Probabilistic methods for long-term demand forecasting for aviation production planning

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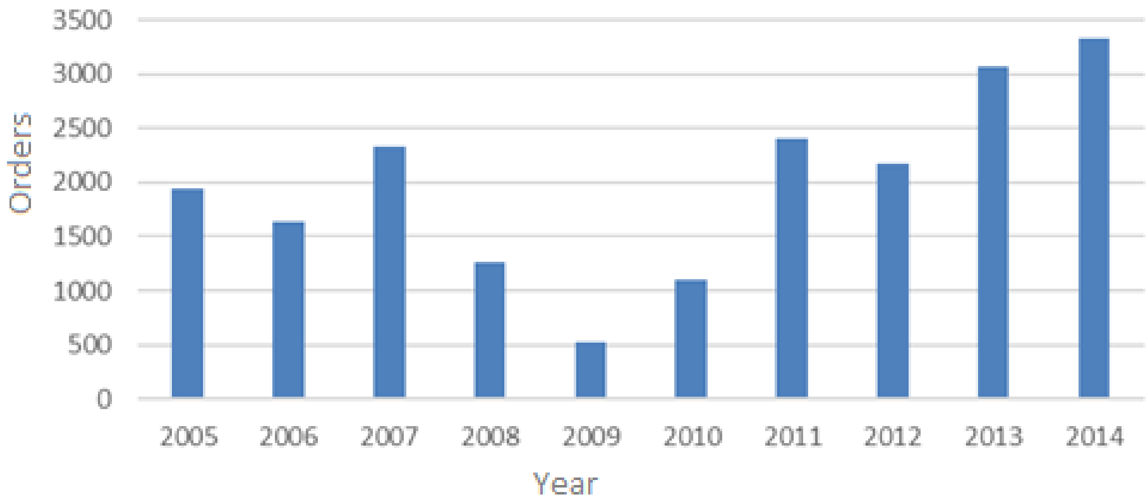
Motivation



Historical order of global commercial airplanes

- Is painting capacity expansion necessary?
- How many hangars need to be built for Boeing?
- When to build?

Research Overview

Forecasting 737 Airplane

- Brownian motion with dependency
- Autoregressive Integrated Moving Average (ARIMA)

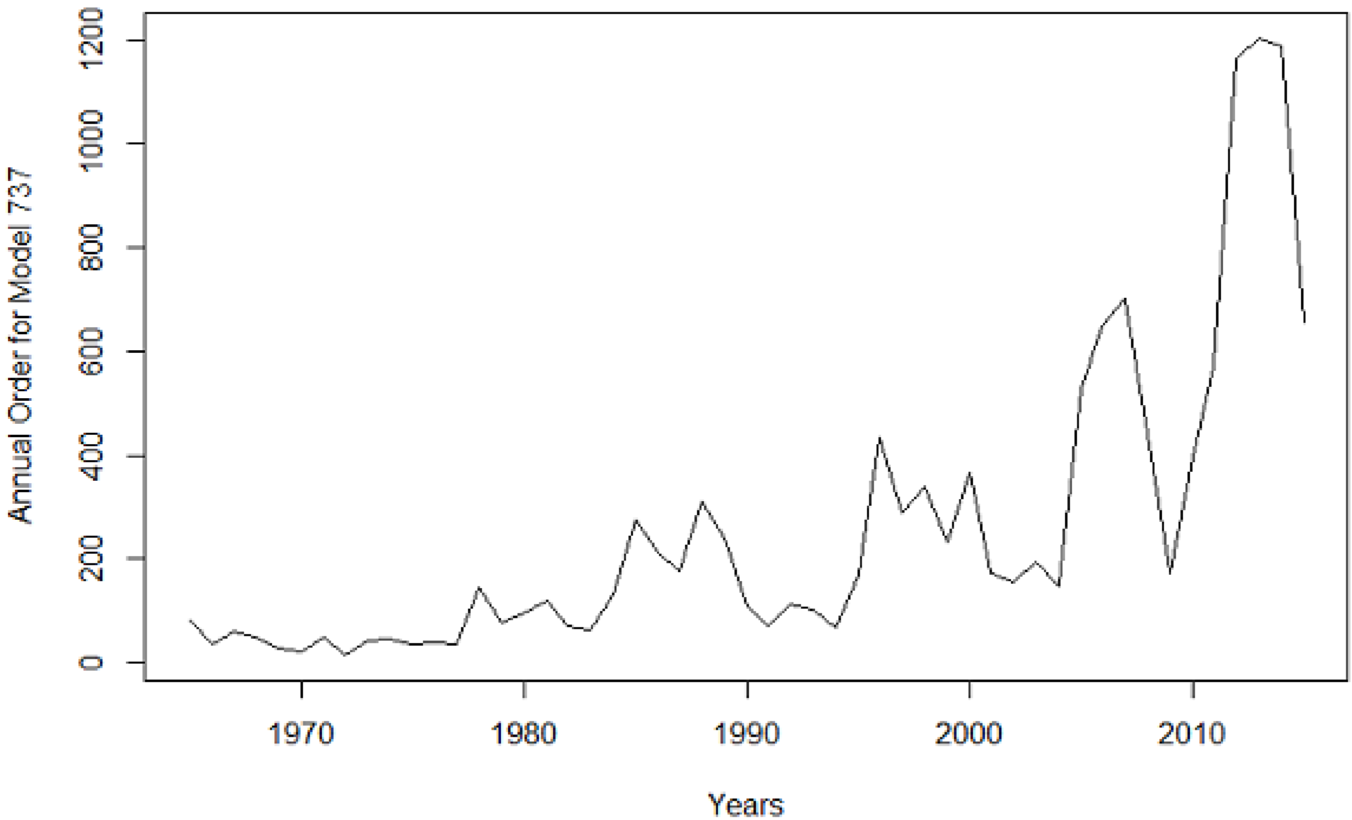
Forecasting 777 Airplane

- Geometric Brownian motion (GBM)
- Alternative GBM fitting
- Starting point adjustment

Demand Forecasting for 737 Airplane

- 737 Airplane
- ARIMA
- Brownian Motion with Dependency
- Comparison

737 Airplane - Historical Annual Order



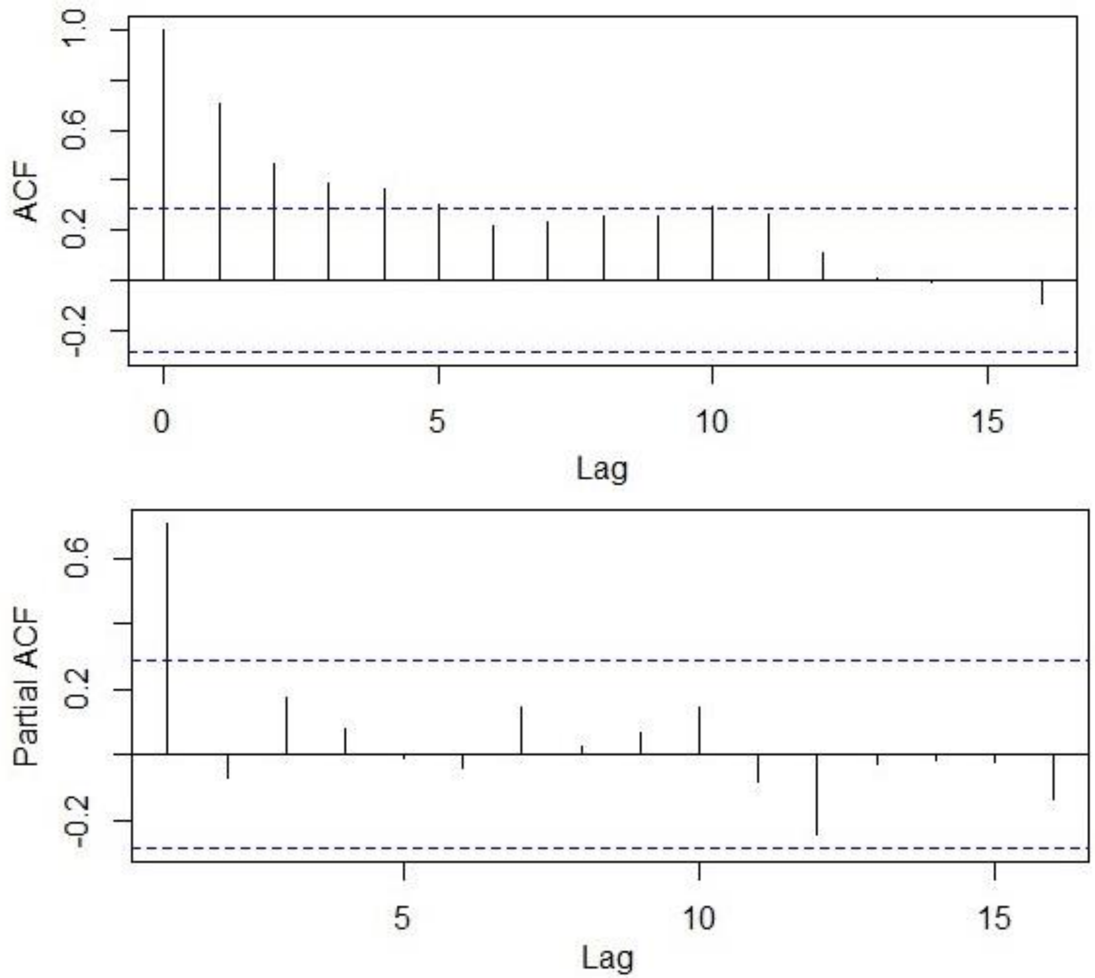
Data source: Boeing Commercial. Available: http://www.boeing.com/commercial/, 2015

737 Airplane - Autocorrelation

ACF: decay
PACF: cut off at lag 1

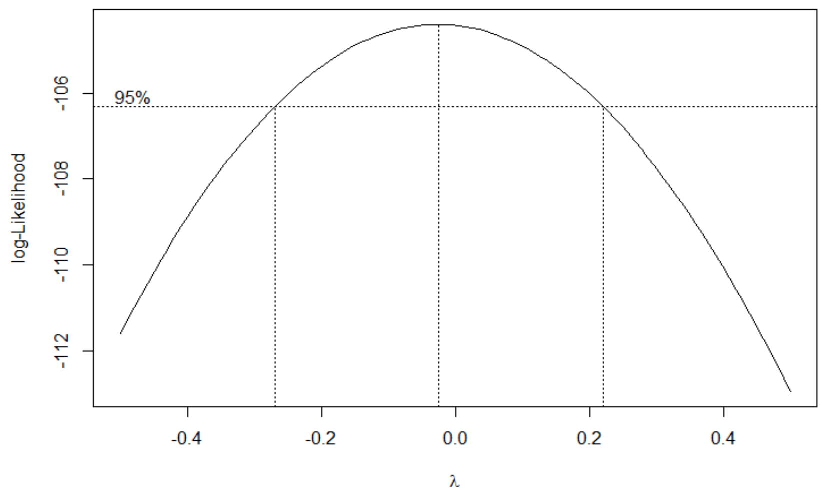
AR(1)?

Non-stationary:
Increasing variance with time

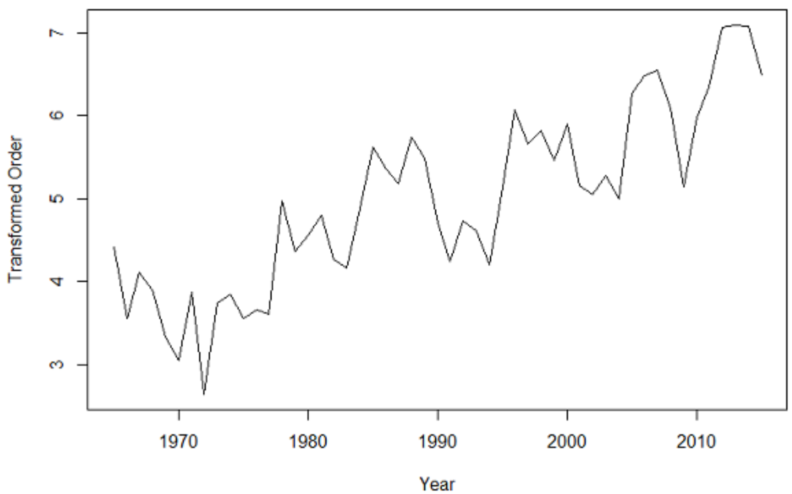


ARIMA – Transformation

$$S(\lambda) = \begin{cases} \frac{X^{\lambda}-1}{\lambda} & if \quad \lambda \neq 0 \\ \log(X) & if \quad \lambda = 0 \end{cases}$$



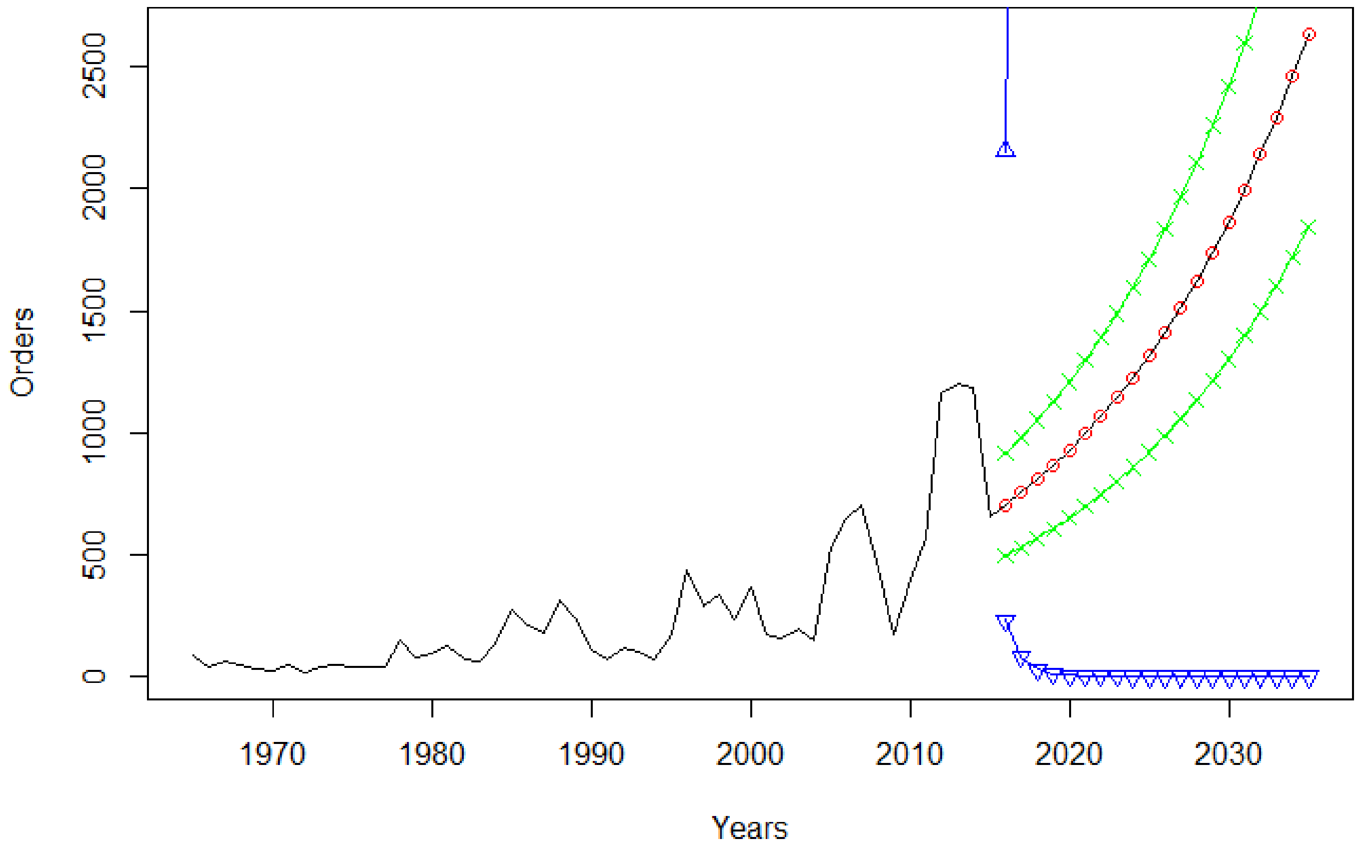
Box-Cox Transformation



After Log Transformation

ARIMA – Model & Prediction

ARIMA (0,1,1) $S_t - S_{t-1} = Z_t - 0.3344Z_{t-1} \qquad \{Z(t)\} \sim WN(0, 0.3243)$



Brownian Motion with dependency

$$X(t) = \sigma B(t) + \mu t + e$$

Where $B(t) \sim N(0, t)$ is a standard Brownian motion

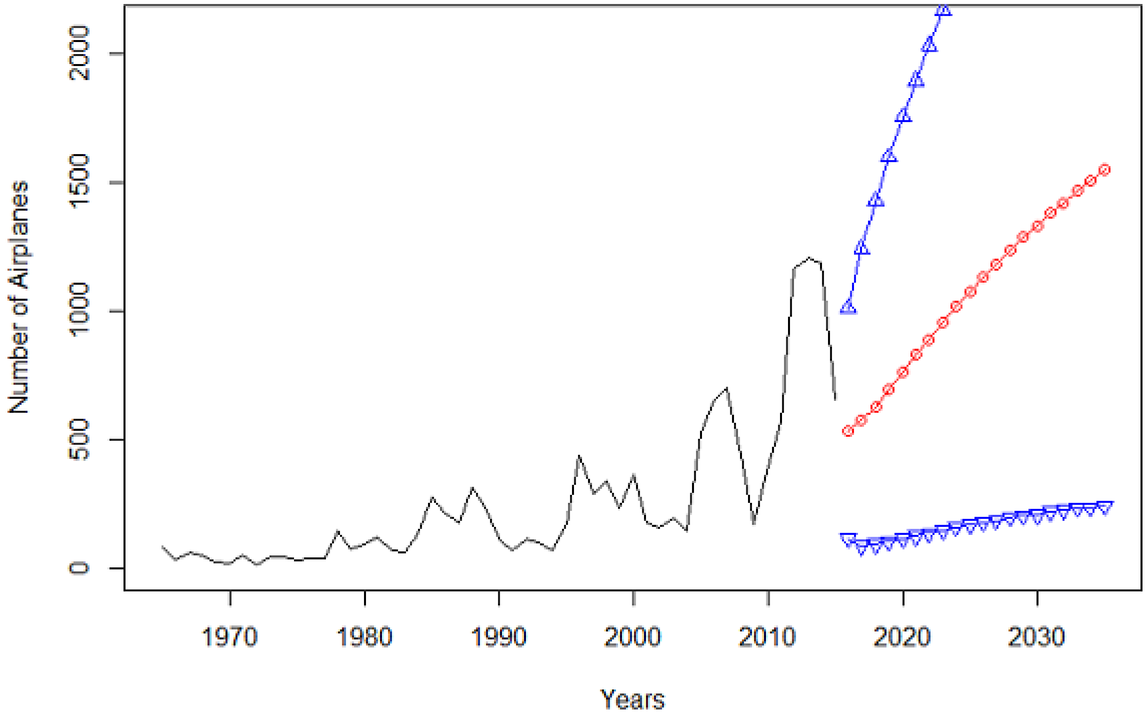
Add correlation ρ at lag 1

$$N_{cor} = \rho N_1 + \sqrt{1 - \rho^2} N_2$$

correlation between $X(t)$ and $X(t+1)$ equals ρ

Brownian Motion with dependency

Drift (μ)	Sigma (σ)	Baseline (b)	Correlation (ρ)
31.7	294.8	483	0.83



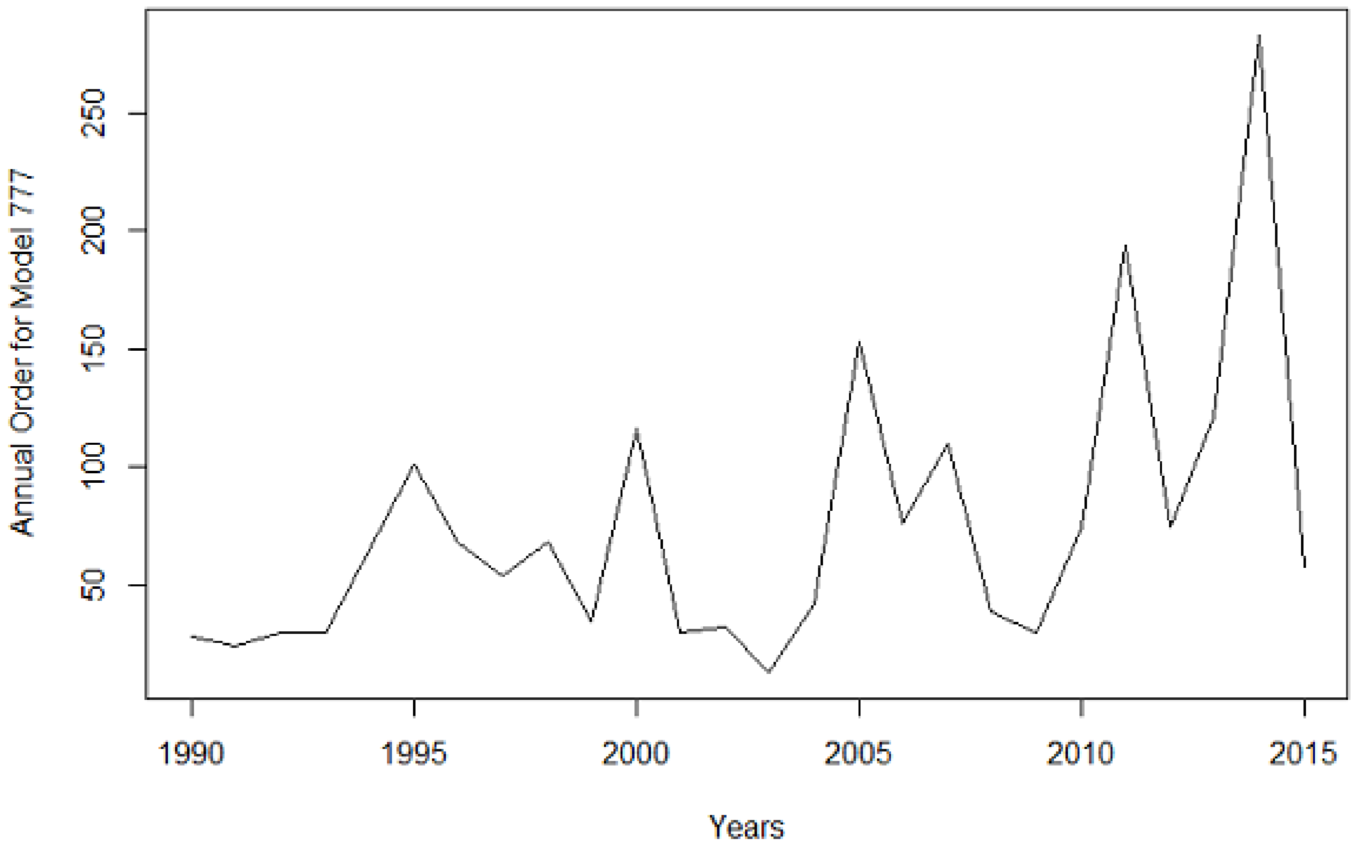
Comparison

	ARIMA	Brownian Motion with dependency
Prediction trend	Handled by differencing	Defined explicitly
Interval	Confidence interval of mean	Probability interval
Input Data - Stationary	Weak stationary	Non-stationary
Input Data - Correlation	lag ≥ 1	lag = 1
Sensitivity	Model parameters	Estimated Trend

Demand Forecasting for 777 Airplane

- 777 Airplane
- Traditional GBM Fitting
- Alternative GBM Fitting
- Start Position Adjustment

777 Airplane - Historical Annual Order

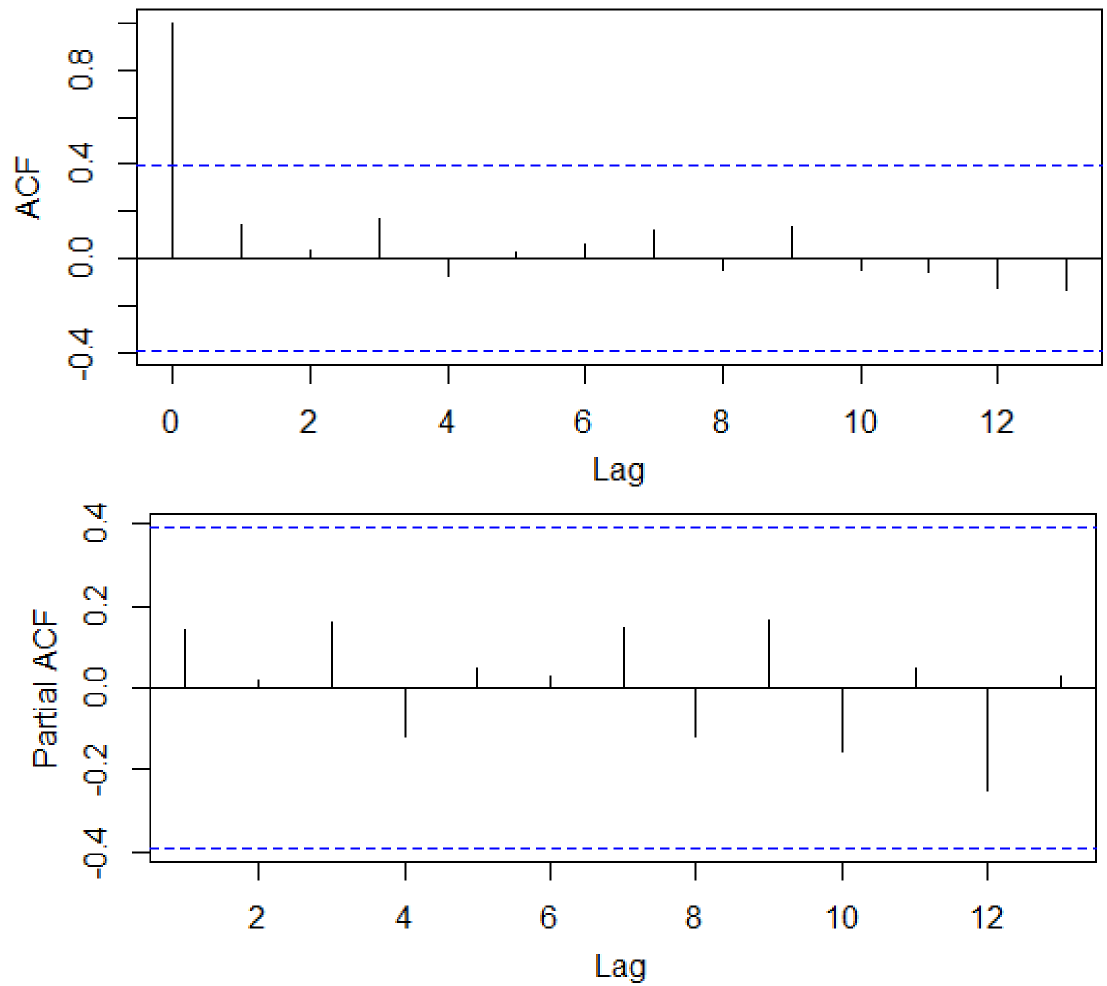


Data source: Boeing Commercial. Available: http://www.boeing.com/commercial/, 2015

777 Airplane - Autocorrelation

No significant autocorrelation

Non-stationary: Increasing variance with time



Traditional GBM Fitting

Brownian motion:

$$X(t) = \sigma B(t) + \mu t + e$$

Geometric Brownian motion:

$$Y(t) = e^{X(t)}$$

$$R(1) = \frac{Y(t+1)}{Y(t)} \sim lognormal(\mu, \sigma^2)$$

Interested in difference between two adjacent years

Alternative GBM Fitting

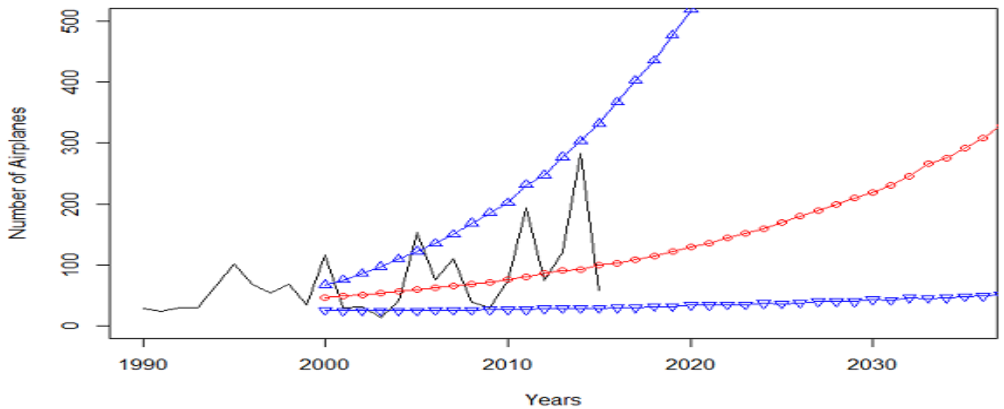
$$R(t) = \frac{Y(t)}{Y(0)} \sim lognormal(\mu t, \sigma^2 t)$$

Interested in fitting model over *t* years

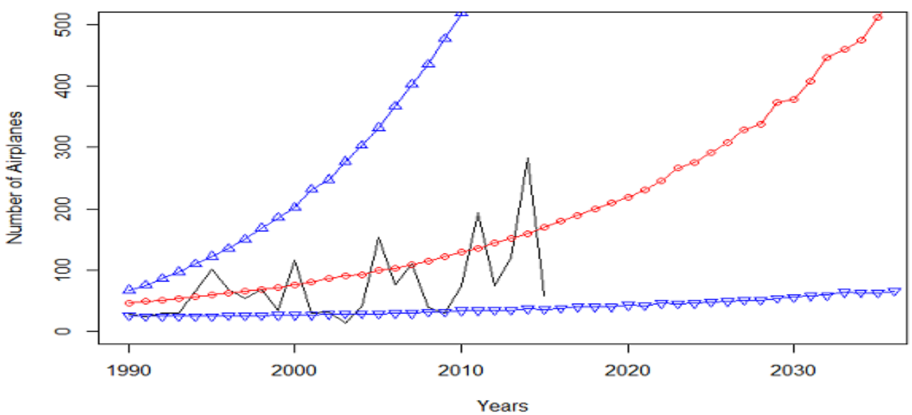
Method	Time Scale	Drift	Sigma	Baseline
Traditional	Year	0.030	0.847	3.635
Alternative	Year	0.0563	0.1913	3.635

Alternative method reduces variance of estimation significantly

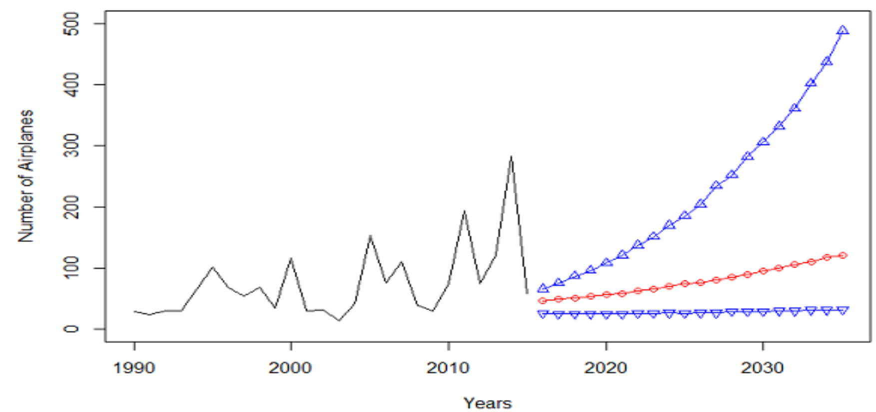
Start Position Adjustment



Fitted GBM starting at year 2000



Fitted GBM starting at year 1990



Fitted GBM starting at year 2016

Conclusion

- Incorporate correlation into Brownian motion
- Comparison of probabilistic model and time series model in forecasting
- Geometric Brownian motion at different starting points for increasing variation
- Use probabilistic model in forecasting to capture varies scenarios rather than single prediction
- Applied to other airplane models as well
- Future work: Multi-variate forecasting