the random error term. OLS estimates of such a model produce biased estimates, and the extent of the bias is called *simultaneity bias*. The implications of simultaneity were recognized long before the estimation methods were devised. Within the regression analysis context, the identification problem has another dimension—that is, whether the difficulty in determining a variable is truly random or not. Moreover, a more serious fundamental question that arises is whether the parameters of a model are estimable.

SEE ALSO Causality; Censoring, Left and Right; Censoring, Sample; Frequency Distributions; Galton, Francis; Identification Problem; Linear Regression; Logistic Regression; Multicollinearity; Ordinary Least Squares Regression; Pearson, Karl; Probabilistic Regression; Probability; Regression; Regression Towards the Mean; Serial Correlation; Specification Error; Specification Tests; Student's T-Statistic; Test Statistics; Tobit

**BIBLIOGRAPHY**


**REGRESSION TOWARDS THE MEAN**

Regression towards the mean is a fundamental yet at first sight puzzling statistical phenomenon occurring between data from two variables, and it is a natural and inherent consequence of correlation being generally imperfect.

The effect of regression towards the mean was recognized in the late nineteenth century by Francis Galton (1822–1911) when investigating the relationship of the heights of parents and their adult children (see Bland and Altman 1994, Stigler 1986). Such height data are positively correlated; tall parents tend to produce tall adult children.

The diagram shows an ellipse that represents a cloud of correlated data points. The X and Y values are assumed for simplicity here to have equal mean and equal standard deviation. The X and Y values for Galton would be parent’s height and adult offspring’s height, but they could be any correlated variables, for example a measure of crime...
on some scale, for a sample of areas at one time, \( X \), and at a later time, \( Y \). The tilt of the ellipse shows that high values earlier are associated with high values later and vice versa; that is, positive correlation exists. Also on the diagram is the line of equality going diagonally bottom left to top right along the major axis of the ellipse. (Equality means that its slope = 1). Any point below this line indicates that the value of \( Y \) is smaller than that of \( X \), whereas a point above indicates that it is greater. If correlation was perfect, the ellipse would narrow and become identical with the line of equality.

Also on the diagram is a line of shallower slope that gives the mean of \( Y \) for a given \( X \). This is the conditional mean of \( Y \). One can see that the conditional mean of \( Y \) given \( X \) is not the line of equality, because taking a vertical slice through the ellipse shows that the bulk of the distribution lies above the line of equality for an \( X \)-value below the mean of \( X \), whereas it is below the line for an \( X \)-value above the mean of \( X \). In fact, the line of the conditional mean for the situation described is, that is, with standard deviations of \( X \) and \( Y \) equal, has a slope equal to the (Pearson) correlation coefficient. Therefore, the expected \( Y \)-value for a given \( X \)-value, in other words the conditional mean, is above the line of equality for \( X \) below the mean of \( X \), and below the line of equality for \( X \) above its mean. Therefore, there is a tendency for values to be closer to the overall \( Y \)-mean, the effect being greater the weaker the correlation is.

This is precisely what Galton found: that the heights of adult children tended to be closer to the mean of the population than their parents’ heights were; that is, they regressed towards the mean. Note that this does not make every one the same height in the end—the distribution can remain stable generation after generation.

A similar situation applies in a more general case than that described when neither the means nor the standard deviations of \( X \) and \( Y \) variables are equal to each other, such as when successive generations are getting taller on average and becoming more variable in absolute terms, that is, in centimeters. In a more general case such as this the elliptical cloud of data points will be shifted up and will have greater vertical extension due to the greater standard deviation of the \( Y \) variable. The major axis of the elliptical cloud will no longer be the line of equality, but will still represent the line that the ellipse shrinks towards as the correlation becomes perfect. As in the earlier case, the line of conditional mean is still at a shallower slope than the major axis, and so the same effect occurs, that there is regression towards the mean such that the expected \( Y \)-value will be fewer \( Y \)-standard deviations from the \( Y \)-mean than the \( X \)-value is \( X \)-standard deviations from the \( X \)-mean. In fact, for an \( X \)-value \( Z_x \) standard deviations from the \( X \)-mean the expected \( Y \)-value will be “(1-correlation coefficient) multiplied by \( Z_x \)" standard deviations in \( Y \) from the major axis line, and equivalently only “correlation coefficient multiplied by \( Z_x \)" standard deviations in \( Y \) from the \( Y \)-mean. So, for example, if the \( X \)-value is 1.5 standard deviations above its mean and the correlation coefficient between \( X \) and \( Y \) is 0.2, then the expected \( Y \)-value is only 0.3 standard deviations above its mean, that is, 1.2 below the original number of standard deviations.

The statistical method of regression owes its name to the discovery by Galton of this effect. Indeed, the regression line is simply the line of the conditional mean, exactly as discussed above. It is a surprise to some that the regression line does not run along the major axis of the cloud of data points. The equation for the line of conditional mean can be determined mathematically (see, for example, Freund 2004, which treats the more general case).

A consequence of the effect of regression towards the mean is if an intervention is applied to a group with high values before, for example a bad state before, and the control is another with lower values, a better state before, one is likely to find that the intervention appears to work even if it really has no superior effect. This is because the expectation is that the higher measurements will become lower. It is therefore vital that comparison is made like with like.

While it is possible to envisage situations that are more complex than those described above, so that the conditional mean is consequently no longer a simple straight line, one should never assume that the effect described is nonexistent.

**BIBLIOGRAPHY**


REGRESSION TAXES
SEE Taxes, Regressive.

REGRET
SEE Farsightedness.

REGULATION
Regulation involves attempts by the government to monitor and correct any disorders in the workings of free markets. Formally, economic regulation refers to all types of taxes and subsidies as well as to governmental controls over prices, market entry, and other aspects of economic activity. Some regulation might directly impose monetary costs (e.g., taxes or fines on noncompliers), while other types of regulation might impose costs indirectly by mandating standards that might be costly to adhere to. Examples of regulation include limits on emissions from vehicles, fire-retardant materials used in children’s bedding, airline safety standards, smoking bans, food safety, and consumer protection laws.

While the extent of government intervention in economic activity remains a matter of heated debate, few individuals would argue for a complete absence of regulation. Two widely accepted issues deserving of regulation might be related to a country’s monetary system (smooth working of the banking system and the money supply) and national defense. These attempts might be focused on both buyers and sellers, or might be directed at one of the parties. Banking laws are examples of laws that affect both buyers and sellers, while regulations by the Occupational Safety and Health Administration (OSHA) can be viewed as aimed directly at sellers. The disorders or imperfections that regulation seeks to rectify might be related to prices (too high prices), quantity or service (not all customers being served), reliability (failure to adhere to schedules), and fairness, among other issues. In practice, common instances of regulation include promotion of competition, safeguarding the interests of buyers or sellers (or both), protecting the environment, and defending national interests. For instance, the Clayton Act and the Sherman Act are two primary laws in the United States that deal with provision of fair market competition.

HISTORICAL PERSPECTIVE
Historically speaking, regulations have changed over time with new technologies, new concerns, and new revelations (e.g., harmful environmental effects of certain known substances). Sometimes, however, certain unexpected events bring about a flurry of regulations (or deregulations) in a rather short period of time. Examples of such events include the Great Depression, the 1973 oil embargo, and certain natural calamities. The Great Depression prompted governments to better regulate their economies so they could prevent wide and sudden variations in the unemployment and inflation rates. In the United States, the Federal Reserve System, which governs the money supply and oversees the banking system, was a direct offshoot of the Great Depression. The oil embargo led to various regulations regarding oil conservation including provisions for minimum fuel efficiency on automobiles. Further, natural disasters such as hurricanes and earthquakes can lead to tougher building codes in vulnerable areas.

Governments generally set up regulatory agencies to impose and monitor regulations. These agencies usually have semi-autonomous status to keep them relatively free of political pressures, although in a number of instances the regulated agencies end up enforcing the regulations passed by the executive branch. These agencies might be national (Federal Communications Commission), or they may be sub-national (Illinois Commerce Commission). In some instances, cross-national organizations such as the World Bank and United Nations impose codes of conduct across nations. However, such regulations generally are difficult to enforce and are usually less effective.

THEORETICAL UNDERPINNINGS
The theoretical underpinnings of regulation may be understood in the context of the three widely cited theories of regulation: (1) public interest theory; (2) capture theory; and (3) economic theory of regulation. According to the public interest theory, regulation is supplied or enacted by governments to correct inefficient and/or unfair market practices or outcomes. However, this theory implicitly assumes that regulators have the capacity and the willpower to determine what is fair and efficient. Since the late twentieth century, the public interest theory has been somewhat revised to recognize that regulatory agencies themselves might be inefficient. It is also unclear from this theory how public interest matters take the form of legislation. The capture theory of regulation can be seen as drawing from both economics and political science. According to this theory, regulatory agencies over time tend to be dominated or influenced by the industries they...