INTRODUCTION TO TIME SERIES ANALYSIS IN PYTHON

Cointegration Models

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What is Cointegration?

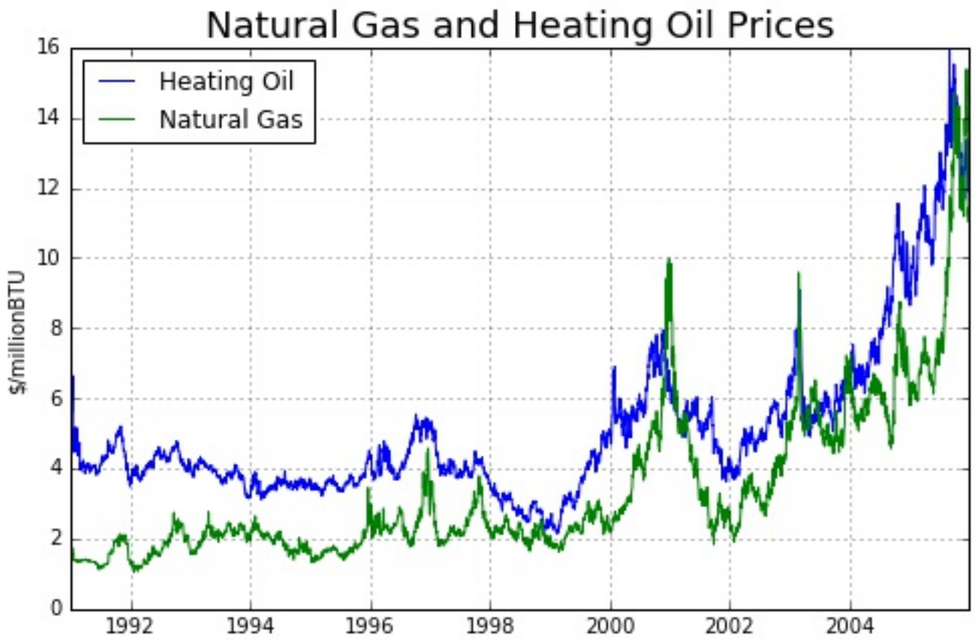
- Two series, P_t and Q_t can be random walks
- But the linear combination $P_t - c\,Q_t$ may not be a random walk!
- If that's true
  - $P_t - c\,Q_t$ is forecastable
  - P_t and Q_t are said to be cointegrated

Analogy: Dog on a Leash

- $P_t =$ Owner
- $Q_t =$ Dog
- Both series look like a random walk
- Difference, or distance betweem them, looks mean reverting
  - If dog falls too far behind, it gets pulled forward
  - If dog gets too far ahead, it gets pulled back

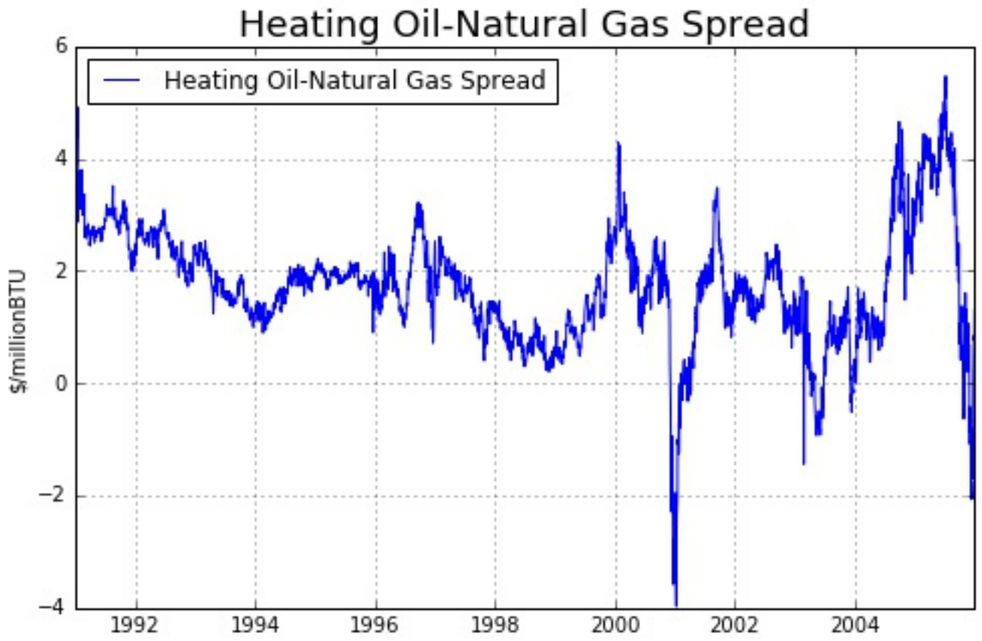
Example: Heating Oil and Natural Gas

- Heating Oil and Natural Gas both look like random walks...



Example: Heating Oil and Natural Gas

- But the spread (difference) is mean reverting



What Types of Series are Cointegrated?

- Economic substitutes
  - Heating Oil and Natural Gas
  - Platinum and Paladium
  - Corn and Wheat
  - Corn and Sugar
  - ...
  - Bitcoin and Ethereum?
- How about competitors?
  - Coke and Pepsi?
  - Apple and Blackberry? No! Leash broke and dog ran away

Two Steps to Test for Cointegration

- Regress P_t on Q_t and get slope c
- Run Augmented Dickey-Fuller test on $P_t - c\,Q_t$ to test for random walk
- Alternatively, can use coint function in statsmodels that combines both steps

```
from statsmodels.tsa.stattools import coint
coint(P,Q)
```

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Let's practice!

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Case Study: Climate Change

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Analyzing Temperature Data

- Temperature data:
  - New York City from 1870-1916
  - Downloaded from National Oceanic and Atmospheric Administration (NOAA)
- Convert index to datetime object
- Plot data

Analyzing Temperature Data

- Test for Random Walk
- Take first differences
- Compute ACF and PACF
- Fit a few AR, MA, and ARMA models
- Use Information Criterion to choose best model
- Forecast temperature over next 30 years

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Let's practice!

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Congratulations

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Advanced Topics

- GARCH Models
- Nonlinear Models
- Multivariate Time Series Models
- Regime Switching Models
- State Space Models and Kalman Filtering
- ...

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Keep practicing!