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```
#include <stdlib.h>
#include <stdio.h>

#include "pnl/pnl_matrix.h"
#include "pnl/pnl_random.h"
#include "pnl/pnl_basis.h"
#include "local_vol_callable.h"

#define eps 0.0000001

typedef struct
{
    double Pbarre;
    double Nbarre;
    double Cbarre;
    double Sbarre;
    double eta;
    double sigma;
    double r;
    double q;
    double gamma0;
    double alpha;
    double R;
    double cbarre;
    double l;//nb de jours (cumulés) où il faut être resté au
    //dessus de Sbarre durant les d dernières dates
    //de monitoring
    double d;//nb de dates de monitoring avant t (toujours
    //>=1 et <=N_trading+1)
} param;

#if defined(PremiaCurrentVersion) && PremiaCurrentVersion < (2011+2) //The "#els

#else

//definition du drift local
static double b(double t, double x, double spot, param *P)
{
    return P->r - P->q + P->gamma0 * pow(spot / x, P->alpha);
```

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}

//definition de la vol locale
static double vol(double t, double x, param *P)
{
    return P->sigma;
}

static double c(double x, double spot, param *P)
{
    return P->cbarre + P->gamma0 * pow(spot / x, P->alpha) * MAX((1.0 - P->eta) *

//definition de la barriere basse
static double low(double x, param *P)
{
    return MAX(x, P->Pbarre);
}

//definition de la barriere haute
static double up(double x, param *P)
{
    return MAX(x, P->Cbarre);
}

//définition du payoff
static double g(double x, param *P)
{
    return MAX(x, P->Nbarre);
}

//definition de mu=r+gamma(S) (elle marche)
static double mu(double spot, double x, param *P)
{
    return P->r + P->gamma0 * pow(spot / x, P->alpha);
}

//simulation par schéma d'euler de la matrice des
//trajectoires. On obtient une matrice de taille (N+1)*M
//(la fonction marche)
```

```

static void simul_asset(PnlMat *asset, int M, int N, double spot, double T, para
{
    double h = T / N;
    int i, j;
    PnlMat *G;
    double Si_1;
    G = pnl_mat_create(0, 0);
    pnl_mat_resize(asset, N + 1, M);
    pnl_mat_rand_normal(G, N, M, type_generator);
    for (j = 0; j < M; j++)
    {
        pnl_mat_set(asset, 0, j, spot);
    }
    for (i = 1; i < N + 1; i++)
    {
        for (j = 0; j < M; j++)
        {
            Si_1 = pnl_mat_get(asset, i - 1, j);
            pnl_mat_set(asset, i, j, Si_1 * (1 + b((i - 1)*h, Si_1, spot, P)*h + v
        }
    }
    pnl_mat_free(&G);
}

```

```

//stocke dans res 1 ou 0, 1 si le sous-jacent est au dessus
//de Sbarre, 0 sinon
static void calcul_H(PnlMatInt *res, PnlMat *asset, int M, int N, int N_trading,
{
    int i, j;
    int coef = N / N_trading;
    pnl_mat_int_resize(res, N_trading + 1, M);
    for (j = 0; j < M; j++)
    {
        for (i = 0; i < N_trading + 1; i++)
        {
            if (pnl_mat_get(asset, coef * i, j) >= P->Sbarre) pnl_mat_int_set(res,
            else pnl_mat_int_set(res, i, j, 0);
        }
    }
}

```

```
}

```

```
//stocke dans res le nom de dates (en cumulé) passées au
//dessus de Sbarre depuis d dates
static void calcul_mod_H(PnlMatInt *res, PnlMatInt *H, int M, int N, int N_trading)
{
    int i, j;
    pnl_mat_int_resize(res, N_trading + 1, M);
    pnl_mat_int_cumsum(H, 'r');
    for (j = 0; j < M; j++)
    {
        for (i = 0; i < P->d; i++) pnl_mat_int_set(res, i, j, pnl_mat_int_get(H, i, j));
        for (i = P->d; i < N_trading + 1; i++) pnl_mat_int_set(res, i, j, pnl_mat_int_get(H, i, j));
    }
}

```

```
//definition du premier instant où H dépasse l
static void theta(PnlVectInt *res, PnlMatInt *mod_H, int M, int N, int N_trading)
{
    int j, i;
    int coef = N / N_trading;
    pnl_vect_int_resize(res, M);
    for (j = 0; j < M; j++)
    {
        i = 0;
        while ((pnl_mat_int_get(mod_H, i, j) < P->l - eps) && (i < N_trading)) i++;
        pnl_vect_int_set(res, j, coef * i);
    }
}

```

```
//definition de beta (voir page 10) matrice de taille
//(N+1)*M (elle marche)
static void beta(PnlMat *res, double spot, PnlMat *asset, double T, int N, param)
{
    int i, j;
    double h = T / N;
    int M = asset->n;
    pnl_mat_resize(res, N + 1, M);
    for (j = 0; j < M; j++) pnl_mat_set(res, 0, j, 0);
    for (i = 1; i < N + 1; i++)

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    {
        for (j = 0; j < M; j++)
        {
            pnl_mat_set(res, i, j, mu(spot, pnl_mat_get(asset, i - 1, j), P));
        }
    }
    pnl_mat_cumsum(res, 'r');
    pnl_mat_mult_double(res, -h);
    pnl_mat_map_inplace(res, exp);
}

//création de la matrice v qui représente le prix. Elle est
//de taille (N+1)*M
static void prix_no_call(PnlMat *res, int M, int N, PnlMat *asset, double spot,
{
    int i, j;
    double Sij, mu_ij, v0;
    PnlVect *Si, *V_iplus1, *alpha, *c_iplus1; //(ligne i de la matrice)
    PnlMat MSi;
    double h = T / N;
    pnl_mat_resize(res, N + 1, M);
    Si = pnl_vect_new();
    alpha = pnl_vect_new();
    c_iplus1 = pnl_vect_create(M);
    V_iplus1 = pnl_vect_new();
    for (j = 0; j < M; j++) pnl_mat_set(res, N, j, g(pnl_mat_get(asset, N, j), P));
    for (i = N - 1; i >= 1; i--)
    {
        for (j = 0; j < M; j++) pnl_vect_set(c_iplus1, j, c(pnl_mat_get(asset, i + 1, j), P));
        pnl_mat_get_row(Si, asset, i);
        pnl_vect_mult_double(Si, 1.0 / spot);
        pnl_mat_get_row(V_iplus1, res, i + 1);
        pnl_vect_plus_vect(V_iplus1, c_iplus1);
        MSi = pnl_mat_wrap_vect(Si);
        pnl_basis_fit_ls(basis, alpha, &MSi, V_iplus1);
        for (j = 0; j < M; j++)
        {
            Sij = pnl_mat_get(asset, i, j) / spot;

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        mu_ij = mu(spot, spot * Si_j, P);
        pnl_mat_set(res, i, j, MIN(up(spot * Si_j, P), MAX(low(spot * Si_j, P),
    }
}
pnl_mat_get_row(V_iplus1, res, 1);
for (j = 0; j < M; j++) pnl_vect_set(c_iplus1, j, c(pnl_mat_get(asset, 1, j),
pnl_vect_plus_vect(V_iplus1, c_iplus1);
v0 = pnl_vect_sum(V_iplus1) / M;
v0 = MIN(up(spot, P), MAX(low(spot, P), exp(-mu(spot, spot, P) * h) * v0));
for (j = 0; j < M; j++) pnl_mat_set(res, 0, j, v0);
pnl_vect_free(&Si);
pnl_vect_free(&alpha);
pnl_vect_free(&c_iplus1);
pnl_vect_free(&V_iplus1);
}

```

```

static void prix(PnlMat *res, PnlMat *res_no_call, int M, int N, PnlMat *asset,
{
    int i, j;
    double Si_j, mu_ij, v0;
    PnlVect *Si, *V_iplus1, *alpha, *c_iplus1; //(ligne i de la matrice)
    PnlMat MSi;
    double h = T / N;
    Si = pnl_vect_new();
    c_iplus1 = pnl_vect_create(M);
    alpha = pnl_vect_new();
    V_iplus1 = pnl_vect_new();
    pnl_mat_resize(res, N + 1, M);
    prix_no_call(res_no_call, M, N, asset, spot, T, P, basis);
    for (j = 0; j < M; j++) pnl_mat_set(res, N, j, (pnl_mat_get(res_no_call, N, j)
    for (i = N - 1; i >= 1; i--)
    {
        for (j = 0; j < M; j++) pnl_vect_set(c_iplus1, j, c(pnl_mat_get(asset, i +
        pnl_mat_get_row(Si, asset, i);
        pnl_vect_mult_double(Si, 1.0 / spot);
        pnl_mat_get_row(V_iplus1, res, i + 1);
        pnl_vect_plus_vect(V_iplus1, c_iplus1);
        MSi = pnl_mat_wrap_vect(Si);
        pnl_basis_fit_ls(basis, alpha, &MSi, V_iplus1);
        for (j = 0; j < M; j++)
    }
}

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    {
        Sij = pnl_mat_get(asset, i, j) / spot;
        mu_ij = mu(spot, spot * Sij, P);
        if (i >= pnl_vect_int_get(res_theta, j))
        {
            pnl_mat_set(res, i, j, pnl_mat_get(res_no_call, i, j));
        }
        else pnl_mat_set(res, i, j, MAX(low(spot * Sij, P), exp(-mu_ij * h)*pn
    }
}
pnl_mat_get_row(V_iplus1, res, 1);
for (j = 0; j < M; j++) pnl_vect_set(c_iplus1, j, c(pnl_mat_get(asset, 1, j),
pnl_vect_plus_vect(V_iplus1, c_iplus1);
v0 = pnl_vect_sum(V_iplus1) / M;
v0 = MAX(low(spot, P), exp(-mu(spot, spot, P) * h) * v0);
for (j = 0; j < M; j++)
{
    if (pnl_vect_int_get(res_theta, j) == 0) pnl_mat_set(res, 0, j, pnl_mat_ge
    else pnl_mat_set(res, 0, j, v0);
}
pnl_vect_free(&Si);
pnl_vect_free(&c_iplus1);
pnl_vect_free(&V_iplus1);
pnl_vect_free(&alpha);
}

//creation du vecteur tau, chaque composante est le premier
//instant avant theta sur une trajectoire où le prix vaut la barrière
//basse, si on dépasse theta, tau vaut N

static void tau(PnlVectInt *res, int M, int N, PnlMat *V, PnlMat *asset, PnlVect
{
    int i, j;

    pnl_vect_int_resize(res, M);
    for (j = 0; j < M; j++)
    {
        i = 0;
        /* printf("low=%f \ n",low(pnl_mat_get(asset,i,j)));
        * printf("V=%f \ n",pnl_mat_get(V,i,j)); */
        while (((pnl_mat_get(V, i, j) > low(pnl_mat_get(asset, i, j), P) + eps) ||

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        if (i >= pnl_vect_int_get(res_theta, j)) pnl_vect_int_set(res, j, N);
        else pnl_vect_int_set(res, j, i);
    }
}

//creation du vecteur zeta, chaque composante est le premier
//instant sur une trajectoire où le prix vaut soit la barrière
//basse soit la barriere haute (inf(tau,theta))
static void zeta(PnlVectInt *res, PnlVectInt *res_tau, PnlVectInt *res_theta)
{
    int M = res_tau->size;
    int j;
    pnl_vect_int_resize(res, M);
    for (j = 0; j < M; j++)
        pnl_vect_int_set(res, j, MIN(pnl_vect_int_get(res_tau, j), pnl_vect_int_get(

}

static void prix_en_0_ls(double *res_prix, PnlMat *asset, int M, int N, int N_tr
{
    PnlMat *V, *res_beta, *res_no_call;
    PnlMatInt *H, *mod_H;
    PnlVectInt *res_zeta, *res_tau, *res_theta;
    PnlVect *tmp_prix;
    int j, i, zeta_j, tau_j, theta_j;
    double sprix, s;
    double h = T / N;
    //initialisation
    V = pnl_mat_new();
    res_no_call = pnl_mat_new();
    res_beta = pnl_mat_new();
    res_zeta = pnl_vect_int_new();
    res_theta = pnl_vect_int_new();
    res_tau = pnl_vect_int_new();
    tmp_prix = pnl_vect_create(M);
    H = pnl_mat_int_new();
    mod_H = pnl_mat_int_new();

    //calcul du vecteur H
    calcul_H(H, asset, M, N, N_trading, spot, P);
    calcul_mod_H(mod_H, H, M, N, N_trading, P);

```



```

//calcul du vecteur theta
theta(res_theta, mod_H, M, N, N_trading, P);

//calcul du prix_no_call protection
prix_no_call(res_no_call, M, N, asset, spot, T, P, basis);

//calcul du prix standard protection
prix(V, res_no_call, M, N, asset, res_theta, spot, T, P, basis);
//calcul de tau, zeta et beta
tau(res_tau, M, N, V, asset, res_theta, P);
zeta(res_zeta, res_tau, res_theta);
beta(res_beta, spot, asset, T, N, P);
//calcul de la somme Monte Carlo
for (j = 0; j < M; j++)
{
    s = 0;
    tau_j = pnl_vect_int_get(res_tau, j);
    theta_j = pnl_vect_int_get(res_theta, j);
    zeta_j = pnl_vect_int_get(res_zeta, j);
    if (tau_j < theta_j)
    {
        pnl_vect_set(tmp_prix, j, pnl_mat_get(res_beta, zeta_j, j)*low(pnl_mat
    }
    else
    {
        pnl_vect_set(tmp_prix, j, pnl_mat_get(res_beta, zeta_j, j)*pnl_mat_get

    for (i = 1; i <= zeta_j; i++) s = s + h * pnl_mat_get(res_beta, i, j) * c(
        pnl_vect_set(tmp_prix, j, pnl_vect_get(tmp_prix, j) + s);
    }
    sprix = pnl_vect_sum(tmp_prix);

pnl_mat_free(&V);
pnl_mat_free(&res_beta);
pnl_mat_int_free(&H);
pnl_mat_int_free(&mod_H);
pnl_vect_int_free(&res_zeta);
pnl_vect_int_free(&res_tau);
pnl_vect_int_free(&res_theta);
pnl_vect_free(&tmp_prix);

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    *res_prix = sprix / M;
}

```

```

static double prix_highly_path_dependent_protection(int M, int N, int N_trading,
{
    PnlMat *asset;
    PnlBasis *basis;
    double sol;
    basis = pnl_basis_create(bindex, m, 1);
    asset = pnl_mat_new();
    simul_asset(asset, M, N, spot, T, P, gen);
    prix_en_0_ls(&sol, asset, M, N, N_trading, spot, T, P, basis);
    pnl_basis_free(&basis);
    pnl_mat_free(&asset);
    return sol;
}

```

```

/**
 * @param prix (output) contains the price on exit
 * @param Mod (input) a pointer to the model type
 * @param Opt (input) a pointer to the option type
 * @param gen (input) the random number generator index
 * @param bindex (input) the basis index
 * @param m (input) the number of basis functions
 * @param M (input) the number of Monte Carlo samples
 * @param steps (input) the number of discretisation steps per day, It must be
 * an integer
 */
int callable_highly_path_dep_protection(double *prix, TYPEMOD *Mod, TYPEOPT *Opt
{
    param *P;
    double T = (double) Opt->Maturity.Val.V_INT / 365.;
    int N = steps * Opt->Maturity.Val.V_INT; //nb dates discrétisation
    int N_trading = Opt->Maturity.Val.V_INT;
    double spot = Mod->S0.Val.V_PDOUBLE;
    P = malloc(sizeof(param));
    P->r = log(1. + Mod->Interest.Val.V_DOUBLE / 100.);
    P->q = log(1. + Mod->Divid.Val.V_DOUBLE / 100.);
    P->cbarre = Opt->Coupon.Val.V_PDOUBLE;
    P->Pbarre = Opt->PutStrike.Val.V_PDOUBLE; //intervient dans low
    P->Nbarre = Opt->Strike.Val.V_PDOUBLE; //intervient dans le payoff g

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P->Cbarre = Opt->CallStrike.Val.V_PDOUBLE; //intervient dans up
P->sigma = Mod->Sigma.Val.V_PDOUBLE;
P->alpha = 1.2;
P->gamma0 = 0.02;
P->eta = Mod->Eta.Val.V_PDOUBLE;
P->R = Opt->Recovery.Val.V_PDOUBLE;
P->Sbarre = Opt->LowerBarrier.Val.V_PDOUBLE;
P->d = Opt->Period.Val.V_PINT;
P->l = Opt->Window.Val.V_PINT;
pnl_rand_init(gen, M, N);

*prix = prix_highly_path_dependent_protection(M, N, N_trading, spot, T, gen, b
free(P);
return OK;
}

#endif
```