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Statement of integrity: By typing the names of all group members in the text boxes below, you confirm that the assignment submitted is original work produced by the group (excluding any non-contributing members identified with an "X" above).	
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Use the box below to explain any attempts to reach out to a non-contributing member. Type (N/A) if all members contributed.   **Note:** You may be required to provide proof of your outreach to non-contributing members upon request.
N/A

GWP1

July 21, 2023

0.1 Step 1

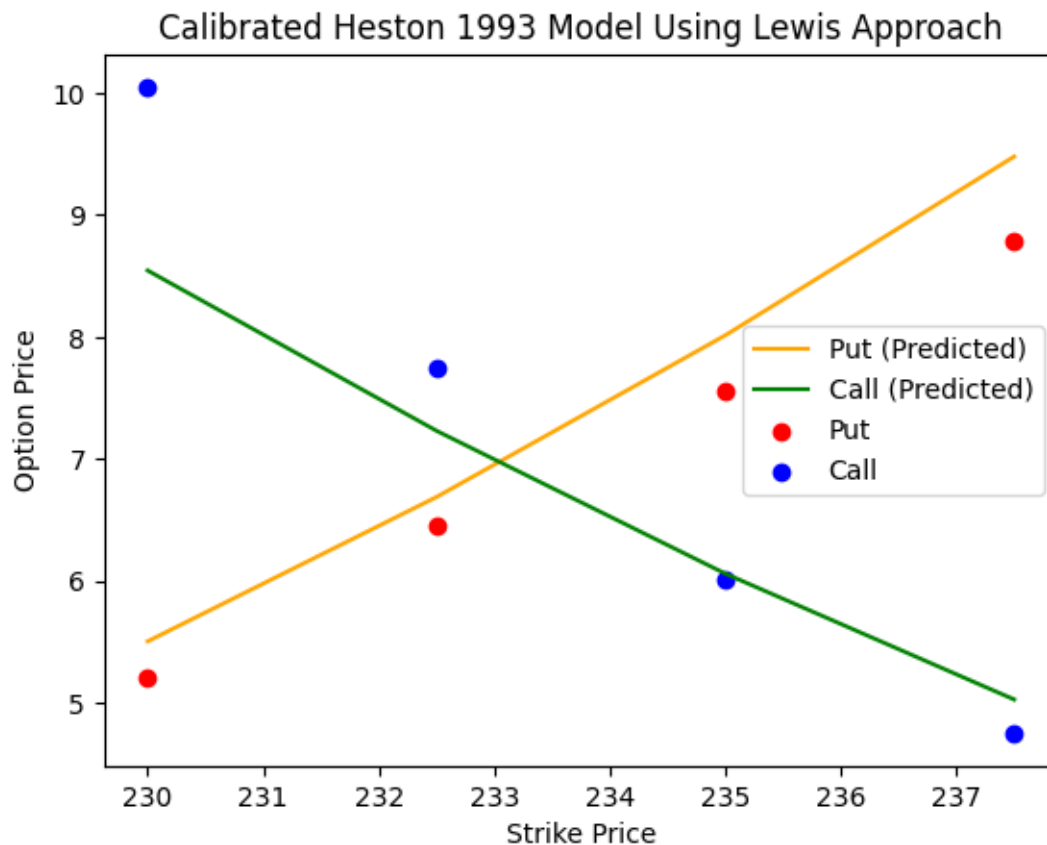### 0.1.1 The Lewis approach to calibrate the Heston (1993) model

To calibrate our Heston model, we choose only those options with 15 days to maturity and strikes that are 2% from S0 (232.9).

```
   Days to Maturity  Strike  Put   Call       T       r
1                15   230.0  5.20  10.05  0.041096  0.015
2                15   232.5  6.45   7.75  0.041096  0.015
3                15   235.0  7.56   6.01  0.041096  0.015
4                15   237.5  8.78   4.75  0.041096  0.015
```

Calibrated Heston 1993 model parameters under Lewis:
```
kappa_v:      12.1999777
theta_v:       0.0103035
sigma_v:       0.0560699
rho:    -0.0128791
v0:      0.1711087
```

Using the Heston 1993 model with calibrated parameters to price options

Calibrated Heston 1993 Model Using Lewis Approach

0.1.2 The Carr-Madan approach to calibrate the Heston (1993) model
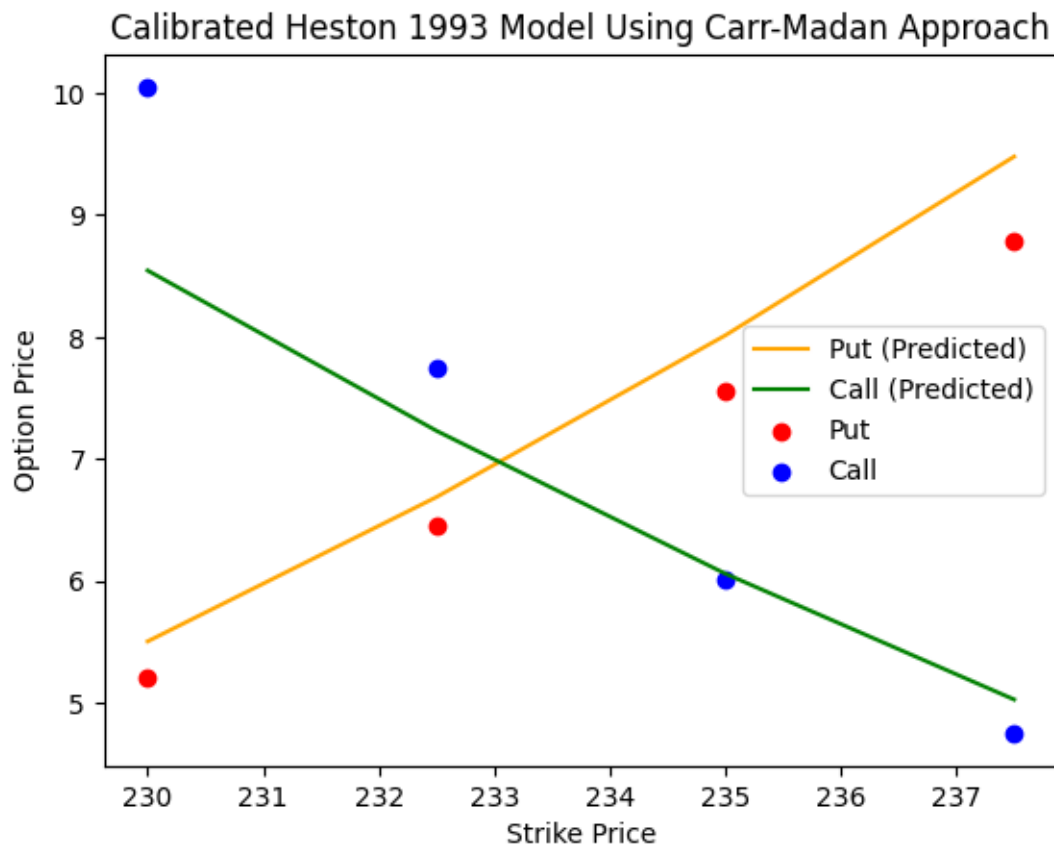
```
Calibrated Heston 1993 model parameters under Carr-Madan:
kappa_v:       7.9619829
theta_v:       0.0176
sigma_v:       0.0615781
rho:     -0.0091954
v0:      0.1573166
```
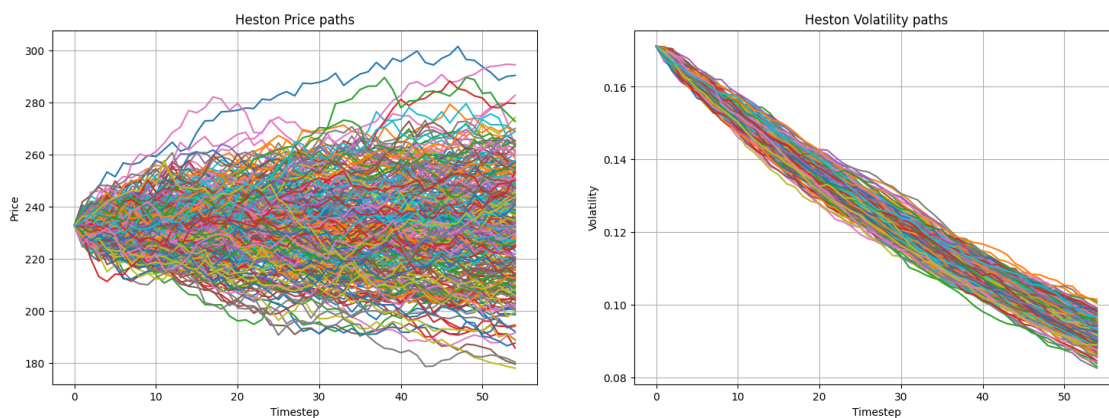
Using the Heston 1993 model with calibrated parameters to price options

Calibrated Heston 1993 Model Using Carr-Madan Approach

κ_v parameter seems off compared to calibrating under Lewis approach. However, the predictions are mostly consistent.

0.2 Pricing asian option with calibrated Heston model


```
Price of Asian option under Heston:       3.85
```

```
4% fee charged to client:               0.15
Total price to be paid by client:       4.0
```

0.3 Step 2

0.3.1 The Lewis approach to calibrate the Bates (1996) model

To calibrate our Heston model, we choose only those options with 60 days to
maturity and strikes that are 2% from S0 (232.9).

```
    Days to Maturity  Strike    Put    Call          T       r
6                 60   230.0  12.15   17.65   0.164384   0.015
7                 60   232.5  13.37   16.86   0.164384   0.015
8                 60   235.0  14.75   16.05   0.164384   0.015
9                 60   237.5  15.62   15.10   0.164384   0.015
```

1st calibration of Bates 1996 model parameters under Lewis:
lamb: 0.906066
mu: -0.0
delta: 0.4137137

c:\users\yuhua\appdata\local\programs\python\python37\lib\site-
packages\ipykernel_launcher.py:36: IntegrationWarning: The occurrence of
roundoff error is detected, which prevents
  the requested tolerance from being achieved. The error may be
  underestimated.

Fully calibrated Bates 1996 model parameters under Lewis:
kappa_v: 10.904418
theta_v: 0.0050051
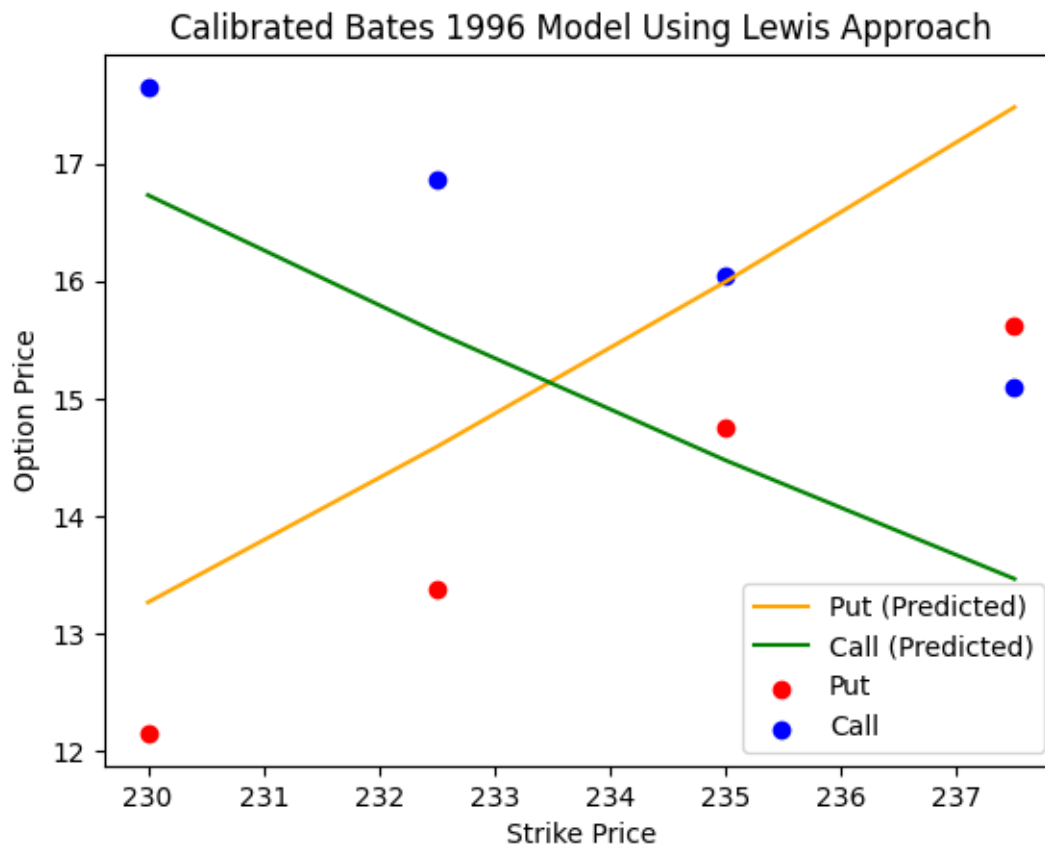sigma_v: 0.0151027
rho: 0.1439716
v0:   0.1778501
lamb: 0.7884493
mu: -0.0
delta: 0.4312459

Using the Bates 1996 model with calibrated parameters to price options

Calibrated Bates 1996 Model Using Lewis Approach

0.3.2 The Carr-Madan approach to calibrate the Bates (1996) model

```
1st calibration of Bates 1996 model parameters under Carr-Madan:
lamb: 0.9060011
mu: -0.0
delta: 0.4137353
Fully calibrated Bates 1996 model parameters under Carr-Madan:
kappa_v:      12.3462662
theta_v:       0.0118535
sigma_v:       2.8e-06
rho:    -0.0206757
v0:      0.1743942
lambda: 0.9050686
mu:      -0.0
delta:   0.4073505
```
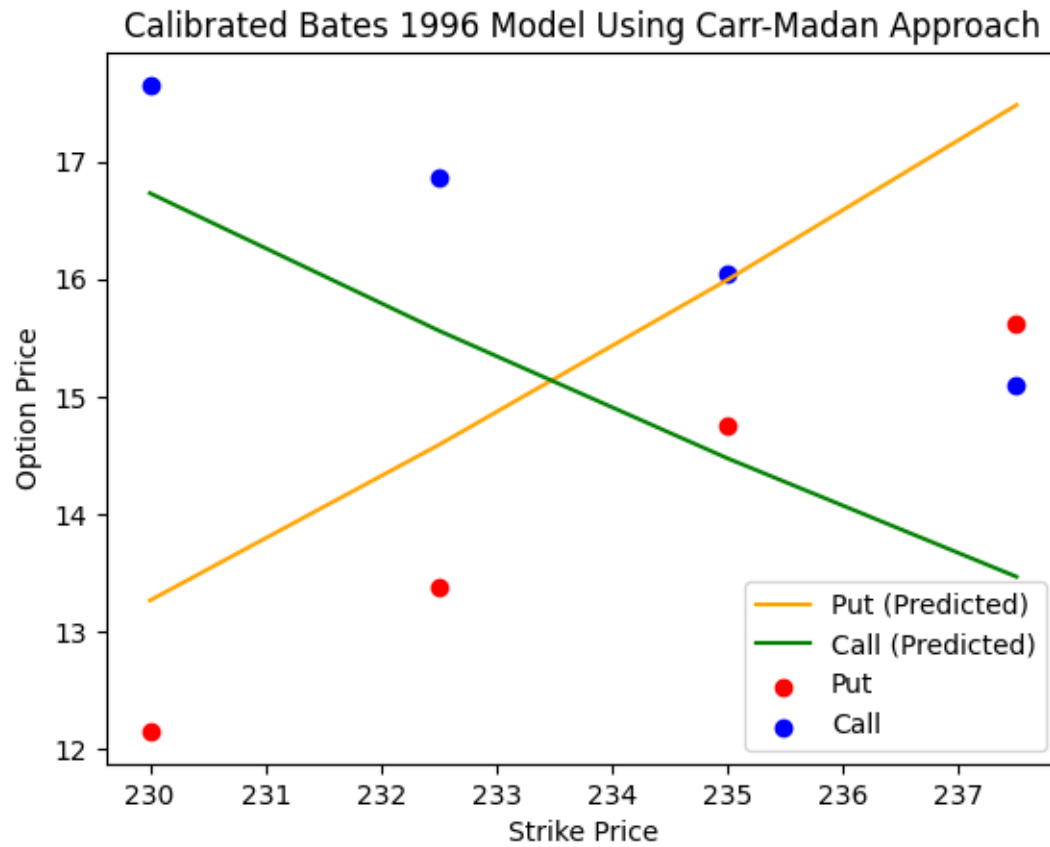
Using the Bates 1996 model with calibrated parameters to price options

Calibrated Bates 1996 Model Using Carr-Madan Approach

Calibrating under the Carr-Madan approach gives vastly different parameters than the Lewis approach. However, the predictions are mostly consistent.

## 0.4 Pricing European put option with calibrated Bates model

Bates Price paths
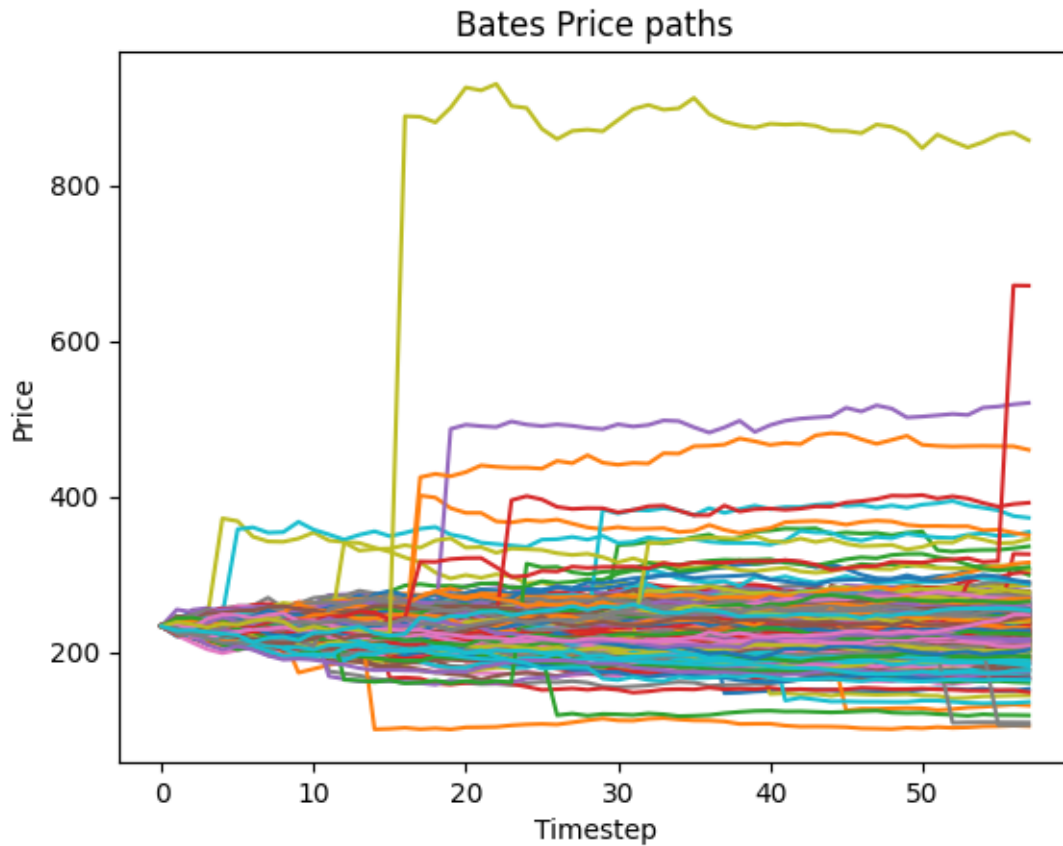
```
Price of European option under Bates:     9.96
4% fee charged to client:                 0.4
Total price to be paid by client:         10.36
```

0.5 Step 3

0.6 Calibrating CIR model

```
Note: Euribor uses the 30/360 convention for month/year.
We use the cubic spline method to interpolate 24 evenly spaced maturities in 1
year.
```
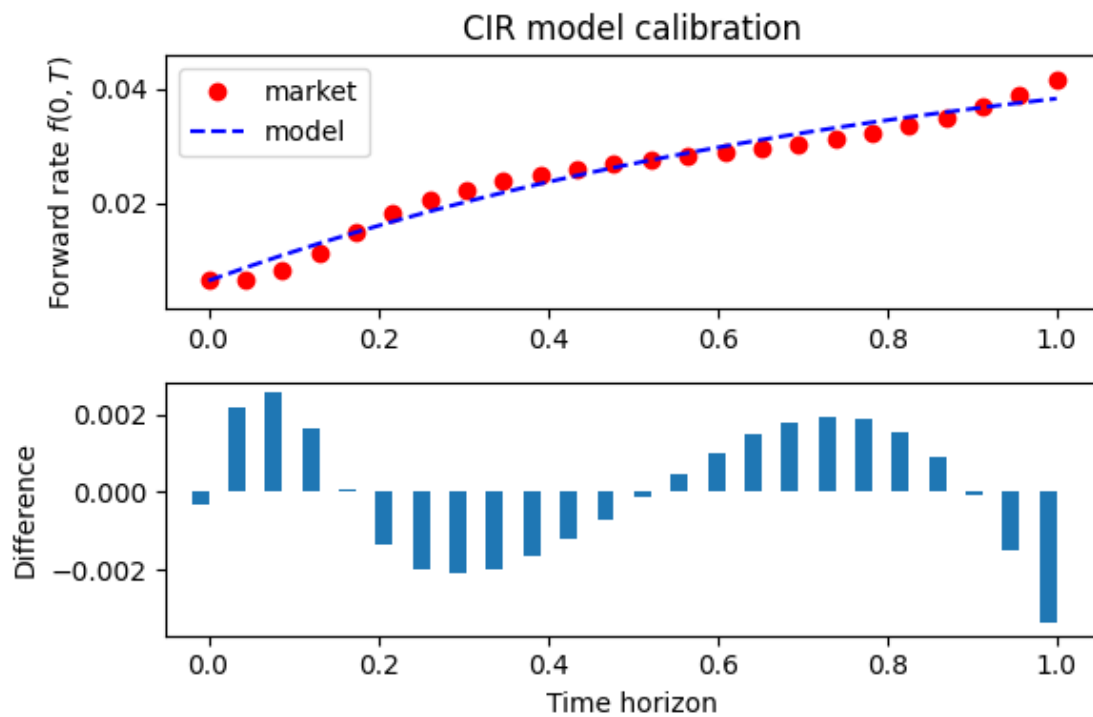
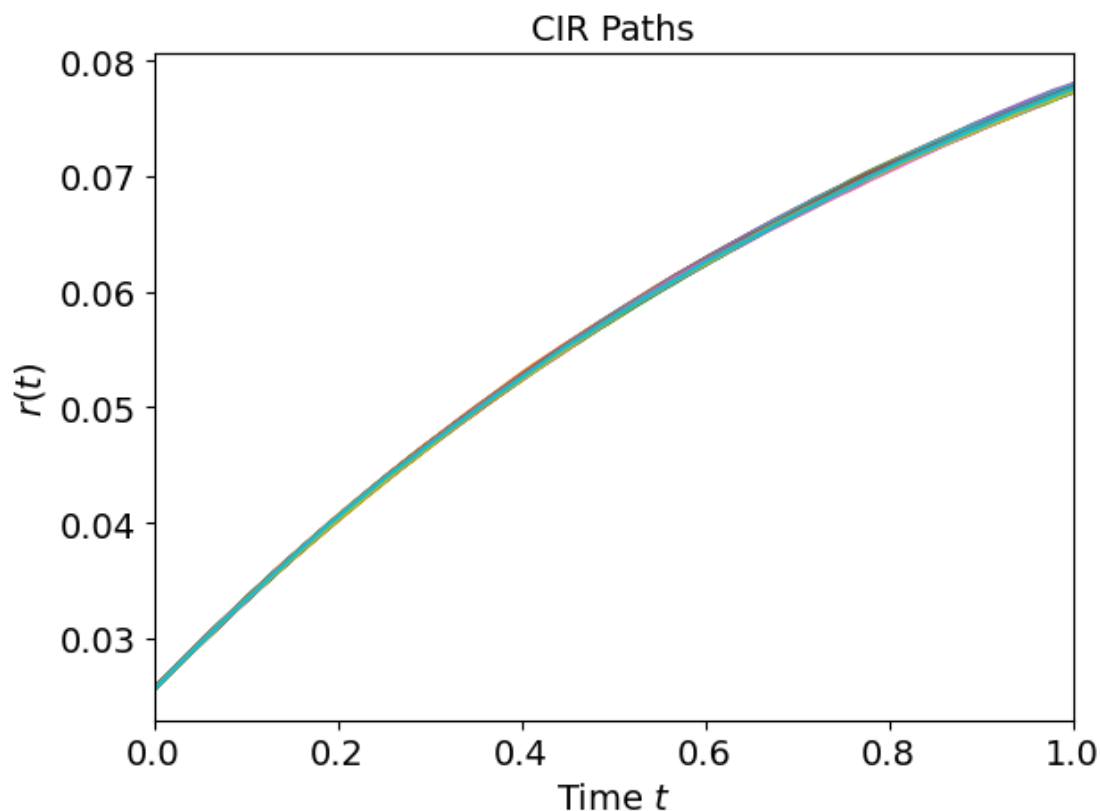Term Structure Euribor
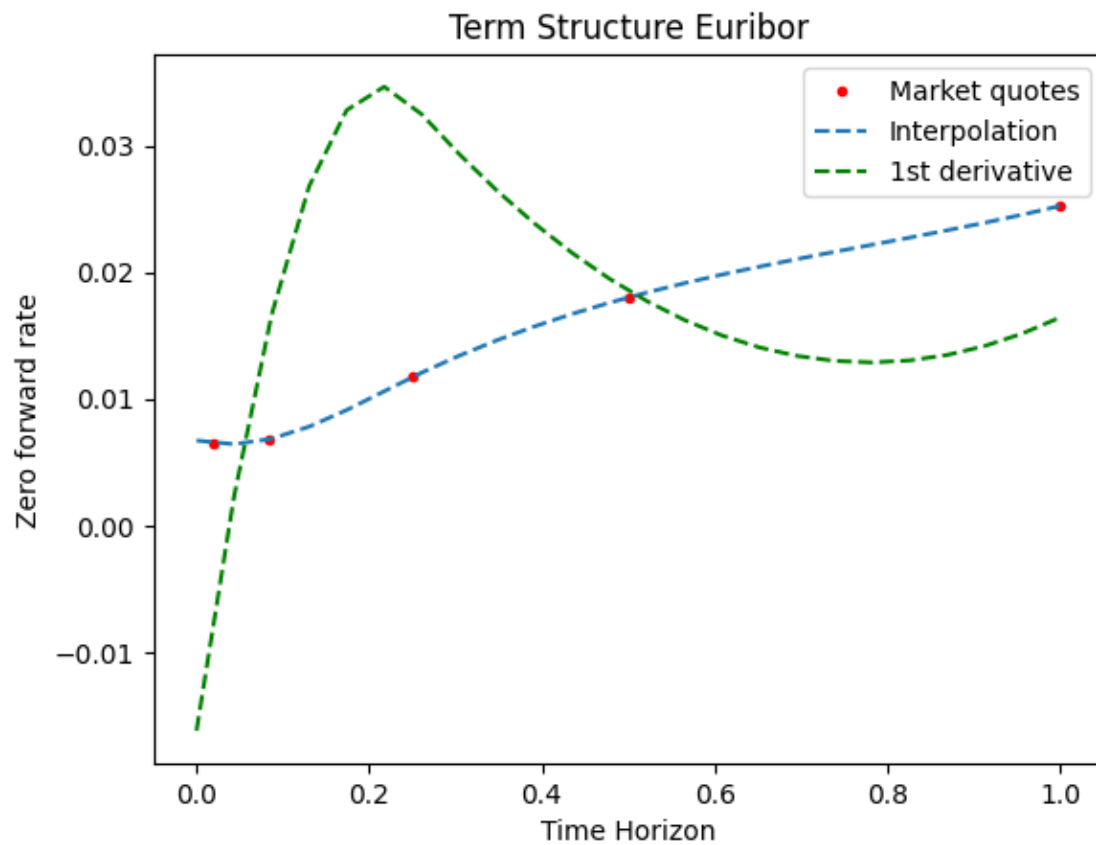
Calibrated CIR model parameters:
kappa_r: 0.989083
theta_r: 0.1086319
sigma_r: 0.0010007

Using the calibrated CIR model to predict Euribor interest rates

CIR model calibration

0.7 Simulating 12-months rate with calibrated CIR model

Using the CIR parameters obtained from calibration previously.

CIR Paths

Let us consider the most extreme 10% to be outlier. To see where the 12-month Euribor rate could be, we can look at the value of the 10th and 90th percentile values.

```
10th percentile:        0.07737
90th percentile:        0.07779
Expected value:         0.07758
```

Graphically, the CIR model say that the 12-month Euribor rate is projected to rise. With the Euro being a major global currency, the Euribor rate can be taken as the risk-free rate (r). Therefore, it affects the pricing in the various models such as Heston 1993 and Bates 1996 used in the previous sections.