

Econometrics Cheat Sheet

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Data & Causality

Basics about data types and causality

Types of data

| | |
|-------------------------|--|
| Experimental | Data from randomized experiment |
| Observational | Data collected passively |
| Cross-sectional | Multiple units, one point in time |
| Time series | Single unit, multiple points in time |
| Longitudinal (or Panel) | Multiple units followed over multiple time periods |

Experimental data

- Correlation \neq Causality
- Very rare in Social Sciences

Statistics basics

We examine a random sample of data to learn about the population

| | |
|-----------------------------|---|
| Random sample | Representation of population |
| Parameter (θ) | Some number describing population |
| Estimator of θ | Rule assigning value of $\hat{\theta}$ to sample e.g. Sample average, $\bar{Y} = \frac{1}{N} \sum_{i=1}^N Y_i$ |
| Estimate of θ | What the estimator spits out for a particular sample ($\hat{\theta}$) |
| Sampling distribution | Distribution of estimates across all possible samples |
| Bias of estimator \hat{W} | $E(\hat{W}) - \theta$ |
| Efficiency | \hat{W} efficient if $\text{Var}(\hat{W}) < \text{Var}(\hat{W}')$ |
| Consistency | \hat{W} consistent if $\hat{\theta} \rightarrow \theta$ as $N \rightarrow \infty$ |

Hypothesis testing

The way we answer yes/no questions about our population using a sample of data, e.g. "Does increasing public school spending increase student achievement?"

| | |
|---------------------------------|--|
| null hypothesis (H_0) | Typically, $H_0: \theta = 0$ |
| alt. hypothesis (H_A) | Typically, $H_A: \theta \neq 0$ |
| significance level (α) | Tolerance for making Type I error; (e.g. 10%, 5%, or 1%) |
| test statistic (T) | Some function of the sample of data |
| critical value (c) | Value of T such that reject H_0 if $ T > c$ c depends on α |
| p -value | c depends on if 1- or 2-sided test Largest α at which fail to reject H_0 ; reject H_0 if $p < \alpha$ |

Simple Regression Model

Regression is useful because we can estimate a ceteris paribus relationship between some variable x and our outcome y

$$y = \beta_0 + \beta_1 x + u$$

We want to estimate $\hat{\beta}_1$, which gives us the effect of x on y .

OLS formulas

To estimate $\hat{\beta}_0$ and $\hat{\beta}_1$, we make two assumptions:

1. $E(u) = 0$
2. $E(xu) = E(x)E(u)$ for all x

When these hold, we get the following formulas:

$$\hat{\beta}_0 = \bar{y} - \hat{\beta}_1 \bar{x}$$

$$\hat{\beta}_1 = \frac{\text{Cov}(y, x)}{\text{Var}(x)}$$

| | |
|---------------------------------|---|
| Best values ($\hat{\beta}_0$) | $\hat{\beta}_0 = \bar{y} - \hat{\beta}_1 \bar{x}$ |
| residuals (\hat{u}_i) | $\hat{u}_i = y_i - \hat{y}_i$ |
| Total Sum of Squares | $TSS = \sum_{i=1}^N (y_i - \bar{y})^2$ |
| Expl. Sum of Squares | $ESS = \sum_{i=1}^N (\hat{y}_i - \bar{y})^2$ |
| Resid. Sum of Squares | $RSS = \sum_{i=1}^N \hat{u}_i^2$ |
| R-squared (R^2) | $R^2 = \frac{ESS}{TSS}$ "frac. of var. in y explained by x " |

Algebraic properties of OLS estimates

- $\sum_{i=1}^N \hat{u}_i = 0$ (mean & sum of residuals is zero)
- $\sum_{i=1}^N x_i \hat{u}_i = 0$ (zero covariance bet. x and residuals)
- The OLS line (SRF) always passes through (\bar{x}, \bar{y})
- $ESS + RSS = TSS$
- $0 \leq R^2 \leq 1$

Interpretation and functional form

- Our model is restricted to be linear in parameters
- But not linear in x
- Other functional forms can give more realistic model

| Model | DV | RHS | Interpretation of $\hat{\beta}_1$ |
|-------------|-----------|-----------|--|
| Level-level | y | x | $\Delta y = \hat{\beta}_1 \Delta x$ |
| Level-log | y | $\log(x)$ | $\Delta y = (\hat{\beta}_1 / 100) (\% \Delta x)$ |
| Log-level | $\log(y)$ | x | $\% \Delta y = (100 \hat{\beta}_1) \Delta x$ |
| Log-log | $\log(y)$ | $\log(x)$ | $\% \Delta y = \hat{\beta}_1 \% \Delta x$ |
| Quadratic | y | $x + x^2$ | $\Delta y = (\hat{\beta}_1 + 2\hat{\beta}_2 x) \Delta x$ |

Note: DV = dependent variable; RHS = right hand side

Multiple Regression Model

Multiple regression is more useful than simple regression because we can more plausibly estimate ceteris paribus relationships (i.e. $E(y|x) = E(y)$ is more plausible)

$$y = \beta_0 + \beta_1 x_1 + \dots + \beta_k x_k + u$$

$\hat{\beta}_1, \dots, \hat{\beta}_k$: partial effect of each of the x 's on y

$$\hat{\beta}_0 = \bar{y} - \hat{\beta}_1 \bar{x}_1 - \dots - \hat{\beta}_k \bar{x}_k$$

$$\hat{\beta}_1 = \frac{\text{Cov}(y, \text{residualized } x_1)}{\text{Var}(\text{residualized } x_1)}$$

where "residualized x_j " means the residuals from OLS regression of x_j on all other x 's (i.e. $x_1, \dots, x_{j-1}, x_{j+1}, \dots, x_k$)

Gauss-Markov Assumptions

1. y is a linear function of the x 's
2. y and x 's are randomly sampled from population
3. No perfect multicollinearity
4. $E(u|x_1, \dots, x_k) = E(u) = 0$ (Zero conditional mean)
5. $\text{Var}(u|x_1, \dots, x_k) = \text{Var}(u) = \sigma^2$ (Homoskedasticity)

When (1)-(4) hold: OLS is unbiased, i.e. $E(\hat{\beta}_j) = \beta_j$

When (1)-(5) hold: OLS is Best Linear Unbiased Estimator

Variance of u (a.k.a. "error variance")

$$\sigma^2 = \frac{RSS}{N - K - 1}$$

$$= \frac{1}{N - K - 1} \sum_{i=1}^N \hat{u}_i^2$$

Variance and Standard Error of $\hat{\beta}_j$

$$\text{Var}(\hat{\beta}_j) = \frac{\sigma^2}{\text{SST}_j(1 - R_j^2)}, \quad j = 1, 2, \dots, k$$

where

$$\text{SST}_j = (N - 1) \text{Var}(x_j) = \sum_{i=1}^N (x_{ij} - \bar{x}_j)^2$$

$R_j^2 = R^2$ from a regression of x_j on all other x 's

Standard deviation: $\sqrt{\text{Var}}$

Standard error: $\sqrt{\text{SE}}$

$$\text{se}(\hat{\beta}_j) = \sqrt{\frac{\sigma^2}{\text{SST}_j(1 - R_j^2)}}, \quad j = 1, \dots, k$$

Classical Linear Model (CLM)

Add a 6th assumption to Gauss-Markov:

- 6. u is distributed $N(0, \sigma^2)$

Need this to know what the distribution of $\hat{\beta}_j$ is. Otherwise, can't conduct hypothesis tests about the β 's

Testing Hypotheses about the β 's

Under A (1)-(6), can test hypotheses about the β 's

t-test for simple hypotheses

To test a simple hypothesis like

$$H_0: \beta_j = 0$$

$$H_A: \beta_j \neq 0$$

use a t-test:

$$t = \frac{\hat{\beta}_j - 0}{\text{se}(\hat{\beta}_j)}$$

where 0 is the null hypothesized value.

Reject H_0 if $p < \alpha$ or if $|t| > c$ (See: Hypothesis testing)

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web intermittent 7a for 10 sec max 5 watt exciter field dc resistance operating temperature 10 100 ohm 40 65 c voltage
regulation storage temperature 1 with 4 engine governing 40 80 c voltage build up dimensions residual voltage at avr
terminal 5 vac 25hz 97mm l 92mm w 39mm h external vr weight 100k ohm 1 2 watt 7

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web ea07 is a self excited analogue type automatic voltage regulator the sensing and power inputs are independent and
accept power input from the auxiliary winding the wide voltage adjustment range fulfills any voltage adjustment
requirements section 2 specification sensing input 4a 5 voltage 90 350 vac 1 phase frequency 50 60 hz

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web sensing power input voltage 160 260 vac 1 phase 2 wire frequency 50 60 hz selectable output voltage max 170 vdc 240 vac input current continuous 5a intermittent 7a for 10 sec resistance min 15 ohm max 100 ohm voltage regulation 1 with 4 engine governing

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web alternator its field is excited by the main exciter voltage v_e under no load it produces a voltage proportional to field current the no load transfer function is where t_{gf} generator field time constant the load causes a voltage drop which is a complex function of direct and quadrature axis currents

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web voltage regulation less than 0.5 with 4 engine speed governing environment operating temperature 40 to 60 c build up voltage storage temperature 40 to 85 c 4 vac 25 hz residual volts at power input terminal relative humidity max 95 vibration 5.5 gs 60 hz soft start ramp time 3 seconds 10 dimensions

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web stably turn the voltage adjustment clockwise to vdc with positive to f and negative to f in reach the required out voltage if there is an series with a current limiting resistor of 3.5 ohms external potentiometer turn the external 20 watt

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web connect a voltmeter to generator output voltage terminals start generator set and run on no load at nominal frequency 50 53hz or 60 63hz if the red led is illuminated refer to the under frequency roll off adjustment carefully turn volt trimmer clockwise until rated voltage is reached

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web ea63 5 is an automatic voltage regulator avr for amg synchronous generator industrial application series the avr is typically supplied by a single phase auxiliary winding wound into the stator slots it also can be supplied by permanent magnet generator Äpmg Åor phase voltage of main terminal 1 2 specification

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web 2 1 operating temperature 30 to 80 c 22 to 176 f 2 2 storage temperature 40 to 80 c 40 to 176 f 2 3 altitude less than 2600 meter 2 4 relative humidity 90 3 technical specification sensing input terminal v v for 220 vac 0 220 terminal v v for 400 vac 0 380 paralleling

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web from single up to three phase voltages and check the average voltage from y yy or wiring accordingly to the generator requirement or user preference the avr is equipped with adjustable under frequency protection and over voltage protection to prevent generator from overloading and over excitation

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