OPÇÕES EXÓTICAS
MSc MATEMÁTICA FINANCEIRA 2010/11
EXAME - Resolução
29/07/11 **Duração: 2.5 horas**

CASO 1

a) Enuncie a estratégia de *static hedging* a adoptar para uma posição curta sobre uma *forward-start call* com vencimento no momento T_2, com inicio de vigência no momento T_1 ($< T_2$) e com *strike* igual a 110% da cotação *spot* no momento T_1.

Consideremos a fórmula de avaliação deste contrato:

$$c_t^f\left(S_t;1.1S_{T_1};T_2\right)=S_t e^{-q(T_1-t)}c_{T_1}\left(1;1.1;T_2\right).$$

Atendendo a que $e^{-q(T_1-t)}c_{T_1}\left(1;1.1;T_2\right)$ é uma constante, basta comprar um número $e^{-q(T_1-t)}c_{T_1}\left(1;1.1;T_2\right)$ de unidades do activo subjacente.

No momento T_1, o valor da carteira de acções será igual a:

$$\left[S_{T_1}e^{q(T_1-t)}\right]e^{-q(T_1-t)}c_{T_1}\left(1;1.1;T_2\right)$$

$$=S_{T_1}c_{T_1}\left(1;1.1;T_2\right)$$

$$=c_{T_1}\left(S_T;1.1S_T;T_2\right)$$

$$=c_{T_1}^f\left(S_{T_1};1.1S_{T_1};T_2\right).$$

b) Deduza a fórmula de avaliação de uma *European-style up-and-out put* com uma barreira (U) superior ao *strike* (X) e sem *rebate*.

Via página 38 dos apontamentos,

$$UO(-1)_t\left(S;X;U>X;R=0;T\right)$$

$$=e^{-r\tau}\int_{-\infty}^{\ln\left(\frac{X}{S_t}\right)}\left(X-S_te^y\right)\left\{\phi\left(y;\mu\tau,\sigma\sqrt{\tau}\right)-\left(\frac{U}{S_t}\right)^{\frac{2\mu}{\sigma^2}}\phi\left[y;2\ln\left(\frac{U}{S_t}\right)+\mu\tau,\sigma\sqrt{\tau}\right]\right\}dy.$$

Fazendo a mudança de variável de integração $z = y - 2\ln\left(\frac{U}{S_t}\right)$,

$UO(-1)_t(S; X; U > X; R = 0; T)$

$$= e^{-r\tau} \int_{-\infty}^{\ln\left(\frac{X}{S_t}\right)} \left(X - S_t e^y\right)\phi\left(y; \mu\tau, \sigma\sqrt{\tau}\right)dy$$

$$-\left(\frac{U}{S_t}\right)^{\frac{2\mu}{\sigma^2}} e^{-r\tau} \int_{-\infty}^{\ln\left(\frac{X}{U^2/S_t}\right)} \left[X - S_t\left(\frac{U}{S_t}\right)^2 e^z\right]\phi\left(z; \mu\tau, \sigma\sqrt{\tau}\right)dz$$

$$= p_t(S; X; T) - \left(\frac{U}{S_t}\right)^{\frac{2\mu}{\sigma^2}} p_t\left(U^2/S_t; X; T\right).$$

c) Enuncie a fórmula de avaliação (no momento "t") de uma *put* com vencimento no momento "T_1", com *strike* "X_1", e sobre uma *cash-or-nothing call* com vencimento no momento "$T_2(> T_1)$", com *strike* "X_1" e *contract size* "M".

Assumindo os pressupostos do modelo de Black-Scholes (1973), valor da put sobre a digital call é dado por:

$$p_t\left[D(1)_t(S_t, X_2, T_2; M); X_1; T_1\right] = e^{-r\tau_1} E_Q\left\{\left[X_1 - D(1)_{T_1}\left(S_{T_1}, X_2, T_2; M\right)\right]^+ \middle| F_t\right\}$$

Seja $\overline{S}$:

$$X_1 = D(1)_{T_1}\left(\overline{S}, X_2, T_2; M\right)$$

$$\Leftrightarrow X_1 = Me^{-r(\tau_2 - \tau_1)}\Phi\left[d_2^M\left(\overline{S}, X_2\right)\right].$$

Então, e visto que $\Phi\left[d_2^M\left(\overline{S}, X_2\right)\right]$ é uma função crescente de $\overline{S}$,

$$p_t\left[D(1)_t(S_t, X_2, T_2; M); X_1; T_1\right] = e^{-r\tau_1} \int_0^{\overline{S}} \left[X_1 - D(1)_{T_1}(S, X_2, T_2; M)\right]Q\left(S_{T_1} \in dS \middle| F_t\right).$$

Por outro lado, dado que

$$S_{T_1} = S_t \exp\left[\left(r - q - \frac{\sigma^2}{2}\right)\tau_1 + \sigma \int_t^{T_1} dW_t^Q\right],$$

então:

$$p_t\left[D(1)_t\left(S_t, X_2, T_2; M\right); X_1; T_1\right]$$

$$= e^{-r\tau_1}\int_0^{\bar{z}}\left[X_1 - D(1)_{T_1}\left(S_t \exp\left(\left(r - q - \frac{\sigma^2}{2}\right)\tau_1 + \sigma z\right), X_2, T_2; M\right)\right]\frac{1}{\sqrt{2\pi\tau_1}}\exp\left(-\frac{z^2}{2\tau_1}\right)dz$$

$$= e^{-r\tau_1}\int_0^{\bar{z}}\left\{X_1 - Me^{-r(\tau_2-\tau_1)}\Phi\left[d_2^M\left(S_t \exp\left(\left(r - q - \frac{\sigma^2}{2}\right)\tau_1 + \sigma z\right), X_2\right)\right]\right\}\frac{1}{\sqrt{2\pi\tau_1}}\exp\left(-\frac{z^2}{2\tau_1}\right)dz$$

$$= e^{-r\tau_1}X_1\int_0^{\bar{z}}\frac{1}{\sqrt{2\pi\tau_1}}\exp\left(-\frac{z^2}{2\tau_1}\right)dz$$

$$- e^{-r\tau_1}\int_0^{\bar{z}}Me^{-r(\tau_2-\tau_1)}\Phi\left[d_2^M\left(S_t \exp\left(\left(r - q - \frac{\sigma^2}{2}\right)\tau_1 + \sigma z\right), X_2\right)\right]\frac{1}{\sqrt{2\pi\tau_1}}\exp\left(-\frac{z^2}{2\tau_1}\right)dz,$$

sendo

$$\bar{z} = \frac{\ln\left(\frac{\bar{S}}{S_t}\right) - \left(r - q - \frac{\sigma^2}{2}\right)\tau_1}{\sigma}.$$

O 1º termo da anterior expressão é fácil de calcular:

$$e^{-r\tau_1} X_1 \int_0^{\bar{z}} \frac{1}{\sqrt{2\pi\tau_1}} \exp\left(-\frac{z^2}{2\tau_1}\right) dz$$

$$= e^{-r\tau_1} X_1 \Phi\left[\frac{\bar{z}}{\sqrt{\tau_1}}\right]$$

$$= e^{-r\tau_1} X_1 \Phi\left[\frac{\ln\left(\frac{\bar{S}}{S_t}\right) - \left(r - q - \frac{\sigma^2}{2}\right)\tau_1}{\sigma\sqrt{\tau_1}}\right]$$

$$= e^{-r\tau_1} X_1 \Phi\left[-\frac{\ln\left(\frac{S_t}{\bar{S}}\right) + \left(r - q - \frac{\sigma^2}{2}\right)\tau_1}{\sigma\sqrt{\tau_1}}\right]$$

$$= e^{-r\tau_1} X_1 \Phi(-\bar{a}_2),$$

sendo

$$\bar{a}_{1,2} = \frac{\ln\left(\frac{S_t}{\bar{S}}\right) + \left(r - q \pm \frac{\sigma^2}{2}\right)\tau_1}{\sigma\sqrt{\tau_1}}.$$

O 2º termo

$$-e^{-r\tau_1} \int_0^{\bar{z}} M e^{-r(\tau_2-\tau_1)} \Phi\left[d_2^M\left(S_t \exp\left(\left(r - q - \frac{\sigma^2}{2}\right)\tau_1 + \sigma z\right), X_2\right)\right] \frac{1}{\sqrt{2\pi\tau_1}} \exp\left(-\frac{z^2}{2\tau_1}\right) dz$$

é equivalente ao 2º termo no lado direito da equação (53) dos handouts, i.e. ao termo associado ao *strike* da underlying options. Portanto,

$$-e^{-r\tau_1} \int_0^{\bar{z}} M e^{-r(\tau_2-\tau_1)} \Phi\left[d_2^M\left(S_t \exp\left(\left(r - q - \frac{\sigma^2}{2}\right)\tau_1 + \sigma z\right), X_2\right)\right] \frac{1}{\sqrt{2\pi\tau_1}} \exp\left(-\frac{z^2}{2\tau_1}\right) dz$$

$$= -M e^{-r\tau_2} N_2\left(-\bar{a}_2; b_2; -\sqrt{\frac{\tau_1}{\tau_2}}\right),$$

onde b_2 é dado pela equação (55) dos handouts.

Em suma,

$$p_t\left[D(1)_t\left(S_t, X_2, T_2; M\right); X_1; T_1\right]$$

$$= e^{-r\tau_1} X_1 \Phi\left(-\bar{a}_2\right) - M e^{-r\tau_2} N_2\left(-\bar{a}_2; b_2; -\sqrt{\frac{\tau_1}{\tau_2}}\right).$$

CASO 2

a)

$$r: \quad e^{r\times 6/12} = 1 + 1.8\% \times 6/12 \Rightarrow r = \frac{12}{6}\ln\left(1 + 1.8\% \times 6/12\right) \cong 1.792\%.$$

$$B_0 = \frac{100\%}{1 + 1.8\% \times 6/12} + RV_0.$$

$$RV_{6M} = \begin{cases} 10\% \Leftarrow S_{6M} < 2{,}760 \times 95\% = 2{,}622 \\ \quad 0\% \Leftarrow ELSE \end{cases}$$

$$= 10\% \times D_{6M}(-1)\left(M = 1; S; X = 2{,}622; T = 6M\right).$$

Portanto,

$$\begin{aligned} RV_0 &= 10\% \times D_0(-1)\left(M = 1; S; X = 2{,}622; T = 6M\right) \\ &= 10\% \times e^{-1.792\% \times 0.5} \times \Phi\left[-d_2^M(2{,}622)\right]. \end{aligned}$$

$$\Phi\left[-d_2^M(2{,}622)\right]=\Phi\left[-\frac{\ln\left(2{,}760 / 2{,}622\right)+\left(1.792\%-2\%-(0.25)^2 / 2\right)\times 0.5}{0.25\times\sqrt{0.5}}\right]$$

$$\begin{aligned}
&=\Phi(-0.1959)\\
&\cong\Phi(-0.2)\\
&=1-\Phi(0.2)\\
&=1-0.5793\\
&=0.4207.
\end{aligned}$$

$$RV_0=10\%\times e^{-1.792\%\times 0.5}\times 0.4207=4.186\%.$$

$B_0=99.11\%+4.186\%\cong 103.29\%>100\%\Rightarrow$ Investir.

b)

Via proposição 20 e equação (57):

$$c_0\left[p_0(S_0;X=2{,}760;0.5y);162.77;0.25y\right]$$

$$=-2{,}760\times e^{-2\%\times 0.5}\times M\left(-a_1^{**},-b_1;\sqrt{\frac{0.25}{0.5}}\right)+2{,}760\times e^{-1.792\%\times 0.5}\times M\left(-a_2^{**},-b_2;\sqrt{0.5}\right)$$

$$-162.77\times e^{-1.792\%\times 0.25}\times\Phi\left(-a_2^{**}\right).$$

Visto que:

$S^{**}=2{,}710;$

$$a_1^{**}=\frac{\ln\left(\frac{2{,}760}{2{,}710}\right)+\left(1.792\%-2\%+\frac{(0.25)^2}{2}\right)\times 0.25}{0.25\times\sqrt{0.25}}\cong 0.20456849;$$

$$a_2^{**}=0.20456849-0.25\times\sqrt{0.25}\cong 0.079568;$$

$$b_1 = \frac{\ln\left(\frac{2{,}760}{2{,}760}\right) + \left(1.792\% - 2\% + \frac{(0.25)^2}{2}\right)\times 0.5}{0.25\times\sqrt{0.5}} \cong 0.08250376;$$

$$b_2 = 0.08250376 - 0.25\times\sqrt{0.5} \cong \text{-}0.09427;$$

então:

$$c_0\left[p_0\left(S_0;X = 2{,}760;0.5y\right);162.77;0.25y\right]$$

$$= -2{,}760\times e^{-2\%\times 0.5}\times M\left(\text{-}\ 0.20456849,-0.08250376;0.707107\right)$$

$$+\,2{,}760\times e^{-1.792\%\times 0.5}\times M\left(\text{-}\ 0.079568,0.09427;0.707107\right)$$

$$-\,162.77\times e^{-1.792\%\times 0.25}\times\Phi\left(-\ 0.079568\right).$$

Utilizando a tabela de probabilidades,

$$c_0\left[p_0\left(S_0;X = 2{,}760;0.5y\right);162.77;0.25y\right]$$

$$= -2{,}760\times e^{-2\%\times 0.5}\times 0.317972 + 2{,}760\times e^{-1.792\%\times 0.5}\times 0.37504 - 162.77\times e^{-1.792\%\times 0.25}\times 0.46829$$

$$\cong 81.125224.$$

c)

$$B_0 = \frac{100\%}{1+1.8\%\times{}^{6}\!/_{12}} + RV_0.$$

Por seu turno,

$$RV_{6M} = \begin{cases} \dfrac{S_{6M} - 2{,}760}{2{,}760} \Leftarrow S_{6M} > 2{,}700 \\ 0\% \Leftarrow ELSE \end{cases}$$

$$\Leftrightarrow RV_{6M} = \frac{1}{2{,}760} \times \begin{cases} S_{6M} - 2{,}760 \Leftarrow S_{6M} > 2{,}700 \\ 0 \Leftarrow ELSE \end{cases}$$

$$\Leftrightarrow RV_{6M} = \frac{1}{2{,}760} \times \begin{cases} S_{6M} - 2{,}700 - 60 \Leftarrow S_{6M} > 2{,}700 \\ 0 \Leftarrow ELSE \end{cases}$$

$$\Leftrightarrow RV_{6M} = \frac{1}{2{,}760} \times \left(\begin{cases} S_{6M} - 2{,}700 \Leftarrow S_{6M} > 2{,}700 \\ 0 \Leftarrow ELSE \end{cases} - \begin{cases} 60 \Leftarrow S_{6M} > 2{,}700 \\ 0 \Leftarrow ELSE \end{cases} \right)$$

$$\Leftrightarrow RV_{6M} = \frac{1}{2{,}760} \times \left(c_{6M}\left(S_{6M};2{,}700;6M\right) - D_{6M}\left(1\right)\left(S_{6M};2{,}700;6M;M = 60\right)\right).$$

Portanto,

$$RV_0 = \frac{1}{2{,}760} \times \left(c_0\left(S_0;2{,}700;6M\right) - D_0\left(1\right)\left(S_0;2{,}700;6M;M = 60\right)\right).$$

Utilizando o enunciado,

$c_0\left(S_0;2{,}700;6M\right) = 220.11$;

Relativamente à cash-or-nothing call,

$$D_0\left(1\right)\left(S_0;2{,}700;6M;M = 60\right) = 60 \times e^{-1.792\% \times 0.5} \times \Phi\left[d_2^M\left(2{,}700\right)\right],$$

sendo

$$\Phi\left[d_2^M\left(2{,}700\right)\right] = \Phi\left[\frac{\ln\left(2{,}760 / 2{,}700\right) + \left(1.792\% - 2\% - (0.25)^2 / 2\right) \times 0.5}{0.2 \times \sqrt{0.5}}\right]$$

$$= \Phi\left(0.0301\right)$$
$$\cong \Phi\left(0.03\right)$$
$$= 0.5120.$$

$$D_0\left(1\right)\left(S_0;2{,}700;6M;M = 60\right) = 60 \times e^{-1.792\% \times 0.5} \times 0.5120 \cong 30.4454.$$

Em suma,

$$RV_0 = \frac{1}{2{,}760} \times (220.11 - 30.4454) \cong 6.87\%,$$

e

$$B_0 = 99.11\% + 6.87\% \cong 105.98\% > 100\% \Rightarrow \text{ Investir.}$$

d)

$$B_0 = \frac{100\%}{1 + 1.8\% \times {}^{6}\!/_{12}} + RV_0.$$

Relativamente à componente de remuneração variável,

$$RV_{6M} = \begin{cases} 40\% \times \max\left(0\%; \dfrac{S_{6M} - S_0}{S_0}\right) \Leftarrow \inf\limits_{0<u\leq 0.5} (S_u) > 2{,}700 \\ 0\% \Leftarrow \inf\limits_{0<u\leq 0.5} (S_u) \leq 2{,}700 \end{cases}$$

$$= \frac{40\%}{S_0} \times \begin{cases} \max(0; S_{6M} - S_0) \Leftarrow \inf\limits_{0<u\leq 0.5} (S_u) > 2{,}700 \\ 0 \Leftarrow \inf\limits_{0<u\leq 0.5} (S_u) \leq 2{,}700 \end{cases}$$

$$= \frac{40\%}{S_0} \times DO(1)_{6M} (S_{6M}; X = S_0; H = 2{,}700; R = 0; T = 0.5y).$$

Portanto, a remuneração variável é dada por uma down-and-out zero rebate call, i.e.

$$RV_0 = \frac{40\%}{S_0} \times DO(1)_0 (S_0; X = 2{,}760; H = 2{,}700; R = 0; T = 0.5y).$$

A down-and-in call sem rebate é avaliada com base na seguinte expressão:

$$DO(1)_t\,(S;X;H;T)$$

$$= c_t\,(S_t;\max(H;X);T) - \left(\frac{H}{S_t}\right)^{\frac{2\mu}{\sigma^2}} c_t\left(\frac{H^2}{S_t};\max(H;X);T\right)$$

$$+ [\max(H;X) - X]e^{-r\tau}\left\{\Phi\left[d_2^M\,(S_t,H)\right] - \left(\frac{H}{S_t}\right)^{\frac{2\mu}{\sigma^2}} \Phi\left[d_2^M\,(H,S_t)\right]\right\}$$

Atendendo a que X = 2,760 > H = 2,700, então a expressão anterior pode ainda ser simplificada:

$$c_t^{do}(S;X;H < X;T) = c_t\,(S_t;X;T) - \left(\frac{H}{S_t}\right)^{\frac{2\mu}{\sigma^2}} c_t\left(\frac{H^2}{S_t};X;T\right).$$

Considerando os dados em apreço,

$$c_0^{do}(S_0;X = 2{,}760;H = 2{,}700;R = 0;T = 0.5y)$$

$$= c_0(S_0 = 2{,}760;X = 2{,}760;T = 0.5y) - \left(\frac{2{,}700}{2{,}760}\right)^{\frac{2\mu}{\sigma^2}} c_t\left(\frac{2{,}700^2}{2{,}760};X = 2{,}760;T = 0.5y\right).$$

Visto que o valor de uma standard call é uma função homógenera de grau 1 no spot e no strike, então

$$c_0^{do}(S_0;X = 2{,}760;H = 2{,}700;R = 0;T = 0.5y)$$

$$= c_0(S_0 = 2{,}760;X = 2{,}760;T = 0.5y)$$

$$-\left(\frac{2{,}700}{2{,}760}\right)^{\frac{2\mu}{\sigma^2}} \times \frac{(2{,}700)^2}{(2{,}760)^2} c_0\left(2{,}760;2{,}760 \times \frac{(2{,}760)^2}{(2{,}700)^2} \cong 2{,}884.03;T = 0.5y\right).$$

Visto que

$$\mu = 1.792\% - 2\% - {(0.25)^2}\big/{2} \cong \text{-}0.03333,$$

e utilizando os dados do enunciado, então

$c_0^{do}\left(S_0; X = 2{,}760; H = 2{,}700; R = 0; T = 0.5y\right)$

$$= 191.14 - \left(\frac{2{,}700}{2{,}760}\right)^{\frac{2\times(-0.03333)}{(0.25)^2}} \times \frac{(2{,}700)^2}{(2{,}760)^2} \times 140.33$$

$\cong 53.659208.$

Em suma,

$$RV_0 = \frac{40\%}{2{,}760} \times 53.659208 \cong 0.78\%,$$

e

$B_0 = 99.11\% + 0.78\% \cong 99.89\% < 100\% \Rightarrow$ Não investir.

e)

$$B_0 = \frac{100\%}{1 + 1.8\% \times 6/12} + RV_0.$$

$$RV_{6M} = 10\% \times 1_{\left\{\sup_{0<u\leq 0.5}(S_u)\geq 2{,}800\right\}}.$$

Portanto,

$$RV_0 = 10\% \times e^{-1.792\%\times 0.5} \times Q\left[\sup_{0<u\leq 0.5}(S_u) \geq 2{,}800\right]$$

$$= 10\% \times e^{-1.792\%\times 0.5} \times Q\left[\sup_{0<u\leq 0.5}\left(\ln\left(\frac{S_u}{S_0}\right)\right) \geq \ln\left(\frac{2{,}800}{S_0}\right)\right]$$

$$= 10\% \times e^{-1.792\%\times 0.5} \times \left\{1 - Q\left[\sup_{0<u\leq 0.5}\left(\ln\left(\frac{S_u}{S_0}\right)\right) < \ln\left(\frac{2{,}800}{S_0}\right)\right]\right\}.$$

Via Proposição 45,

$$Q\left[\sup_{0<u\leq 0.5}\left(\ln\left(\frac{S_u}{S_0}\right)\right)<\ln\left(\frac{2{,}800}{S_0}\right)\right]$$

$$=\Phi\left[-d_2^M(2{,}760;2{,}800)\right]-\left(\frac{2{,}800}{2{,}760}\right)^{\frac{2\times(-0.03333)}{(0.25)^2}}\Phi\left[d_2^M(2{,}800;2{,}760)\right]$$

$$=\Phi\left[\frac{\ln\left(2{,}760/2{,}800\right)+\left(1.792\%-2\%-(0.25)^2/2\right)\times 0.5}{0.25\times\sqrt{0.5}}\right]$$

$$-\left(\frac{2{,}800}{2{,}760}\right)^{\frac{2\times(-0.03333)}{(0.25)^2}}\Phi\left[\frac{\ln\left(2{,}800/2{,}760\right)+\left(1.792\%-2\%-(0.25)^2/2\right)\times 0.5}{0.25\times\sqrt{0.5}}\right]$$

$$=\Phi(-0.1757)-\left(\frac{2{,}800}{2{,}760}\right)^{\frac{2\times(-0.03333)}{(0.25)^2}}\Phi(-0.0129)$$

$\cong 0.072278173.$

Portanto,

$$RV_0=10\%\times e^{-1.792\%\times 0.5}\times\{1-0.072278173\}$$

$\cong 9.194\%.$

$B_0=99.11\%+9.194\%=108.30\%>100\%\Rightarrow$ Depositar.

f)

$$B_0=\frac{100\%}{1+1.8\%\times 6/12}+RV_0.$$

Daqui a 6 meses:

$$RV_{6M} = 60\% \times \begin{cases} \dfrac{S_{3M} - S_{6M}}{S_{3M}} \Leftarrow S_{6M} < S_{3M} \\ 0\% \Leftarrow ELSE \end{cases}$$

$$= \frac{60\%}{S_{3M}} \times \begin{cases} S_{3M} - S_{6M} \Leftarrow S_{6M} < S_{3M} \\ 0 \Leftarrow ELSE \end{cases}$$

$$= \frac{60\%}{S_{3M}} \times p_{6M}\left(S_{6M}; X = S_{3M}; T = 6M\right)$$

$$RV_{3M} = \frac{60\%}{S_{3M}} \times p_{3M}\left(S_{3M}; X = S_{3M}; T = 6M\right) = 60\% \times p_{3M}\left(1; X = 1; T = 6M\right)$$

Consequentemente,

$$RV_0 = \frac{60\% \times p_{3M}\left(1; X = 1; T = 6M\right)}{1 + 1.4\% \times \dfrac{3}{12}}.$$

Visto que o valor de uma standard put é uma função homógenera de grau 1 no spot e no strike, então

$$p_{3M}\left(1; X = 1; T = 6M\right)$$

$$= \frac{p_0\left(2{,}760; X = 2{,}760; T = 3M\right)}{2{,}760}$$

$$= \frac{137.61}{2{,}760} \cong 4.986\%.$$

Portanto,

$$RV_0 = \frac{60\% \times 4.986\%}{1 + 1.4\% \times \dfrac{3}{12}} \cong 2.981\%,$$

e

$$B_0 = 99.11\% + 2.981\% = 102.09\%.$$

Margem de intermediação = 103.00% - 102.09% = 0.91%.