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10 Apêndice

Apêndice A.1 – Derivação da Equação Diferencial de Black & Scholes

A análise de Black & Scholes tem como premissa a ausência de oportunidades de arbitragem e que o retorno da carteira deve ser a taxa de juros livre de risco.

Notação:

Π = carteira
w = warrant(opção)
x = preço da ação no tempo t
r = taxa de juros sem risco
v^2 = variância
c = preço de exercício
t^* = dia de maturação
$w_1 = \partial w / \partial x$
$w_{11} = \partial^2 w / \partial x^2$
$w_2 = \partial w / \partial t$

Suponha uma carteira livre de risco:

$$\Pi = x + mw \qquad \text{(A.1.1)}$$

Onde m é o número de opções (compradas) na carteira.

Se Π é uma carteira livre de risco, para que não haja possibilidade de arbitragem, tem-se:

$$d\Pi = r\Pi dt \qquad \text{(A.1.2)}$$

Premissas adotadas no modelo:

1) Movimento Geométrico Browniano

$$\frac{dx}{x} = \mu dt + vdz \qquad \text{(A.1.3)}$$

onde,

μ é a média dos retornos da ação.

$dz \sim N(0, dt)$

2)

$$w = f(x, t\,; r, v, c)$$

Fazendo a expansão de Taylor:

$$dw = \frac{\partial f}{\partial x}dx + \frac{\partial f}{\partial t}dt + \frac{1}{2}\frac{\partial^2 f}{\partial x^2}dx^2 + \frac{1}{2}\frac{\partial^2 f}{\partial t^2}dt^2 + \frac{\partial^2 f}{\partial x \partial t}dxdt + \ldots + \frac{1}{n!}\frac{\partial^n f}{\partial x^n}dx^n + \frac{1}{n!}\frac{\partial^n f}{\partial t^n}dt^n \ldots$$

2.a) Lema de Itô

$$dw = \frac{\partial f}{\partial x}dx + \frac{\partial f}{\partial t}dt + \frac{1}{2}\frac{\partial^2 f}{\partial x^2}dx^2 \qquad \text{(A.1.4)}$$

Os demais termos da expansão de Taylor foram desprezados por terem valor praticamente zero.

O termo $\frac{1}{2}\frac{\partial^2 f}{\partial x^2}dx^2$ não pode ser desprezado como os demais pois pela equação (A.1.3) tem-se que $\frac{dx}{x} = \mu dt + vdz$ com $dz \sim N(0, dt)$.

$$dx = x\mu dt + xvdz \quad \therefore \quad dx^2 = (x\mu dt + xvdz)^2$$

$$dx^2 = x^2\mu^2 dt^2 + 2x^2\mu v dtdz + x^2 v^2 dz^2$$

Como $dt^2 \to 0$ e $dtdz \to 0$, logo :

$$dx^2 = x^2 v^2 dz^2 \qquad \text{(A.1.5)}$$

Analisando dz^2:

$$Var(dz) = E\left[dz^2\right] - \{E[dz]\}^2$$

$$E\left[dz^2\right] = Var(dz) + \{E[dz]\}^2 = dt + 0 = dt \qquad \text{(A.1.6)}$$

$$Var\left[dz^2\right] = E\left[dz^4\right] - \left\{E\left[dz^2\right]\right\}^2 \qquad \text{(A.1.7)}$$

A curtose pode ser representada como: $E\left[(x-\mu)^4\right] = 3\sigma^4$

Neste caso em especial, tem-se que:

$$E\left[(dz-0)^4\right] = 3(Var(dz))^2$$

$$E\left[dz^4\right] = 3dt^2 \qquad \text{(A.1.8)}$$

Substituindo (A.1.6) e (A.1.8) em (A.1.7):

$$Var\left[dz^2\right] = E\left[dz^4\right] - \left\{E\left[dz^2\right]\right\}^2 = 3dt^2 - dt^2 = 2dt^2 = 0$$

$$Var\left[dz^2\right] = 0 \qquad \text{(A.1.9)}$$

Portanto, dz^2 tem média dt e variância 0(zero), o que nos faz concluir que trata-se de uma variável determinística, ou seja:

$$dz^2 = dt \tag{A.1.10}$$

Substituindo (A.1.10) em (A.1.5):

$$dx^2 = \frac{1}{2} v^2 x^2 dt \tag{A.1.11}$$

Substituindo (A.1.11) em (A.1.4):

$$dw = w_1 dx + w_2 dt + \frac{1}{2} w_{11} v^2 x^2 dt \tag{A.1.12}$$

3) Da Equação (A.1.1)

$$d\Pi = dx + mdw \tag{A.1.13}$$

Ao substituir *dw* obtido na equação (A.1.12) na equação (A.1.13), tem-se:

$$d\Pi = dx + m\left(w_1 dx + w_2 dt + \frac{1}{2} w_{11} v^2 x^2 dt \right)$$

$$d\Pi = (1 + mw_1)dx + mw_2 dt + \frac{1}{2} mw_{11} v^2 x^2 dt \tag{A.1.14}$$

$(1 + mw_1)dx$ é uma parcela que representa risco já que dx está relacionado com as variações no preço do ativo. Afim de se eliminar esse risco, deve-se fazer:

$$(1 + mw_1) = 0 \quad \therefore \quad m = -\frac{1}{w_1} \text{ (o sinal negativo indica uma posição vendida)} \tag{A.1.15}$$

Continuando:

$$d\Pi = mw_2 dt + \frac{1}{2} mw_{11} v^2 x^2 dt \tag{A.1.16}$$

Da equação (A.1.2)

$$d\Pi = r\Pi dt = r(x + mw)dt \tag{A.1.2}$$

Igualando (A.1.16) e (A.1.2):

$$mw_2 dt + \frac{1}{2} mw_{11} v^2 x^2 dt = (rx + rmw)dt \tag{A.1.17}$$

Dividindo toda equação por mdt:

$$w_2 + \frac{1}{2} w_{11} v^2 x^2 = \frac{rx}{m} + rw \tag{A.1.18}$$

Como $m = -\frac{1}{w_1} \quad \Rightarrow \quad \frac{1}{m} = -w_1$

Substituindo na equação (A.1.18), chega-se a equação diferencial parcial

$$\frac{\partial w}{\partial t} + \frac{1}{2} v^2 x^2 \frac{\partial^2 w}{\partial x^2} + rx \frac{\partial w}{\partial x} - rw = 0 \tag{A.1.19}$$

Apêndice A.2 – Distribuição da Taxa de Retorno

A propriedade lognormal dos preços do ativo pode ser usada para fornecer informações sobre a distribuição de probabilidade da taxa de retorno, continuamente capitalizada, obtida entre os instantes t e T. Defininamos a taxa de retorno ao ano continuamente capitalizada, realizada entre os instante t e T, como η. Segue-se que:

$$S_T = Se^{\eta(T-t)}$$

e

$$\eta = \frac{1}{T-t}\ln\frac{S_T}{S} \tag{A.2.1}$$

onde,

S = preço do ativo

Como:

$$\ln S_T - \ln S = \ln\frac{S_T}{S}$$

Como a váriavel *ln S* segue o processo generalizado de Wiener, tem-se que a mudança em *ln S* entre o instante *t* e *T* é normalmente distribuída:

$$\ln\frac{S_T}{S} \sim \phi\left[\left(\mu - \frac{\sigma^2}{2}\right)(T-t), \sigma\sqrt{T-t}\right] \tag{A.2.2}$$

A partir das propriedades das distribuições normais, tem-se pela equação (A.2.1):

$$\eta \sim \phi\left[\mu - \frac{\sigma^2}{2}, \frac{\sigma}{\sqrt{T-t}}\right] \tag{A.2.3}$$

Assim sendo, a taxa de retorno continuamente capitalizada é distribuída normalmente com média $\mu - \sigma^2/2$ e desvio padrão $\sigma/\sqrt{T-t}$.

Apêndice A.3 – Modelos de Equilíbrio

Os modelos de equilíbrio geralmente começam com pressupostos acerca de variáveis econômicas, derivando um processo para a taxa livre de risco de curto prazo, *r*. Em seguida, eles exploram a implicação do processo para preços de títulos e opções. A taxa de curto prazo, *r*, no instante *t*, é a taxa que se aplica a um período de tempo infinitesalmente curto no instante *t*, sendo às vezes denominada de *taxa instantânea de curto prazo*. É importante enfatizar que o importante não é o processo de *r* no mundo real, pois, o preço de um título ou derivativo depende unicamente do processo seguido por *r* num mundo neutro ao risco.

O valor de um derivativo de taxa de juros, que fornece retorno f_T no instante *T* pode ser:

$$\hat{E}\left[e^{-\bar{r}(T-t)} f_T\right] \qquad \text{(A.3.1)}$$

onde $\bar{r}$ é o valor médio de *r* no intervalo de tempo entre *t* e *T* e $\hat{E}$ denota o valor esperadonum mundo neutro ao risco.

Define-se *P(t,T)* como o preço, no instante *t*,do título de desconto cujo retorno é \$1 no instante *T*. A partir da equação (A.3.1), tem-se:

$$P(t,T) = \hat{E}\left[e^{-\bar{r}(T-t)}\right] \qquad \text{(A.3.2)}$$

Se *R(t,T)* for a taxa de juros, continuamente capitalizada, no instante *t*, para o período *t – T*:

$$P(t,T) = e^{-R(t,T)(T-t)} \qquad \text{(A.3.3)}$$

de modo que:

$$R(t,T) = -\frac{1}{T-t}\ln P(t,T) \qquad \text{(A.3.4)}$$

e, da equação (A.3.2):

$$R(t,T) = -\frac{1}{T-t} \ln \hat{E}\left[e^{-\bar{r}(T-t)}\right] \tag{A.3.5}$$

Essa equação permite que a estrutura a termo das taxas de juros seja obtida, em determinado instante, a partir do valor de *r* naquele instante e apartir do processo para *r* com neutralidade ao risco. Ela demonstra que, uma vez definido todo o processo para *r*, teremos definido toda a estrutura a termo inicial das taxas de juros e como ela poderá desenvolver-se em todos os instantes futuros.

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Anexos

Anexo A.1 – Dados

A.1.1
Estrutura a termo de juros

```
dtTime,offset,size,1,2,5,21,42,63,126,189,365,730,1095,1460
2004/07/01,13560,12,0.1580,0.1578,0.1577,0.1577,0.1623,0.1598,0.1647,0.1678,0.1703,0.1770,0.1828,0.1849
2004/07/02,13572,12,0.1580,0.1577,0.1576,0.1575,0.1623,0.1591,0.1627,0.1655,0.1675,0.1720,0.1754,0.1754
2004/07/05,13584,12,0.1580,0.1577,0.1575,0.1578,0.1620,0.1590,0.1621,0.1643,0.1655,0.1691,0.1729,0.1729
2004/07/06,13596,12,0.1580,0.1576,0.1574,0.1583,0.1622,0.1597,0.1635,0.1663,0.1679,0.1736,0.1774,0.1803
2004/07/07,13608,12,0.1579,0.1576,0.1575,0.1588,0.1621,0.1600,0.1635,0.1669,0.1688,0.1752,0.1792,0.1827
2004/07/08,13620,12,0.1579,0.1578,0.1577,0.1596,0.1624,0.1607,0.1661,0.1691,0.1715,0.1771,0.1818,0.1840
2004/07/09,13632,12,0.1577,0.1577,0.1577,0.1596,0.1624,0.1608,0.1661,0.1691,0.1715,0.1771,0.1818,0.1840
2004/07/12,13644,12,0.1578,0.1576,0.1575,0.1603,0.1619,0.1603,0.1646,0.1677,0.1695,0.1755,0.1779,0.1779
2004/07/13,13656,12,0.1578,0.1576,0.1575,0.1607,0.1617,0.1601,0.1650,0.1676,0.1692,0.1753,0.1805,0.1839
2004/07/14,13668,12,0.1578,0.1576,0.1575,0.1611,0.1615,0.1601,0.1646,0.1678,0.1699,0.1753,0.1803,0.1823
2004/07/15,13680,12,0.1577,0.1575,0.1574,0.1614,0.1612,0.1598,0.1642,0.1671,0.1690,0.1733,0.1776,0.1792
2004/07/16,13692,12,0.1577,0.1575,0.1574,0.1618,0.1609,0.1595,0.1635,0.1662,0.1677,0.1726,0.1773,0.1805
2004/07/19,13704,12,0.1577,0.1575,0.1574,0.1621,0.1607,0.1596,0.1640,0.1667,0.1683,0.1736,0.1784,0.1821
2004/07/20,13716,12,0.1577,0.1575,0.1574,0.1625,0.1605,0.1596,0.1641,0.1669,0.1685,0.1744,0.1794,0.1810
2004/07/21,13728,12,0.1576,0.1575,0.1574,0.1632,0.1609,0.1602,0.1653,0.1683,0.1701,0.1772,0.1831,0.1852
2004/07/22,13740,12,0.1576,0.1573,0.1571,0.1634,0.1606,0.1603,0.1659,0.1694,0.1714,0.1784,0.1837,0.1872
2004/07/23,13752,12,0.1576,0.1572,0.1570,0.1636,0.1605,0.1606,0.1670,0.1712,0.1737,0.1814,0.1875,0.1896
2004/07/26,13764,12,0.1576,0.1572,0.1570,0.1638,0.1602,0.1607,0.1674,0.1720,0.1746,0.1827,0.1854,0.1854
2004/07/27,13776,12,0.1576,0.1612,0.1633,0.1644,0.1599,0.1602,0.1668,0.1708,0.1732,0.1806,0.1829,0.1829
2004/07/28,13788,12,0.1576,0.1577,0.1577,0.1577,0.1589,0.1602,0.1658,0.1693,0.1716,0.1781,0.1835,0.1851
2004/07/29,13800,12,0.1578,0.1578,0.1578,0.1578,0.1593,0.1607,0.1674,0.1718,0.1747,0.1828,0.1850,0.1850
2004/07/30,13812,12,0.1581,0.1583,0.1584,0.1584,0.1598,0.1617,0.1690,0.1733,0.1763,0.1850,0.1921,0.1950
2004/08/02,13824,12,0.1582,0.1583,0.1584,0.1584,0.1600,0.1616,0.1688,0.1733,0.1765,0.1857,0.1919,0.1950
2004/08/03,13836,12,0.1582,0.1583,0.1584,0.1584,0.1597,0.1611,0.1685,0.1733,0.1766,0.1854,0.1883,0.1883
2004/08/04,13848,12,0.1583,0.1585,0.1586,0.1588,0.1604,0.1622,0.1706,0.1761,0.1797,0.1890,0.1958,0.1981
2004/08/05,13860,12,0.1584,0.1587,0.1589,0.1594,0.1614,0.1634,0.1725,0.1787,0.1832,0.1937,0.2007,0.2045
2004/08/06,13872,12,0.1585,0.1583,0.1582,0.1586,0.1600,0.1618,0.1700,0.1750,0.1784,0.1864,0.1917,0.1953
2004/08/09,13884,12,0.1586,0.1585,0.1585,0.1589,0.1602,0.1621,0.1704,0.1754,0.1786,0.1867,0.1918,0.1932
2004/08/10,13896,12,0.1588,0.1585,0.1584,0.1588,0.1601,0.1622,0.1710,0.1764,0.1798,0.1875,0.1900,0.1900
2004/08/11,13908,12,0.1588,0.1585,0.1583,0.1587,0.1598,0.1617,0.1700,0.1748,0.1777,0.1845,0.1866,0.1866
2004/08/12,13920,12,0.1587,0.1586,0.1585,0.1591,0.1604,0.1626,0.1709,0.1759,0.1789,0.1862,0.1913,0.1939
2004/08/13,13932,12,0.1588,0.1587,0.1586,0.1593,0.1607,0.1630,0.1710,0.1759,0.1790,0.1855,0.1905,0.1925
2004/08/16,13944,12,0.1589,0.1585,0.1583,0.1590,0.1603,0.1622,0.1701,0.1746,0.1774,0.1841,0.1883,0.1903
2004/08/17,13956,12,0.1588,0.1585,0.1584,0.1590,0.1601,0.1623,0.1703,0.1748,0.1774,0.1837,0.1877,0.1895
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2004/09/09,14148,12,0.1593,0.1598,0.1602,0.1611,0.1632,0.1659,0.1733,0.1775,0.1802,0.1866,0.1911,0.1935
2004/09/10,14160,12,0.1594,0.1603,0.1608,0.1620,0.1644,0.1672,0.1741,0.1782,0.1808,0.1864,0.1886,0.1886
2004/09/13,14172,12,0.1595,0.1604,0.1609,0.1621,0.1644,0.1672,0.1738,0.1773,0.1796,0.1849,0.1886,0.1909
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2005/02/25,15540,12,0.1875,0.1881,0.1884,0.1886,0.1896,0.1906,0.1910,0.1884,0.1849,0.1741,0.1667,0.1620
2005/02/28,15552,12,0.1884,0.1738,0.1627,0.1848,0.1667,0.1874,0.1880,0.1883,0.1885,0.1897,0.1905,0.1910
2005/03/01,15564,12,0.1874,0.1881,0.1885,0.1887,0.1898,0.1908,0.1913,0.1887,0.1853,0.1747,0.1678,0.1626
2005/03/02,15576,12,0.1874,0.1882,0.1887,0.1889,0.1905,0.1913,0.1916,0.1892,0.1859,0.1752,0.1682,0.1630
2005/03/03,15588,12,0.1874,0.1880,0.1884,0.1887,0.1898,0.1907,0.1907,0.1882,0.1847,0.1743,0.1677,0.1633
2005/03/04,15600,12,0.1877,0.1731,0.1657,0.1607,0.1841,0.1874,0.1880,0.1884,0.1888,0.1899,0.1905,0.1903
2005/03/07,15612,12,0.1875,0.1880,0.1883,0.1888,0.1899,0.1905,0.1901,0.1874,0.1839,0.1723,0.1655,0.1598
2005/03/08,15624,12,0.1875,0.1882,0.1885,0.1891,0.1899,0.1905,0.1901,0.1875,0.1839,0.1725,0.1652,0.1590
2005/03/09,15636,12,0.1902,0.1908,0.1903,0.1877,0.1839,0.1720,0.1646,0.1591,0.1875,0.1882,0.1886,0.1893
2005/03/10,15648,12,0.1875,0.1884,0.1889,0.1897,0.1906,0.1910,0.1909,0.1882,0.1844,0.1730,0.1659,0.1603
2005/03/11,15660,12,0.1875,0.1883,0.1887,0.1895,0.1902,0.1906,0.1904,0.1876,0.1841,0.1727,0.1659,0.1606
2005/03/14,15672,12,0.1875,0.1885,0.1891,0.1900,0.1906,0.1910,0.1909,0.1884,0.1850,0.1748,0.1684,0.1635
2005/03/15,15684,12,0.1876,0.1889,0.1896,0.1904,0.1912,0.1915,0.1912,0.1888,0.1858,0.1765,0.1706,0.1658
2005/03/16,15696,12,0.1885,0.1761,0.1692,0.1635,0.1856,0.1875,0.1888,0.1896,0.1904,0.1908,0.1912,0.1908
2005/03/17,15708,12,0.1925,0.1920,0.1917,0.1922,0.1934,0.1943,0.1947,0.1923,0.1897,0.1775,0.1697,0.1646
2005/03/18,15720,12,0.1924,0.1921,0.1919,0.1924,0.1938,0.1949,0.1959,0.1936,0.1913,0.1801,0.1717,0.1669
2005/03/21,15732,12,0.1924,0.1920,0.1918,0.1926,0.1943,0.1957,0.1974,0.1955,0.1927,0.1819,0.1746,0.1695
2005/03/22,15744,12,0.1965,0.1945,0.1803,0.1728,0.1681,0.1916,0.1924,0.1920,0.1917,0.1926,0.1940,0.1953
2005/03/23,15756,12,0.1924,0.1920,0.1918,0.1928,0.1945,0.1957,0.1973,0.1955,0.1928,0.1827,0.1771,0.1726
2005/03/24,15768,12,0.1924,0.1921,0.1919,0.1927,0.1938,0.1945,0.1954,0.1931,0.1907,0.1812,0.1759,0.1723
2005/03/28,15780,12,0.1925,0.1927,0.1928,0.1928,0.1936,0.1943,0.1953,0.1932,0.1909,0.1819,0.1770,0.1730
2005/03/29,15792,12,0.1925,0.1926,0.1927,0.1927,0.1936,0.1942,0.1953,0.1933,0.1911,0.1825,0.1775,0.1733
2005/03/30,15804,12,0.1925,0.1926,0.1926,0.1926,0.1939,0.1944,0.1953,0.1932,0.1910,0.1821,0.1772,0.1729
2005/03/31,15816,12,0.1925,0.1926,0.1926,0.1926,0.1940,0.1945,0.1956,0.1937,0.1918,0.1830,0.1778,0.1737
2005/04/01,15828,12,0.1925,0.1927,0.1928,0.1930,0.1941,0.1949,0.1960,0.1944,0.1925,0.1836,0.1784,0.1742

A.1.2

Histórico de CDI

Data,CDI (% a.a),Data,CDI (% a.a),Data,CDI (% a.a),Data,CDI (% a.a)
01-Jul-04,15.71,10-Sep-04,15.81,24-Nov-04,17.19,02-Feb-05,18.26
02-Jul-04,15.69,13-Sep-04,15.86,25-Nov-04,17.17,03-Feb-05,18.25
05-Jul-04,15.69,14-Sep-04,15.87,26-Nov-04,17.17,04-Feb-05,18.25
06-Jul-04,15.7,15-Sep-04,15.89,29-Nov-04,17.18,09-Feb-05,18.25
07-Jul-04,15.69,16-Sep-04,16.16,30-Nov-04,17.2,10-Feb-05,18.23
08-Jul-04,15.73,17-Sep-04,16.15,01-Dec-04,17.22,11-Feb-05,18.23
09-Jul-04,15.77,20-Sep-04,16.17,02-Dec-04,17.21,14-Feb-05,18.22
12-Jul-04,15.71,21-Sep-04,16.12,03-Dec-04,17.2,15-Feb-05,18.22
13-Jul-04,15.71,22-Sep-04,16.15,06-Dec-04,17.19,16-Feb-05,18.2
14-Jul-04,15.69,23-Sep-04,16.14,07-Dec-04,17.19,17-Feb-05,18.7
15-Jul-04,15.71,24-Sep-04,16.17,08-Dec-04,17.17,18-Feb-05,18.69
16-Jul-04,15.7,27-Sep-04,16.17,09-Dec-04,17.17,21-Feb-05,18.69
19-Jul-04,15.7,28-Sep-04,16.17,10-Dec-04,17.19,22-Feb-05,18.69
20-Jul-04,15.7,29-Sep-04,16.14,13-Dec-04,17.19,23-Feb-05,18.68
21-Jul-04,15.71,30-Sep-04,16.17,14-Dec-04,17.2,24-Feb-05,18.68
22-Jul-04,15.69,01-Oct-04,16.18,15-Dec-04,17.2,25-Feb-05,18.68
23-Jul-04,15.7,04-Oct-04,16.16,16-Dec-04,17.69,28-Feb-05,18.68
26-Jul-04,15.71,05-Oct-04,16.15,17-Dec-04,17.69,01-Mar-05,18.67
27-Jul-04,15.7,06-Oct-04,16.15,20-Dec-04,17.7,02-Mar-05,18.65
28-Jul-04,15.7,07-Oct-04,16.15,21-Dec-04,17.69,03-Mar-05,18.65
29-Jul-04,15.7,08-Oct-04,16.15,22-Dec-04,17.7,04-Mar-05,18.64
30-Jul-04,15.74,11-Oct-04,16.15,23-Dec-04,17.71,07-Mar-05,18.66
02-Aug-04,15.75,13-Oct-04,16.17,24-Dec-04,17.71,08-Mar-05,18.64
03-Aug-04,15.76,14-Oct-04,16.16,27-Dec-04,17.71,09-Mar-05,18.63
04-Aug-04,15.77,15-Oct-04,16.16,28-Dec-04,17.7,10-Mar-05,18.62
05-Aug-04,15.78,18-Oct-04,16.16,29-Dec-04,17.72,11-Mar-05,18.62
06-Aug-04,15.77,19-Oct-04,16.15,30-Dec-04,17.75,14-Mar-05,18.62
09-Aug-04,15.77,20-Oct-04,16.15,31-Dec-04,17.76,15-Mar-05,18.63
10-Aug-04,15.76,21-Oct-04,16.63,03-Jan-05,17.76,16-Mar-05,18.64
11-Aug-04,15.77,22-Oct-04,16.67,04-Jan-05,17.72,17-Mar-05,19.15
12-Aug-04,15.76,25-Oct-04,16.69,05-Jan-05,17.72,18-Mar-05,19.17
13-Aug-04,15.75,26-Oct-04,16.69,06-Jan-05,17.72,21-Mar-05,19.18
16-Aug-04,15.76,27-Oct-04,16.67,07-Jan-05,17.71,22-Mar-05,19.19
17-Aug-04,15.75,28-Oct-04,16.67,10-Jan-05,17.71,23-Mar-05,19.2
18-Aug-04,15.73,29-Oct-04,16.66,11-Jan-05,17.7,24-Mar-05,19.21
19-Aug-04,15.74,01-Nov-04,16.67,12-Jan-05,17.72,28-Mar-05,19.2
20-Aug-04,15.74,03-Nov-04,16.7,13-Jan-05,17.7,29-Mar-05,19.2
23-Aug-04,15.77,04-Nov-04,16.7,14-Jan-05,17.72,30-Mar-05,19.19
24-Aug-04,15.77,05-Nov-04,16.71,17-Jan-05,17.74,31-Mar-05,19.21
25-Aug-04,15.74,08-Nov-04,16.71,18-Jan-05,17.73,01-Apr-05,19.21
26-Aug-04,15.74,09-Nov-04,16.71,19-Jan-05,17.73
27-Aug-04,15.78,10-Nov-04,16.71,20-Jan-05,18.22
30-Aug-04,15.81,11-Nov-04,16.71,21-Jan-05,18.23
31-Aug-04,15.82,12-Nov-04,16.72,24-Jan-05,18.24
01-Sep-04,15.79,16-Nov-04,16.73,25-Jan-05,18.24
02-Sep-04,15.81,17-Nov-04,16.72,26-Jan-05,18.22
03-Sep-04,15.78,18-Nov-04,17.21,27-Jan-05,18.23
06-Sep-04,15.79,19-Nov-04,17.21,28-Jan-05,18.22
08-Sep-04,15.8,22-Nov-04,17.21,31-Jan-05,18.25
09-Sep-04,15.78,23-Nov-04,17.19,01-Feb-05,18.25

A.1.3

Opção de compra JA54

Data do pregão,Mercadoria,Vencimento,Preço de exercício,Volume negociado,Negócios efetuados,Contratos negociados,Cotação média,Cotação do último negócio,Contrato objeto da opção
2004-06-17, D11, JA54,17,0,0,0,0,0, ABR5
2004-06-18, D11, JA54,17,0,0,0,0,0, ABR5
2004-06-21, D11, JA54,17,0,0,0,0,0, ABR5
2004-06-22, D11, JA54,17,0,0,0,0,0, ABR5
2004-06-23, D11, JA54,17,0,0,0,0,0, ABR5
2004-06-24, D11, JA54,17,0,0,0,0,0, ABR5
2004-06-25, D11, JA54,17,0,0,0,0,0, ABR5

Data do pregão,Mercadoria,Vencimento,Preço de exercício,Volume negociado,Negócios efetuados,Contratos negociados,Cotação média,Cotação do último negócio,Contrato objeto da opção
2004-06-28, D11, JA54,17,0,0,0,0,0, ABR5
2004-06-29, D11, JA54,17,0,0,0,0,0, ABR5
2004-06-30, D11, JA54,17,0,0,0,0,0, ABR5
2004-07-01, D11, JA54,17,189000,1,500,378,378, ABR5
2004-07-02, D11, JA54,17,0,0,0,0,0, ABR5
2004-07-05, D11, JA54,17,90000,1,300,300,300, ABR5
2004-07-06, D11, JA54,17,0,0,0,0,0, ABR5
2004-07-07, D11, JA54,17,0,0,0,0,0, ABR5
2004-07-08, D11, JA54,17,0,0,0,0,0, ABR5
2004-07-12, D11, JA54,17,61800,1,200,309,309, ABR5
2004-07-13, D11, JA54,17,0,0,0,0,0, ABR5
2004-07-14, D11, JA54,17,0,0,0,0,0, ABR5
2004-07-15, D11, JA54,17,386060,3,1500,257.37,262.12, ABR5
2004-07-16, D11, JA54,17,0,0,0,0,0, ABR5
2004-07-19, D11, JA54,17,340000,3,1500,226.67,225, ABR5
2004-07-20, D11, JA54,17,0,0,0,0,0, ABR5
2004-07-21, D11, JA54,17,120000,1,500,240,240, ABR5
2004-07-22, D11, JA54,17,140500,1,500,281,281, ABR5
2004-07-23, D11, JA54,17,0,0,0,0,0, ABR5
2004-07-26, D11, JA54,17,204000,2,600,340,340, ABR5
2004-07-27, D11, JA54,17,0,0,0,0,0, ABR5
2004-07-28, D11, JA54,17,0,0,0,0,0, ABR5
2004-07-29, D11, JA54,17,0,0,0,0,0, ABR5
2004-07-30, D11, JA54,17,185000,1,500,370,370, ABR5
2004-08-02, D11, JA54,17,0,0,0,0,0, ABR5
2004-08-03, D11, JA54,17,0,0,0,0,0, ABR5
2004-08-04, D11, JA54,17,770000,1,2000,385,385, ABR5
2004-08-05, D11, JA54,17,0,0,0,0,0, ABR5
2004-08-06, D11, JA54,17,0,0,0,0,0, ABR5
2004-08-09, D11, JA54,17,397500,2,1000,397.5,395, ABR5
2004-08-10, D11, JA54,17,947500,4,2500,379,370, ABR5
2004-08-11, D11, JA54,17,547500,2,1500,365,365, ABR5
2004-08-12, D11, JA54,17,586250,4,1750,335,320, ABR5
2004-08-13, D11, JA54,17,0,0,0,0,0, ABR5
2004-08-16, D11, JA54,17,0,0,0,0,0, ABR5
2004-08-17, D11, JA54,17,0,0,0,0,0, ABR5
2004-08-18, D11, JA54,17,0,0,0,0,0, ABR5
2004-08-19, D11, JA54,17,1385500,8,5000,277.1,270, ABR5
2004-08-20, D11, JA54,17,250000,1,1000,250,250, ABR5
2004-08-23, D11, JA54,17,120000,2,500,240,240, ABR5
2004-08-24, D11, JA54,17,842700,13,3500,240.77,257, ABR5
2004-08-25, D11, JA54,17,265000,1,1000,265,265, ABR5
2004-08-26, D11, JA54,17,412500,3,1500,275,280, ABR5
2004-08-27, D11, JA54,17,1019250,3,3250,313.62,321, ABR5
2004-08-30, D11, JA54,17,0,0,0,0,0, ABR5
2004-08-31, D11, JA54,17,0,0,0,0,0, ABR5
2004-09-01, D11, JA54,17,0,0,0,0,0, ABR5
2004-09-02, D11, JA54,17,295000,8,1000,295,295, ABR5

2004-09-03, D11, JA54,17,549500,3,2000,274.75,273, ABR5
2004-09-06, D11, JA54,17,0,0,0,0,0, ABR5
2004-09-08, D11, JA54,17,0,0,0,0,0, ABR5
2004-09-09, D11, JA54,17,135000,1,500,270,270, ABR5
2004-09-10, D11, JA54,17,0,0,0,0,0, ABR5
2004-09-13, D11, JA54,17,146000,1,500,292,292, ABR5
2004-09-14, D11, JA54,17,125000,1,500,250,250, ABR5
2004-09-15, D11, JA54,17,253900,5,1100,230.82,233, ABR5
2004-09-16, D11, JA54,17,0,0,0,0,0, ABR5
2004-09-17, D11, JA54,17,0,0,0,0,0, ABR5
2004-09-20, D11, JA54,17,0,0,0,0,0, ABR5
2004-09-21, D11, JA54,17,0,0,0,0,0, ABR5
2004-09-22, D11, JA54,17,0,0,0,0,0, ABR5
2004-09-23, D11, JA54,17,0,0,0,0,0, ABR5
2004-09-24, D11, JA54,17,0,0,0,0,0, ABR5
2004-09-27, D11, JA54,17,54000,1,300,180,180, ABR5
2004-09-28, D11, JA54,17,0,0,0,0,0, ABR5
2004-09-29, D11, JA54,17,265000,2,2000,132.5,135, ABR5
2004-09-30, D11, JA54,17,0,0,0,0,0, ABR5

Data do pregão,Mercadoria,Vencimento,Preço de exercício,Volume negociado,Negócios efetuados,Contratos negociados,Cotação média,Cotação do último negócio,Contrato objeto da opção
2004-10-01, D11, JA54,17,66200,2,500,132.4,134, ABR5
2004-10-04, D11, JA54,17,0,0,0,0,0, ABR5
2004-10-05, D11, JA54,17,0,0,0,0,0, ABR5
2004-10-06, D11, JA54,17,0,0,0,0,0, ABR5
2004-10-07, D11, JA54,17,0,0,0,0,0, ABR5
2004-10-08, D11, JA54,17,0,0,0,0,0, ABR5
2004-10-11, D11, JA54,17,0,0,0,0,0, ABR5
2004-10-13, D11, JA54,17,0,0,0,0,0, ABR5
2004-10-14, D11, JA54,17,0,0,0,0,0, ABR5
2004-10-15, D11, JA54,17,27000,1,200,135,135, ABR5
2004-10-18, D11, JA54,17,0,0,0,0,0, ABR5
2004-10-19, D11, JA54,17,0,0,0,0,0, ABR5
2004-10-20, D11, JA54,17,0,0,0,0,0, ABR5
2004-10-21, D11, JA54,17,160000,2,1000,160,160, ABR5
2004-10-22, D11, JA54,17,0,0,0,0,0, ABR5
2004-10-25, D11, JA54,17,0,0,0,0,0, ABR5
2004-10-26, D11, JA54,17,295000,3,1500,196.67,200, ABR5
2004-10-27, D11, JA54,17,0,0,0,0,0, ABR5
2004-10-28, D11, JA54,17,320500,3,1500,213.67,214, ABR5
2004-10-29, D11, JA54,17,0,0,0,0,0, ABR5
2004-11-01, D11, JA54,17,0,0,0,0,0, ABR5
2004-11-03, D11, JA54,17,0,0,0,0,0, ABR5
2004-11-04, D11, JA54,17,0,0,0,0,0, ABR5
2004-11-05, D11, JA54,17,0,0,0,0,0, ABR5
2004-11-08, D11, JA54,17,0,0,0,0,0, ABR5
2004-11-09, D11, JA54,17,0,0,0,0,0, ABR5
2004-11-10, D11, JA54,17,0,0,0,0,0, ABR5
2004-11-11, D11, JA54,17,0,0,0,0,0, ABR5
2004-11-12, D11, JA54,17,0,0,0,0,0, ABR5
2004-11-16, D11, JA54,17,0,0,0,0,0, ABR5
2004-11-17, D11, JA54,17,0,0,0,0,0, ABR5
2004-11-18, D11, JA54,17,0,0,0,0,0, ABR5
2004-11-19, D11, JA54,17,0,0,0,0,0, ABR5
2004-11-22, D11, JA54,17,0,0,0,0,0, ABR5
2004-11-23, D11, JA54,17,0,0,0,0,0, ABR5
2004-11-24, D11, JA54,17,0,0,0,0,0, ABR5
2004-11-25, D11, JA54,17,944000,1,4000,236,236, ABR5
2004-11-26, D11, JA54,17,0,0,0,0,0, ABR5
2004-11-29, D11, JA54,17,0,0,0,0,0, ABR5
2004-11-30, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-01, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-02, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-03, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-06, D11, JA54,17,0,0,0,0,0, ABR5

2004-12-07, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-08, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-09, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-10, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-13, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-14, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-15, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-16, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-17, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-20, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-21, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-22, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-23, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-27, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-28, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-29, D11, JA54,17,0,0,0,0,0, ABR5
2004-12-30, D11, JA54,17,0,0,0,0,0, ABR5

Anexo A.2 – Código desenvolvido no programa MathLab

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global N;      % Numero de dias uteis
global dt;     % Incremento de tempo
global dS;     % Incremento preco do ativo subscrito
global M;      % Numero de valores "discretos" de S
global sigma;  % volatilidade anual
global r;      % Taxa livre de risco
global S;      % Exercice price
global dU;     % dias uteis entre o vencimento do ativo objeto e o vencimento da
opcao

%Abre arquivo

FID2 = fopen('Config_file.txt','rt');

if FID2 == -1

  LOG = strcat('Erro ao carregar Config_file.txt - ',datestr(now));

else

  LOG = strcat('Nao houve erros ao carregar MV_ValorAcao.txt - ',datestr(now));

end

a = 1 / 6 - 1/(4 * sqrt(3)) * sigma * sqrt(dt);
b = 2 / 3;
c = 1 / 6 + 1 / (4*sqrt(3)) * sigma * sqrt(dt);

F = zeros(M + 1, N + 1);

% CC no Vencimento

for j = 1 : M + 1

  F(j , N + 1) = max(S - (100000 / ((1 + j / 100) ^ (dU / 252))), 0);

end

% CC se S = 0

for i = 1 : N + 1

  F(1, i) = 0;

end

% CC se S = Smax

for i = 1 : N + 1
```

```
  F(M + 1, i) = 100000 / ((1 + M / 100)) ^ (dU / 252);
end
for i = N : -1 : 1
  for j = 2 : M
      F(j, i) = 1 / (1 + r * dt) * (c * F(j - 1, i + 1) + b * F(j, i + 1) + a * F(j + 1, i +
1));
  end
end
```