Time Series Analysis and Forecasting

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John Carlo P. Daquis
Assistant Professor 4
UP Diliman School of Statistics

Learning Objectives

Learning Objectives

The time series analysis and basic forecasting training course aims to provide participants with an understanding of the principles and steps in making statistical forecasts based on time-series data.

Learning Objectives

Specifically, this course will train the participants

- to know the basic concepts and considerations in time series analysis;
- to effectively describe time series data;
- to use software for time series analysis and basic forecasting;
- to decompose a time series;
- to perform basic forecasting methods; and
- To forecast using exponential smoothing.

Chapter Outline

Chapter Outline

I. Some Preliminaries

1. Basic Concepts in Forecasting
2. The Time Series Data
3. Forecast Accuracy Measures
4. Time Series Decomposition

Basic Concepts in Forecasting

Basic Concepts in Forecasting

What is forecasting?

- Forecasting is a process of making statements concerning future events.
- Perhaps the most practical application or role of forecasting is its importance in planning, decision making and policy analysis.
- Forecasting can either be one of the two methods: **Qualitative forecasting** and **quantitative forecasting.**

Basic Concepts in Forecasting

What is qualitative forecasting?

- Qualitative forecasting in its core are composed of methods based on experiences, opinions of experts and even ordinary people.
- One example of qualitative forecasting is the **Delphi method**. This pertains to prediction using a panel of experts.

Basic Concepts in Forecasting

What is qualitative forecasting?

- Qualitative forecasting is used when
  - the historical data to be used in forecasting is either scarce or unavailable; or
  - the attribute to be forecasted is not quantifiable.

Basic Concepts in Forecasting

What is quantitative forecasting?

- Quantitative forecasting on the other hand uses time series data and uses mathematical formula or regression-based procedures to produce forecasts
- A central assumption in quantitative forecasting is that the behavior of the observed data will continue into the future.

Basic Concepts in Forecasting

What is quantitative forecasting?

- The following are the steps in quantitative forecasting:


1. Identify pattern from the data.


2. Estimate the model that will fit the data (e.g. exponential smoothing).


3. Use the estimated model in forecasting.


4. Assess the accuracy of forecasts.

Basic Concepts in Forecasting

Basic steps in forecasting

Step 1. Determine the primary objective of the forecasting project and specify clearly.

- the variable or variables to be forecasted
- the periodicity of the forecast (e.g., monthly, quarterly, annually)
- the length of the forecast (short-term, medium-term, long-term)

Basic Concepts in Forecasting

Basic steps in forecasting

Step 2. Collect the data.

- It is necessary to collect historical data of the variables to be forecasted.
- Ensure that the tabulation of the data is comparable and consistent over time.
- Note missing observations and prepare to backcast values later.

Definition of Forecasting

Basic steps in forecasting

Step 3. Perform descriptive analysis on the time series data.

- Graph the data for visual inspection.
- Calculate some descriptive statistics.
- Examine its components: trend, seasonality, cycle and irregularities.
- Support your data insights with some background literature.

Basic Concepts in Forecasting

Basic steps in forecasting

Step 4. Perform the forecasting method.

- This forecasting method may be based on a formula (e.g. simple moving averages, trend models).
- A more sophisticated model can also be used (e.g. exponential smoothing, ARIMA models).

Basic Concepts in Forecasting

Basic steps in forecasting

Step 5. Evaluate the model's forecasting ability.

- Forecast accuracy can be based on
  - In-sample forecasts to see how well the method captures the series behavior.
  - Out-of-sample forecasts to see how well the method can predict future (thus unknown) values).

Basic Concepts in Forecasting

Basic considerations in forecasting

There are six basic considerations in forecasting:

1. Forecast accuracy
2. Forecast object
3. Forecast statement
4. Forecast horizon
5. Information set
6. Parsimony

Basic Concepts in Forecasting

Forecast accuracy

It is important to know the distance of the forecast from the actual value. This is called the **error**.

$$e_t = y_t^{actual} - y_t^{forecast}$$

The error, or noise series is important in assessing forecast accuracy. The general idea is that the lower the error, the better the forecast is.

Basic Concepts in Forecasting

Forecast object

- The forecast object we will be dealing with in this training are **time series forecasts** – future value(s) of a variable of interest.
- Other forecast objects can be **event outcome forecasts** wherein an event will take place at a particular moment but the outcome is uncertain (e.g. appointment of a manager).

Basic Concepts in Forecasting

Forecast object

- **Event timing forecasts** on the other hand is when one predicts when an event is going to happen (e.g. when is another financial crisis going to happen?).

Basic Concepts in Forecasting

Forecast statement

In making time series forecasts, one should consider if the forecast will be a

- **point forecast**; an
- **interval forecast**; or a
- **density/distribution forecast**.

This course will discuss point forecasts.

Basic Concepts in Forecasting

Forecast horizon

Forecast horizon is defined as the number of periods between the most current time point and the date of the forecast being made.

This is usually denoted as an h-step ahead forecast.

Basic Concepts in Forecasting

Forecast horizon

For example, in doing monthly forecasts, the choice of h depends on the decision that the forecast will guide:

Short-term	:	one to three months
Medium term	:	>3 months to 2 years
Long term	:	more than two years

Basic Concepts in Forecasting

Information set

Forecast quality depends quality and quantity of the data at hand called the information set.

The **information set** is nothing but a set of time series used. It can be

- **univariate** : only one time series is used; or
- **multivariate** : more than one time series are used to estimate a single or a vector of models.

Basic Concepts in Forecasting

Parsimony

The parsimony principle states that, with all other things being the same, **simple models are preferred than complex models**.

Parsimonious models are generally less prone to overfitting, hence better out-of-sample forecasts.

Basic Concepts in Forecasting

The process of time series analysis

Basic Concepts in Forecasting

Objectives in forecasting: prediction

The task of predicting future values is an invaluable step for **decision-making** and **target-setting**.

Forecasting and prediction can be used interchangeably. Forecasting is based on the principle that "what we expect in the future is much like what we have in the past".

Basic Concepts in Forecasting

Objectives in forecasting: control

Good forecasts yield **good decisions** and **preemptive action** to control a given process, whether it is about next month's demand for a product or an early warning for a natural disaster.

Basic Concepts in Forecasting

Objectives in forecasting: applications

Applications of forecasting include the following

1. Economic planning
2. Forecasting of sales
3. Supply chain planning
4. Production and capacity planning
5. The evaluation of policies and economic strategies
7. Financial risk management

The Time Series Data

The Time Series Data

What is a time series?

A time series is a sequence of observations that is usually collected at regular intervals.

It is a series of observations indexed by time. We usually denote a time series as

y_t = response or value at time *t*.

The Time Series Data

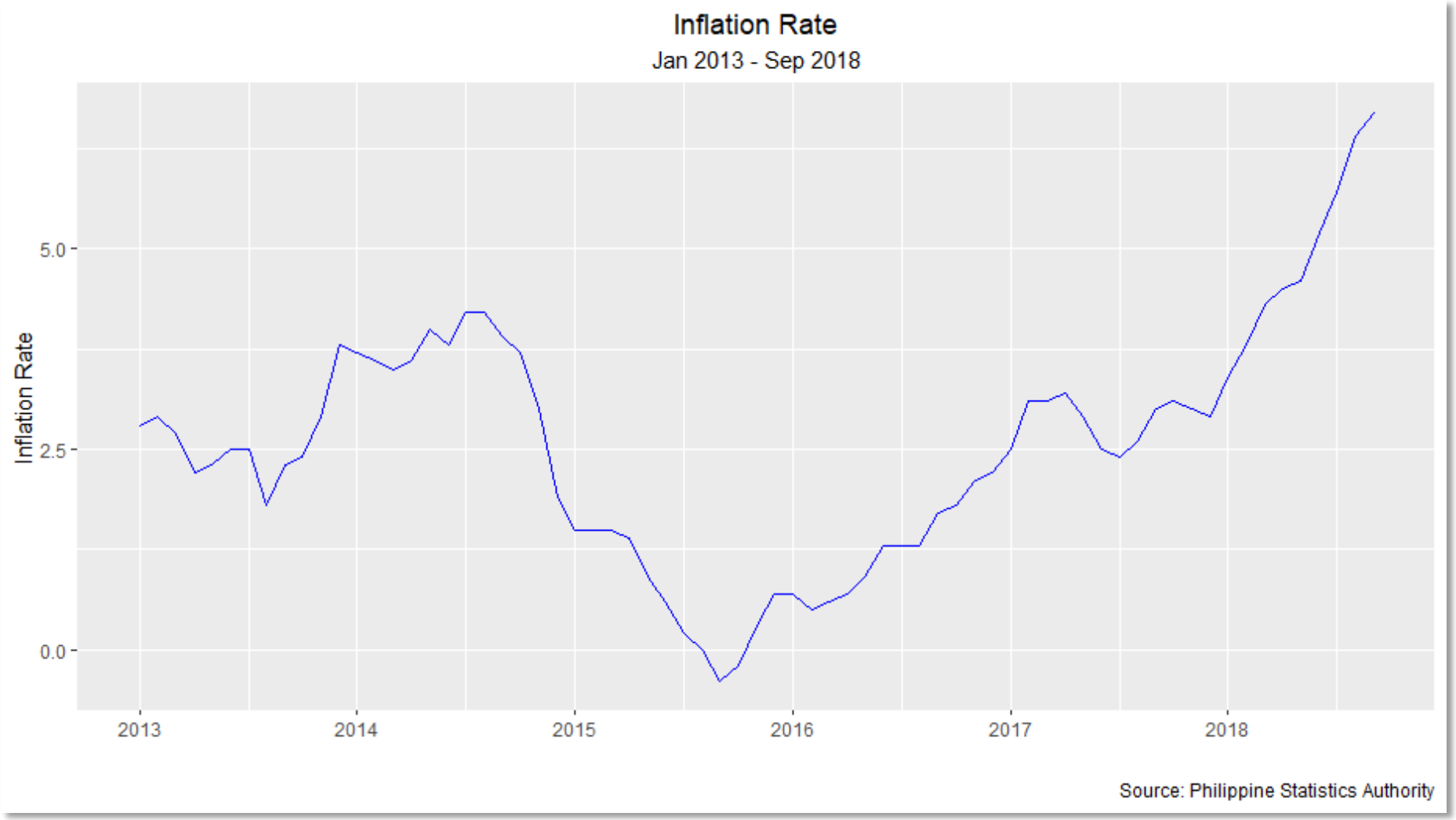
Examples of time series

The following are seven timepoints of annual production:

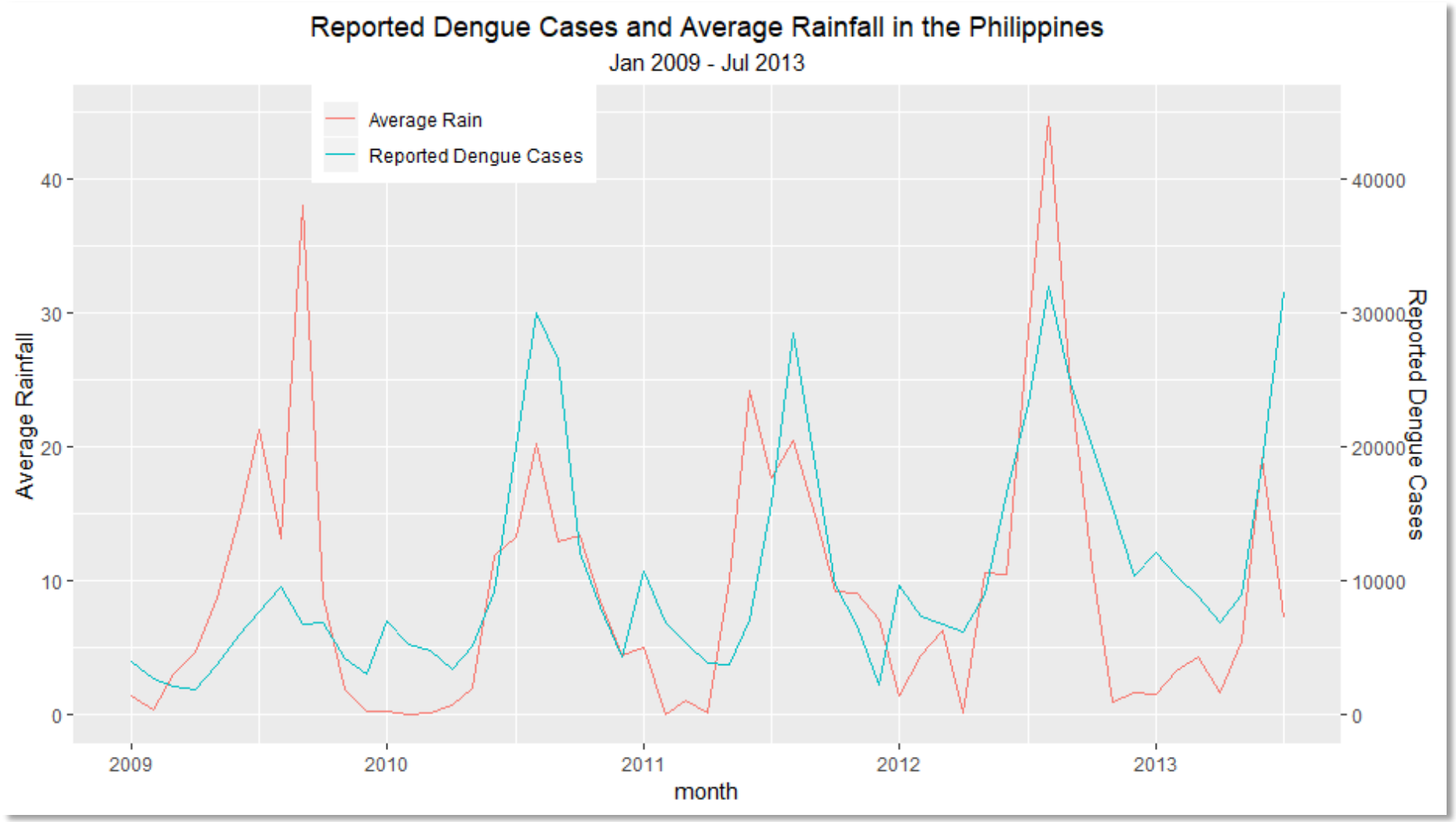
Year:	2010	2011	2012	2013	2014	2015	2017
Prod:	75.3	74.2	78.5	79.7	80.2	75.3	74.2

This would comprise a time series. This is because production is well defined, collected and measured at equally spaced intervals.

The Time Series Data



The Time Series Data



The Time Series Data

Examples of time series

Economics: monthly data for unemployment, quarterly gross national income, monthly consumer price index

Finance: daily exchange rate, share price, daily price of oil per barrel

Environmental: daily rainfall, air quality readings, CO_2 emissions

The Time Series Data

Examples of time series

Medicine: ECG brain wave activity,
recovery time of a patient

Agriculture: annual palay yield in metric tons,
quarterly inventory of broilers

Social: weekly crime rate,
monthly satisfaction index

The Time Series Data

Autocorrelation

Also known as **serial correlation**, it is the similarity of behavior between the observations of a time series.

It is the correlation between a time series point with other past observations, hence "auto"correlation.

The Time Series Data

Autocorrelation

In forecasting, we use this autocorrelation structure, finding repeated patterns and use that quantified behavior to predict about a future value.

To see the autocorrelation pattern, we use **correlograms**.

Forecast Accuracy Measures

Forecast Accuracy Measures

Model evaluation measures

One criterion that is used to evaluate a forecasting method is how the predicted values track historical data.

That is, how far do forecasted values deviate from the original observations.

As a general rule, the **smaller** the values of say, MAE, MAPE or RMSE the more accurate the forecasts are.

Forecast Accuracy Measures

Mean Absolute Error (MAE)

Let y_t = actual series
$\hat{y}_t$ = predicted series
T = number of time points

$$MAE = \frac{1}{T}\sum_{t=1}^{T}|y_t - \hat{y}_t|$$

Forecast Accuracy Measures

Mean Absolute Percentage Error (MAPE)

Let y_t = actual series
$\hat{y}_t$ = predicted series
T = number of time points

$$MAPE = \frac{1}{T}\sum_{t=1}^{T}\left|\frac{y_t - \hat{y}_t}{y_t}\right| \times 100\%$$

Forecast Accuracy Measures

Root Mean Squared Error (RMSE)

Let y_t = actual series
$\hat{y}_t$ = predicted series
T = number of time points

$$RMSE = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(y_t - \hat{y}_t)^2}$$

Forecast Accuracy Measures

Root Mean Squared Error (RMSE)

Let y_t = actual series
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Time Series Decomposition

Time Series Decomposition

Components of a time series

There are four components of a time series

TREND

CYCLE

SEASONALITY

IRREGULARITY

Time Series Decomposition

Key features of a time series

- The decomposition of time series is a statistical task that deconstructs a time series into several of its components, each representing one of the underlying categories of patterns.
- This is an important technique for time series analysis, especially with seasonal adjustment.
- RStudio can decompose a time series, using X-12 ARIMA.

Time Series Decomposition

Additive and multiplicative models

- Decomposition models are either **additive** or **multiplicative**. The additive decomposition model is adequate when the time series fluctuations remain constant across all levels of trend.
- The multiplicative model is used when the time series exhibits increasing or decreasing seasonal variation.

Time Series Decomposition

Additive and multiplicative models

- Additive decomposition model:

$$y_t = y_t^{tr} + y_t^{se} + y_t^{cy} + y_t^{ir}$$

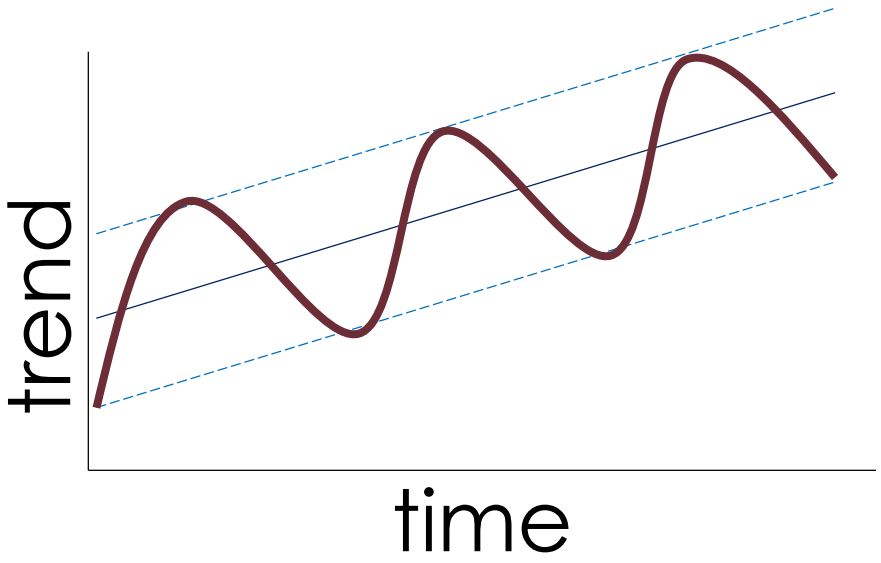
- Multiplicative decomposition model:

$$y_t = y_t^{tr} \times y_t^{se} \times y_t^{cy} \times y_t^{ir}$$

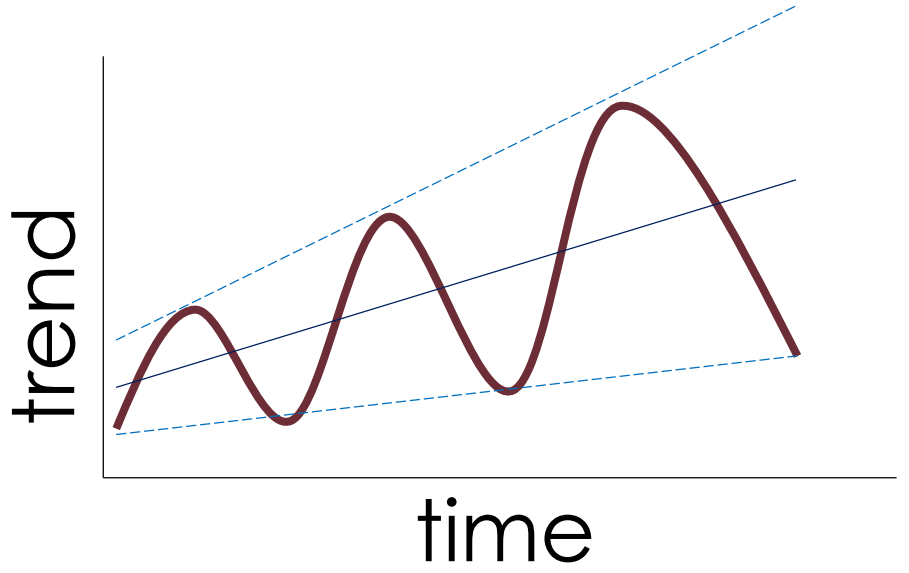
Time Series Decomposition

Additive vs. multiplicative seasonality

additive seasonality



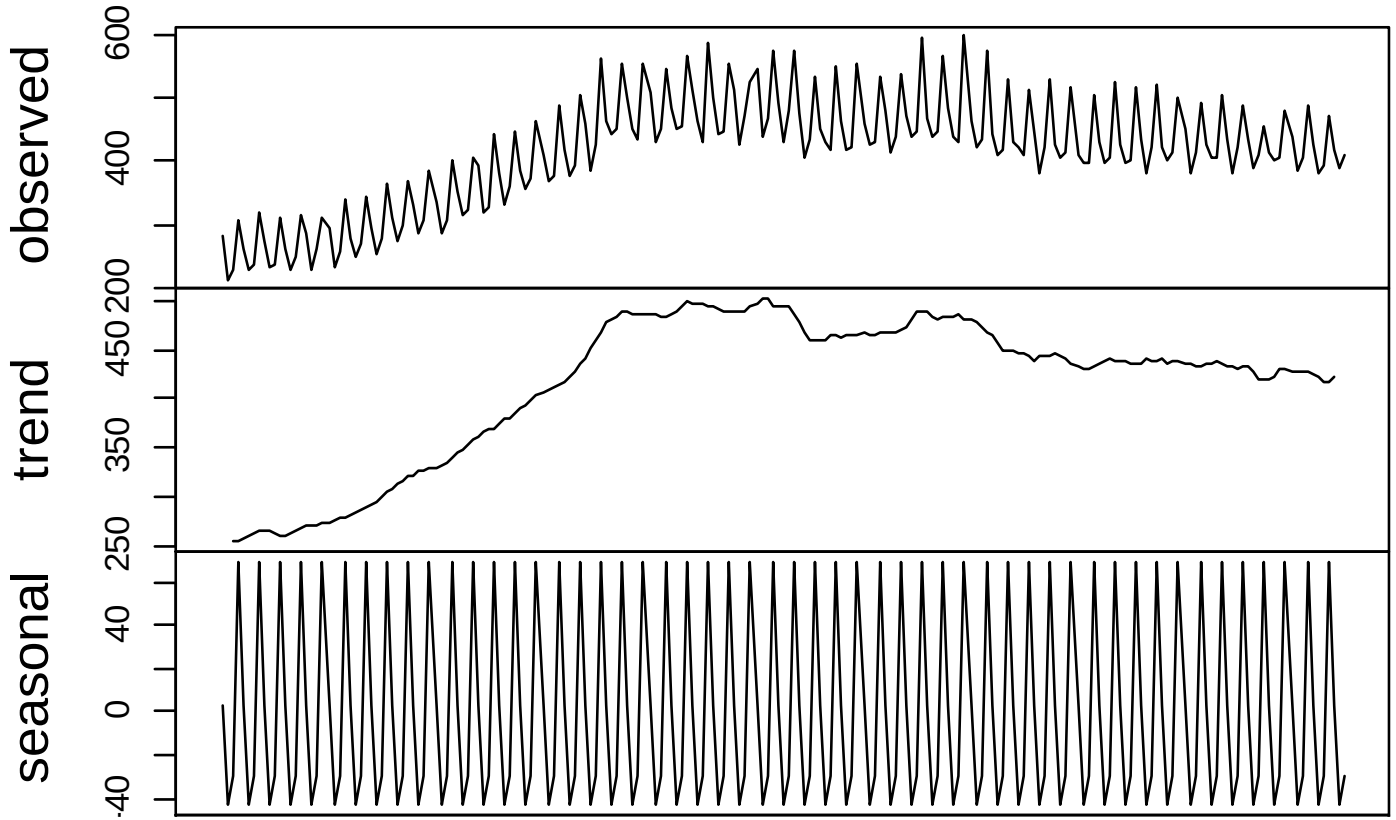
multiplicative seasonality



Time Series Decomposition

Additive and multiplicative models

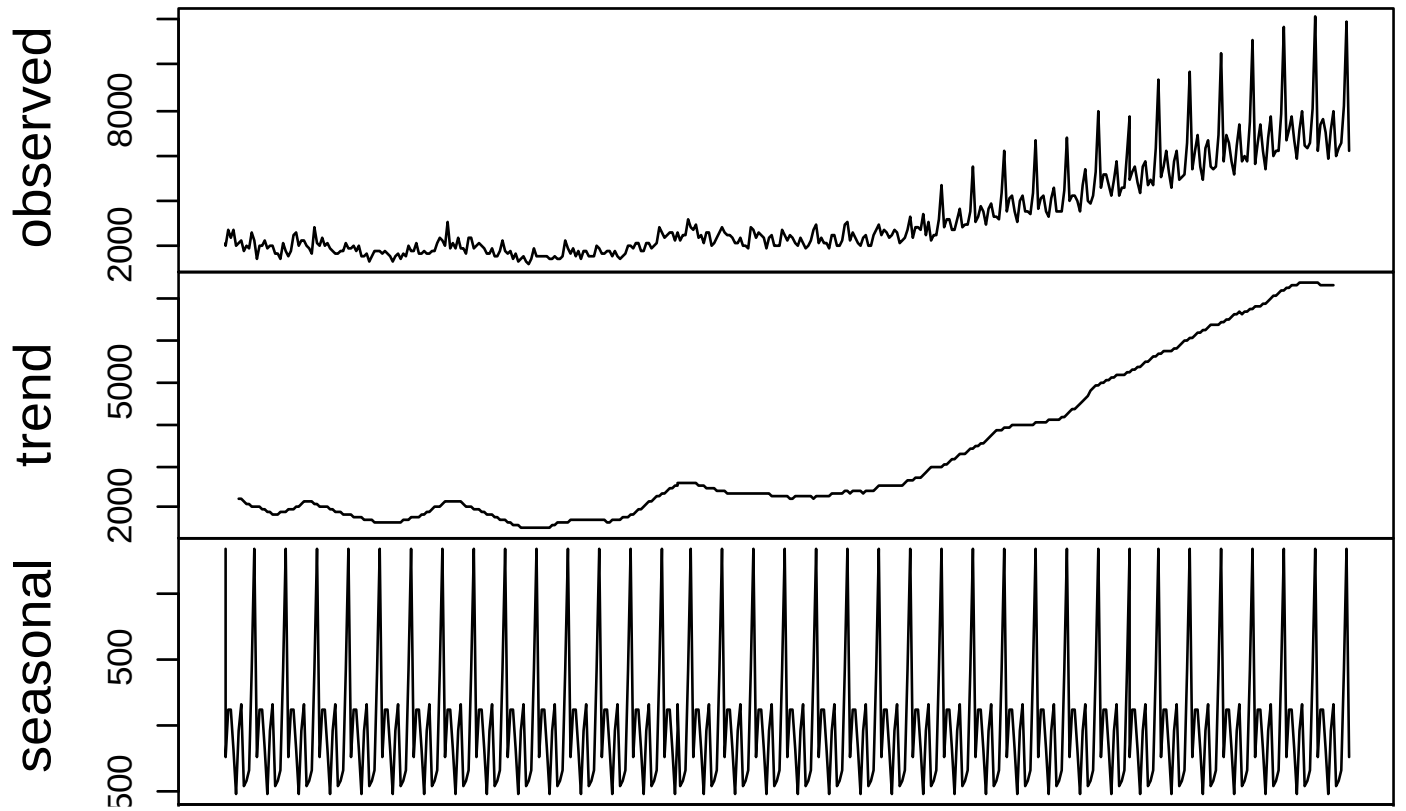
Note how constant the seasonal fluctuations are across time. This exhibits an **additive** decomposition.



Time Series Decomposition

Additive and multiplicative models

The seasonal fluctuations now vary, increasing as trend increases. This exhibits a **multiplicative** decomposition.



Time Series Decomposition

Trend

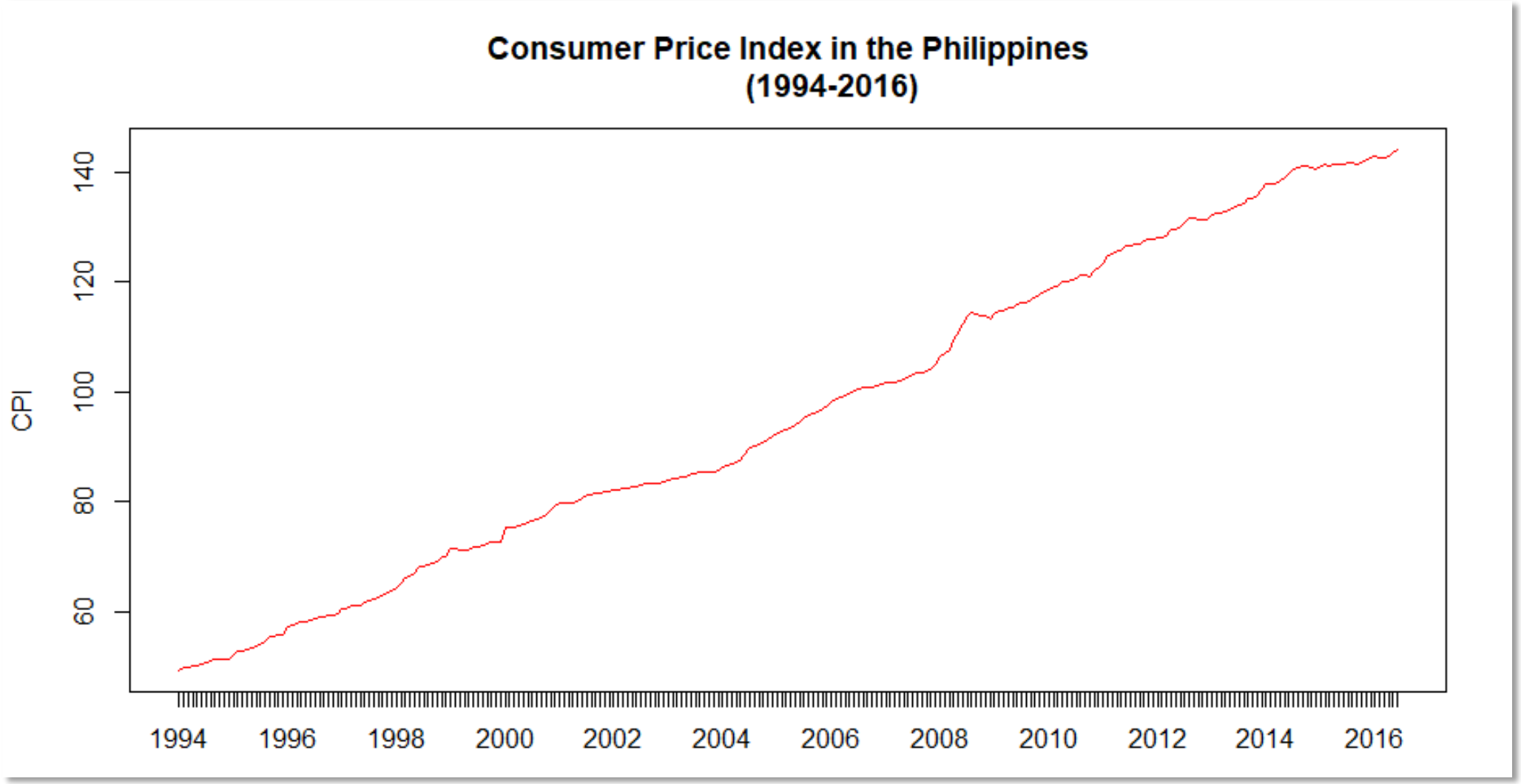
- The first component is the general tendency of a time series to increase, decrease or stagnate over a long period of time.
- Trend is regarded as a **long term movement** of the time series. It can be linear, or non-linear.
- It answers the question: "**Do the values tend to increase or decrease over time?**"

Time Series Decomposition

Trend

- The trend is a reflection of the underlying level of the series. In economic time series, this is typically due to influences such as population growth, price inflation and general economic development.

Time Series Decomposition



Time Series Decomposition

Seasonality

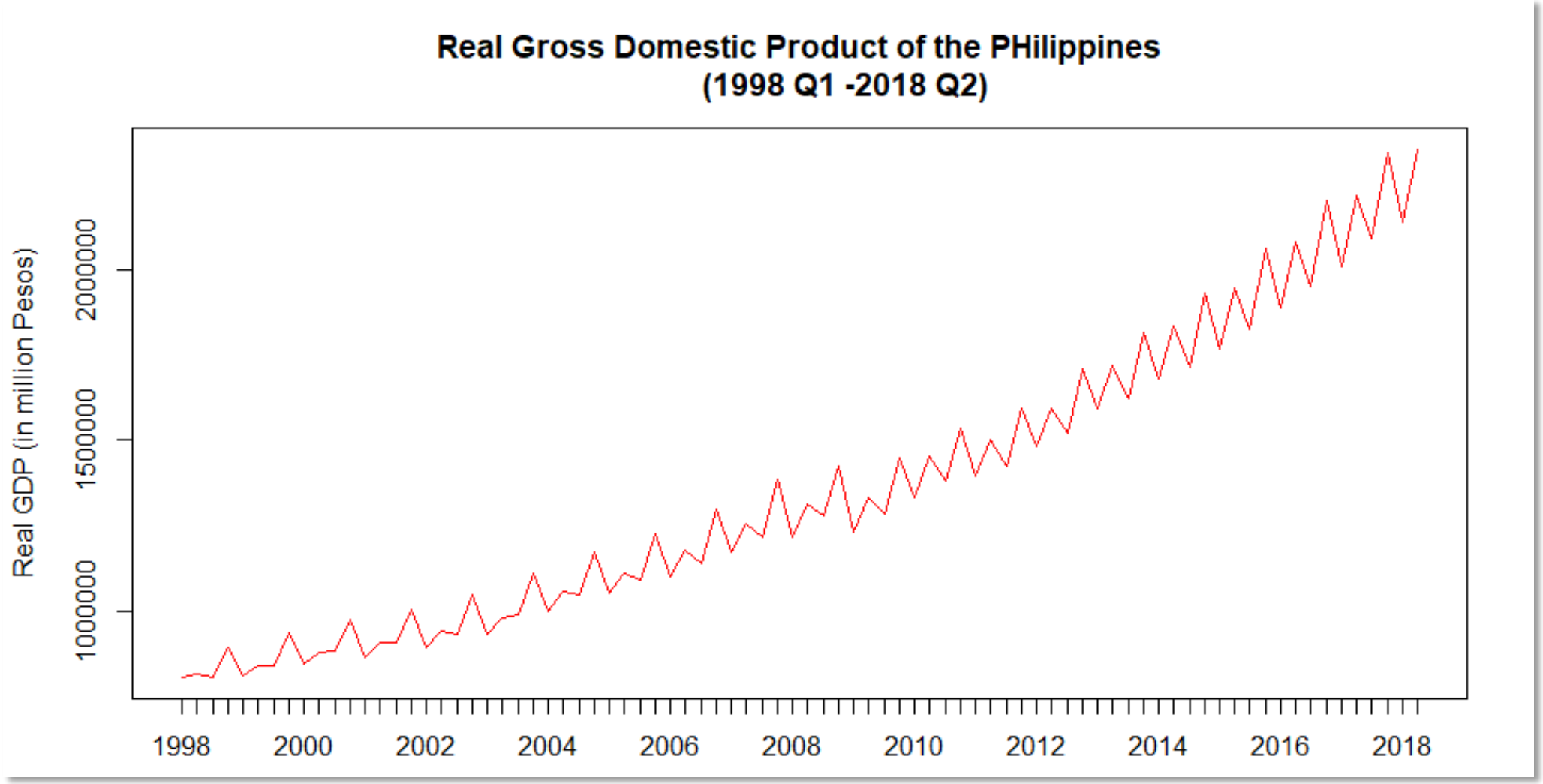
- Seasonality are **regular fluctuations** within a period no longer than a year.
- Seasonality is of a fixed and known period. It is a regular periodic pattern that repeats from year to year.
- It answers the question: "**Is there a regular pattern of high points (peaks) and low points (troughs) that occur from year to year?**"

Time Series Decomposition

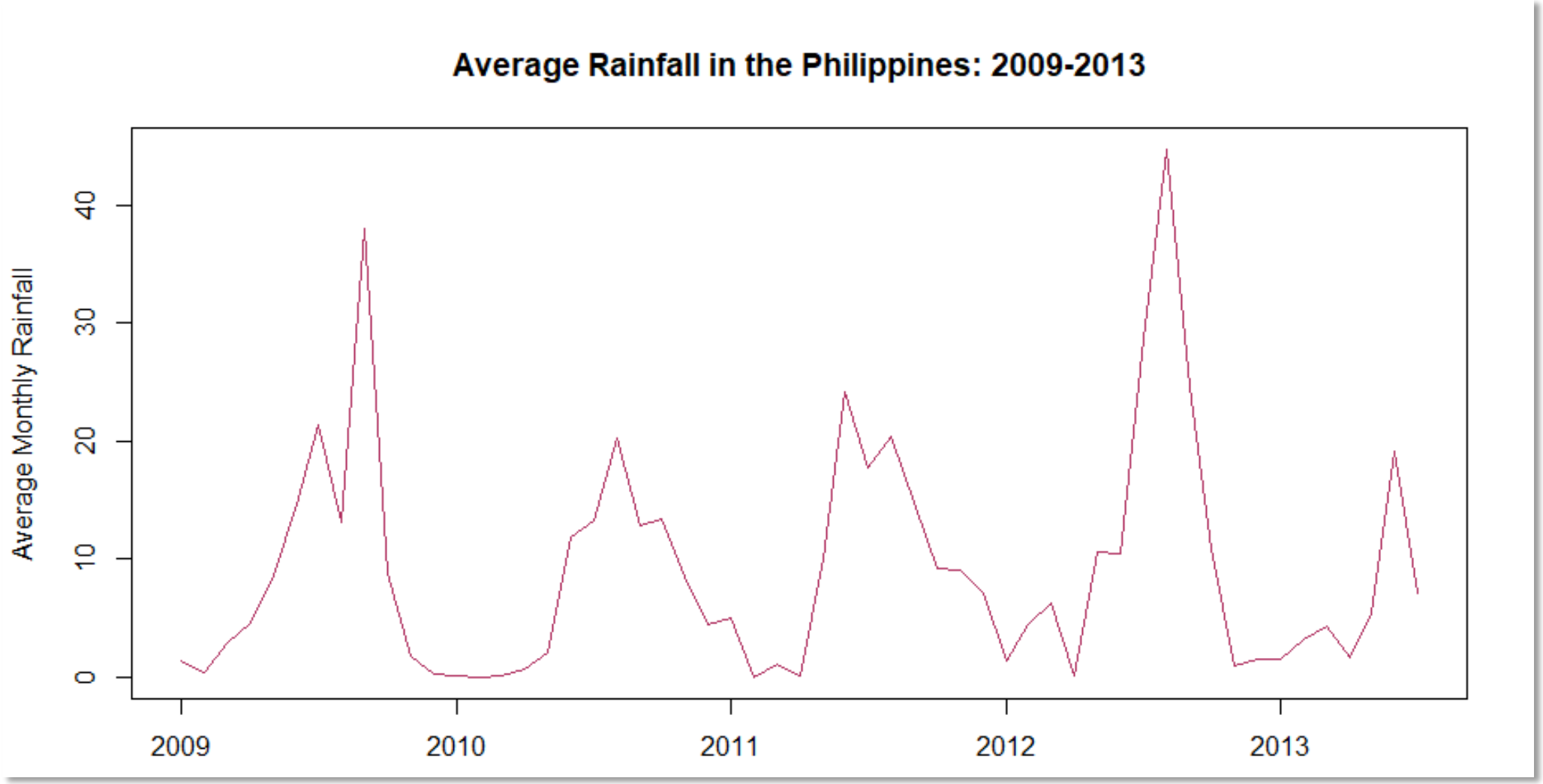
Seasonality

- Seasonality exists because the time series is influenced by seasonal factors:
  - Calendar effects (Christmas, holidays)
  - Institutional factors (tax period, salary/bonus dates, start and end of classes)
  - Weather
  - Periodic expectations (higher remittances during Christmas season, increased tourist arrivals during summer)

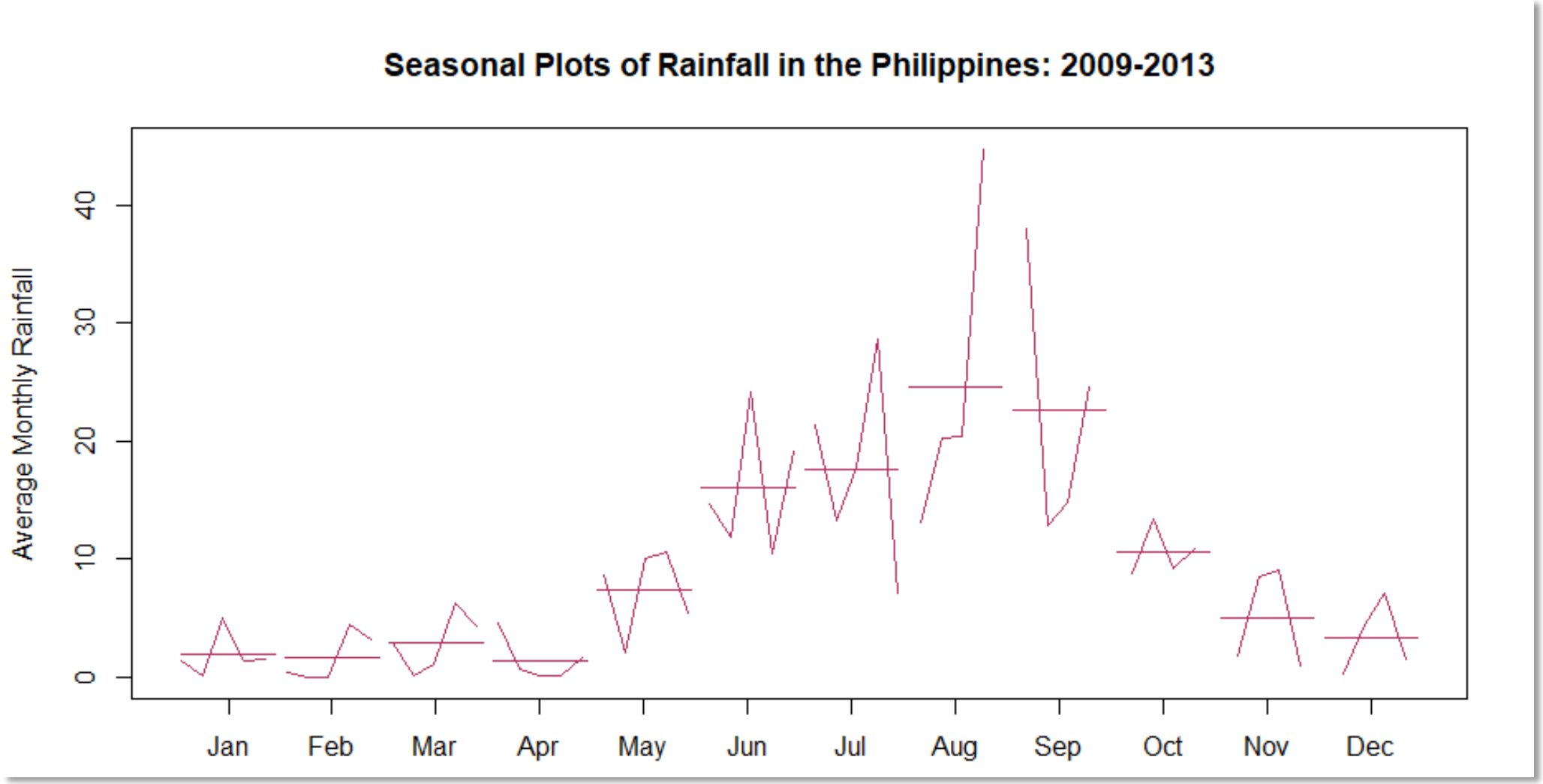
Time Series Decomposition



Time Series Decomposition



Time Series Decomposition



Time Series Decomposition

Cycle

- This crucial component of time series captures any long-term dynamics in the time series not accounted by trend or seasonality.
- Cycle is typically referred to as the **long-term rise and fall** with periods that irregularly occur for more than a year or for an unfixed period of time.

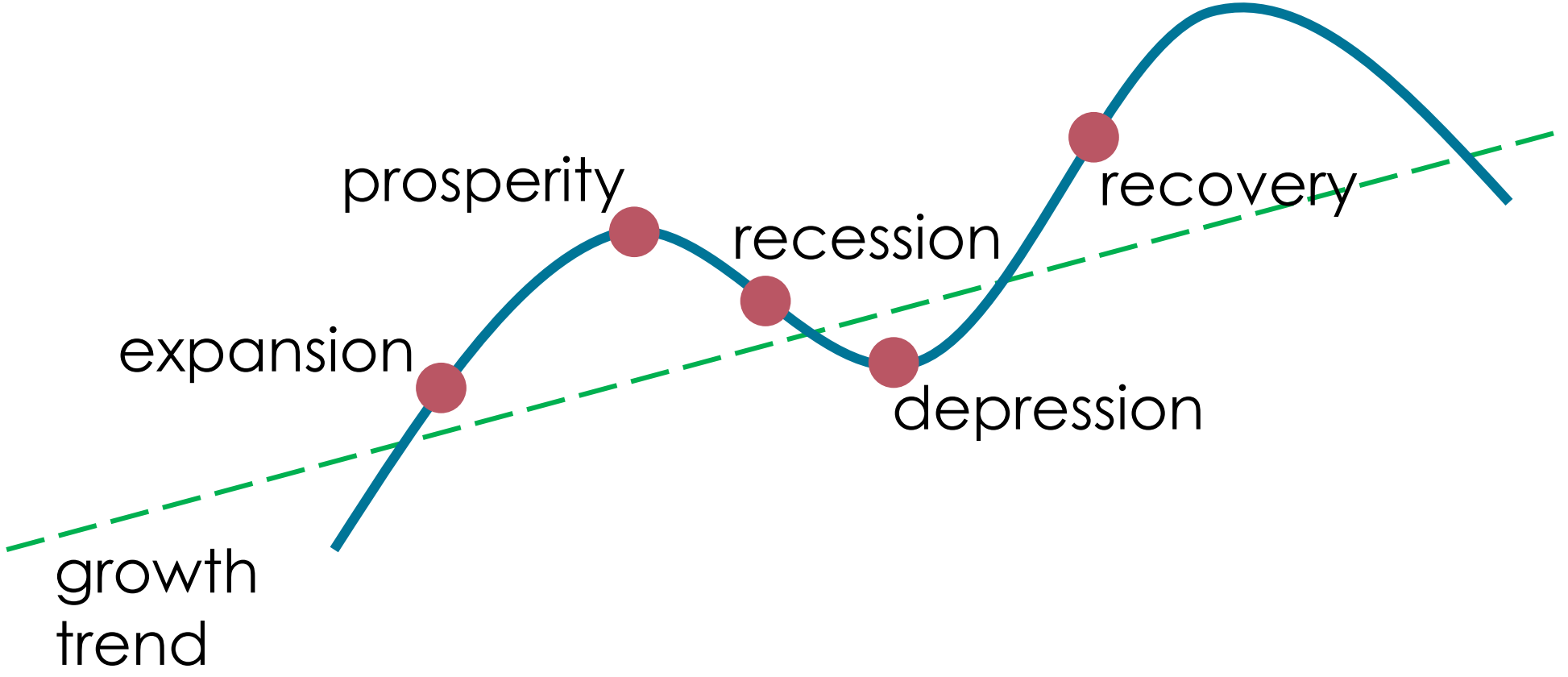
Time Series Decomposition

Cycle

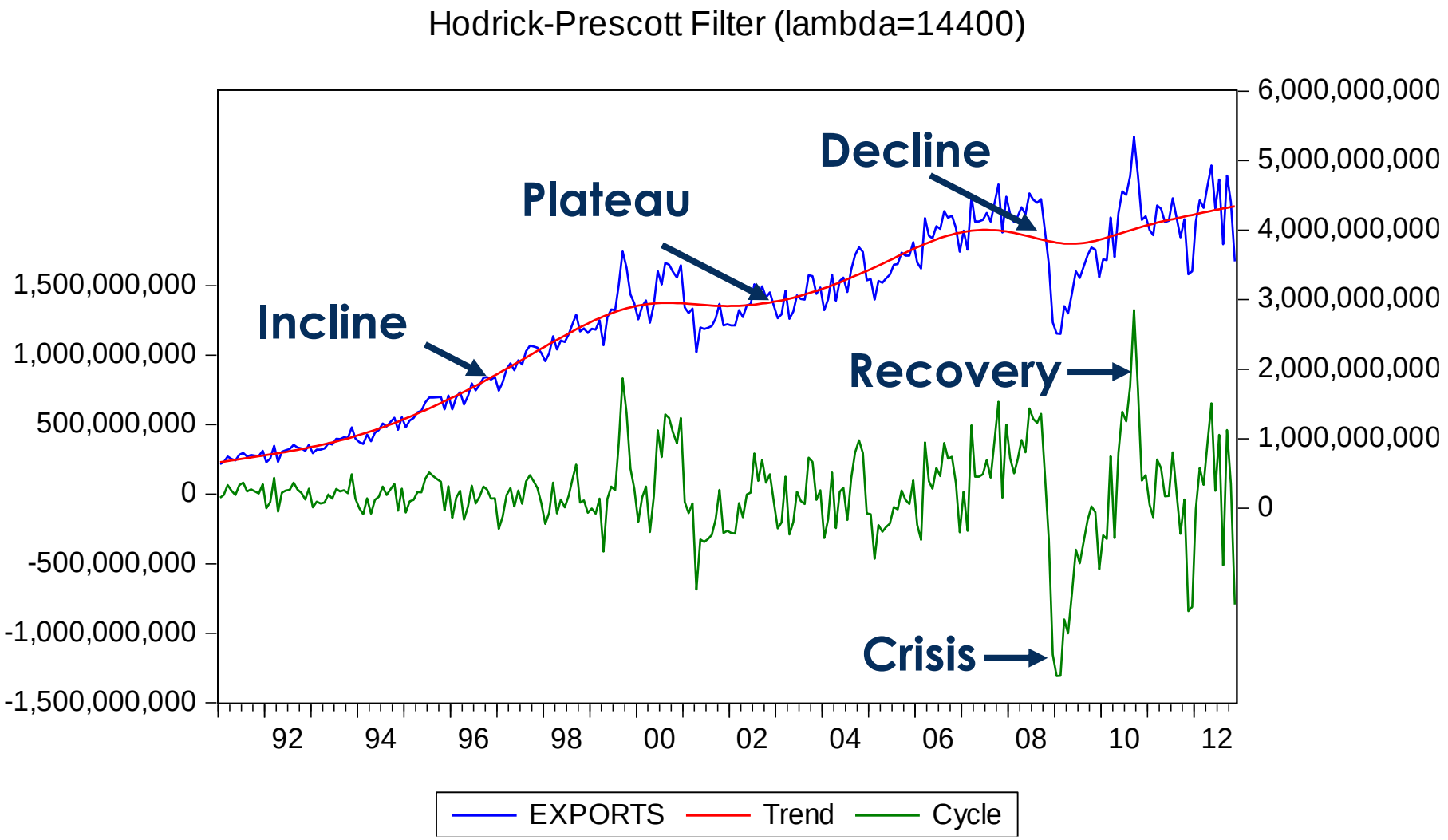
As opposed to seasonal variation, a cycle spans for more than a year. As an example, a business cycle consists of four phases: prosperity (boom), recession (decline), depression and recovery.

Time Series Decomposition

The business cycle



Time Series Decomposition



Time Series Decomposition

Irregular component

- The irregular component represents the unforeseeable movements related to events of all kinds.
- Irregularity is a signal which can also be referred to as **noise or shock**.
- This is the remaining component of the time series after the trend, seasonality and cycle components are removed.

Time Series Decomposition

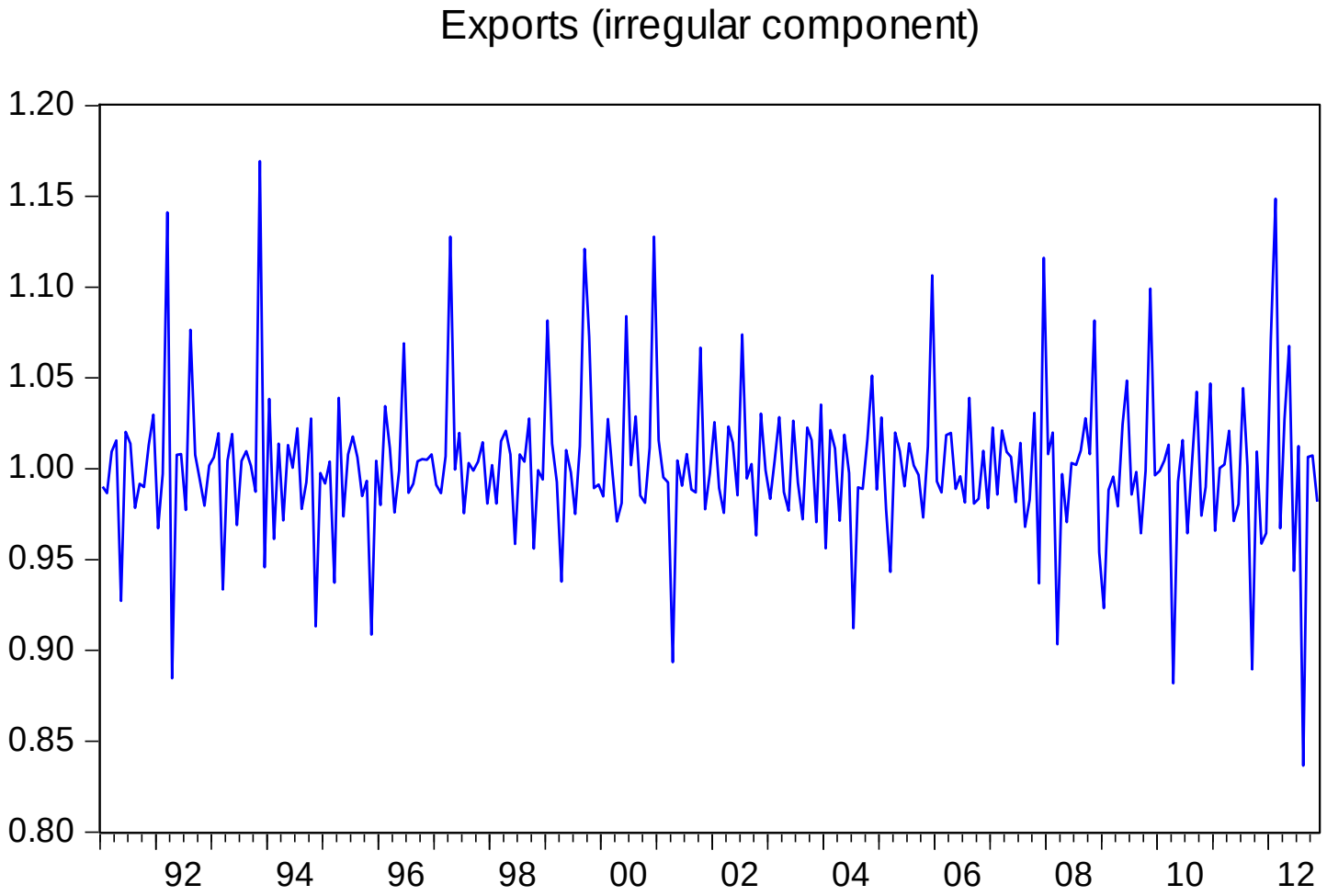
Components of a time series: irregularity

Irregularity uncovers three features:

- the **volatility** or the variability of data;
- **outliers** which are present in the time series;
- and **change in pattern** which includes
  - trend changes
  - seasonal fluctuation shifts and
  - structural breaks in the time series.

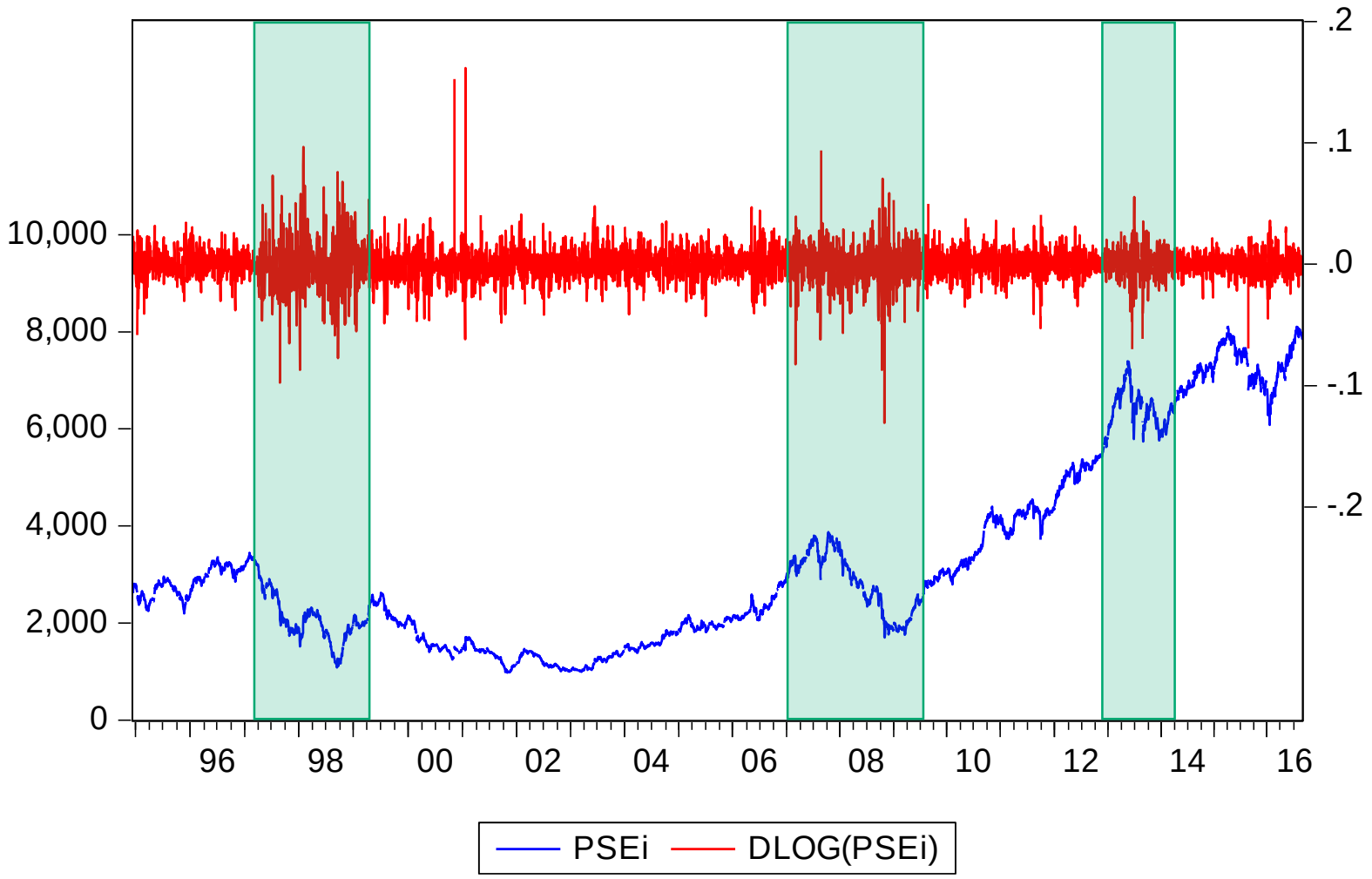
Time Series Decomposition

Note how some spikes are larger than the others.



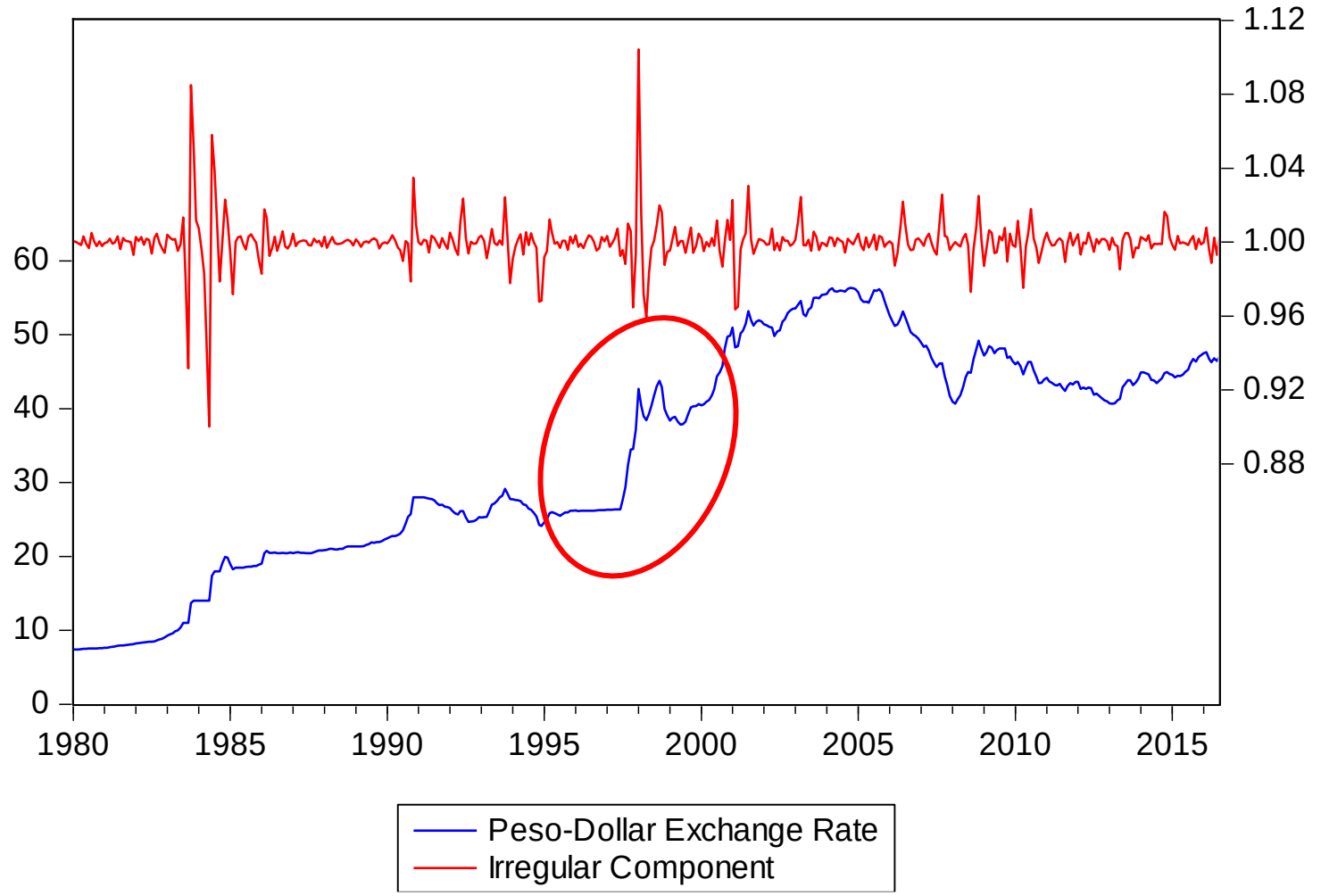
Time Series Decomposition

With **volatility clustering**, where high-volatility is followed by high volatility while low volatility is followed by low volatility.

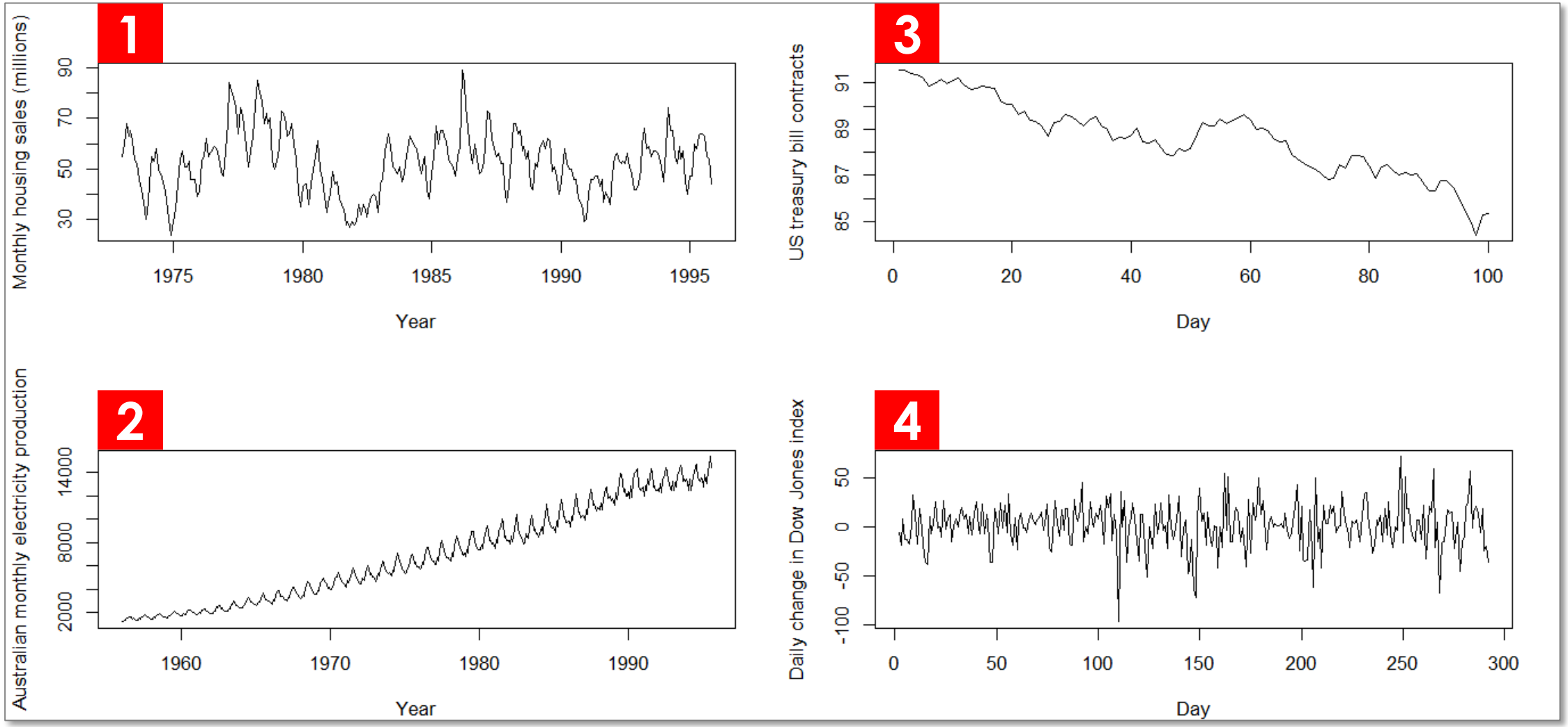


Time Series Decomposition

Structural breaks occur when there is an unexpected shift in a time series.



Time Series Decomposition



Time Series Decomposition

Combinations of the time series components

1. **Monthly housing sales**: In this time series, we see strong seasonality within a year and a cyclic movement that occurs for more than a year. There is obvious trend over this period.
2. **Electricity production**: Seasonality and trend is strong in the time series. Cyclic behavior is not observed.

Time Series Decomposition

Combinations of the time series components

3. **Treasury bill contracts**: A downward trend is seen. There is no seasonal pattern. Possibly, if the series is longer, one might see some cyclic pattern.
4. **The Dow Jones Index**: No trend, seasonality and cycle is present. These irregularities, or random fluctuations do not appear to be very predictable.


Thank
You