

[Help](#)

```
#include "heshw2d_std.h"
#include "enums.h"
#include "error_msg.h"

#include "pnl/pnl_random.h"
#include "pnl/pnl_cdf.h"

#if defined(PremiaCurrentVersion) && PremiaCurrentVersion < (2015+2) //The "#els
static int CHK_OPT(MC_HybridTree)(void *Opt, void *Mod)
{
    return NONACTIVE;
}
int CALC(MC_HybridTree)(void *Opt, void *Mod, PricingMethod *Met)
{
    return AVAILABLE_IN_FULL_PREMIA;
}
#else

static double **V,**Q;
static double **y,**f,* y_rf;
static int **f_down,**f_up;
static int **y_down,**y_up;
static int **rf_down, * rf_up;
static double **pu_y,**pd_y;
static double **pu_f,**pd_f;
static double **pu_rf, * pd_rf;
static double **r,**rf,**discount, * discount_rf;
static double *initial_yield;

/*ZCB Data*/
static double* tm; /*Times T of maturities read in the file initialyield.dat */
static double* Pm; /*Values of the zero coupon P(0,tm) read in the file initialyi
int n_price1;

static double *shift_r,*Pc,*shift_rf;
static char *init_tr_rd,*init_tr_rf;

/*Memory Allocation*/
```

```
static int memory_allocation(int Nt)
{
    int i;

    shift_r= (double *)malloc((Nt+1)*sizeof(double));
    shift_rf = malloc((Nt + 1) * sizeof(double));
    initial_yield= (double *)malloc((Nt+2)*sizeof(double));
    Pc= (double *)malloc((Nt+2)*sizeof(double));

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

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

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

```

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

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

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

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

pd_y=(double**)calloc(Nt+1,sizeof(double*));

```

```

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

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

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

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

pd_rf = (double **)calloc(Nt + 1, sizeof(double *));
if (pd_rf == NULL)

```

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

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

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

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

```
f_down=(int**)calloc(Nt+1,sizeof(int*));
if (f_down==NULL)
```

```

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

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

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

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

rf_down = (int **)calloc(Nt + 1, sizeof(int *));
if (rf_down == NULL)

```

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

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

return OK;
}

static void free_memory(int Nt)
{
    int i;

    free(shift_r);
    free(shift_rf);
    free(initial_yield);
    free(Pc);

    for (i = 0; i < Nt + 1; i++)
        free(r[i]);
    free(r);

    for (i = 0; i < Nt + 1; i++)
        free(rf[i]);
    free(rf);

    for (i = 0; i < Nt + 1; i++)
        free(discount[i]);
}
```

```
free(discount);

for (i = 0; i < Nt + 1; i++)
    free(discount_rf[i]);
free(discount_rf);

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

for (i = 0; i < Nt + 1; i++)
    free(Q[i]);
free(Q);

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

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

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

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

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

for (i = 0; i < Nt + 1; i++)
    free(y_rf[i]);
free(y_rf);

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



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

    for (i = 0; i < Nt + 1; i++)
        free(pu_rf[i]);
    free(pu_rf);

    for (i = 0; i < Nt + 1; i++)
        free(pd_rf[i]);
    free(pd_rf);

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

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

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

    for (i = 0; i < Nt + 1; i++)
        free(rf_up[i]);
    free(rf_up);

    for (i = 0; i < Nt + 1; i++)
        free(rf_down[i]);
    free(rf_down);

    return;
}

static int lecture_tr(int flag_rd)
{

    int i;
```

```
char ligne[30];
char *pligne;
double p, tt_value;
FILE *Entrees;

if (flag_rd)
    Entrees = fopen(init_tr_rd, "r");
else
    Entrees = fopen(init_tr_rf, "r");

if (Entrees == NULL)
{
    printf("Le FICHIER N'A PU ETRE OUVERT. VERIFIER LE CHEMIN\ n");
}

/* i is the number of libe that has been read */
i = 0;
pligne = ligne;
Pm = malloc(200 * sizeof(double));
tm = malloc(200 * sizeof(double));

while (1)
{
    pligne = fgets(ligne, sizeof(ligne), Entrees);
    if (pligne == NULL) break;
    else
    {
        sscanf(pligne, "%lf t=%lf", &p, &tt_value);
        /* The line read must be written "0.943290 t=0.5" where 0.943290 is a
        Pm[i] = p; /*save the price of the zero coupon*/
        tm[i] = tt_value; /*save the corresponding time*/
        i++;
    }
}

fclose(Entrees);

return i;
}
```

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

```
static double compute_v(double R, double omega)
{
    double val;

    val = SQR(R) * SQR(omega) / 4.;
    if (R > 0.)
        val = SQR(R) * SQR(omega) / 4.;
    else
        val = 0.0;
    return val;
}
```

```
/*Calibration of the tree v*/
static int tree_v(double tt, double v02, double kappa2, double theta, double omega2)
{
    int i, j;
    int z;
    double Ru, Rd;
    double mu_r, v_curr;
    double dt, sqrt_dt;

    /*Fixed tree for R=f*/
    f[0][0] = compute_f(v02, omega2);

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

    V[0][0] = compute_v(f[0][0], omega2);
    f[1][0] = f[0][0] - sqrt_dt;
    f[1][1] = f[0][0] + sqrt_dt;
    V[1][0] = compute_v(f[1][0], omega2);
    V[1][1] = compute_v(f[1][1], omega2);
}
```

```

for (i = 1; i < Nt; 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_v(f[i + 1][j], omega2);
    V[i + 1][j + 1] = compute_v(f[i + 1][j + 1], omega2);
  }

for (i = 1; i < Nt; i++)
  for (j = 0; j <= i; j++)

    /*Evolve tree for f*/
    for (i = 0; i < Nt; i++)
    {
      for (j = 0; j <= i; j++)
      {
        /*Compute mu_f*/
        v_curr = V[i][j];

        mu_r = kappa2 * (theta - v_curr);

        z = 0;
        while ((V[i][j] + mu_r * dt < V[i + 1][j - z])
              && (j - z >= 0))
        {
          z = z + 1;
        }
        f_down[i][j] = -z;
        Rd = V[i + 1][j - z];

        if (z > 0)
          z = 0;
        else z = 1;

        while ((V[i][j] + mu_r * dt > V[i + 1][j + z])
              && (j + z <= i))
        {
          z = z + 1;
        }
      }
    }

```

```

    Ru = V[i + 1][j + z];

    f_up[i][j] = z;
    pu_f[i][j] = (V[i][j] + mu_r * dt - Rd) / (Ru - Rd);

    if ((Ru - 1.e-9 > V[i + 1][i + 1]) || (j + f_up[i][j] > i + 1))
    {
        pu_f[i][j] = 1;

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

}
return 1;
}

```

```

/*Calibration of the tree the interest rate r Hwicek model*/
static int tree_rd(double tt, double r0, double kappa, double omega, int Nt)
{
    int i, j;
    int z;
    double Ru, Rd;
    double dt, sqrt_dt;
    double mu_r, v_curr;

    y[0][0] = 0.;

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

    y[1][0] = y[0][0] - sqrt_dt;

```

```

y[1][1] = y[0][0] + sqrt_dt;

for (i = 1; i < Nt; 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;
  }

/*Evolve tree for f*/
for (i = 0; i < Nt; i++)
{
  for (j = 0; j <= i; j++)
  {
    /*Compute mu_f*/
    v_curr = y[i][j];

    mu_r = -kappa * v_curr;

    z = 0;
    while ((y[i][j] + mu_r * dt < y[i + 1][j - z])
           && (j - z >= 0))
    {
      z = z + 1;
    }
    y_down[i][j] = -z;
    Rd = y[i + 1][j - z];

    if (z > 0)
      z = 0;
    else z = 1;

    while ((y[i][j] + mu_r * dt > y[i + 1][j + z])
           && (j + z <= i))
    {
      z = z + 1;
    }

    Ru = y[i + 1][j + z];
  }
}

```

```

    y_up[i][j] = z;
    pu_y[i][j] = (y[i][j] + mu_r * dt - Rd) / (Ru - Rd);

    if ((Ru - 1.e-9 > y[i + 1][i + 1]) || (j + y_up[i][j] > i + 1))
    {
        pu_y[i][j] = 1;

        y_up[i][j] = i + 1 - j;
        y_down[i][j] = i - j;
    }

    if ((Rd + 1.e-9 < y[i + 1][0]) || (j + y_down[i][j] < 0))
    {
        pu_y[i][j] = 0.;
        y_up[i][j] = 1 - j;
        y_down[i][j] = 0 - j;
    }
    pd_y[i][j] = 1. - pu_y[i][j];
}

return 1;
}

/*Calibration of the tree the interest rate r foreign Hwicek model*/
static int tree_rf(double tt, double r0f, double kappa_rf, double omega_rf, int
{
    int i, j;
    int z;
    double Ru, Rd;
    double dt, sqrt_dt;
    double mu_rf, v_curr;

    y_rf[0][0] = 0.;

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

    y_rf[1][0] = y_rf[0][0] - sqrt_dt;
    y_rf[1][1] = y_rf[0][0] + sqrt_dt;

```

```

for (i = 1; i < Nt; i++)
  for (j = 0; j <= i; j++)
  {
    y_rf[i + 1][j] = y_rf[i][j] - sqrt_dt;
    y_rf[i + 1][j + 1] = y_rf[i][j] + sqrt_dt;
  }

/*Evolve tree for f*/
for (i = 0; i < Nt; i++)
{
  for (j = 0; j <= i; j++)
  {
    /*Compute mu_f*/
    v_curr = y_rf[i][j];

    mu_rf = -kappa_rf * v_curr;

    z = 0;
    while ((y_rf[i][j] + mu_rf * dt < y_rf[i + 1][j - z])
           && (j - z >= 0))
    {
      z = z + 1;
    }
    rf_down[i][j] = -z;
    Rd = y_rf[i + 1][j - z];

    if (z > 0)
      z = 0;
    else z = 1;

    while ((y_rf[i][j] + mu_rf * dt > y_rf[i + 1][j + z])
           && (j + z <= i))
    {
      z = z + 1;
    }

    Ru = y_rf[i + 1][j + z];

    rf_up[i][j] = z;
    pu_rf[i][j] = (y_rf[i][j] + mu_rf * dt - Rd) / (Ru - Rd);
  }
}

```



```

        if ((Ru - 1.e-9 > y_rf[i + 1][i + 1]) || (j + rf_up[i][j] > i + 1))
        {
            pu_rf[i][j] = 1;

            rf_up[i][j] = i + 1 - j;
            rf_down[i][j] = i - j;
        }
        if ((Rd + 1.e-9 < y_rf[i + 1][0]) || (j + rf_down[i][j] < 0))
        {
            pu_rf[i][j] = 0.;
            y_up[i][j] = 1 - j;
            rf_down[i][j] = 0 - j;
        }
        pd_rf[i][j] = 1. - pu_rf[i][j];
    }
}

return 1;
}

static int interpolate(int n_price, int imax, double *t)
{
    int i, iF, j;

    n_price--;

    i = 0;
    while (t[i] <= tm[1])
    {
        initial_yield[i] = (tm[1] - t[i]) / tm[1] + t[i] * Pm[1] / tm[1];

        i++;
    }
    for (j = 0; j < n_price; j++)
    {
        while (t[i] < tm[j + 1] && i <= imax + 1)
        {
            initial_yield[i] = (tm[j + 1] - t[i]) / (tm[j + 1] - tm[j]) * Pm[j] +
            i++;
        }
    }
}

```

```

        }
    }
    if (t[i] > tm[n_price] && i <= imax + 1)
    {
        for (iF = i ; iF <= imax ; iF++)
        {
            initial_yield[iF] = Pm[n_price] + (Pm[n_price] - Pm[n_price - 1]) / (t
        }
    }

    return 1;
}

```

```

/*Calibration of the tree consistent with dynamic of the Hull-White Process*/
static int calibration_bond_rd(int flat_flag, double tt, double r0, double omega)
{
    double sum;
    int i, j, jj, n_price;
    double dt;
    int flag_rd;

    dt = tt / (double)Nt;

    /*Initialilise Yield Curve*/
    if (flat_flag == 0)
    {
        for (i = 1; i <= Nt + 1; i++)
            initial_yield[i] = r0;
    }
    else
    {
        double *t_vect;
        t_vect = (double *)malloc((Nt + 3) * sizeof(double));

        for (i = 0; i <= Nt + 2; i++)
            t_vect[i] = i * dt;

        flag_rd = 0;
    }
}

```

```

n_price = lecture_tr(flag_rd);

/* We search in initialyield.dat the biggest value before time T */
if (tt > tm[n_price - 1])
{
    printf("\ nError : time bigger than the last time value entered in ini
}

interpole(n_price, Nt, t_vect);

free(tm);
free(Pm);
free(t_vect);

}

for (i = 1; i <= Nt + 1; i++)
{
    if (flat_flag == 0)
    {
        Pc[i] = exp(-initial_yield[i] * i * dt);
    }
    else
    {
        Pc[i] = initial_yield[i];
    }
}

/*Initalise first node*/
Q[0][0] = 1.;

/*Evolve tree for the x=ln r*/
for (i = 0; i <= Nt; i++)
{
    /*Update pure security prices*/
    if (i > 0)
        for (j = 0; j <= i; j++)
        {
            sum = 0.;

```

```

        for (jj = 0; jj <= i - 1; jj++)
        {
            if (jj + y_up[i - 1][jj] == j)
                sum += Q[i - 1][jj] * pu_y[i - 1][jj] * discount[i - 1][jj];
            if (jj + y_down[i - 1][jj] == j)
                sum += Q[i - 1][jj] * pd_y[i - 1][jj] * discount[i - 1][jj];
        }

        Q[i][j] = sum;
    }

    /*Compute a[i]*/
    if (i == 0)
        shift_r[0] = -log(Pc[1]) / dt;
    else
    {
        sum = 0.;
        for (j = 0; j <= i; j++)
        {
            sum += Q[i][j] * exp(-omega * y[i][j] * dt);
        }
        shift_r[i] = (log(sum) - log(Pc[i + 1])) / dt;
    }

    /*Compute x,r and discount factor d*/
    for (j = 0; j <= i; j++)
    {
        r[i][j] = omega * y[i][j] + shift_r[i];
        discount[i][j] = exp(-r[i][j] * dt);
    }
}

return 1;
}

/*Calibration of the tree consistent with dynamic of the Hull-White Process*/
static int calibration_bond_rf(int flat_flag, double tt, double r0f, double omeg
{
    double sum;
    int i, j, jj, n_price;

```

```

double dt;
int flag_rd;

dt = tt / (double)Nt;

/*Initialilise Yield Curve*/
if (flat_flag == 0)
{
    for (i = 1; i <= Nt + 1; i++)
        initial_yield[i] = r0f;
}
else
{
    double *t_vect;
    t_vect = (double *)malloc((Nt + 3) * sizeof(double));

    for (i = 0; i <= Nt + 2; i++)
        t_vect[i] = i * dt;

    flag_rd = 0;
    n_price = lecture_tr(flag_rd);

    /* We search in initialyield.dat the biggest value before time T */
    if (tt > tm[n_price - 1])
    {
        printf("\ nError : time bigger than the last time value entered in ini
    }

    interpolate(n_price, Nt, t_vect);

    free(tm);
    free(Pm);
    free(t_vect);
}

for (i = 1; i <= Nt + 1; i++)
{
    if (flat_flag == 0)
    {
        Pc[i] = exp(-initial_yield[i] * i * dt);
    }
}

```

```

        else
        {
            Pc[i] = initial_yield[i];
        }
    }
    /*Initialise first node*/
    Q[0][0] = 1.;

    /*Evolve tree for the x=ln r*/
    for (i = 0; i <= Nt; i++)
    {
        /*Update pure security prices*/
        if (i > 0)
            for (j = 0; j <= i; j++)
            {
                sum = 0.;

                for (jj = 0; jj <= i - 1; jj++)
                {
                    if (jj + y_up[i - 1][jj] == j)
                        sum += Q[i - 1][jj] * pu_rf[i - 1][jj] * discount_rf[i - 1][jj];
                    if (jj + y_down[i - 1][jj] == j)
                        sum += Q[i - 1][jj] * pd_rf[i - 1][jj] * discount_rf[i - 1][jj];
                }

                Q[i][j] = sum;
            }
        /*Compute a[i]*/
        if (i == 0)
            shift_rf[0] = -log(Pc[1]) / dt;
        else
        {
            sum = 0.;
            for (j = 0; j <= i; j++)
            {
                sum += Q[i][j] * exp(-omega_rf * y_rf[i][j] * dt);
            }
            shift_rf[i] = (log(sum) - log(Pc[i + 1])) / dt;
        }

        /*Compute x,r and discount factor d*/

```

```

        for (j = 0; j <= i; j++)
        {
            rf[i][j] = omega_rf * y_rf[i][j] + shift_rf[i];
            discount_rf[i][j] = exp(-rf[i][j] * dt);
        }
    }

    return 1;
}

/*Compute Price Option*/
int Mc_HybridTree_HesHw2d(double s0, NumFunc_1 *p, double tt, double v02, int
{
    double price_sample, mean_price,var_price;
    int init_mc,ipath,i,k1,k2,k3;
    int simulation_dim;
    double alpha, z_alpha;
    double pterror_price;
    double int_r,vol,interest_rate,y_s,dividend,y_s_rf;
    double dt,sqrt_dt;
    double g1,w_t_1;
    double Yt,St;
    double new_vol,new_y_s,new_y_s_rf;
    double mu_z;
    double sigma_z;
    double kappa, omega, rho_Sr, kappa_rf, omega_rf, rho_Srf, kappa2, omega2, rho_
    double rho_vr, rho_vrf, rho_rrf; //UNUSED IN THIS CODE
    double rho3;

    //-----Initialisation of variable
    kappa2 = GET(kappa_vect, 0);
    kappa = GET(kappa_vect, 1);
    kappa_rf = GET(kappa_vect, 2);

    omega2 = GET(sigma_vect, 0);
    omega = GET(sigma_vect, 1);
    omega_rf = GET(sigma_vect, 2);

    rho_Sv = GET(rho, 0);
    rho_Sr = GET(rho, 1);

```

```

rho_Srf = GET(rho, 2);
rho_vr = GET(rho, 3);
rho_vrf = GET(rho, 4);
rho_rrf = GET(rho, 5);

if ((fabs(rho_vr) > 0) || (fabs(rho_vrf) > 0) || (fabs(rho_rrf) > 0))
    return UNTREATED_CASE;

if (SQR(rho_Sv) + SQR(rho_Sr) + SQR(rho_Srf) >= 1.)
    return UNTREATED_CASE;

init_tr_rd = curve_rd;
init_tr_rf = curve_rf;

/*Memory Allocation*/
if (memory_allocation(Nt) != OK) return FAIL;

//Tree construction for r_d
tree_rd(tt, r0, kappa, omega, Nt);
calibration_bond_rd(flat_flag_rd, tt, r0, omega, Nt);

///Tree construction for r_f
tree_rf(tt, r0f, kappa_rf, omega_rf, Nt);
calibration_bond_rf(flat_flag_rf, tt, r0f, omega_rf, Nt);

//Tree construction for v
tree_v(tt, v02, kappa2, theta, omega2, Nt);

/* Value to construct the confidence interval */
alpha= (1.- confidence)/2.;
z_alpha=pnl_inv_cdfnor(1.- alpha);

/*Initialisation*/
mean_price= 0.0;
var_price= 0.0;

dt=tt/(double)Nt;
sqrt_dt=sqrt(dt);
/* Test after initialization for the generator */
simulation_dim =Nt;

```



```

/* MC sampling */
init_mc = pnl_rand_init(generator, simulation_dim, N_MC);
rho3=sqrt(1-SQR(rho_Sv)-SQR(rho_Sr)-SQR(rho_Srf));
for(ipath= 1;ipath<=N_MC;ipath++)
{
    vol=V[0][0];
    interest_rate=r[0][0];
    dividend=rf[0][0];
    y_s=y[0][0];
    y_s_rf=y_rf[0][0];
    Yt=log(s0);
    k1=0;
    k2=0;
    k3=0;
    int_r=0;
    for(i=0;i<Nt;i++)
    {
        g1=pnl_rand_normal(generator);//V
        w_t_1=sqrt_dt*g1;//V
        interest_rate=r[i][k1];
        dividend=rf[i][k3];

        //Simulate V
        if(pnl_rand_uni(generator)<pu_f[i][k2])
            k2+=f_up[i][k2];
        else
            k2+=f_down[i][k2];

        new_vol=V[i+1][k2];

        //Simulate r and y
        if(pnl_rand_uni(generator)<pu_y[i][k1])
            k1+=y_up[i][k1];
        else
            k1+=y_down[i][k1];

        new_y_s=y[i+1][k1];

        //Simulate dividend and yf
        if(pnl_rand_uni(generator)<pu_rf[i][k3])

```

```

k3+=rf_up[i][k3];
    else
k3+=rf_down[i][k3];

    new_y_s_rf=y_rf[i+1][k3];

    mu_z=interest_rate-dividend-0.5*vol-rho_Sv/omega2*kappa2*(theta-vol)+sqrt(vol)
    sigma_z=rho3*sqrt(vol);

    Yt+=mu_z*dt+sigma_z*w_t_1+rho_Sv/omega2*(new_vol-vol)+rho_Sr*sqrt(vol)*(new_y_

    St=exp(Yt);
    y_s=new_y_s;
    vol=new_vol;
    y_s_rf=new_y_s_rf;

    int_r+=interest_rate;
}

price_sample=exp(-int_r*dt)*(p->Compute)(p->Par,St);

/* Sum */
mean_price+=price_sample;

/* Sum of squares */
var_price+= SQR(price_sample);

}

*ptprice=(mean_price/(double)N_MC);
pterror_price= sqrt(var_price/(double)N_MC-SQR(*ptprice))/sqrt((double)N_MC-1)

/* Price Confidence Interval */
*inf_price= *ptprice - z_alpha*(pterror_price);
*sup_price= *ptprice + z_alpha*(pterror_price);

/*Memory Disallocation*/
free_memory(Nt);

return OK;

```

```

}

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

    return Mc_HybridTree_HesHw2d(ptMod->S0.Val.V_PDOUBLE,
                                   ptOpt->PayOff.Val.V_NUMFUNC_1,
                                   ptOpt->Maturity.Val.V_DATE - ptMod->T.Val.V_DATE,
                                   ptMod->v0.Val.V_PDOUBLE,
                                   ptMod->flat_flag_rd.Val.V_INT,
                                   MOD(GetYield_rd)(ptMod),
                                   MOD(GetCurve_rd)(ptMod),
                                   ptMod->flat_flag_rf.Val.V_INT,
                                   MOD(GetYield_rf)(ptMod),
                                   MOD(GetCurve_rf)(ptMod),
                                   ptMod->theta.Val.V_PDOUBLE,
                                   ptMod->kappa.Val.V_PNLVECT,
                                   ptMod->sigma.Val.V_PNLVECT,
                                   ptMod->rho.Val.V_PNLVECT,
                                   Met->Par[0].Val.V_PINT,
                                   Met->Par[1].Val.V_PINT,
                                   Met->Par[2].Val.V_ENUM.value,
                                   Met->Par[3].Val.V_PDOUBLE,
                                   &(Met->Res[0].Val.V_DOUBLE), &(Met->Res[1].Val.V_DO
    }

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

#endif //PremiaCurrentVersion

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

```

```

        Met->HelpFilenameHint = "mc_hybridtree_heshw2d";
        Met->Par[0].Val.V_INT = 300;
        Met->Par[1].Val.V_INT = 100000;
        Met->Par[2].Val.V_ENUM.value = 0;
        Met->Par[2].Val.V_ENUM.members = &PremiaEnumMCRNGs;
        Met->Par[3].Val.V_DOUBLE = 0.95;
    }

    return OK;
}

PricingMethod MET(MC_HybridTree) =
{
    "MC_HybridTree",
    { {"N steps time", INT, {100}, ALLOW},
      {"N Iterations", INT, {100}, ALLOW},
      {"RandomGenerator", ENUM, {100}, ALLOW},
      {"Confidence Value", DOUBLE, {100}, ALLOW},
      {" ", PREMIA_NULLTYPE, {0}, FORBID}
    },
    CALC(MC_HybridTree),
    { {"Price", DOUBLE, {100}, FORBID},
      {"Inf Price", DOUBLE, {100}, FORBID},
      {"Sup Price", DOUBLE, {100}, FORBID} ,
      {" ", PREMIA_NULLTYPE, {0}, FORBID}
    },
    CHK_OPT(MC_HybridTree),
    CHK_ok,
    MET(Init)
};

```