Chapter 575

Probit Analysis

Introduction

Probit Analysis is a method of analyzing the relationship between a stimulus (dose) and the quantal (all or nothing) response. Quantitative responses are almost always preferred, but in many situations, they are not practical. In these cases, it is only possible to determine if a certain response (such as death) has occurred. In a typical quantal response experiment, groups of animals are given different doses of a drug. The percent dying at each dose level is recorded. These data may then be analyzed using Probit Analysis.

The Probit Model assumes that the percent response is related to the log dose as the cumulative normal distribution. That is, the log doses may be used as variables to read the percent dying from the cumulative normal. Using the normal distribution, rather than other probability distributions, influences the predicted response rate at the high and low ends of possible doses, but has little influence near the middle. Hence, much of the comparison of different drugs is done using response rates of fifty percent. The probit model may be expressed mathematically as follows:

$$P = \alpha + \beta[\log_{10}(Dose)]$$

where *P* is five plus the inverse normal transform of the response rate (called the Probit). The five is added to reduce the possibility of negative probits, a situation that caused confusion when solving the problem by hand.

The popularity of the method is due in large part to the work of Finney (1971), in his book Probit Analysis. He explains the proper use and analysis of quantal response data. In **NCSS**, we have coded the algorithms given in his book, and we refer you to it for further information and background.

Data Structure

The data below are suitable for analysis by this procedure. Note that the first variable, Dose, gives the dose level of the treatment. The second variable, Subjects, gives the number of individuals receiving a specific dose level. The third variable, Response, gives the number of treated individuals who exhibited the response of interest.

These data are contained on the Survival dataset.

Survival Dataset

Dose	Subjects	Response
50	102	19
60	121	26
70	111	24
80	105	31
90	117	54
100	108	83

Example 1 – Probit Analysis

This section presents an example of how perform a probit analysis using the data that were shown earlier and found in the Survival dataset.

Setup

To run this example, complete the following steps:

1 Open the Survival example dataset

- From the File menu of the NCSS Data window, select **Open Example Data**.
- Select **Survival** and click **OK**.

2 Specify the Probit Analysis procedure options

- Find and open the **Probit Analysis** procedure using the menus or the Procedure Navigator.
- The settings for this example are listed below and are stored in the **Example 1** settings file. To load these settings to the procedure window, click **Open Example Settings File** in the Help Center or File menu.

Variables Tab

R: Count Variable ..... **Response**
N: Sample Size Variable..... **Subjects**
X: Dose Variable..... **Dose**

3 Run the procedure

- Click the **Run** button to perform the calculations and generate the output.

Probit Estimation Section

Probit Estimation Section

Parameter	Estimate	Std. Error
Alpha	-4.545974	1.032341
Beta	4.901165	0.5483724
LD50	1.947695	0.01304145
Dose50	88.65325	2.662173

Alpha

The estimated value of the intercept, with its associated standard error.

Beta

The estimated value of the slope, with its associated standard error.

LD50

The estimated value, on the log10(dose) scale, at which 50% responded.

Dose50

The estimated value, on the dose scale, at which 50% responded.

Probit Detail Section

Probit Detail Section

Dose	Actual Percent	Probit Percent	N	R	E(R)	Difference	Chi-Square
50	18.63	11.14	102	19.00	11.36	7.64	5.77
60	21.49	20.30	121	26.00	24.56	1.44	0.11
70	21.62	30.75	111	24.00	34.14	-10.14	4.35
80	29.52	41.35	105	31.00	43.41	-12.41	6.05
90	46.15	51.28	117	54.00	60.00	-6.00	1.23
100	76.85	60.12	108	83.00	64.93	18.07	12.62

Overall Model Test

Total Chi-Square	30.13
D.F.	4
Prob Level	0.00

This report displays a table that would have been used if the calculations were carried out by hand. It is presented more for completeness than for any analytic purpose. It does, however, let you investigate the goodness-of-fit of the dose-response model to the data by considering the Chi-square values.

Dose

The dose level.

Actual Percent

The ratio of the count to the sample size (R/N).

Probit Percent

The estimated ratio (R/N) based on the probit model.

N

The sample size.

R

The count (number responding).

E(R)

The expected count based on the probit model.

Difference

The difference between the actual and the expected counts.

Chi-Square

The Chi-Square statistic for testing the significance (non-zero) of the difference. Since these are single degree of freedom tests, the value should be greater than 3.81 to be significant at the 0.05 level.

Total Chi-Square

The total of the Chi-Square values, used to test the overall significance of the differences from the model.

D.F.

The degrees of freedom of the Chi-Square test.

Prob Level

The probability to the right of the above Chi-Square value. The significance level of the Total Chi-Square test.

Dose Percentile Section

Dose Percentile Section

Percentile	Probit	Log(Dose)	Std. Error Log(Dose)	Dose	Std. Error Dose
1	2.6737	1.4730	0.0468	29.7196	3.2008
5	3.3551	1.6121	0.0318	40.9346	2.9993
10	3.7184	1.6862	0.0242	48.5530	2.7013
20	4.1584	1.7760	0.0158	59.7002	2.1685
25	4.3255	1.8101	0.0132	64.5768	1.9640
30	4.4756	1.8407	0.0115	69.2946	1.8364
40	4.7467	1.8960	0.0108	78.7052	1.9529
50	5.0000	1.9477	0.0130	88.6533	2.6622
60	5.2533	1.9994	0.0171	99.8587	3.9219
70	5.5244	2.0547	0.0222	113.4200	5.8064
75	5.6745	2.0853	0.0253	121.7063	7.0888
80	5.8416	2.1194	0.0288	131.6477	8.7309
90	6.2816	2.2092	0.0383	161.8727	14.2814
95	6.6449	2.2833	0.0463	191.9991	20.4873
99	7.3263	2.4223	0.0616	264.4519	37.5022

This report displays the dose levels yielding various predicted response rates.

Percentile

The response rate times 100.

Probit

The normal transform of the percentage plus five. (The five is added to avoid the possibility of a negative probit. This practice was helpful when calculations were done by hand, but is based solely on tradition now that calculations are carried out by computer.)

Log Dose

The logarithm of the dose level (base 10).

Std. Error Log(Dose)

The standard error of the estimated log dose level.

Dose

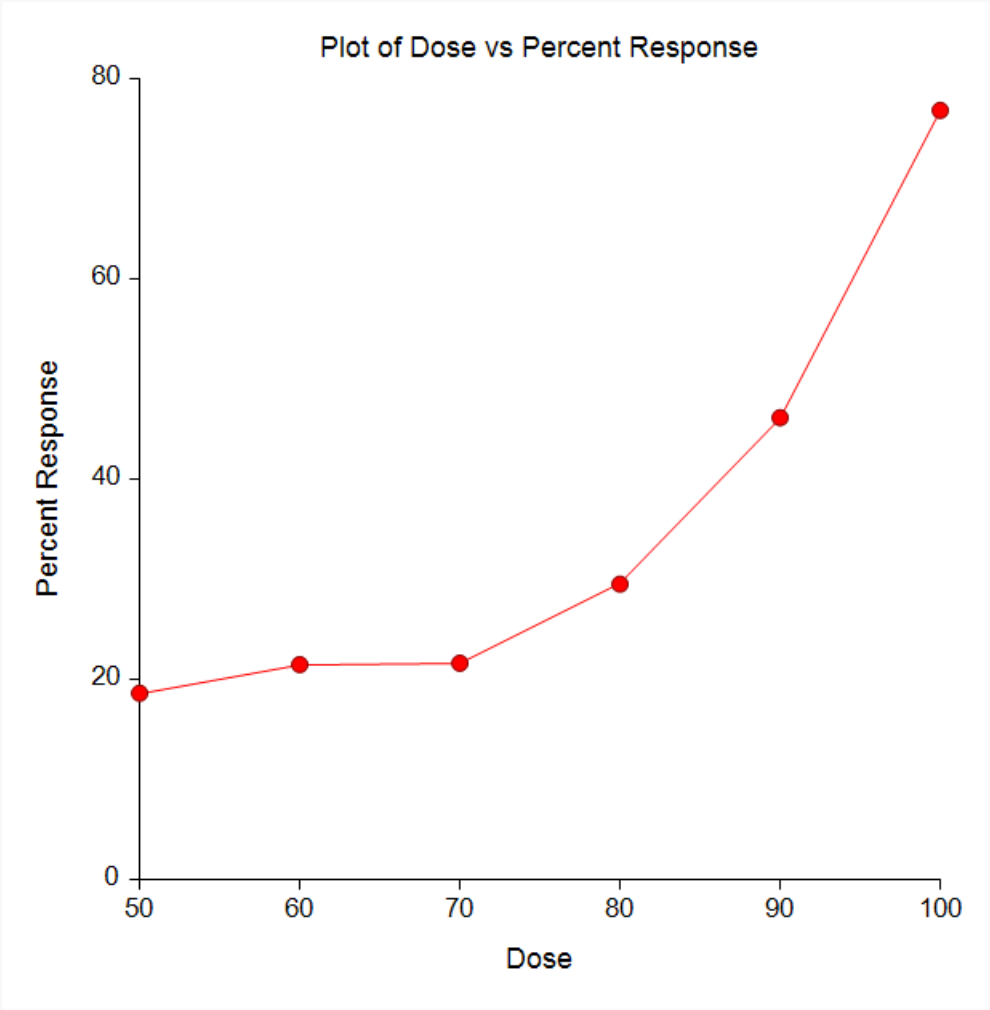
The dose level.

Std. Error Dose

The standard error of the estimated dose level.

Dose vs Response Plot

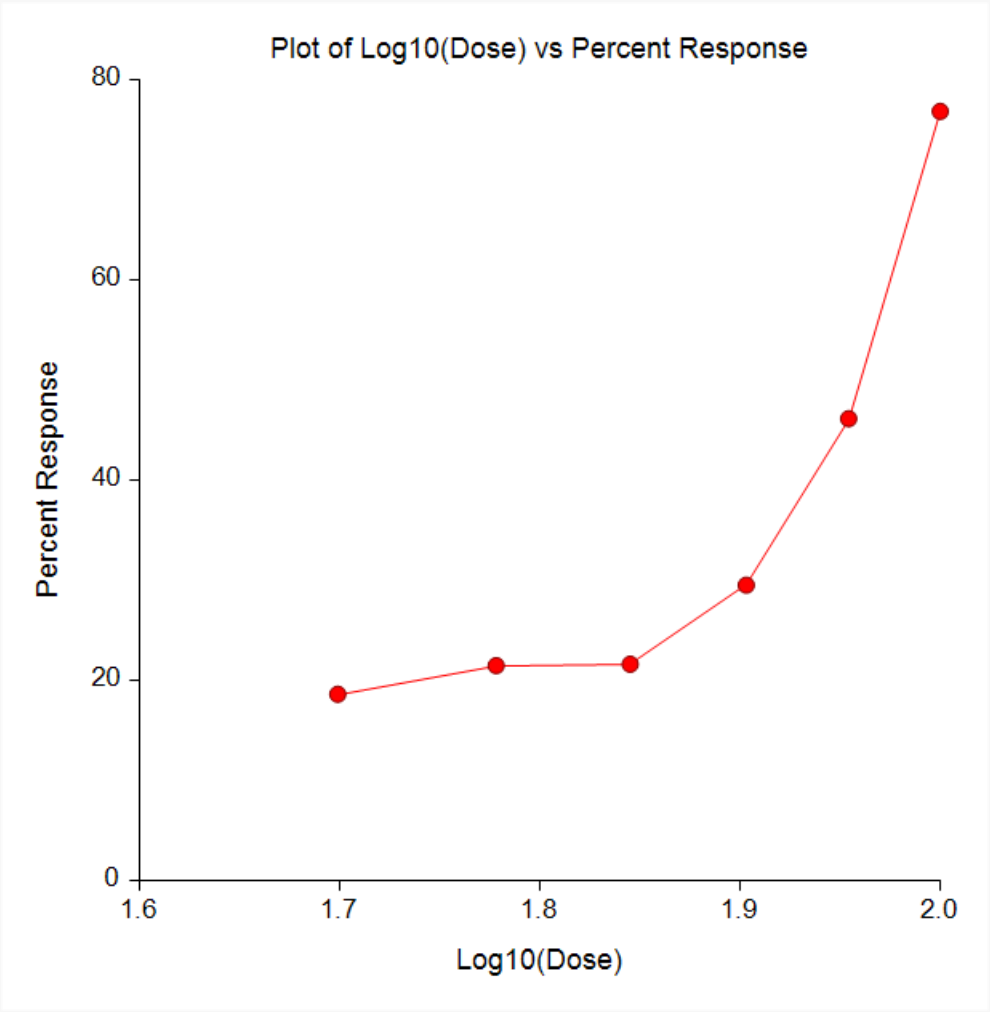
Dose vs Response Plot



This plot lets you look at the relationship between percent response and dose. Usually, this plot will be nonlinear.

Log(Dose) vs Response Plot

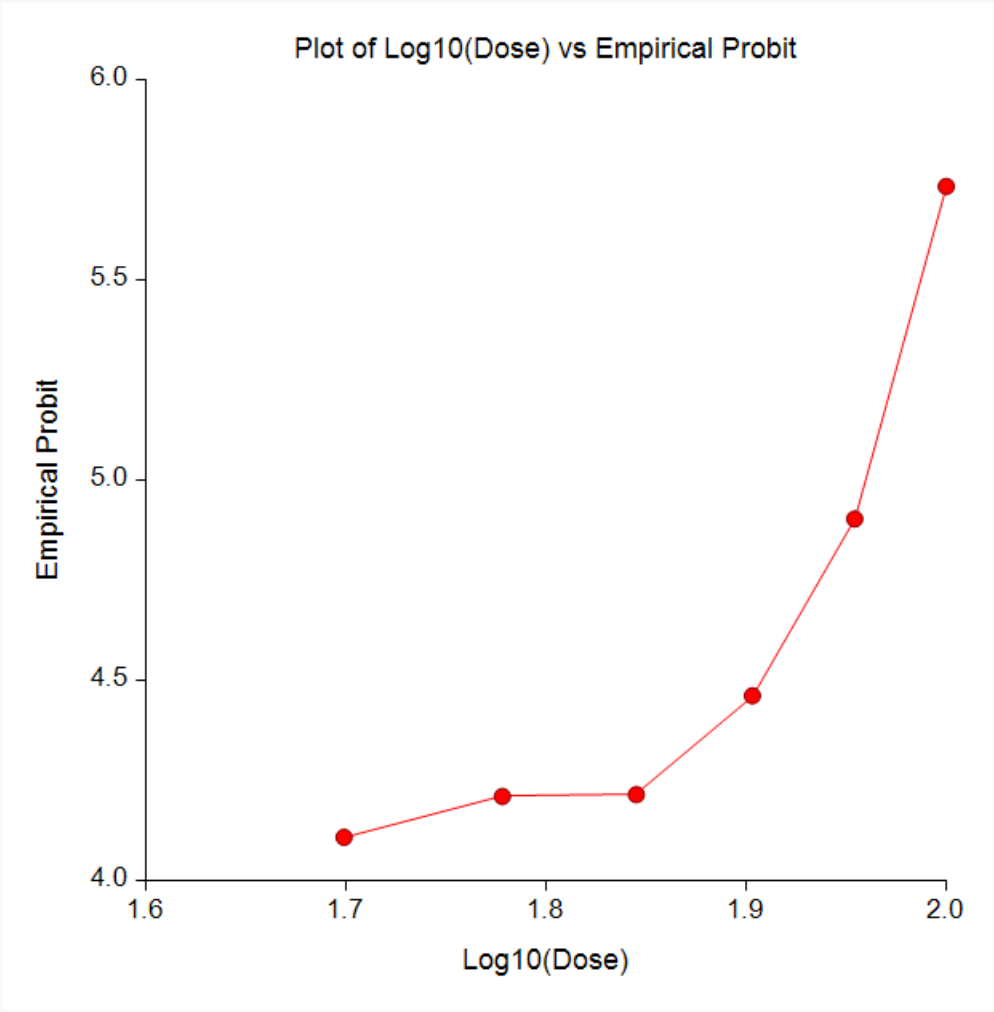
Log(Dose) vs Response Plot



This plot lets you look at the relationship between percent response and log dose. Usually, this plot will be nonlinear.

Log(Dose) vs Probit Plot

Log(Dose) vs Probit Plot



This plot presents the probit model. If the probit model is to be a good approximation, this plot should show a linear relationship. Obviously, in this example, the relationship is quadratic, indicating that the probit model should be modified--perhaps by using the square of Log dose.