程序代写代做 CS编程辅导

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F[illegible] Econometrics

[illegible] ARMA models

Genera; L[illegible]cess and characterization

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Time Series Models (Mai[illegible]ical Aspects)

- View time series as stochastic processes
- Notions of stationarity (Covariance Stationary)
- Models for stationary time series
  - General linear process (GLP): useful representation especially for computing expectations...
- Characteristics of models
  - Patterns in the AC and PAC of a model: White noise

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Motivation

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- Describe empirically relevant patterns in the data ??
- Obtain the distribution of future values, conditional on the past, in order to forecast the future values and evaluate the likelihood of certain events ??
- Provide insight in possible sources of non-stationarity

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A **time series** $y_1, \ldots, y_T$ is a sequence of values a specific variable y has taken on at equally spaced times (e.g. daily, quarterly, yearly, ...) over some period of time.

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These observations will be considered as being generated by some **stochastic Data Generating Process** (DGP)

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- A time series $y_1, \ldots, y_T$ is generated by a stochastic process y_t, for $t = 1, \ldots, T$.

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- A time series $y_1, \ldots, y_T$ is a collection of realizations of a random variable y_t ordered in time.

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A **time series model** tries to describe the stochastic process y_t b[illegible] a relatively simple mo[illegible] **[illegible]ariate time series models** are a class of models where [illegible]pts to model and predict (economic) variables u[illegible] information contained in their ow[illegible] past values and possibly current and past values of an error term.

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These models are (mainly) a-theoretical:

- not based upon any underlying theoretical model
- attempt to capture empirically relevant patterns in the data

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$\Leftrightarrow$ **Structural models**

- generally based upon any underlying theoretical model
- attempt to model a variable from the current and/or past values of other explanatory variables (suggested by theory)

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A series y_t is **strictly stationary** if the distribution of its values is not affected by an arbi along the time axis:

$$f \quad y_{t+k}) \qquad \forall k \tag{1}$$

$\rightarrow$ The entire distribution of y_t is not affected by an arbitrary shift along the time axis. See for example Figure 1.

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A series y_t is **covariance** or **weakly stationary** if it satisfies:

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- $E(y_t) = \mu < \infty$
- $Var(y_t) = E(y_t - \mu)^2 = \sigma^2 < \infty$
- $Cov(y_t, y_{t-k}) = E(y_t - \mu)(y_{t-k} - \mu) = \gamma_k \quad \forall k$

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$\rightarrow$ The first and the second moment of the distribution of y_t are finite and not affected by an arbitrary shift along the time axis.

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- After being hit by a [illegible] stationary series tends to return to its mean (called [illegible]**ersion**) and fluctuations around this mean (measure[illegible]variance) will have a broadly constant amplitude.

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- If a time series is not stationary in the sense defined above, it is called **non-stationary**, i.e. non-stationary series will have a time-varying mean and/or a time-varying variance and/or time-varying covariances.
  - Non-stationarity can have different sources: linear trend, structural break, unit root, ...

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Defining stationarity and non-stationarity

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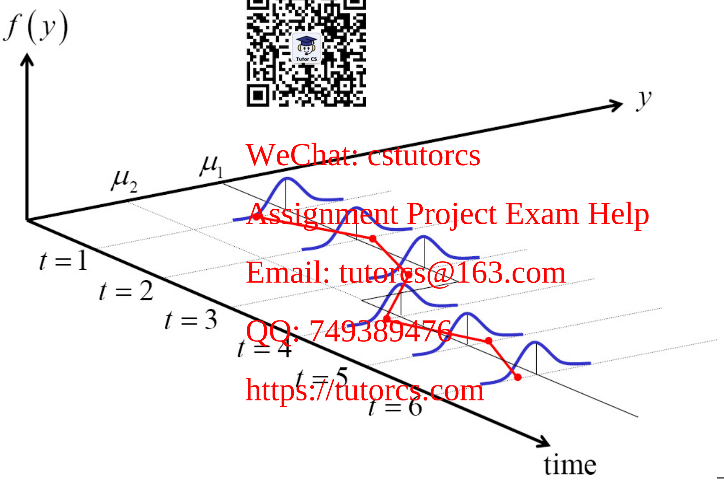
Figure 5 : A non-stationary process (structural break)



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- If the dependence stru[illegible]ble (stationary), it can be learned from historical data.
- Strict Stationarity
  - A time series is strictly stationary (SS) if its joint distribution at any set of points in time is invariant to any time shift.

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$$\text{eg: dist}(y_{t_1}, y_{t_2}) = \text{dist}(y_{t_1+s}, y_{t_2+s})$$

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- Covariance Stationarity
  - A time series is covariance stationary (CS) if its mean, variance and autocovariance are all independent of the time index t, and its variance is finite.

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$$E(y_t) = \mu, Var(y_t) = \gamma_0 < \infty, Cov(y_t, y_{t-j}) = \gamma_j \text{ for all } j$$

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Autocorrelation and Partial Autocorrelation Function

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Assuming covariance stationarity, particular useful tools when building ARMA models are the so-called Autocorrelation and Partial Autocorrelation Functions.

In general, the joint distribution of all values of y_t is characterised by the so-called **autocovariances**, i.e. the covariances between y_t and all of its lags y_{t-k}.

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The **sample autocovariances** γ_k can be obtained as

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$$\gamma_k = cov(y_t, y_{t-k}), \qquad k = 1, 2, \ldots \tag{2}$$

$$= \frac{1}{T-k} \sum_{t=k+1}^{T} (y_t - \overline{y})(y_{t-k} - \overline{y}), \tag{3}$$

where $\overline{y} = T^{-1} \sum_{t=1}^{T} y_t$ is the sample mean.

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As the autocovariances are not independent of the units in which the variables are meas [illegible] common to standardize by defining **autocorrelations** ρ_k a [illegible]

$$\rho_k = \frac{cov(y_t, y_{t-k})}{var(y_t)} = \frac{\gamma_k}{\gamma_0}. \quad (4)$$

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Note that $\rho_0 = 1$ and $-1 \leq \rho_k \leq 1$.

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The autocorrelations ρ_k considered as a function of k are referred to as the **autocorrelation function** (ACF) or correlogram of the series y_t. The ACF provides useful information on the properties of the DGP of a series as it describes the dependencies among observations.

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If the data are generated from a **stationary process**, it can be shown that under the null hypothesis:

$$\rho_k = 0 \quad \forall k > 0$$

the sample autocorrelation coefficients are **asymptotically normally distributed** with mean zero and variance $\frac{1}{T}$.

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Therefore, in finite sample it holds:

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$$\rho_k \sim N\left(0, T^{-1}\right)$$

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The **individual significance** of an autocorrelation coefficient can be tested by constructing the 95% confidence interval:

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$$\left[-1.96/\sqrt{T}; 1.96/\sqrt{T}\right]$$

Looking at a large number of autocorrelations, we will see that some exceed two standard deviations as a result of pure chance even though the true [illegible] the DGP are zero (Type I error).

The **joint significanc**[illegible]up of m autocorrelation coefficients can be tested by the so-called Box-Pierce Q-statistic:

$$Q = T \sum_{k=1}^{m} \rho_k^2 \tag{5}$$

If the data are generated from a stationary process, Q is asymptotically χ^2 distributed with m degrees of freedom.

Superior small sample performance is obtained by modifying the q statistic (reported in EViews output):

$$Q^* = T(T+2) \sum_{k=1}^{m} \rho_k^2 / (T-k) \tag{6}$$

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Partial Autocorrelation Function

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- An alternative piece of [illegible]on is provided by the so-called partial autocorrelation function (PACF). The partial autocorrelation p_j s the correlation between y_t and $y_{t?k}$ conditional on $y_{t?1}, \cdots, y_{t?k+1}$. It measures the dependency between y_t and $y_{t?k}$ keeping constant in-between values.

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- The sample partial autocorrelations can be calculated from OLS regressions:
  - $\hat{p}_1 = \hat{\phi}_{11}$ in $y_t = \phi_{10} + \phi_{11} y_{t-1} + e_{1t}$
  - $\hat{p}_2 = \hat{\phi}_{22}$ in $y_t = \phi_{20} + \phi_{21} y_{t-1} + \phi_{22} y_{t-2} + e_{2t}$
  - $\hat{p}_3 = \hat{\phi}_{33}$ in $y_t = \phi_{30} + \phi_{31} y_{t-1} + \phi_{32} y_{t-2} + phi_{33} y_{t-2} + e_{3t}$

    $\cdots$

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Defining a White Noise Process

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A series y_t is called a **white noise process** if its DGP has a constant mean, a constant variance and is serially uncorrelated. Formally:

$$E(y_t) = E(y_{t-1}) = \dots = \mu$$

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$$Var(y_t) = Var(y_{t-1}) = \dots = \sigma^2$$

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$$Cov(y_t, y_{t-k}) = Cov(y_{t-j}, y_{t-j-k}) = \begin{cases} \sigma^2 & \text{if} \quad k = 0 \\ 0 & \text{otherwise} \end{cases}$$

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y_t is a **zero-mean white noise process** if $\mu = 0$.

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Defining a White Noise Process

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- A time series ϵ_t is a w[illegible]f its is covariance stationary with zero mean and no autocorrelation.
  - By definition:

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$$E(\epsilon_t) = 0, Var(\epsilon_t) = \sigma^2, Cov(\epsilon_i, \epsilon_{t-j}) = 0, \text{ for all} j \neq 0.$$

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  - A white noise is denoted as: $y_t \sim WN(0, \sigma^2)$
    A white noise is not necessarily $i.i.d$ (independent and identically distributed)
  - An $i.i.d$ white noise is denoted as: i.i.d $WN(0, \sigma^2)$
  - , White noises are building blocks of time series models.

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Test whether a time series is white noise

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- Key feature of a $WN(0, \sigma^2)$ is H_0: **no autocorrelation**
- The sampling distribution of the ACF and PACF for a WN is approximately $N(0, 1/T)$

▷ Reject H_0

if either ACF or PAC is outside the $\pm 1.96/\sqrt{T}$ bands; or

the Ljung-Box Q-stats have small p-values.

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Test whether a time series is white noise

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eg. NYSE Composite return ... r_t^2.

Correlogram of RC2

Sample: 1 1931
Included observations: 19[illegible]

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.179	0.179	62.044	0.000
		2	0.168	0.140	116.47	0.000
		3	0.175	0.131	176.00	0.000
		4	0.109	0.044	198.89	0.000
		5	0.184	0.130	264.80	0.000
		6	0.113	0.035	289.54	0.000
		7	0.136	0.067	325.24	0.000
		8	0.112	0.030	349.60	0.000
		9	0.108	0.039	372.11	0.000
		10	0.095	0.015	389.80	0.000
		11	0.107	0.042	411.90	0.000
		12	0.102	0.028	432.21	0.000
		13	0.066	-0.006	440.72	0.000
		14	0.053	-0.016	446.26	0.000
		15	0.041	-0.016	449.58	0.000
		16	0.097	0.052	467.86	0.000
		17	0.040	-0.018	470.96	0.000
		18	0.068	0.024	479.94	0.000
		19	0.063	0.014	487.77	0.000
		20	0.045	0.005	491.70	0.000

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General linear Process

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- **Why general linear p**
  - ▷ **Wold decompositi**variance stationary process can be expressed as a general linear process.

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$$y_t = \mu + \sum_{i=0}^{\infty} b_i \epsilon_{t-i}, \epsilon_t \sim WN(0, \sigma^2)$$

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  - Because $b_i \to 0$ as $i \to \infty$,it is possible to use finite parameters to characterise CS time series. This leads to practical (parsimonious) models (ARMA).

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- **Will mainly consider the cases with iid WN in this topic, for which "conditional"="unconditional"**

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  - $E(\epsilon_t|\epsilon_{t-j}) = E(\epsilon_t)$ (ϵ_t is not predictable)
  - $Var(\epsilon_t|\epsilon_{t-j}) = Var(\epsilon_t)$ for all $j = 1, 2, , 3, \cdots$

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Conditional Expectat

- The general linear i.i.d WN:

$$y_t = \mu + \sum_{i=0}^{\infty} b_i \epsilon_{t-i}, \epsilon_t \sim WN(0, \sigma^2)$$

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- Let Ω_t be the information set based on

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$$\{y_t, y_{t-1}, \cdots, \epsilon_t, \epsilon t - 2, \cdots\}$$

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Conditional mean and variance of y_{t+h} for $h = 1, 2, \cdots$:

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- $E(y_{t+h}|\Omega_t) = \mu + \sum_{i=h}^{\infty} b_i \epsilon_{t+h-i}$,
- $Var(y_{t+h}|\Omega_t) = \sigma^2 \sum_{i=0}^{h-1} b_i^2$

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- What happens when $h \to \infty$?
  - ▷ Limited memory: info at t is not relevant to remote future.

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- $y_{t+h} = \mu + \underbrace{b_0\varepsilon_{t+h} + \cdots + b_{h-1}\varepsilon_{t+1}} + \underbrace{b_h\varepsilon_t + b_{h+1}\varepsilon_{t-1} + \cdots}_{\text{in } \Omega_t}$.
- $E(y_{t+h}|\Omega_t) = \mu + \sum_{i=0}^{\infty} b_{h+i}\varepsilon_{t-i}$,
- $\text{Var}(y_{t+h}|\Omega_t) = \sigma^2 \sum_{i=0}^{h-1} b_i^2$

ε_{t+1} = 1-step forecast error

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eg. When $h = 2$,

- $y_{t+2} = \mu + \underbrace{b_0\varepsilon_{t+2} + b_1\varepsilon_{t+1}}_{\text{not in } \Omega_t} + \underbrace{b_2\varepsilon_t + b_3\varepsilon_{t-1} + \cdots}_{\text{in } \Omega_t}$,

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- $E(y_{t+2}|\Omega_t) = \mu + b_2\varepsilon_t + b_3\varepsilon_{t-1} + \cdots$,
- $\text{Var}(y_{t+2}|\Omega_t) = \sigma^2(b_0^2 + b_1^2)$.

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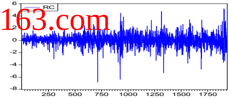

Conditional variance is smaller than unconditional variance. Variance being constant, not ideal to capture the **clustering** in return series. Need ARCH-type model.

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- Use the information Ω_t to forecast y_{t+h} for $h \geq 1$. Let $f_{t+h|t}$ be the forecast based on Ω_t.
- Choose $f_{t+h|t}$ to minimize the MSFE

$$\text{MSFE} = E[(y_{t+h} - f_{t+h|t})^2 | \Omega_t].$$

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- The optimal point forecast is

$$f^*_{t+h|t} = E(y_{t+h}|\Omega_t).$$

Forecast error:
$e_{t+h|t} = y_{t+h} - f^*_{t+h|t}$,
$\text{Var}(e_{t+h|t}|\Omega_t) = \text{Var}(y_{t+h}|\Omega_t)$.

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- If μ, b_i, σ^2 are known, the 2-se interval forecast is

$$E(y_{t+h}|\Omega_t) \pm 2\sqrt{\text{Var}(y_{t+h}|\Omega_t)} \quad \text{or}$$

$$\left(\mu + \sum_{i=h}^{\infty} b_i \varepsilon_{t+h-i}\right) \pm 2\left(\sigma^2 \sum_{i=0}^{h-1} b_i^2\right)^{1/2}.$$

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Summary: What to take from this lecture?

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1. White noise is the building block of time series models
2. In order to model the dynamics of a time series, use the white noise process to piece together the dynamics: GLP
3. GLP useful representation: compute expectations, variance and ACF
4. Special models: AR, MA

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