

# Time Series Analysis

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# Overview

## ❖ What is Time Series Data?

Index Prices:

- Crude Oil
- Gold
- Bitcoin

## ❖ What is Time Series Analysis?

- Uses
- Forecasting

# Time Series Data

➤ **A collection of observations of a particular variable made chronologically.**

- Numerical

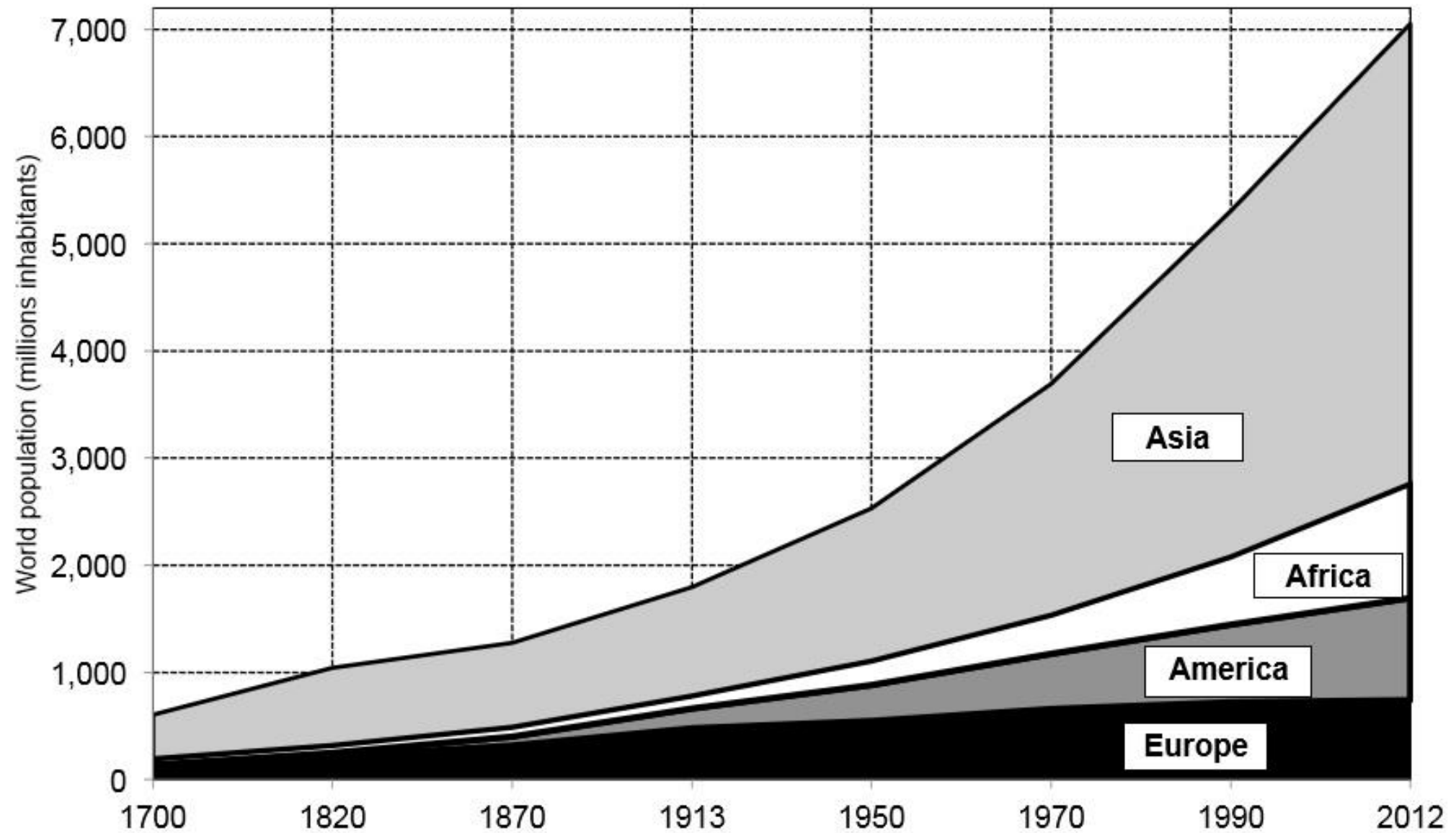
- Same time intervals

- Large in size

➤ **Examples:**

**Webster University enrollment per year, Gross Domestic Product (GDP), population census, unemployment rate, daily temperature, etc.**

**Figure 2.1. The growth of world population 1700-2012**



World population rose from 600 million inhabitants in 1700 to 7 billion in 2012.

Sources and series: see [piketty.pse.ens.fr/capital21c](http://piketty.pse.ens.fr/capital21c).

# Time Series Analysis

- **Methods for analyzing time series data in order to extract meaningful statistics and other characteristics of the data.**
  - **Interpretation**
  - **Forecasting**
  - **Hypothesis testing**
  - **Trend analysis**
  - **Control (response)**
  - **Simulations**

**Fields: economics, finance, geology, meteorology, business, biology, etc.**

# Uses of Time Series Analysis

- **Description** (monitoring data)
  - Describe patterns over time
- **Explanation**
  - Consider all possible factors in understanding the behavior of a series
- **Forecasting**
  - Prediction of future values based on the past
  - Helpful for business decisions: production, inventory, personal, etc.
- **Improving past behavior**
  - Identifying factors influencing. Example: action over increasing levels of air pollution


# Trend Analysis

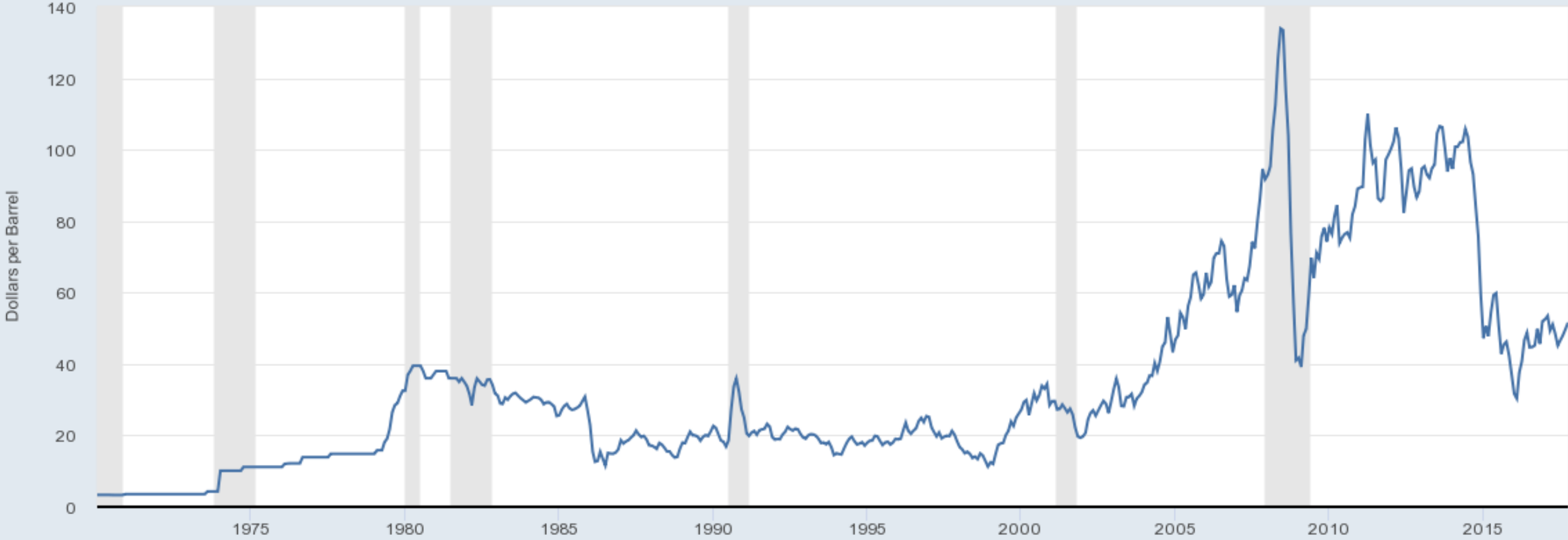
- Sustained movements in the variable of interest in a specific direction.
  - Horizontal pattern (mean)
  - Trend pattern (upwards or downwards)
  - Season pattern (depending on weather or frequency of events)
  - Cyclical pattern (Up, down, up, ...)

# Oil Prices (per barrel)

Historical max: \$145

July, 2008

**FRED**  — Spot Crude Oil Price: West Texas Intermediate (WTI)



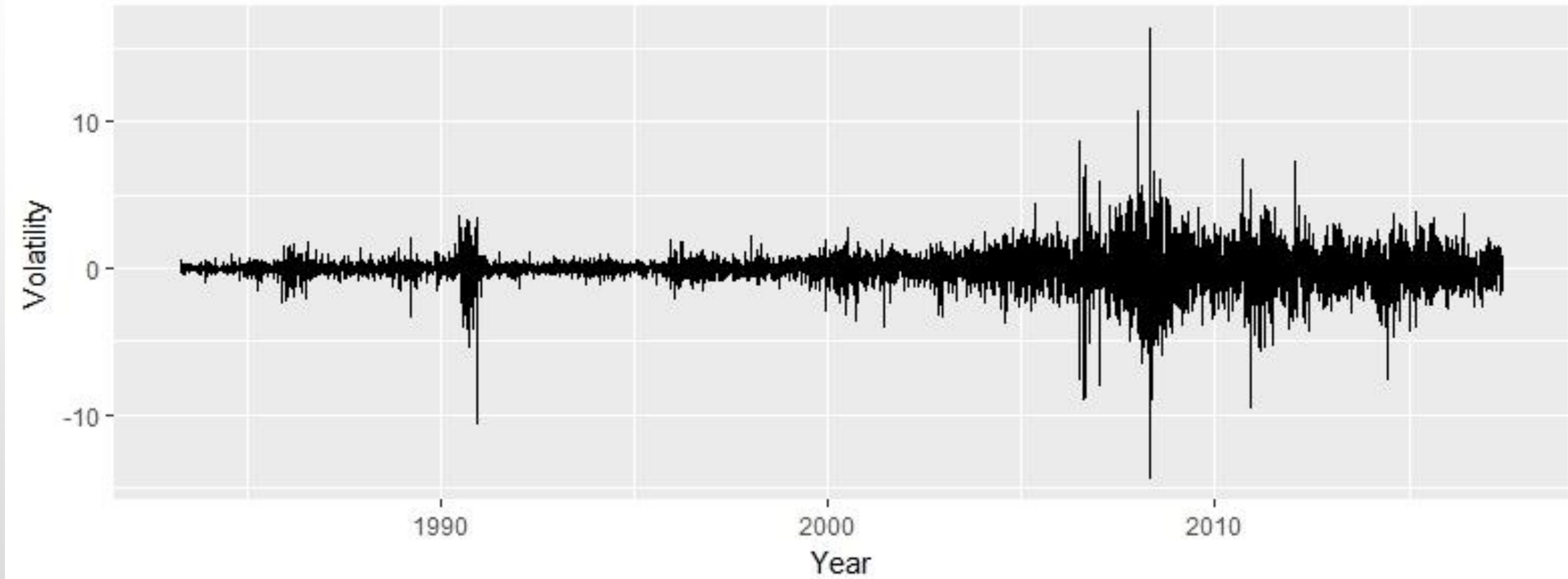
Shaded areas indicate U.S. recessions

Source: Federal Reserve Bank of St. Louis

[myf.red/g/fLai](https://myf.red/g/fLai)



# Volatility of Oil Prices



# Forecasting

- **Estimating how a series of observations will continue in the future**
  - **Considering current and past values**
- **Models assume the future will show patterns from the past**
- ✓ **Uncertainty about the future**
- ✓ **Easier to forecast in the short-term**

# ARMA & ARIMA Models

## Autoregressive (AR) models

$$y_t = c + \phi_1 y_{t-1} + \phi_2 y_{t-2} + \dots + \phi_p y_{t-p} + e_t, \quad e_t \sim \text{white noise}$$

Multiple regression with *lagged observations* as predictors

## Moving Average (MA) models

$$y_t = c + e_t + \theta_1 e_{t-1} + \theta_2 e_{t-2} + \dots + \theta_q e_{t-q}, \quad e_t \sim \text{white noise}$$

Multiple regression with *lagged errors* as predictors

## Autoregressive Moving Average (ARMA) models

$$y_t = c + \phi_1 y_{t-1} + \dots + \phi_p y_{t-p} + \theta_1 e_{t-1} + \dots + \theta_q e_{t-q} + e_t$$

Multiple regression with *lagged observations* and *lagged errors* as predictors

## ARIMA(p, d, q) models

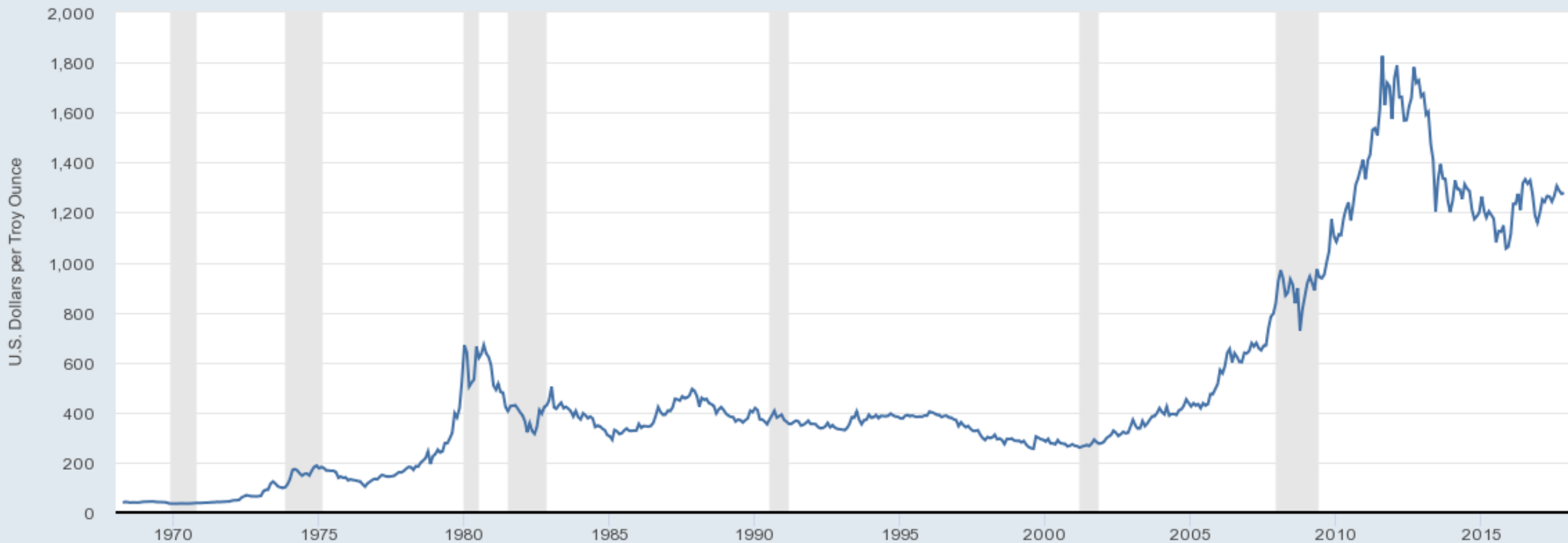
Combine ARMA model with *d* - lots of *differencing*

# Gold Prices (per ounce)

Historical Max: \$1,895

September, 2011

**FRED**  — Gold Fixing Price 10:30 A.M. (London time) in London Bullion Market, based in U.S. Dollars



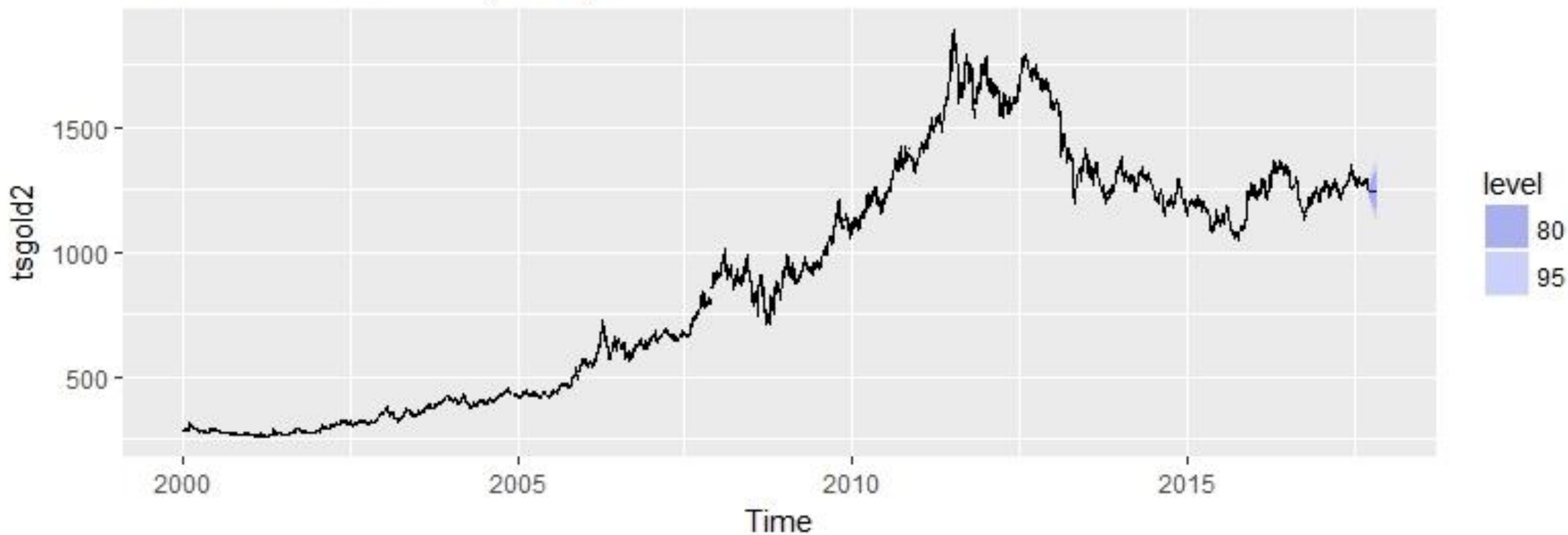
Shaded areas indicate U.S. recessions

Source: ICE Benchmark Administration Limited (IBA)

[myf.red/g/flak](https://myf.red/g/flak)

# Forecasting Gold Prices

Forecasts from ARIMA(0,1,4)



# Bitcoin Prices

Historical Max: \$19,187

December 16, 2017

Market Price (USD)

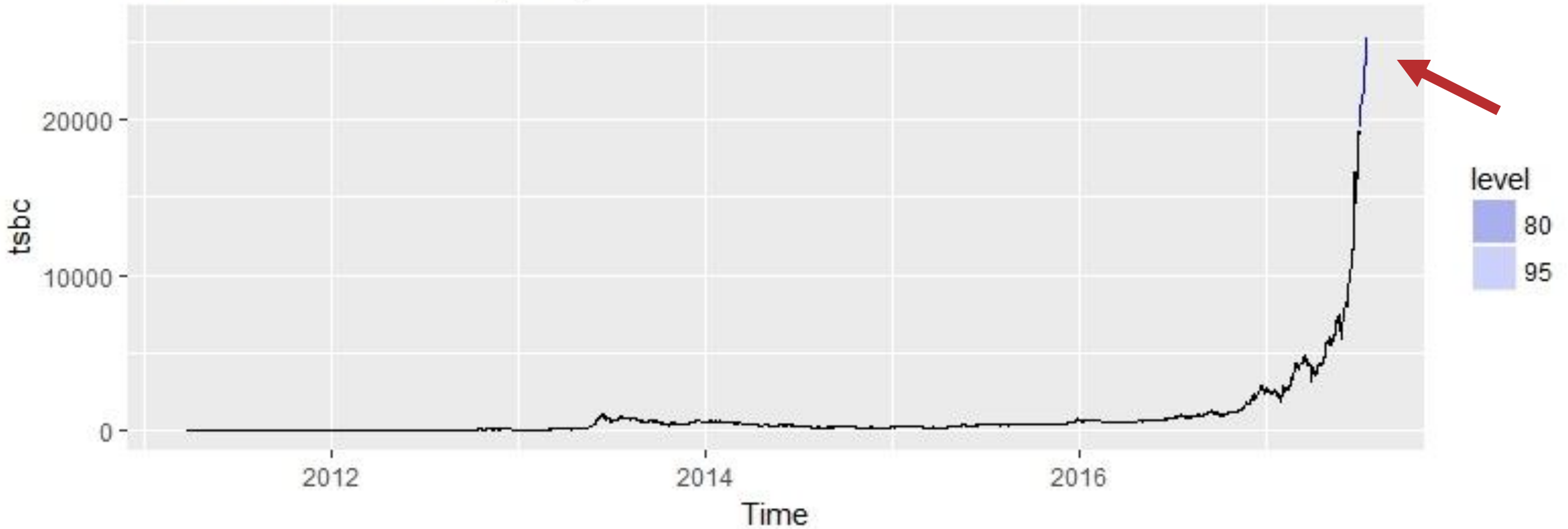
source: blockchain.info



# Forecast of Bitcoin

Expected to cross \$25,000 in 12 days

Forecasts from ARIMA(2,2,5)



# Summary

❖ **What is Time Series Data?**

❖ **What is Time Series Analysis?**

➤ **Uses**

➤ **Forecasting**



# References

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