

# Econometrics Cheat Sheet

by Tyler Ransom, University of Oklahoma  
tjr@ou.edu

## 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 ( $\theta$ )	Some number describing population
Estimator of $\theta$	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 $\theta$	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 ( $\alpha$ )	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 $\alpha$
$p$ -value	$c$ depends on if 1- or 2-sided test Largest $\alpha$ 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  $\beta$ 's

## Testing Hypotheses about the $\beta$ 's

Under A (1)-(6), can test hypotheses about the  $\beta$ '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)

# Econometrics Study Guide

**J Elliott**



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