

# Econometric Methods

Manisha Sharma

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# Sample Preview of The Chapter

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# ECONOMETRIC METHODS

## BASIC ECONOMETRIC THEORY

1

## Introduction to Econometrics

### INTRODUCTION

Econometrics is the result of a certain outlook on the role of economics, consists of the application of mathematical statistics to economic data to lend empirical support to the models constructed by mathematical economics and to obtain numerical results.

Economics has emerged as a specialized branch of economics. It may be defined as the social science in which the tools of economic theory, mathematics and statistical inference are applied to the analysis of economic phenomena.

Today, we would say that econometrics is the unified study of economic models, mathematical statistics, and economic data within the field of econometrics there are sub-divisions and specialization. Econometric theory concerns the development of tools and methods and the study of the properties of econometric methods.

Applied econometric is a term describing the development of quantitative economic models and the application of econometric methods of these models using economic data.

### CHAPTER AT A GLANCE

#### THE NATURE OF ECONOMETRICS

Econometrics means, "Economic Measurement". Although measurement is an important part of econometrics, the scope of econometrics is much broader.

Economic theory makes statements or hypotheses that are mostly qualitative in nature. For example,

microeconomic theory states that, other things remaining the same, a reduction in the price of a commodity is expected to increase the quantity demanded of that commodity. Thus, economic theory postulates a negative or inverse relationship between the price and quantity demanded of a commodity. But the theory itself does not provide any numerical measure of the relationship between the two *i.e.*, it does not tell by how much the quantity will go up or down as a result of a certain change in the price of the commodity.

The main concern of mathematical economics is to express economic theory in mathematical form without regard to measurability or mainly interested in the theory. Econometric is noted previously, is mainly interested in the empirical verification of economic theory. As we shall see the econometrician often uses the mathematical equations proposed by the mathematical economist puts these equations in such a form that they lend themselves to empirical testing. And this conversion of mathematical into econometric equations requires a great deal of ingenuity and practical skill.

The traditional or classical methodology, which still dominates empirical research in economics and other social and behavioural sciences. Traditional econometric methodology proceeds along the following lines:

- Statement of theory of hypothesis.
- Specification of the mathematical model of the theory.
- Specification of the statistical, or econometric model.

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- Obtaining the data.
- Estimation of the parameters of the econometric model.
- Hypothesis testing.
- Using the model for control or policy purpose.

**PROBABILITY DISTRIBUTION**

Galileo was the first Italian mathematician, who attempt at a quantitative measure of probability while dealing with some problems related to the theory of dice in gambling. But the first foundation of the mathematical theory of probability was laid in the mid-seventeenth century by two French mathematicians B Pascal and P Fermat, while solving a number of problems by French gambler and noble man Chevalier De-Mere to Pascal.

Russian mathematician also have made very valuable contributions to the modern theory of probability. In this section we shall explain the various term which are used in the definition of probability under different approaches.

**Random Experiment:** If in each trial of an experiment conducted under identical conditions, the outcome is not unique, but may be any one of the possible outcomes then such an experiment is called a random experiment.

**Outcome:** The result of a random experiment will be called an outcome.

**Trial and Event:** Any particular performance of a random experiment is called a trial and outcome or combination of outcomes are termed as events.

If the total number of possible outcomes of a random experiment is known as the exhaustive events or case.

If the number of cases favourable to an event in a trial is the number of outcomes which entail the happening of the event is called favourable events or cases.

**Mutually Exclusive Events:** Events are said to be mutually exclusive or incompatible if the happening of any one of them precludes the happening of all the other *i.e.*, if no two or more of them can happen simultaneously in the same trial.

**Probability Function:** P(A) is the probability function defined on a field B of events if the following properties exists:

- (i)  $\forall A \in B, P(A) \geq 0$ . It is called property of non-negativity.
- (ii)  $P(S) = 1$ . It is called property of certainty.
- (iii) If  $\{A_n\}$  is any finite or infinite sequence of disjoint events in B, then

$$P\left(\bigcup_{i=1}^n A_i\right) = \sum_{i=1}^n P(A_i).$$

It is called property of additivity.

**Distribution Function**

Let  $x$  be a random variable. The function  $F$  defined  $\forall x$  by  $F(x) = P(X \leq x) = P\{\omega: X(\omega) \leq x\}, -\infty < x < \infty$  is called the distribution function of the random variable.

**Remark:** (i) If  $F$  is the distribution function of random variable  $X$  and if  $a < b$ , then

$$P(a < x \leq b) = F(b) - F(a)$$

(ii) If  $F$  is the distribution function of one dimensional random variable  $X$  then.

$$\rightarrow 0 \leq F(x) \leq 1$$

$$\rightarrow F(x) \leq F(y) \text{ if } x < y$$

(iii) All distribution functions are monotonically non-decreasing and lie between 0 and 1.

**Discrete Probability Distribution**

A real valued function defined on a discrete sample space is called a discrete random variable.

If  $X$  is a discrete random variable with distinct values  $x_1, x_2, \dots, x_n, \dots$  then the function

$$P(x) = \begin{cases} P(X = x_i) = P_i & \text{if } x = x_i \\ 0 & \text{if } x \neq x_i \end{cases}$$

Where,  $i = 1, 2, 3, \dots$

**Remark:** (i)  $0 \leq F(x) \leq 1, -\infty < x < \infty$

(ii)  $F(x)$  is non-decreasing function of  $x$ .

(iii)  $F(x)$  is continuous function of  $x$  on the right.

(iv) The discontinuity of  $F(x)$  are at the most countable.

**Binomial Distribution**

Binomial distribution was discovered by James Bernoulli in the year 1700 and was first published posthumously in 1713, eight year after his death.

A random variable  $X$  is said to follow binomial distribution if it assumes only non-negative values and its probability mass function is given by:

$$P(X = x) = P(x) = \begin{cases} \binom{n}{x} p^x q^{n-x}; & x = 0, 1, 2, \dots; q = 1 - p \\ 0 & \text{Otherwise} \end{cases}$$

**Remark:** (i) The two independent constants  $n$  and  $p$  in the distributions are known as the parameters of the distribution. ' $n$ ' is also sometimes known as the degree of the binomial distribution.

(ii) This experiment consists of a sequence of  $n$  repeated trials.

(iii) Each trial result in an outcome that may be classified either as a success or a failure is called the probability mass function of random variable of  $X$ .

**Remark:** (i) Here, the number  $p(x); i = 1, 2, 3, \dots$  must satisfy the following conditions:

(a)  $P(x_i) \geq 0 \quad \forall i$

(b)  $\sum_{i=1}^{\infty} P(x_i) = 1$

(ii) The set of values which X takes is called the spectrum of the random variable.

**Continuous Probability Distribution**

A random variable is said to be continuous when its different values cannot be put in one-one correspondence with a set of positive integers. A continuous random variable is a random variable that (at least conceptually) can be measured to any desired degree of accuracy.

If X is a continuous random variable with the p.d.f.

$f(x)$ , then the function  $F_x(x) = P(X \leq x) = \int_{-\infty}^x f(t) dt$ ;

$-\infty < x < \infty$  is called the continuous distribution function.

**Normal Distribution:** The normal distribution was first distribution in 1733 by English mathematician De-Moivre who obtained this continuous distribution as a limiting case of the binomial distribution and applied it to problems arising in the game of chance.

A random variable X is said to have a normal distribution with parameter  $\mu$  and  $\sigma^2$ , if its p.d.f. is given by the probability law:

$$f(x; \mu, \sigma) = \frac{1}{\sigma \sqrt{2\pi}} \exp \left\{ -\frac{1}{2} \left( \frac{x - \mu}{\sigma} \right)^2 \right\}$$

$$\Rightarrow f(x; \mu, \sigma) = \frac{1}{\sigma \sqrt{2\pi}} e^{-(x-\mu)^2/\sigma^2}; -\infty < x < \infty,$$

$-\infty < \mu < \infty, \sigma > 0$

Where  $\mu$  = Mean

$\sigma^2$  = Variance

**Remark:** (i) When random variable is normally distribution with mean  $\mu$  and standard deviation  $\sigma$ , it is customary to write X is distributed as  $N(\mu, \sigma^2)$  i.e.,  $X \sim N(\mu, \sigma^2)$ .

(ii) The p.d.f. of standard normal variable Z is given by:

$\phi(Z) = \frac{1}{\sqrt{2\pi}} e^{-z^2/2}$ ,  $-\infty < z < \infty$  and the

corresponding distribution function, defined by  $\Phi(z)$  is given by:

$$\Phi(Z) = P(Z \leq z) = \int_{-\infty}^z \phi(u) du = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^z e^{-u^2/2} du$$

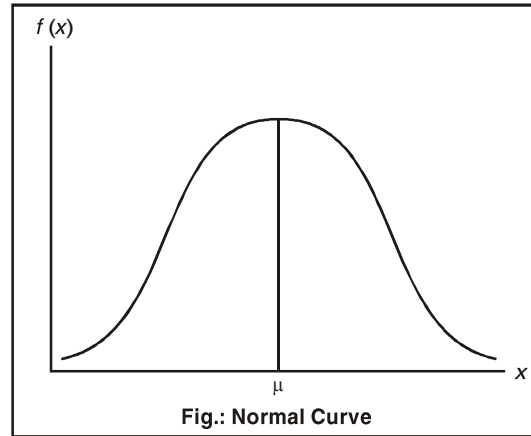


Fig.: Normal Curve

**The Student's-t Distribution**

W.S. Gosset, who wrote under Pseudonym (pen-name) of student defined his  $t$  in a slightly different way viz,  $t = (\bar{x} - \mu) / s$  and investigated its sampling distribution, some what empirically in a paper entitled 'The Probable Error of the Mean' published in 1908. Professor R.A. Fisher later on defined his own ' $t$ ' and gave a rigorous proof for its sampling distribution in 1926. The salient feature of ' $t$ ' is that both the statistic and its sampling distribution are functionally independent of  $\sigma$ , the population standard deviation.

Let  $x_i (i=1, 2, 3, \dots, n)$  be a random sample of size  $n$  from a normal population with  $\mu$  and variance  $\sigma^2$ . There the student's -  $t$  distribution is defined by:

$$t = \frac{\bar{x} - \mu}{s / \sqrt{n}}$$

Where  $\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$ , is the sample mean and

$s^2 = \frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2$ , is an unbiased estimate of the population variance  $\sigma^2$ , and it follows student's  $t$ -distribution with  $(n-1)$  d. f. with probability density function.

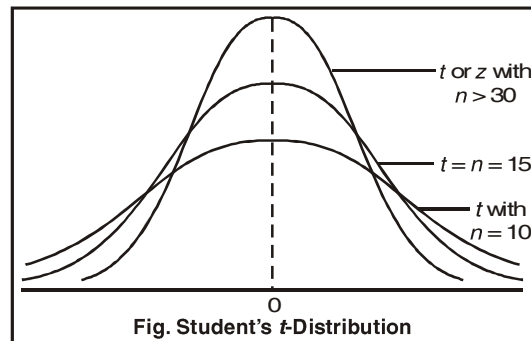


Fig. Student's t-Distribution

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**Chi-Square Distribution**

The square of a standard normal variate is known as a Chi-square variate with degree of freedom is 'one'.

Thus if  $X \sim N(\mu, \sigma^2)$ , then  $Z = \frac{X - \mu}{\sigma} \sim N(0,1)$  and  $Z^2$

$= \left(\frac{X - \mu}{\sigma}\right)^2$  is a Chi-square variate with 'one' degree of freedom.

In general if  $X_i, (i = 1, 2, 3, \dots, n)$  are  $n$  independent normal variates with means  $\mu$  and variance  $\sigma_i^2, (i = 1,$

$2, 3, \dots, n)$  then  $\chi^2 = \sum_{i=1}^n \left(\frac{X_i - \mu_i}{\sigma_i}\right)^2$ , is a Chi-square variate with 'n' degree of freedom.

**Remark:** (i) If a random variable has a Chi-square distribution with degree of freedom 'n' we write  $X \sim \chi^2_{(n)}$  and its p.d.f.

$$f(x) = \frac{1}{2^{n/2} \sqrt{(n/2)}} e^{-x/2} x^{(n/2)-1}; 0 \leq x < \infty$$

(ii) If  $X \sim \chi^2_{(n)}$ , then  $\frac{1}{2} X \sim \chi\left(\frac{1}{2} n\right)$

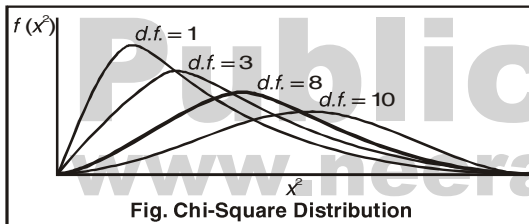


Fig. Chi-Square Distribution

**F-Distribution:** If  $Z_1$  and  $Z_2$  are two independent Chi-square variates with  $k_1$  and  $k_2$  d.f. respectively, then F-statistic is defined by:

$$F = \frac{Z_1 / k_1}{Z_2 / k_2}$$

In other words, F is defined as the ratio of two independent Chi-square variates divided by their respective degree of freedom and it follows Snedecor's F-distribution with  $(k_1, k_2)$  d.f. with probability function given by:

$$f(F) = \frac{\left(\frac{k_1}{k_2}\right)^{k_1/2}}{B\left(\frac{k_1}{2}, \frac{k_2}{2}\right)} \cdot \frac{F^{k_1/2 - 1}}{\left(1 + \frac{k_1}{k_2} F\right)^{(k_1 + k_2)/2}}, \quad 0 \leq F < \infty.$$

**Remark:** (i) A statistic F following Snedecor's F-distribution with  $(k_1, k_2)$  d.f. will be denoted by  $F \sim F(k_1, k_2)$

(ii) The sampling F-distribution does not involve any population parameters and depends only on the degree of freedom  $k_1$  and  $k_2$ .

**SAMPLING DISTRIBUTION**

Before giving the notation of sampling we will first define population. In an econometric investigation the interest usually lies in the assessment of the general magnitude and the study of variation with respect to one or more characteristics relating to individuals belonging to a group. This group of individuals under study is called population or universe. Thus, in statistics population is an aggregate of objects animate or inanimate under study. The population may be finite or infinite.

If the population is infinite complete enumeration is not possible. Also if the units are destroyed in the course of inspection, 100% inspection, though possible is not at all desirable. But even if the population is finite on the inspection is not destructive, 100% inspection is not taken recourse to because of multiplicity of causes, viz, administrative and financial implication, time factor, etc., and we take the help of sampling.

A finite subset of statistical individuals in a population is called a sample and the number of individual in a sample is called the sample size.

For the purpose of determining population characteristics instead of enumerating the entire population, the individuals in the sample only are observed. Then the sample characteristics are utilised to approximately determine or estimate the population. For example, on examining the sample of a particular stuff we arrive at a decision of purchasing or rejecting that stuff. The error involved in such approximation is known as sampling error and is inherent and unavoidable in any and every sampling scheme.

There are four types of sampling is:

- (i) Purposive Sampling
- (ii) Random Sampling.
- (iii) Stratified Sampling
- (iv) Systematic Sampling.

**STATISTICAL INFERENCE**

Let us consider a random variable X with p.d.f.  $f(x, \theta)$ . In most common applications, though not always, the function form of the population distribution is assumed to be known except for the value of some unknown parameter (s)  $\theta$  which may take any value on a set  $\Theta$ . This is expressed by writing the p.d.f in the form  $f(x, \theta), \theta \in \Theta$ . The set  $\Theta$ , which is the set of all possible values of  $\theta$  is called the parameter space.