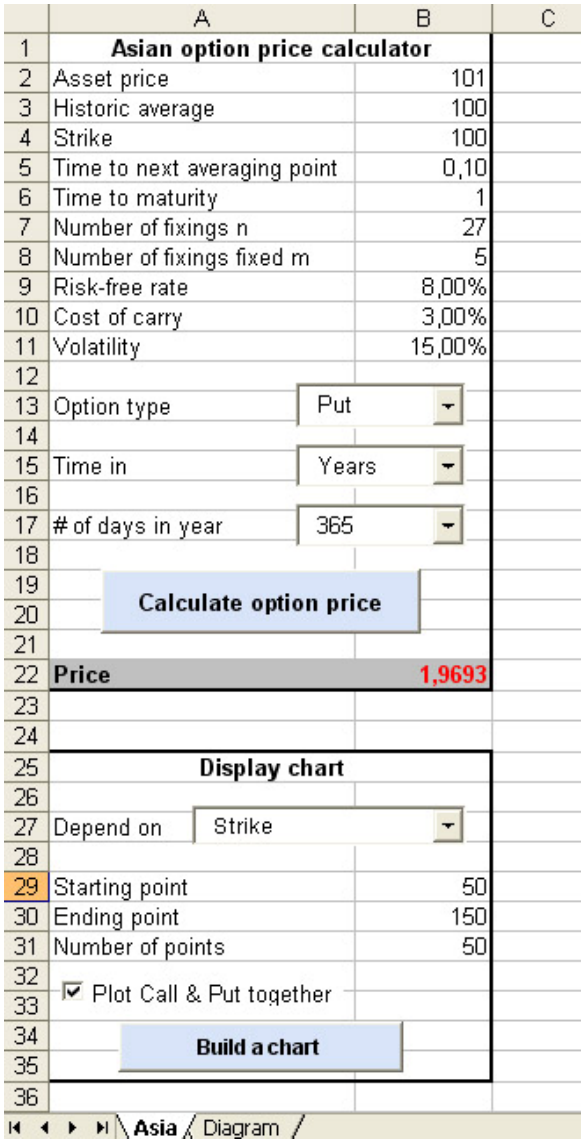
and S_A is the realized average so far. Similarly, the value of an Asian put with one fixing left is

$$p_A = p_{BSM}\left(S, \hat{X}, T, r, b, \sigma\right)\frac{1}{n},$$

where p_{BSM} is the generalized Black- Scholes put formula.

For calculating the value of the Cumulative normal distribution function we use Abromowitz and Stegun approximation.

3. Application overview



	A	B	C
1	**Asian option price calculator**		
2	Asset price	101	
3	Historic average	100	
4	Strike	100	
5	Time to next averaging point	0,10	
6	Time to maturity	1	
7	Number of fixings n	27	
8	Number of fixings fixed m	5	
9	Risk-free rate	8,00%	
10	Cost of carry	3,00%	
11	Volatility	15,00%	
12			
13	Option type	Put	
14			
15	Time in	Years	
16			
17	# of days in year	365	
18			
19	**Calculate option price**		
20			
21			
22	**Price**	1,9693	
23			
24			
25	**Display chart**		
26			
27	Depend on	Strike	
28			
29	Starting point	50	
30	Ending point	150	
31	Number of points	50	
32			
33	Plot Call & Put together		
34	**Build a chart**		
35			
36			

Asia / Diagram

Figure 3.1: The main spreadsheet form.

The application for pricing an Asian option price is developed in Ms Excel & VBA environment. It is realized on three Excel spreadsheets.

First spreadsheet “Asia” contains option price calculator and Display chart form.

Second spreadsheet, namely “Diagram”, is the one where generated chart is placed.

All input data is dynamically stated. It means that all numbers in column B can be changed and are entered by user.

Option type is selected from the respective combobox, as well as measure of time and the number of days in year. Number of days in the year can take on such values:

- 365
- 252
- 366
- 360

It depends on a day-counting convention, selected by the user.

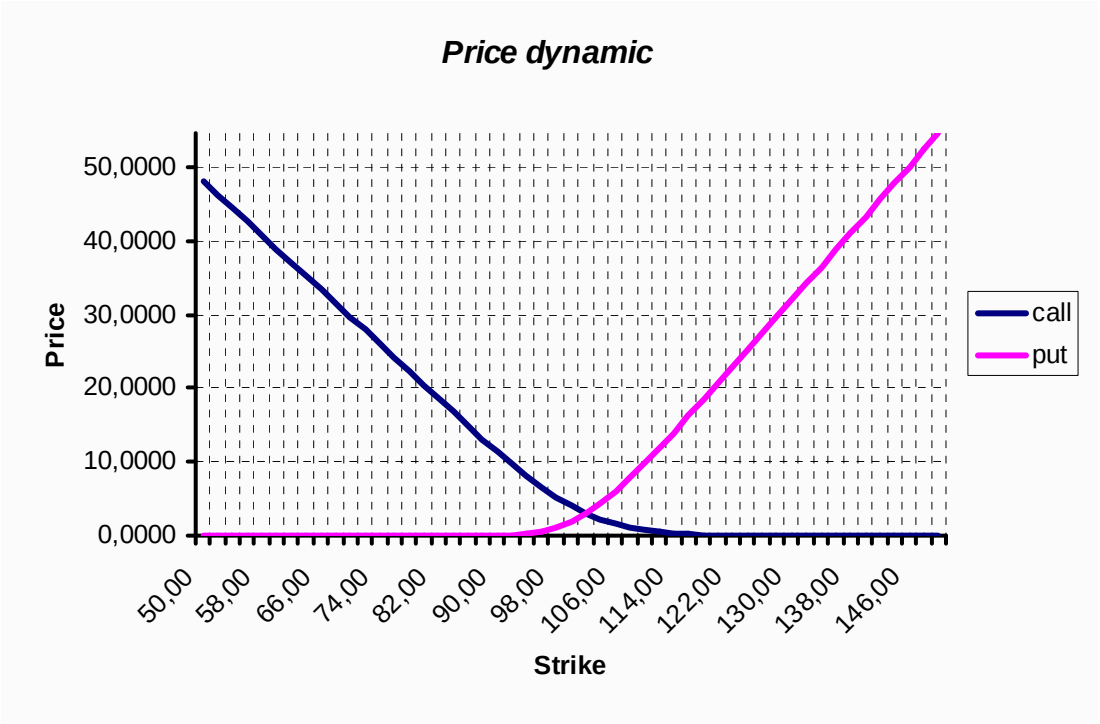


Figure 3.2 Dynamics of price depending on strike.

Constructing a diagram form is realized as follows:

Respective drop-down list contains all variables on which option price depends. While one is selected by the user to be independent variable, all other are fixed and considered to be constants.

By ticking off “Plot Call & Put together” checkbox the user gives instruction to display price of the Call and Put options simultaneously depending on the same variable. It is illustrated on the figure.

4. Real-world example.

Let us take ABB stock that is traded on Stockholm exchange. Consider that we want to issue an Asian call option on it. In the table below price (SEK) of an Asian call for different combinations of strike and time to maturity values is presented.

Volatility	Average	Time in days	Strike		
			130	140	150
10,10%	141,54	63	**14,5780**	**4,8532**	**0,1618**
7,40%	142,74	126	**14,9755**	**5,3079**	**0,2417**
5,10%	141,52	252	**15,1617**	**5,6202**	**0,2791**

Table 4.1: Asian call price for different combinations of strike and time to maturity.

Current (October 8, 2010) price is 144,94 SEK.

Risk-free rate is taken annually to be 3,5%.

5. Conclusion

Pricing of Asian options has its own specific due to the fact that option's payoff function depends on not only underlying asset's price on the maturity, but on overall price dynamics. Curran's approximation is one of the developed by modern financial theory methods of Asian options pricing. In this paper we developed Ms Excel based application and tried to make it as general as possible. However, there are still ways to improve it. For example, it can be upgraded by adding a function which generates 3-dimensional plot of option's Greeks depending on user selected variables. In addition it would be interesting to compare results of Curran's approximation with other existing models. For that reason research will be continued.

6. List of references.

[1] Palmer, Brian (July 14, 2010), *Why Do We Call Financial Instruments "Exotic"? Because some of them are from Japan.*, Slate.

[2] Michael Curran, *Valuing Asian and Portfolio Options by Conditioning on the Geometric Mean Price*, MANAGEMENT SCIENCE, Vol. 40, No. 12, December 1994, pp. 1705-1711.

[3] Espen Gaarder Haug, *The complete guide to Option Pricing Formulas,* 2nd ed., Mc-Graw-Hill, New York, 2007

7. Appendix

VBA code

```
'Calculates option price
Public Function curran(cp As Integer, S As Double, avs As Double, k As Double, t1 As Double, T As Double, n As Double, m As Double, r As Double, b As Double, v As Double)

'Function arguments:

'cp  = call/put flag
'S   = asset price
'avs = historical average
'k   = strike
't1  = time between averaging points
'T   = time to maturity in years
'n   = number of averaging points
'm   = number of fixings
'r   = risk-free rate
'b   = cost of carry
'v   = volatility

Dim dt As Double, my As Double, myi As Double
Dim vxi As Double, vi As Double, vx As Double
Dim Km As Double, sum1 As Double, sum2 As Double
Dim ti As Double, EA As Double
Dim i As Long

On Error Resume Next

'TIme in days or years
If Sheets("asia").ComboBox3.Value = "Days" Then
   t1 = (t1 / Sheets("asia").ComboBox4.Value) * T
   T = T / Sheets("asia").ComboBox4.Value
End If

dt = (T - t1) / (n - 1)

If b = 0 Then
   EA = S
Else
   EA = S / n * Exp(b * t1) * (1 - Exp(b * dt * n)) / (1 - Exp(b * dt))
End If

If m > 0 Then
If avs > n / m * k Then
'put alue is 0
If cp = -1 Then
   'put alue is 0
   curran = 0
ElseIf cp = 1 Then
   'excercise is certain for a call
   avs = avs * m / n + EA * (n - m) / n
   curran = (avs - k) * Exp(-r * T)
End If
   GoTo Finish
   'only one fixings left
ElseIf m = n - 1 Then
```

```
    k = n * k - (n - 1) * avs
    curran = GBlackScholes(cp, S, k, T, r, b, v) * 1 / n
    GoTo Finish
End If

End If

If m > 0 Then
    k = n / (n - m) * k - m / (n - m) * avs
End If

vx = v * Sqr(t1 + dt * (n - 1) * (2 * n - 1) / (6 * n))
my = Log(S) + (b - v * v * 0.5) * (t1 + (n - 1) * dt / 2)
sum1 = 0
'Calculating second term of a sum
For i = 1 To n
    ti = dt * i + t1 - dt
    vi = v * Sqr(t1 + (i - 1) * dt)
    vxi = v * v * (t1 + dt * ((i - 1) - i * (i - 1) / (2 * n)))
    myi = Log(S) + (b - v * v * 0.5) * ti
    sum1 = sum1 + Exp(myi + vxi / (vx * vx) * (Log(k) - my) + (vi * vi - vxi * vxi / (vx * vx)) * 0.5)
Next i

Km = 2 * k - 1 / n * sum1
sum2 = 0
'Calculating second term of the sum
For i = 1 To n
    ti = dt * i + t1 - dt
    vi = v * Sqr(t1 + (i - 1) * dt)
    vxi = v * v * (t1 + dt * ((i - 1) - i * (i - 1) / (2 * n)))
    myi = Log(S) + (b - v * v * 0.5) * ti
    sum2 = sum2 + Exp(myi + vi * vi * 0.5) * NormProb(cp * ((my - Log(Km)) / vx + vxi / vx))
Next i

'returning the value of the function (option price)
curran = Exp(-r * T) * cp * (1 / n * sum2 - k * NormProb(cp * (my - Log(Km)) / vx)) * (n - m) / n

Finish:

End Function

'Abromowitz and Stegun approximation for the cunulative normal distribution function
Public Function NormProb(X As Double) As Double

Dim T As Double
Const b1 = 0.31938153
Const b2 = -0.356563782
Const b3 = 1.781477937
Const b4 = -1.821255978
Const b5 = 1.330274429
Const p = 0.2316419
Const c = 0.39894228

If X >= 0 Then
    T = 1# / (1# + p * X)
    NormProb = (1# - c * Exp(-X * X / 2#) * T * (T * (T * (T * (T * b5 + b4) + b3) + b2) + b1))
Else
    T = 1# / (1# - p * X)
    NormProb = (c * Exp(-X * X / 2#) * T * (T * (T * (T * (T * b5 + b4) + b3) + b2) + b1))
End If
End Function
```

```
'Generalized BlackScholes formula for call option
Public Function GBlackScholes(cp As Integer, S As Double, k As Double, T As Double, r As Double, b As Double, v As Double) As Double

Dim d1 As Double, d2 As Double

d1 = (Log(S / X) + (b + v ^ 2 / 2) * T) / (v * Sqr(T))
d2 = d1 - v * Sqr(T)

If cp = 1 Then
   GBlackScholes = S * Exp((b - r) * T) * NormProb(d1) - k * Exp(-r * T) * NormProb(d2)
ElseIf cp = -1 Then
   GBlackScholes = k * Exp(-r * T) * NormProb(-d2) - S * Exp((b - r) * T) * NormProb(-d1)
End If

End Function

'Construction of graph
Sub graph()

Dim cp As Integer, S As Double, avs As Double, k As Double, t1 As Double, T As Double, b As Double, r As Double, v As Double, n As Double, m As Double

'Initial input parameters
S = Sheets("asia").Cells(2, 2)
avs = Sheets("asia").Cells(3, 2)
k = Sheets("asia").Cells(4, 2)
t1 = Sheets("asia").Cells(5, 2)
T = Sheets("asia").Cells(6, 2)
n = Sheets("asia").Cells(7, 2)
m = Sheets("asia").Cells(8, 2)
r = Sheets("asia").Cells(9, 2)
b = Sheets("asia").Cells(10, 2)
v = Sheets("asia").Cells(11, 2)
'call or put
If Sheets("asia").ComboBox1.Value = "Call" Then
cp = 1
Else
cp = -1
End If

Sheets("didata").Cells.Clear

'initial values for diagram data
If Sheets("asia").Cells(29, 2) = "" Or Sheets("asia").Cells(30, 2) = "" Or Sheets("asia").Cells(31, 2) = "" Then
MsgBox "Input all data, please"
GoTo Finish
End If

Start = Sheets("asia").Cells(29, 2)
endd = Sheets("asia").Cells(30, 2)
steps = Sheets("asia").Cells(31, 2)
   buf = Start
   ds = (endd - Start) / steps
      For i = 1 To steps + 1
         Sheets("didata").Cells(i, 1) = buf
         buf = buf + ds
      Next i

'select independent variale
```

```
Select Case Sheets("asia").ComboBox2.Value

Case "Risk-free rate"
   For i = 1 To steps + 1
   r = Sheets("didata").Cells(i, 1)
   If Sheets("asia").CheckBox1.Value Then
      k = Sheets("asia").Cells(4, 2)
      Sheets("didata").Cells(i, 2) = curran(1, S, avs, k, t1, T, n, m, r, b, v)
      k = Sheets("asia").Cells(4, 2)
      Sheets("didata").Cells(i, 3) = curran(-1, S, avs, k, t1, T, n, m, r, b, v)
   ElseIf cp = 1 Then
   k = Sheets("asia").Cells(4, 2)
   Sheets("didata").Cells(i, 2) = curran(cp, S, avs, k, t1, T, n, m, r, b, v)
   Else
   k = Sheets("asia").Cells(4, 2)
   Sheets("didata").Cells(i, 3) = curran(cp, S, avs, k, t1, T, n, m, r, b, v)
   End If
   Next i

Case "Strike"
   For i = 1 To steps + 1
   k = Sheets("didata").Cells(i, 1)
   If Sheets("asia").CheckBox1.Value Then
      Sheets("didata").Cells(i, 2) = curran(1, S, avs, k, t1, T, n, m, r, b, v)
      Sheets("didata").Cells(i, 3) = curran(-1, S, avs, k, t1, T, n, m, r, b, v)
   ElseIf cp = 1 Then
   Sheets("didata").Cells(i, 2) = curran(cp, S, avs, k, t1, T, n, m, r, b, v)
   Else
   Sheets("didata").Cells(i, 3) = curran(cp, S, avs, k, t1, T, n, m, r, b, v)
   End If
   Next i

Case "Cost of carry"
   For i = 1 To steps + 1
   b = Sheets("didata").Cells(i, 1)
   If Sheets("asia").CheckBox1.Value Then
      k = Sheets("asia").Cells(4, 2)
      Sheets("didata").Cells(i, 2) = curran(1, S, avs, k, t1, T, n, m, r, b, v)
      k = Sheets("asia").Cells(4, 2)
      Sheets("didata").Cells(i, 3) = curran(-1, S, avs, k, t1, T, n, m, r, b, v)
   ElseIf cp = 1 Then
   k = Sheets("asia").Cells(4, 2)
   Sheets("didata").Cells(i, 2) = curran(cp, S, avs, k, t1, T, n, m, r, b, v)
   Else
   k = Sheets("asia").Cells(4, 2)
   Sheets("didata").Cells(i, 3) = curran(cp, S, avs, k, t1, T, n, m, r, b, v)
   End If
   Next i

Case "Volatility"
   For i = 1 To steps + 1
   v = Sheets("didata").Cells(i, 1)
   If Sheets("asia").CheckBox1.Value Then
      k = Sheets("asia").Cells(4, 2)
      Sheets("didata").Cells(i, 2) = curran(1, S, avs, k, t1, T, n, m, r, b, v)
      k = Sheets("asia").Cells(4, 2)
      Sheets("didata").Cells(i, 3) = curran(-1, S, avs, k, t1, T, n, m, r, b, v)
   ElseIf cp = 1 Then
   k = Sheets("asia").Cells(4, 2)
   Sheets("didata").Cells(i, 2) = curran(cp, S, avs, k, t1, T, n, m, r, b, v)
   Else
   k = Sheets("asia").Cells(4, 2)
```

```
    Sheets("didata").Cells(i, 3) = curran(cp, S, avs, k, t1, T, n, m, r, b, v)
    End If
    Next i

Case "Historical average"
    For i = 1 To steps + 1
    avs = Sheets("didata").Cells(i, 1)
    If Sheets("asia").CheckBox1.Value Then
        k = Sheets("asia").Cells(4, 2)
        Sheets("didata").Cells(i, 2) = curran(1, S, avs, k, t1, T, n, m, r, b, v)
        k = Sheets("asia").Cells(4, 2)
        Sheets("didata").Cells(i, 3) = curran(-1, S, avs, k, t1, T, n, m, r, b, v)
    ElseIf cp = 1 Then
    k = Sheets("asia").Cells(4, 2)
    Sheets("didata").Cells(i, 2) = curran(cp, S, avs, k, t1, T, n, m, r, b, v)
    Else
    k = Sheets("asia").Cells(4, 2)
    Sheets("didata").Cells(i, 3) = curran(cp, S, avs, k, t1, T, n, m, r, b, v)
    End If
    Next i

Case "Asset price"
    For i = 1 To steps + 1
    S = Sheets("didata").Cells(i, 1)
    If Sheets("asia").CheckBox1.Value Then
        k = Sheets("asia").Cells(4, 2)
        Sheets("didata").Cells(i, 2) = curran(1, S, avs, k, t1, T, n, m, r, b, v)
        k = Sheets("asia").Cells(4, 2)
        Sheets("didata").Cells(i, 3) = curran(-1, S, avs, k, t1, T, n, m, r, b, v)
    ElseIf cp = 1 Then
    k = Sheets("asia").Cells(4, 2)
    Sheets("didata").Cells(i, 2) = curran(cp, S, avs, k, t1, T, n, m, r, b, v)
    Else
    k = Sheets("asia").Cells(4, 2)
    Sheets("didata").Cells(i, 3) = curran(cp, S, avs, k, t1, T, n, m, r, b, v)
    End If
    Next i

Case "Number of m fixings"
    For i = 1 To steps + 1
    m = Sheets("didata").Cells(i, 1)
    If Sheets("asia").CheckBox1.Value Then
        k = Sheets("asia").Cells(4, 2)
        Sheets("didata").Cells(i, 2) = curran(1, S, avs, k, t1, T, n, m, r, b, v)
        k = Sheets("asia").Cells(4, 2)
        Sheets("didata").Cells(i, 3) = curran(-1, S, avs, k, t1, T, n, m, r, b, v)
    ElseIf cp = 1 Then
    k = Sheets("asia").Cells(4, 2)
    Sheets("didata").Cells(i, 2) = curran(cp, S, avs, k, t1, T, n, m, r, b, v)
    Else
    k = Sheets("asia").Cells(4, 2)
    Sheets("didata").Cells(i, 3) = curran(cp, S, avs, k, t1, T, n, m, r, b, v)
    End If
    Next i

Case "Number of n fixings"
    For i = 1 To steps + 1
    n = Sheets("didata").Cells(i, 1)
    If Sheets("asia").CheckBox1.Value Then
        k = Sheets("asia").Cells(4, 2)
        Sheets("didata").Cells(i, 2) = curran(1, S, avs, k, t1, T, n, m, r, b, v)
        k = Sheets("asia").Cells(4, 2)
```

```
        Sheets("didata").Cells(i, 3) = curran(-1, S, avs, k, t1, T, n, m, r, b, v)
    ElseIf cp = 1 Then
    k = Sheets("asia").Cells(4, 2)
    Sheets("didata").Cells(i, 2) = curran(cp, S, avs, k, t1, T, n, m, r, b, v)
    Else
    k = Sheets("asia").Cells(4, 2)
    Sheets("didata").Cells(i, 3) = curran(cp, S, avs, k, t1, T, n, m, r, b, v)
    End If
    Next i

Case "Time to maturity"
    For i = 1 To steps + 1
    'T = Sheets("didata").Cells(i, 1)
    If Sheets("asia").CheckBox1.Value Then
        T = Sheets("didata").Cells(i, 1)
        k = Sheets("asia").Cells(4, 2)
        Sheets("didata").Cells(i, 2) = curran(1, S, avs, k, t1, T, n, m, r, b, v)
        T = Sheets("didata").Cells(i, 1)
        k = Sheets("asia").Cells(4, 2)
        Sheets("didata").Cells(i, 3) = curran(-1, S, avs, k, t1, T, n, m, r, b, v)
    ElseIf cp = 1 Then
    k = Sheets("asia").Cells(4, 2)
    Sheets("didata").Cells(i, 2) = curran(cp, S, avs, k, t1, T, n, m, r, b, v)
    Else
    k = Sheets("asia").Cells(4, 2)
    Sheets("didata").Cells(i, 3) = curran(cp, S, avs, k, t1, T, n, m, r, b, v)
    End If
    Next i

End Select

'estimate min & max for diagram scaling
If Sheets("asia").CheckBox1.Value Then
Maxc = Sheets("didata").Cells(1, 2)
minc = Sheets("didata").Cells(1, 2)
maxp = Sheets("didata").Cells(1, 2)
minp = Sheets("didata").Cells(1, 2)
For i = 1 To steps + 1
    If Sheets("didata").Cells(i, 2) > Maxc Then
        Maxc = Sheets("didata").Cells(i, 2)
    ElseIf Sheets("didata").Cells(i, 2) < Min Then
        minc = Sheets("didata").Cells(i, 2)
    End If

    If Sheets("didata").Cells(i, 3) > maxp Then
        maxp = Sheets("didata").Cells(i, 3)
    ElseIf Sheets("didata").Cells(i, 3) < minp Then
        minp = Sheets("didata").Cells(i, 3)
    End If
Next i

If maxp > Maxc Then
Max = maxp
Else
Max = Maxc
End If

If minp < minc Then
Min = minp
Else
Min = minc
End If
```

```
Else

If cp = 1 Then
Max = Sheets("didata").Cells(1, 2)
Min = Sheets("didata").Cells(1, 2)
For i = 1 To steps + 1
   If Sheets("didata").Cells(i, 2) > Max Then
      Max = Sheets("didata").Cells(i, 2)
   ElseIf Sheets("didata").Cells(i, 2) < Min Then
      Min = Sheets("didata").Cells(i, 2)
   End If
Next i
Else
Max = Sheets("didata").Cells(1, 3)
Min = Sheets("didata").Cells(1, 3)
For i = 1 To steps + 1
   If Sheets("didata").Cells(i, 3) > Max Then
      Max = Sheets("didata").Cells(i, 3)
   ElseIf Sheets("didata").Cells(i, 3) < Min Then
      Min = Sheets("didata").Cells(i, 3)
   End If
Next i
End If

End If
'create the diagram
Sheets("Diagram").Select
   ActiveChart.ChartArea.Select
   Selection.Clear
   ActiveChart.ChartType = xlLine
   ActiveChart.SeriesCollection.NewSeries
    ActiveChart.SeriesCollection.NewSeries
   ActiveChart.SeriesCollection(1).XValues = Range(Sheets("didata").Cells(1, 1),
Sheets("didata").Cells(steps + 1, 1))
      If Sheets("asia").CheckBox1.Value Then
      ActiveChart.SeriesCollection(1).Values = Range(Sheets("didata").Cells(1, 2),
Sheets("didata").Cells(steps + 1, 2))
      ActiveChart.SeriesCollection(2).Values = Range(Sheets("didata").Cells(1, 3),
Sheets("didata").Cells(steps + 1, 3))
      'add legend
      ActiveChart.SeriesCollection(1).Name = "=""call"""
      ActiveChart.SeriesCollection(2).Name = "=""put"""
      ActiveChart.HasLegend = True
      ActiveChart.Legend.Select
      Selection.Position = xlRight
      Else

      If cp = 1 Then
      ActiveChart.SeriesCollection(1).Values = Range(Sheets("didata").Cells(1, 2),
Sheets("didata").Cells(steps + 1, 2))
      Else
      ActiveChart.SeriesCollection(1).Values = Range(Sheets("didata").Cells(1, 3),
Sheets("didata").Cells(steps + 1, 3))
      End If

      End If
   With ActiveChart
      .HasTitle = True
      .ChartTitle.Characters.Text = "Price dynamic"
      .Axes(xlCategory, xlPrimary).HasTitle = True
      .Axes(xlCategory, xlPrimary).AxisTitle.Characters.Text = Sheets("asia").ComboBox2.Value
```

```
        .Axes(xlValue, xlPrimary).HasTitle = True
        .Axes(xlValue, xlPrimary).AxisTitle.Characters.Text = "Price"
    With ActiveChart.Axes(xlValue)
        .MinimumScale = Min
        .MaximumScale = Max
        .MinorUnitIsAuto = True
        .MajorUnitIsAuto = True
        .Crosses = xlAutomatic
        .ReversePlotOrder = False
        .ScaleType = xlLinear
        .DisplayUnit = xlNone
    End With
    End With
'formatting chart
ActiveChart.Axes(xlValue).Select
    With Selection.Border
        .ColorIndex = 57
        .Weight = xlMedium
        .LineStyle = xlContinuous
    End With
    With Selection
        .MajorTickMark = xlOutside
        .MinorTickMark = xlNone
        .TickLabelPosition = xlNextToAxis
    End With
    ActiveChart.Axes(xlCategory).Select
    With Selection.Border
        .ColorIndex = 57
        .Weight = xlMedium
        .LineStyle = xlContinuous
    End With
    With Selection
        .MajorTickMark = xlOutside
        .MinorTickMark = xlNone
        .TickLabelPosition = xlNextToAxis
    End With
    ActiveChart.SeriesCollection(1).Select
    With Selection.Border
        .ColorIndex = 57
        .Weight = xlThick
        .LineStyle = xlContinuous
    End With
    With Selection
        .MarkerBackgroundColorIndex = xlNone
        .MarkerForegroundColorIndex = xlNone
        .MarkerStyle = xlNone
        .Smooth = False
        .MarkerSize = 3
        .Shadow = False
    End With

    If Sheets("asia").CheckBox1.Value Then
    ActiveChart.SeriesCollection(2).Select
    With Selection.Border
        .ColorIndex = 57
        .Weight = xlThick
        .LineStyle = xlContinuous
    End With
    With Selection
        .MarkerBackgroundColorIndex = xlNone
        .MarkerForegroundColorIndex = xlNone
        .MarkerStyle = xlNone
```

```
        .Smooth = False
        .MarkerSize = 3
        .Shadow = False
    End With
    End If

    ActiveChart.ChartArea.Select
    With ActiveChart.Axes(xlCategory)
        .HasMajorGridlines = True
        .HasMinorGridlines = False
    End With
    With ActiveChart.Axes(xlValue)
        .HasMajorGridlines = True
        .HasMinorGridlines = False
    End With
    ActiveChart.Axes(xlCategory).MajorGridlines.Select
    With Selection.Border
        .ColorIndex = 57
        .Weight = xlHairline
        .LineStyle = xlDot
    End With
    ActiveChart.Axes(xlValue).MajorGridlines.Select
    With Selection.Border
        .ColorIndex = 57
        .Weight = xlHairline
        .LineStyle = xlDot
    End With
    ActiveChart.Axes(xlValue).Select
    Selection.TickLabels.NumberFormat = "0.0000"
    ActiveChart.Axes(xlCategory).Select
    Selection.TickLabels.NumberFormat = "0.00"

Finish:
End Sub
```