FRE-6971 Final Project (Part 1 of 2), Spring 2017 (due 5/16/2017 at 12pm)

Instructions:

Your work for this final must be independent. It's understood that some discussions with classmates might occur, but I encourage you to work as independently as possible. Incomplete work is not a failure. Copying somebody else's work is.

Part 1, Definitions:

Model A (advanced):

2-factor Ho-Lee with constant drift:

$$
\begin{aligned}
r(t) &= x_1(t) + x_2(t) \\
\mathrm{dx}_1(t) &= \mu_1\,\mathrm{dt} + \sigma_1 \mathrm{dW}_1(t) \\
\mathrm{dx}_2(t) &= \mu_2\mathrm{dt} + \sigma_2 \mathrm{dW}_2(t) \\
\mathrm{dW}_1(t)\mathrm{dW}_2(t) &= \rho\mathrm{dt}
\end{aligned}
$$

Model B (medium):

1-Factor Vasicek Model:

$\mathrm{dr}(t) = \{\mu - \kappa r(t)\}\mathrm{dt} + \sigma\ \mathrm{dW(t)}$

Model C (easy):

Ho-Lee (with constant drift)

$\mathrm{dr}(t) = \mu\,\mathrm{dt} + \sigma\ \mathrm{dW(t)}$

Model DNS: Dynamic Nelson-Siegel model

Part 1, Data:

- Eurdollar futures rates (not constant-maturity) on 4/4/2017

Date	ED1	ED2	ED3	ED4	ED5	ED6	ED7	ED8	ED9	ED10
2017-04-04	1.285	1.425	1.52	1.61	1.72	1.825	1.94	2.01	2.08	2.145

Date	ED11	ED12	ED13	ED14	ED15	ED16	ED17	ED18	ED19	ED20
2017-04-04	2.225	2.27	2.325	2.37	2.43	2.465	2.505	2.55	2.6	2.635

- 'Final_CM_ED_Vol.csv' contains daily normal volatility of constant-maturity futures rates: 3m-forward, 6m forward, 9m forward, ..., 4y9m forward (in basis points).

Part 1, Steps:

Pick one of the Term Structure Models (A, B or C), and carry out the following steps:

1. Derive & implement model Eurodollar futures rate as a function of TSM parameters (analytical formula or solution to a system of ODEs). Use model A or B or C.

2. Setup a calibration of all TSM parameters to an array of Eurodollar futures rates as of 4/4/2017 (above). Utilize scipy.optimize.leastsq. Inspect Jacobian matrix and a condition number to detect collinearity. Proceed with a PCA-based rank reduction if the problem is collinear. Feel free to use Ridge regression as an alternative.

3. Repeat 2 using DNS model (fitting all parameters and treating futures rates as if they were forward rates).

4. Derive & implement the Eurodollar futures volatility in the model as a function of TSM parameters (analytical formula or solution to a system of ODEs). Use model A or B or C.

5. Fit TSM parameters to volatility data. Utilize scipy.optimize.leastsq. Inspect Jacobian matrix and a condition number to detect collinearity. Proceed with a PCA-based rank reduction if the problem is collinear. Feel free to use Ridge regression as an alternative.

6. Joint fit to Eurodollar rates & volatilities. Compute sensitivites of Eurodollars and Eurodollar volatilities to TSM parameters and setup a joint fit (Hint: fit some parameters to Eurodollars, some parameters to Eurodollar volatilities, and iterate until the 2-stage fit process is converged)

7. Analyze all results

Part1, Additional Instructions:

i. More complex model can lead to a higher grade on a final. However, it's better to use an easy or medium model (B or C) and carry out all or most of the estimation steps, than to use model A, and get stuck on the derivation step.

ii. Consider the need for parameter transformations to insure that fitted values are reasonable. You might want to use a cholesky form of the covariance matrix, if you are using Model A. If you are stuck and need to simplify, use Model A with zero correlation.

iii. If you understand what needs to be done, but you are struggling with code - for a partial credit it's ok to describe your algorithm as a pseudo-code.