

## [Help](#)

```
#include <stdlib.h>
#include "
href../../mod/bscir2d/bscir2d_stda/bscir2d_stda_h_src.pdfbscir2d_stda.h"
#include "
href../../common/error_msg_h_src.pdferror_msg.h"
#include "pnl/pnl_matrix.h"

#if defined(PremiaCurrentVersion) && PremiaCurrentVersion < (2010+2) //The "#els
static int CHK_OPT(TR_cgmz)(void *Opt, void *Mod)
{
    return NONACTIVE;
}
int CALC(TR_cgmz)(void *Opt, void *Mod, PricingMethod *Met)
{
    return AVAILABLE_IN_FULL_PREMIA;
}
#else

static char *infilename;
static double **V, * *S;
static double **y, * *f;
static int **f_down, * *f_up;
static int **y_down, * *y_up;
static double **pu_y, * *pd_y;
static double **pu_f, * *pd_f;
static double *n_min, *n_max, *GM;
static double ** *RF, * **EQL;
static double *vm, *vpm, *vm1, *vpm1, *vm2, *vpm2, *coeff;
static int Ns;

//Singular points
static int **nb_critical, * *nb_critical1;
static int MAX_SING_POINTS = 2000;
static double *lm_insurance;

static void SortVect(unsigned long n, double *arr)
{
    PnlVect a;
    PnlVectInt *i;
```

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    a = pnl_vect_wrap_array(arr, n);
    i = pnl_vect_int_create(0);
    pnl_vect_qsort_index(&a, i, 'i');
    pnl_vect_int_free(&i);
}

static double linear_interpolation(double val, int j, int k)
{
    double res;
    int l;

    if (val < RF[j][k][0])
        return EQL[j][k][0];
    else if (val > RF[j][k][nb_critical[j][k]])
        return EQL[j][k][nb_critical[j][k]];
    else if (fabs(val - RF[j][k][nb_critical[j][k]]) < 1.e-8)
        return EQL[j][k][nb_critical[j][k]];
    else
    {
        l = 0;
        while ((RF[j][k][l] < val) && (l <= nb_critical[j][k])) l++;
        if (l == 0)
            res = EQL[j][k][0];
        else
            res = ((val - RF[j][k][l - 1]) * EQL[j][k][l] + (RF[j][k][l] - val) * EQ

        return res;
    }
}

/*Memory Allocation*/
static int memory_allocation(int Nst)
{
    int i, j;

    n_min = (double *)malloc((Nst + 1) * sizeof(double));
    n_max = (double *)malloc((Nst + 1) * sizeof(double));
    GM = (double *)malloc((Nst + 1) * sizeof(double));
    vm = (double *)malloc(MAX_SING_POINTS * sizeof(double));
    vpm = (double *)malloc(MAX_SING_POINTS * sizeof(double));

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vm1 = (double *)malloc(MAX_SING_POINTS * sizeof(double));
vpm1 = (double *)malloc(MAX_SING_POINTS * sizeof(double));
vm2 = (double *)malloc(MAX_SING_POINTS * sizeof(double));
vpm2 = (double *)malloc(MAX_SING_POINTS * sizeof(double));
coeff = (double *)malloc(MAX_SING_POINTS * sizeof(double));

V = (double **)calloc(Nst + 1, sizeof(double *));
if (V == NULL)
    return MEMORY_ALLOCATION_FAILURE;
for (i = 0; i < Nst + 1; i++)
{
    V[i] = (double *)calloc(Nst + 1, sizeof(double));
    if (V[i] == NULL)
        return MEMORY_ALLOCATION_FAILURE;
}

S = (double **)calloc(Nst + 1, sizeof(double *));
if (S == NULL)
    return MEMORY_ALLOCATION_FAILURE;
for (i = 0; i < Nst + 1; i++)
{
    S[i] = (double *)calloc(Nst + 1, sizeof(double));
    if (S[i] == NULL)
        return MEMORY_ALLOCATION_FAILURE;
}

pu_y = (double **)calloc(Nst + 1, sizeof(double *));
if (pu_y == NULL)
    return MEMORY_ALLOCATION_FAILURE;
for (i = 0; i < Nst + 1; i++)
{
    pu_y[i] = (double *)calloc(Nst + 1, sizeof(double));
    if (pu_y[i] == NULL)
        return MEMORY_ALLOCATION_FAILURE;
}

pd_y = (double **)calloc(Nst + 1, sizeof(double *));
if (pd_y == NULL)
    return MEMORY_ALLOCATION_FAILURE;
for (i = 0; i < Nst + 1; i++)
{

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    pd_y[i] = (double *)calloc(Nst + 1, sizeof(double));
    if (pd_y[i] == NULL)
        return MEMORY_ALLOCATION_FAILURE;
}

pu_f = (double **)calloc(Nst + 1, sizeof(double *));
if (pu_f == NULL)
    return MEMORY_ALLOCATION_FAILURE;
for (i = 0; i < Nst + 1; i++)
{
    pu_f[i] = (double *)calloc(Nst + 1, sizeof(double));
    if (pu_f[i] == NULL)
        return MEMORY_ALLOCATION_FAILURE;
}

pd_f = (double **)calloc(Nst + 1, sizeof(double *));
if (pd_f == NULL)
    return MEMORY_ALLOCATION_FAILURE;
for (i = 0; i < Nst + 1; i++)
{
    pd_f[i] = (double *)calloc(Nst + 1, sizeof(double));
    if (pd_f[i] == NULL)
        return MEMORY_ALLOCATION_FAILURE;
}

y = (double **)calloc(Nst + 1, sizeof(double *));
if (y == NULL)
    return MEMORY_ALLOCATION_FAILURE;
for (i = 0; i < Nst + 1; i++)
{
    y[i] = (double *)calloc(Nst + 1, sizeof(double));
    if (y[i] == NULL)
        return MEMORY_ALLOCATION_FAILURE;
}

f = (double **)calloc(Nst + 1, sizeof(double *));
if (f == NULL)
    return MEMORY_ALLOCATION_FAILURE;
for (i = 0; i < Nst + 1; i++)
{
    f[i] = (double *)calloc(Nst + 1, sizeof(double));

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        if (f[i] == NULL)
            return MEMORY_ALLOCATION_FAILURE;
    }

    f_down = (int **)calloc(Nst + 1, sizeof(int *));
    if (f_down == NULL)
        return MEMORY_ALLOCATION_FAILURE;
    for (i = 0; i < Nst + 1; i++)
    {
        f_down[i] = (int *)calloc(Nst + 1, sizeof(int));
        if (f_down[i] == NULL)
            return MEMORY_ALLOCATION_FAILURE;
    }

    f_up = (int **)calloc(Nst + 1, sizeof(int *));
    if (f_up == NULL)
        return MEMORY_ALLOCATION_FAILURE;
    for (i = 0; i < Nst + 1; i++)
    {
        f_up[i] = (int *)calloc(Nst + 1, sizeof(int));
        if (f_up[i] == NULL)
            return MEMORY_ALLOCATION_FAILURE;
    }

    y_down = (int **)calloc(Nst + 1, sizeof(int *));
    if (y_down == NULL)
        return MEMORY_ALLOCATION_FAILURE;
    for (i = 0; i < Nst + 1; i++)
    {
        y_down[i] = (int *)calloc(Nst + 1, sizeof(int));
        if (y_down[i] == NULL)
            return MEMORY_ALLOCATION_FAILURE;
    }

    y_up = (int **)calloc(Nst + 1, sizeof(int *));
    if (y_up == NULL)
        return MEMORY_ALLOCATION_FAILURE;
    for (i = 0; i < Nst + 1; i++)
    {
        y_up[i] = (int *)calloc(Nst + 1, sizeof(int));
        if (y_up[i] == NULL)

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        return MEMORY_ALLOCATION_FAILURE;
    }

    nb_critical = (int **)calloc(Nst + 1, sizeof(int *));
    if (nb_critical == NULL)
        return MEMORY_ALLOCATION_FAILURE;
    for (i = 0; i < Nst + 1; i++)
    {
        nb_critical[i] = (int *)calloc(2 * Nst + 1, sizeof(int));
        if (nb_critical[i] == NULL)
            return MEMORY_ALLOCATION_FAILURE;
    }

    nb_critical1 = (int **)calloc(Nst + 1, sizeof(int *));
    if (nb_critical1 == NULL)
        return MEMORY_ALLOCATION_FAILURE;
    for (i = 0; i < Nst + 1; i++)
    {
        nb_critical1[i] = (int *)calloc(2 * Nst + 1, sizeof(int));
        if (nb_critical1[i] == NULL)
            return MEMORY_ALLOCATION_FAILURE;
    }

    RF = (double ** *)malloc((Nst + 1) * sizeof(double **));
    for (i = 0; i <= Nst; i++)
        RF[i] = (double **)malloc((Nst + 1) * sizeof(double *));
    for (i = 0; i <= Nst; i++)
        for (j = 0; j <= Nst; j++)
            RF[i][j] = (double *)malloc(MAX_SING_POINTS * sizeof(double));

    EQL = (double ** *)malloc((Nst + 1) * sizeof(double **));
    for (i = 0; i <= Nst; i++)
        EQL[i] = (double **)malloc((Nst + 1) * sizeof(double *));
    for (i = 0; i <= Nst; i++)
        for (j = 0; j <= Nst; j++)
            EQL[i][j] = (double *)malloc(MAX_SING_POINTS * sizeof(double));

    return 1;
}

static void free_memory(int Nst)

```

```

{
    int i, j;

    free(n_min);
    free(n_max);
    free(GM);
    free(vm);
    free(vpm);
    free(vm1);
    free(vpm1);
    free(vm2);
    free(vpm2);
    free(coeff);

    for (i = 0; i < Nst + 1; i++)
        free(S[i]);
    free(S);

    for (i = 0; i < Nst + 1; i++)
        free(V[i]);
    free(V);

    for (i = 0; i < Nst + 1; i++)
        free(pu_y[i]);
    free(pu_y);

    for (i = 0; i < Nst + 1; i++)
        free(pd_y[i]);
    free(pd_y);

    for (i = 0; i < Nst + 1; i++)
        free(y[i]);
    free(y);

    for (i = 0; i < Nst + 1; i++)
        free(y_up[i]);
    free(y_up);

    for (i = 0; i < Nst + 1; i++)
        free(y_down[i]);
    free(y_down);
}

```

```

for (i = 0; i < Nst + 1; i++)
    free(pu_f[i]);
free(pu_f);

for (i = 0; i < Nst + 1; i++)
    free(pd_f[i]);
free(pd_f);

for (i = 0; i < Nst + 1; i++)
    free(f[i]);
free(f);

for (i = 0; i < Nst + 1; i++)
    free(f_up[i]);
free(f_up);

for (i = 0; i < Nst + 1; i++)
    free(f_down[i]);
free(f_down);

for (i = 0; i < Nst + 1; i++)
    free(nb_critical[i]);
free(nb_critical);

for (i = 0; i < Nst + 1; i++)
    free(nb_critical1[i]);
free(nb_critical1);

for (i = 0; i < Nst + 1; i++)
    for (j = 0; j < Nst + 1; j++)
        free(RF[i][j]);
for (j = 0; j < Nst + 1; j++)
    free(RF[j]);
free(RF);

for (i = 0; i < Nst + 1; i++)
    for (j = 0; j < Nst + 1; j++)
        free(EQL[i][j]);
for (j = 0; j < Nst + 1; j++)
    free(EQL[j]);

```



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    free(EQL);
}

static double compute_f(double r, double omega)
{
    return 2.*sqrt(r) / omega;
}

static double compute_r(double R, double omega)
{
    double val;

    if (R > 0.)
        val = SQR(R) * SQR(omega) / 4.;
    else
        val = 0.;
    return val;
}

static double compute_y(double s, double r, double sigma, double omega, double rho)
{
    double Y;

    Y = (log(s) / sigma - rho * 2.*sqrt(r) / omega) * 1. / sqrt(1. - SQR(rho));

    return Y;
}

static double compute_S(double Y, double R, double sigma, double rho)
{
    double val;

    val = exp(sigma * (sqrt(1. - SQR(rho)) * Y + rho * R));

    return val;
}

/*Calibration of the tree*/
static int calibration(double r0, double s0, double tt, double kappa, double omega)
{
    int i, j;

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double mu_f;
int z, j_step;
double Ru, Rd;
double val1, val2;
int j1, j2;
double sqrt_dt, dt;
int cont1, cont2;
int count_jump_r;

dt = tt / (double)Ns;
sqrt_dt = sqrt(dt);

/*Fixed tree for R=f*/
f[0][0] = compute_f(r0, omega);

j1 = -(int)(f[0][0] / sqrt_dt);
val1 = f[0][0] + j1 * sqrt_dt;

j2 = -(int)(f[0][0] / sqrt_dt + 1);
val2 = f[0][0] + j2 * sqrt_dt;

if ((fabs(val1) < 0.00001) || (fabs(val2) < 0.00001))
{
    Ns = Ns + 2;
    dt = tt / (double)Ns;
    sqrt_dt = sqrt(dt);
    printf("Change of step number N=%d\ n", Ns);
}

V[0][0] = compute_r(f[0][0], omega);
f[1][0] = f[0][0] - sqrt_dt;
f[1][1] = f[0][0] + sqrt_dt;
V[1][0] = compute_r(f[1][0], omega);
V[1][1] = compute_r(f[1][1], omega);
for (i = 1; i < Ns; i++)
    for (j = 0; j <= i; j++)
    {
        f[i + 1][j] = f[i][j] - sqrt_dt;
        f[i + 1][j + 1] = f[i][j] + sqrt_dt;
        V[i + 1][j] = compute_r(f[i + 1][j], omega);
        V[i + 1][j + 1] = compute_r(f[i + 1][j + 1], omega);
    }

```

```

    }

cont1 = 0;
cont2 = 0;
count_jump_r = 0;

/*Evolve tree for f*/
for (i = 0; i < Ns; i++)
{
    for (j = 0; j <= i; j++)
    {
        /*node F=R*/
        /*Compute mu_f*/
        mu_f = (kappa * (4.*theta - SQR(f[i][j]) * SQR(omega)) - SQR(omega)) /
        z = (int)floor(mu_f * sqrt_dt); /*Compute f+ e f-*/

        if (z % 2 == 0)
            j_step = z;
        else
            j_step = z + 1;

        Rd = f[i][j] + (j_step - 1) * sqrt_dt;
        Ru = f[i][j] + (j_step + 1) * sqrt_dt;

        if (j_step != 0)
        {
            count_jump_r++;
        }

        pu_f[i][j] = (mu_f * dt + (f[i][j] - Rd)) / (Ru - Rd);

        f_down[i][j] = (int)(j_step / 2);
        f_up[i][j] = (int)(j_step / 2) + 1;

        if (Ru - 1.e-9 > f[i + 1][i + 1])
        {
            cont1++;
            pu_f[i][j] = 1;
            f_up[i][j] = i + 1 - j;
            f_down[i][j] = i - j;
        }
    }
}

```

```

        if (Rd + 1.e-9 < f[i + 1][0])
        {
            pu_f[i][j] = 0.;
            cont2++;
            f_up[i][j] = -j + 1;
            f_down[i][j] = -j;
        }
        pd_f[i][j] = 1. - pu_f[i][j];
    }
}

/*Initalise first node Y */
y[0][0] = compute_y(s0, r0, sigma, omega, rho);
S[0][0] = compute_S(y[0][0], f[0][0], sigma, rho);

y[1][0] = y[0][0] - sqrt_dt;
y[1][1] = y[0][0] + sqrt_dt;
S[1][0] = compute_S(y[1][0], f[1][0], sigma, rho);
S[1][1] = compute_S(y[1][1], f[1][1], sigma, rho);

for (i = 1; i < Ns; i++)
    for (j = 0; j <= i; j++)
    {
        y[i + 1][j] = y[i][j] - sqrt_dt;
        y[i + 1][j + 1] = y[i][j] + sqrt_dt;
        S[i + 1][j] = compute_S(y[i + 1][j], f[i + 1][j], sigma, rho);
        S[i + 1][j + 1] = compute_S(y[i + 1][j + 1], f[i + 1][j + 1], sigma, rho);
    }
return 1;
}

////////////////////////////////////
/*Compute Equity-Linked Policy Price*/
static double compute_price(double premium, double r0, double s0, double tt, dou
{
    int i, j, k, l, n_k, kk, jj;
    double puu, pud, pdu, pdd, stock;
    int fv_up, fv_down, yv_up, yv_down;
    double pu_ys, pd_ys;

```

```

double mu_f, mu_y, mu_x;
int z, j_step;
double Ru, Rd;
double val_rf;
int flag_monit;
double stockuu, stockud, stockdu, stockdd;
double val_min, val_max;
double prezzo1, prezzo2, prezzo3, prezzo4;
double rf1, rf2, rf3, rf4;
double tol1, tol2;
int max_critical = -100.;
int max_critical1 = -100.;
int old_nb_critical, index;
double x1, x2, y1, y2, b, a;
double val;
double pv, qm;
int i1;
double error, errp, m1;
double sqrt_dt, dt;
double D_m, price;

dt = tt / (double)Ns;
sqrt_dt = sqrt(dt);
tol1 = 0.00000001;
tol2 = 0.000000001;

// warnings
val_min = 0.;
val_max = 0.;
n_k = 0;
//Maximum and minimum number of equities
n_min[0] = D / s0;
n_max[0] = D / s0;

for (i = 1; i <= Ns; i++)
{
    if ((i % n_passi) == 0)
    {
        if (rho >= 0)
        {
            n_min[i] = n_min[i - 1] + D / compute_S(y[i][i], f[i][i], sigma, r

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        n_max[i] = n_max[i - 1] + D / compute_S(y[i][0], f[i][0], sigma, r);
    }
    else
    {
        n_min[i] = n_min[i - 1] + D / compute_S(y[i][i], f[i][0], sigma, r);
        n_max[i] = n_max[i - 1] + D / compute_S(y[i][0], f[i][i], sigma, r);
    }
}
else
{
    n_min[i] = n_min[i - 1];
    n_max[i] = n_max[i - 1];
}
}

GM[0] = 0;
val = D;
for (i = 1; i <= Ns; i++)
{
    if ((i % n_passi) == 0)
    {
        if (delta > 0)
            GM[i] = D * exp(delta) * (exp(delta * (double)(i) * dt) - 1) / (exp(delta) - 1);
        else
            GM[i] = (double)i * dt * D;
        val = GM[i] + D;
    }
    else
    {
        if (((i - 1) % n_passi) == 0)
            GM[i] = val * exp(delta * dt);
        else
            GM[i] = GM[i - 1] * exp(delta * dt);
    }
}

/*Singular points at Maturity for Equity-linked policy*/
for (j = 0; j <= Ns; j++)
    for (k = 0; k <= Ns; k++)
    {
        stock = compute_S(y[Ns][j], f[Ns][k], sigma, rho);
    }

```

```

if ((stock * n_min[Ns - 1] < GM[Ns]) && (stock * n_max[Ns - 1] > GM[Ns]))
{
    RF[j][k][0] = stock * n_min[Ns - 1];
    RF[j][k][1] = GM[Ns];
    RF[j][k][2] = stock * n_max[Ns - 1];

    EQL[j][k][0] = GM[Ns];
    EQL[j][k][1] = GM[Ns];
    EQL[j][k][2] = RF[j][k][2];

    nb_critical[j][k] = 2;
}
else if ((stock * n_min[Ns - 1] > GM[Ns]))
{
    RF[j][k][0] = stock * n_min[Ns - 1];
    RF[j][k][1] = stock * n_max[Ns - 1];
    EQL[j][k][0] = RF[j][k][0];
    EQL[j][k][1] = RF[j][k][1];
    nb_critical[j][k] = 1;
}
else if ((stock * n_max[Ns - 1] < GM[Ns]))
{
    RF[j][k][0] = stock * n_min[Ns - 1];
    RF[j][k][1] = stock * n_max[Ns - 1];
    EQL[j][k][0] = GM[Ns];
    EQL[j][k][1] = GM[Ns];
    nb_critical[j][k] = 1;
}
}

/*Dynamic Programming*/
for (i = Ns - 1; i >= 0; i--)
{
    if (life == 1)
        qm = (lm_insurance[x_age + (int)(i * dt)] - lm_insurance[x_age + (int)(i
    else qm = 0;

```

```
pv = 1. - qm;
```

```
if (((i) % n_passi) == 0) && (i != Ns) && (i > 0))
    flag_monit = 1;
else flag_monit = 0;
```

```
for (j = 0; j <= i; j++)
    for (k = 0; k <= i; k++)
    {
```

```
        /*node Y*/
```

```
        mu_x = (V[i][k] - 0.5 * SQR(sigma)) / sigma;
```

```
        mu_f = (kappa * (4.*theta - SQR(f[i][k]) * SQR(omega)) - SQR(omega))
```

```
        mu_y = (mu_x - rho * mu_f) / sqrt(1. - SQR(rho));
```

```
        z = (int)floor(mu_y * sqrt_dt); /*Compute y+ e y-*/
```

```
        if (z % 2 == 0)
```

```
            j_step = z;
```

```
        else
```

```
            j_step = z + 1;
```

```
        Rd = y[i][j] + (j_step - 1) * sqrt_dt;
```

```
        Ru = y[i][j] + (j_step + 1) * sqrt_dt;
```

```
        pu_ys = (mu_y * dt + (y[i][j] - Rd)) / (Ru - Rd);
```

```
        yv_down = (int)(j_step / 2);
```

```
        yv_up = (int)(j_step / 2) + 1;
```

```
        if (Ru - 1.e-9 > y[i + 1][i + 1])
```

```
        {
```

```
            pu_ys = 1.;
```

```
            yv_up = i + 1 - j;
```

```
            yv_down = i - j;
```

```
        }
```

```
        if (Rd + 1.e-9 < y[i + 1][0])
```

```
        {
```



```

        pu_ys = 0.;
        yv_up = -j + 1;
        yv_down = -j;
    }

pd_ys = 1. - pu_ys;

puu = pu_ys * pu_f[i][k];
pud = pu_ys * pd_f[i][k];
pdu = pd_ys * pu_f[i][k];
pdd = pd_ys * pd_f[i][k];

fv_up = f_up[i][k];
fv_down = f_down[i][k];

//Current stock
stock = compute_S(y[i][j], f[i][k], sigma, rho);

//Next stocks
stockuu = compute_S(y[i + 1][j + yv_up], f[i + 1][k + fv_up], sigma,
stockud = compute_S(y[i + 1][j + yv_up], f[i + 1][k + fv_down], sigma,
stockdu = compute_S(y[i + 1][j + yv_down], f[i + 1][k + fv_up], sigma,
stockdd = compute_S(y[i + 1][j + yv_down], f[i + 1][k + fv_down], sigma,

//Val Min et Val max
if (i == 0)
{
    val_min = D;
    val_max = D;
}
else if ((flag_monit == 1) && (i > 0))
{
    val_min = stock * n_min[i - 1];
    val_max = stock * n_max[i - 1];
}
else if ((flag_monit == 0) && (i >= 0))
{
    val_min = stock * n_min[i - 1];
    val_max = stock * n_max[i - 1];
}

```

```

//RF min
vm[0] = val_min;

//interior RF
if (i > 0)
{
    n_k = 1;

    //uu
    for (l = 0; l <= nb_critical[j + yv_up][k + fv_up]; l++)
    {
        if (flag_monit == 0)
            val_rf = RF[j + yv_up][k + fv_up][l] * stock / stockuu;
        else
            val_rf = (RF[j + yv_up][k + fv_up][l]) * stock / stockuu -

        if ((val_rf < val_max) && (val_rf > val_min))
        {
            vm[n_k] = val_rf;
            n_k++;
        }
    }
    //ud
    for (l = 0; l <= nb_critical[j + yv_up][k + fv_down]; l++)
    {

        if (flag_monit == 0)
            val_rf = RF[j + yv_up][k + fv_down][l] * stock / stockud;
        else
            val_rf = (RF[j + yv_up][k + fv_down][l]) * stock / stockud

        if ((val_rf < val_max) && (val_rf > val_min))
        {
            vm[n_k] = val_rf;
            n_k++;
        }
    }

    //du
    for (l = 0; l <= nb_critical[j + yv_down][k + fv_up]; l++)
    {

```

```

        if (flag_monit == 0)
            val_rf = RF[j + yv_down][k + fv_up][1] * stock / stockdu;
        else
            val_rf = (RF[j + yv_down][k + fv_up][1]) * stock / stockdu;

        if ((val_rf < val_max) && (val_rf > val_min))
        {
            vm[n_k] = val_rf;
            n_k++;
        }
    }
//dd
for (l = 0; l <= nb_critical[j + yv_down][k + fv_down]; l++)
{
    if (flag_monit == 0)
        val_rf = RF[j + yv_down][k + fv_down][1] * stock / stockdd;
    else
        val_rf = (RF[j + yv_down][k + fv_down][1]) * stock / stockdd;

    if ((val_rf < val_max) && (val_rf > val_min))
    {
        vm[n_k] = val_rf;
        n_k++;
    }
}
}
//RF max
vm[n_k] = val_max;
nb_critical1[j][k] = n_k;

/*Sorting*/

SortVect(nb_critical1[j][k], vm);

/*Eliminate close singular points*/
vm1[0] = vm[0];

kk = 0;
l = 0;
do

```

```

{
    do
    {
        l++;
    }
    while ((vm[l] <= vm[kk] + tol1) && (l < nb_critical1[j][k]));
    kk++;
    vm[kk] = vm[l];

}
while ((l < nb_critical1[j][k]));

nb_critical1[j][k] = kk;

if (fabs(vm[nb_critical1[j][k]] - vm[nb_critical1[j][k] - 1]) < to
    nb_critical1[j][k]--;

//Compute Singular ordinate
for (n_k = 0; n_k <= nb_critical1[j][k]; n_k++)
{
    val_rf = vm[n_k];
    if (flag_monit == 0)
    {
        rf1 = val_rf * stockuu / stock;
        prezzo1 = linear_interpolation(rf1, j + yv_up, k + fv_up);

        rf2 = val_rf * stockud / stock;
        prezzo2 = linear_interpolation(rf2, j + yv_up, k + fv_down);
        rf3 = val_rf * stockdu / stock;
        prezzo3 = linear_interpolation(rf3, j + yv_down, k + fv_up);
        rf4 = val_rf * stockdd / stock;
        prezzo4 = linear_interpolation(rf4, j + yv_down, k + fv_down);
    }
    else
    {
        rf1 = (val_rf + D) * stockuu / stock;
        prezzo1 = linear_interpolation(rf1, j + yv_up, k + fv_up);
        rf2 = (val_rf + D) * stockud / stock;
        prezzo2 = linear_interpolation(rf2, j + yv_up, k + fv_down);
        rf3 = (val_rf + D) * stockdu / stock;
        prezzo3 = linear_interpolation(rf3, j + yv_down, k + fv_up);
    }
}

```

```

        rf4 = (val_rf + D) * stockdd / stock;
        prezzo4 = linear_interpolation(rf4, j + yv_down, k + fv_down);
    }

    vpm1[n_k] = exp(-V[i][k] * dt) *
        (puu * prezzo1 + pud * prezzo2 + pdu * prezzo3 + pdd * prezzo4);

    vpm1[n_k] *= pv;

    prezzo1 = MAX(rf1, GM[i + 1]);
    prezzo2 = MAX(rf2, GM[i + 1]);
    prezzo3 = MAX(rf3, GM[i + 1]);
    prezzo4 = MAX(rf4, GM[i + 1]);
    vpm1[n_k] += exp(-V[i][k] * dt) * qm * (puu * prezzo1 + pud * prezzo2 + pdu * prezzo3 + pdd * prezzo4);
}

//Subtract the premium
if ((flag_monit == 1) || (i == 0))
{
    for (l = 0; l <= nb_critical1[j][k]; l++)
    {
        vpm1[l] = vpm1[l] - premium;
    }
}

max_critical1 = MAX(nb_critical1[j][k], max_critical1);

//Upper Bound
i1 = 0;
index = 0;
vm2[0] = vm1[0];
vpm2[0] = vpm1[0];
while (i1 < nb_critical1[j][k] - 1)
{
    l = 1;
    do
    {
        l++;
        m1 = (vpm1[i1 + l] - vpm1[i1]) / (vm1[i1 + l] - vm1[i1]);
        error = 0.;
        for (jj = 1; jj <= l - 1; jj++)

```

```

        {
            errp = m1 * (vm1[i1 + jj] - vm1[i1]) + vpm1[i1] - vpm1[i1 + jj];
            if (errp < 0) errp = -errp;
            if (errp > error) error = errp;
        }
    }
    while (!((error > h_up) || ((i1 + 1) == nb_critical1[j][k])));
    index++;
    vm2[index] = vm1[i1 + 1 - 1];
    vpm2[index] = vpm1[i1 + 1 - 1];
    i1 = i1 + 1 - 1;
}
while (i1 < nb_critical1[j][k])
{
    index++;
    vm2[index] = vm1[i1 + 1];
    vpm2[index] = vpm1[i1 + 1];
    i1 = i1 + 1;
}
nb_critical1[j][k] = index;

//Copy
for (l = 0; l <= nb_critical1[j][k]; l++)
{
    vm1[l] = vm2[l];
    vpm1[l] = vpm2[l];
}

//Early exercise
D_m = D;
D = 0.;
if (am == 1)
    if ((flag_monit == 1) && (i > 0))
    {
        old_nb_critical = nb_critical1[j][k];

        //American with reference fund
        if ((vm1[old_nb_critical] - D) >= vpm1[old_nb_critical])
        {
            if ((vm1[0] - D) >= vpm1[0])
            {

```

```

        vm2[0] = vm1[0];
        vm2[1] = vm1[old_nb_critical];
        vpm2[0] = vm2[0] - D;
        vpm2[1] = vm2[1] - D;
        nb_critical1[j][k] = 1;
    }
else if (vpm1[0] > (vm1[0] - D))
{
    l = 1;
    while ((vpm1[l] > (vm1[l] - D)) && (l <= nb_critical1[j][k]))

    if (l < nb_critical1[j][k])
    {
        x1 = vm1[l - 1];
        x2 = vm1[l];
        y1 = vpm1[l - 1];
        y2 = vpm1[l];
        a = (y2 - y1) / (x2 - x1);
        b = (y1 * x2 - x1 * y2) / (x2 - x1);

        vm2[l] = (D + b) / (1. - a);
        vpm2[l] = vm2[l] - D;
        vm2[l + 1] = vm1[old_nb_critical];
        vpm2[l + 1] = vm2[l + 1] - D;
        nb_critical1[j][k] = l + 1;
    }
}
//Copy
for (l = 0; l <= nb_critical1[j][k]; l++)
{
    vm1[l] = vm2[l];
    vpm1[l] = vpm2[l];
}

}

old_nb_critical = nb_critical1[j][k];

//American with guaranted minimum
if (GM[i] >= vpm1[old_nb_critical])
{

```

```

        vm2[0] = vm1[0];
        vm2[1] = vm1[old_nb_critical];
        vpm2[0] = GM[i];
        vpm2[1] = GM[i];
        nb_critical1[j][k] = 1;
    }
else if (GM[i] > vpm1[0])
{
    l = 1;
    while (((vpm1[l]) <= GM[i]) &&
           (l <= nb_critical1[j][k]))
        l++;

    vm2[0] = vm1[0];
    vpm2[0] = GM[i];

    x1 = vm1[l - 1];
    x2 = vm1[l];
    y1 = vpm1[l - 1];
    y2 = vpm1[l];
    a = (y2 - y1) / (x2 - x1);
    b = (y1 * x2 - x1 * y2) / (x2 - x1);

    vm2[1] = (GM[i] - b) / a;
    vpm2[1] = GM[i];

    index = 2;

    while (l <= nb_critical1[j][k])
    {
        vm2[index] = vm1[l];
        vpm2[index] = vpm1[l];
        index++;
        l++;
    }
    nb_critical1[j][k] = index - 1;
}
else
for (l = 0; l <= nb_critical1[j][k]; l++)
{
    vm2[l] = vm1[l];

```



```

        vpm2[l] = vpm1[l];
    }
}
D = D_m;

max_critical = MAX(nb_critical1[j][k], max_critical);

//Copy
for (l = 0; l <= nb_critical1[j][k]; l++)
{
    RF[j][k][l] = vm2[l];
    EQL[j][k][l] = vpm2[l];
}
}

for (j = 0; j <= i; j++)
    for (k = 0; k <= i; k++)
        nb_critical[j][k] = nb_critical1[j][k];

}

price = EQL[0][0][0];

/*Price*/
return price;

}

```

```

static int cgmz(int am, double s0, NumFunc_1 *p, double tt, double sigma, double
{
    double val;
    int n_obs, i;
    FILE *f_in;
    int life = 1;

    lm_insurance = (double *)malloc(120 * sizeof(double));
    f_in = fopen(infile, "rb");

    //Read Statistics Mortality
    for (i = 0; i < 120; i++)

```

```

    {
        fscanf(f_in, "%lf\ n", &val);
        lm_insurance[i] = val;
    }

n_obs = (int)tt;
Ns = n_obs * n_step_for_period;

/*Memory Allocation*/
memory_allocation(Ns + 2);

//Calibrate interest rate tree
calibration(r0, s0, tt, kappa, omega, theta, rho, sigma, delta);

//Compute Price of equity-linked policy
*ptprice = compute_price(premium, r0, s0, tt, kappa, omega, theta, rho, sigma,

fclose(f_in);

//Memory desallocation
free_memory(Ns + 2);
free(lm_insurance);

return OK;
}

int CALC(TR_cgmz)(void *Opt, void *Mod, PricingMethod *Met)
{
    TYPEOPT *ptOpt = (TYPEOPT *)Opt;
    TYPEMOD *ptMod = (TYPEMOD *)Mod;

    double kappa, theta, omega;

    omega = ptMod->Sigma.Val.V_PDDOUBLE;
    kappa = ptMod->k.Val.V_PDDOUBLE;
    theta = ptMod->theta.Val.V_PDDOUBLE;
    infilename = ptOpt->MortalityData.Val.V_FILENAME;
    if (2 * kappa * theta < SQR(omega))
    {
        Fprintf(TOSCREEN, "UNTREATED CASE\ n\ n\ n");
        return WRONG;
    }
}

```

```

    }
    else
        return cgmz(ptOpt->EuOrAm.Val.V_BOOL, ptMod->S0.Val.V_PDOUBLE, ptOpt->PayOff
}

static int CHK_OPT(TR_cgmz)(void *Opt, void *Mod)
{
    if ((strcmp(((Option *)Opt)->Name, "EquityLinkedSurrenderEndowment") == 0))
        return OK;
    return WRONG;
}

#endif //PremiaCurrentVersion
static int MET(Init)(PricingMethod *Met, Option *Opt)
{
    if (Met->init == 0)
    {
        Met->init = 1;

        Met->Par[0].Val.V_INT2 = 10;
        Met->Par[1].Val.V_PDOUBLE = 0.001;
    }

    return OK;
}

PricingMethod MET(TR_cgmz) =
{
    "TR_CGMZ",
    {"Step Numbers between Monitoring Dates", INT2, {100}, ALLOW}, {"Tollerance E
CALC(TR_cgmz),
{"Price", DOUBLE, {100}, FORBID}, {" ", PREMIA_NULLTYPE, {0}, FORBID}},
    CHK_OPT(TR_cgmz),
    CHK_tree,
    MET(Init)
};

```