Implied Volatility using Python’s Pandas Library

Brian Spector

Thalesians Meetup London
15th January 2014
Overview

• Motivation
• Python
• Pandas
• Implied Volatility
  – Timings in python
  – Different Volatility Curves
  – Fitting data points
Python

• Dynamically typed language
• Uses white spaces (as oppose to brackets) for control statements.
• Has grown in popularity:

<table>
<thead>
<tr>
<th>Programming Language</th>
<th>2014</th>
<th>2009</th>
<th>2004</th>
<th>1999</th>
</tr>
</thead>
<tbody>
<tr>
<td>Python Ranking</td>
<td>8</td>
<td>6</td>
<td>11</td>
<td>22</td>
</tr>
</tbody>
</table>

Python

• Why use python?
  – Cheap
  – Easy to learn
  – Powerful
Python

• Why use python?
  – Cheap
  – Easy to learn
  – Powerful

• Why use python over R?
  – “I would rather do math in a programming language than programming in a math language.”
Python

• What python has:
  – Many built-in powerful packages
  – OO programming
    • Classes
    • Base + Derived Classes
  – Plotting

• What python does not have:
  – Operator Overloading
  – Multiple constructors
  – Speed
  – Pointers
  – ???
Numpy

• Has made numerical computing much easier in recent years.
• Numpy matrices / arrays
• Numpy.linalg
• Behind many of these functions are LAPACK + BLAS!
Scipy

- Special functions (scipy.special)
- Integration (scipy.integrate)
- Optimization (scipy.optimize)
- Interpolation (scipy.interpolate)
- Fourier Transforms (scipy.fftpack)
- Signal Processing (scipy.signal)
- Linear Algebra (scipy.linalg)
- Sparse Eigenvalue Problems with ARPACK
- Compressed Sparse Graph Routines scipy.sparse.csgraph
- Spatial data structures and algorithms (scipy.spatial)
- Statistics (scipy.stats)
- Multidimensional image processing (scipy.ndimage)
nag4py

• Built on top of NAG C Library + Documentation
• 1600 NAG functions easily accessible from python
• 25 examples programs to help users call NAG functions

from nag4py.c05 import c05ayc
from nag4py.util import NagError,Nag_Comm
Pandas

• Data Analysis Package
• Many nice built in functions
• Common tools:
  – Series / DataFrame
  – Reading + Writing CSVs
  – Indexing, missing data, reshaping
  – Common time series functionality

(Examples)
Implied Volatility

- Black Scholes Formula for pricing a call/put option is a function of 6 variables:
  \[ C(S_0, K, T, \sigma, r, d) = S_0 N(d_1) - Ke^{-rT}N(d_2) \]

- Where
  \[ d_{1,2} = \frac{1}{\sigma \sqrt{T}} \left[ ln \left( \frac{S}{K} \right) + T \left( r \pm \frac{\sigma^2}{2} \right) \right] \]
  \[ N(x) = \text{Standard Normal CDF} \]
Implied Volatility

• We can observe the following in the market:
  • \( C(S_0, K, T, \sigma, r, d) = C \)
  • But what is \( \sigma \)?
  • \( \sigma_{imp} \rightarrow C_{BS}(S_0, K, T, \sigma_{imp}, r, d) = Market\ Price \)
Implied Volatility

• We can observe the following in the market:
  • $C(S_0, K, T, \sigma, r, d) = C$
  • But what is $\sigma$?
  • $\sigma_{imp} \rightarrow C_{BS}(S_0, K, T, \sigma_{imp}, r, d) = Market\ Price$
  • Does $\sigma_{imp}$ exist?
Implied Volatility

• We can observe the following in the market:
  • $C(S_0, K, T, \sigma, r, d) = C$
  • But what is $\sigma$?
  • $\sigma_{imp} \rightarrow C_{BS}(S_0, K, T, \sigma_{imp}, r, d) = Market\ Price$
  • Does $\sigma_{imp}$ exist?
    – Yes
      (Examples)
Implied Volatility – Different Curves?
Implied Volatility – Different Curves?

• No hyphen or letter present = Composite
  A = AMEX American Stock Exchange
  B = BOX Boston Stock Exchange - Options
  E = CBOE Chicago Board Options Exchange
  I = BATS
  J = NASDAQ OMX BX
  O = NASDAQ OMX
  P = NYSE Arca
  X = PHLX Philadelphia Stock Exchange
  Y = C2 Exchange
  4 = Miami Options Exchange
  8 = ISE International Securities Exchange
Implied Volatility

• Reasons for skews/smiles?
  – Risk Preferences
  – Fat tailed distributions
## Implied Volatility Timings

<table>
<thead>
<tr>
<th>Method</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>fsolve + python BSM</td>
<td></td>
</tr>
<tr>
<td>fsolve + NAG BSM</td>
<td></td>
</tr>
<tr>
<td>nag4py</td>
<td></td>
</tr>
<tr>
<td>NAG C</td>
<td></td>
</tr>
</tbody>
</table>
# Implied Volatility Timings

<table>
<thead>
<tr>
<th>Method</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>fsolve + python BSM</td>
<td>~180 seconds</td>
</tr>
<tr>
<td>fsolve + NAG BSM</td>
<td></td>
</tr>
<tr>
<td>nag4py</td>
<td></td>
</tr>
<tr>
<td>NAG C</td>
<td></td>
</tr>
</tbody>
</table>
# Implied Volatility Timings

<table>
<thead>
<tr>
<th>Method</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>fsolve + python BSM</td>
<td>~180 seconds</td>
</tr>
<tr>
<td>fsolve + NAG BSM</td>
<td>~15 seconds</td>
</tr>
<tr>
<td>nag4py</td>
<td></td>
</tr>
<tr>
<td>NAG C</td>
<td></td>
</tr>
<tr>
<td>Method</td>
<td>Timing</td>
</tr>
<tr>
<td>------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>fsolve + python BSM</td>
<td>~180 seconds</td>
</tr>
<tr>
<td>fsolve + NAG BSM</td>
<td>~15 seconds</td>
</tr>
<tr>
<td>nag4py</td>
<td>~10 seconds</td>
</tr>
<tr>
<td>NAG C</td>
<td></td>
</tr>
</tbody>
</table>
# Implied Volatility Timings

<table>
<thead>
<tr>
<th>Method</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>fsolve + python BSM</td>
<td>~180 seconds</td>
</tr>
<tr>
<td>fsolve + NAG BSM</td>
<td>~15 seconds</td>
</tr>
<tr>
<td>nag4py</td>
<td>~10 seconds</td>
</tr>
<tr>
<td>NAG C</td>
<td>~.29 seconds</td>
</tr>
</tbody>
</table>
Implied Volatility Timings

<table>
<thead>
<tr>
<th>Method</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>fsolve + python BSM</td>
<td>~180 seconds</td>
</tr>
<tr>
<td>fsolve + NAG BSM</td>
<td>~15 seconds</td>
</tr>
<tr>
<td>nag4py</td>
<td>~10 seconds</td>
</tr>
<tr>
<td>NAG C</td>
<td>~.29 seconds</td>
</tr>
</tbody>
</table>

- Derivatives?
- We have the derivative, vega
  - \( \frac{\partial C}{\partial \sigma} = S \times T \times N'(d_1) \)
Fitting Data Points

• In our script we had $k = l = 3$...
  – What if we try different values?
Fitting Data Points

• In our script we had $k = l = 3$...
  – What if we try different values?
  • Poor results, can we do better?
Questions?

- Further reading see:
  - http://pandas.pydata.org/
  - http://www.nag.co.uk/python.asp