

## 2 Introduction to Regression Analysis

### Basic Concept

1. Regression Analysis is a process of estimating the functional relationship between a random variable  $Y$  (called *dependent variable*) and one or more other *non-random* variables  $X$ s (called *independent variables*).
2. In regression analysis, we assume that the relationship between the dependent variable  $Y$  and the independent variables  $X$ s is linear, as in the following form:

$$Y = \beta_0 + \beta_1 X_1 + \dots + \beta_k X_k + \varepsilon \quad (1)$$

3. If equation (1) above involves only one independent variable (i.e.,  $Y = \beta_0 + \beta_1 X_1 + \varepsilon$ ), it is called a *simple regression* model. If it involves more than one independent variable, it is referred to as a *multiple regression* model.
4. In equation (1) above, we assume that all  $X$ s are independent (uncorrelated) and, in addition, the values of  $X$ s are given constants (not random variables). The *random errors*,  $\varepsilon$ 's (epsilons), are assumed to be independently and normally distributed with mean equal to zero and a constant (but unknown) variance  $\sigma^2$ . With these assumptions, the expected value of  $Y$  is:

$$E(Y) = E(\beta_0 + \beta_1 X_1 + \dots + \beta_k X_k + \varepsilon) = \beta_0 + \beta_1 X_1 + \dots + \beta_k X_k \quad (2)$$

5. Since the coefficients ( $\beta$ 's) of equation (1) are unknown, we need to make estimations based on the data collected for  $X$  and  $Y$ . In Regression Analysis, the method used to estimate these coefficients is called "*the least squares method*" – so called because the resulting mathematical function (called the *least squares equation*, *least squares line*, or simply *regression line*) has the smallest sum of squared estimation errors (minimum SSE). The least squares equation can be written as:

$$\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \dots + \hat{\beta}_k x_k \quad (3)$$

where  $\hat{y}$  (the fitted value of  $y$ ) is used to estimate  $E(y)$ , and  
 $\hat{\beta}_i$  (the fitted values of  $\beta_i$ ) is used to estimate  $\beta_i$ .

Note that  $\hat{\beta}_i$  are obtained by solving the following  $k + 1$  equations (called *normal equations*) simultaneously:

$$\frac{\partial}{\partial \beta_i} \sum_{i=1}^n (y_i - \hat{y}_i)^2 = \frac{\partial}{\partial \beta_i} \sum_{i=1}^n (y_i - \hat{\beta}_0 - \hat{\beta}_1 x_{i1} - \dots - \hat{\beta}_k x_{ik})^2 = 0 \quad i = 0, \dots, k \quad (4)$$

6. If all assumptions mentioned above hold, the sample statistics such as  $\hat{\beta}_i$  will hold some important properties that allow us to perform statistical analysis on the regression model obtained.

# Regression Analysis Basic Concepts

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