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:

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

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

Procedure Options

This section describes the options available in this procedure.

Variables Tab

This panel specifies the variables used in the analysis.

Count Variable

R: Count Variable

This variable contains the number of individuals with the desired response. It must be less than the number of animals. The analysis adds one-half to zero and subtracts one-half if the R = N. This slight modification avoids division by zero in the calculations.

Sample Size Variable

N: Sample Size Variable

This is the variable containing the total number of individuals sampled at a particular dose level.

Dose Variable

X: Dose Variable

This option contains the name of the variable containing the dose levels. Note that the analysis uses the log (base 10) transformation of dose levels.

Group Variable

Group Variable

An optional categorical (grouping) variable may be specified. If it is used, a separate analysis is conducted for each unique value of this variable.

Reports Tab

The following options control the display of reports and plots.

Select Reports

Probit Estimation Report ... Dose Percentiles Report

These options specify whether to display the corresponding report.

Percentiles

A separate row in the Dose Percentile report is created for each percentage value given here. This is a list of numbers between 0 and 100 separated by blanks or commas.

Report Options

Precision

Specify the precision of numbers in the report. A single-precision number will show seven-place accuracy, while a double-precision number will show thirteen-place accuracy. Note that the reports are formatted for single precision. If you select double precision, some numbers may run into others. Also note that all calculations are performed in double precision regardless of which option you select here. This is for reporting purposes only.

Variable Names

This option lets you select whether to display only variable names, variable labels, or both.

Value Labels

This option lets you select whether to display only values, value labels, or both. Use this option if you want to automatically attach labels to the values of the group variable (like 1=Yes, 2=No, etc.). See the section on specifying Value Labels elsewhere in this manual.

Plots Tab

These options control the attributes of the corresponding plots.

Select Plots

Dose - Response Plot ... Probit Plot

These options specify whether to display the corresponding plot. Click the plot format button to change the plot settings.

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.

You may follow along here by making the appropriate entries or load the completed template **Example 1** by clicking on Open Example Template from the File menu of the Probit Analysis window.

1 Open the Survival dataset.

- From the File menu of the NCSS Data window, select **Open Example Data**.
- Click on the file **Survival.NCSS**.
- Click **Open**.

2 Open the Probit Analysis window.

- Using the Analysis menu or the Procedure Navigator, find and select the **Probit Analysis** procedure.
- On the menus, select **File**, then **New Template**. This will fill the procedure with the default template.

3 Specify the variables.

- On the Probit Analysis window, select the **Variables tab**.
- Double-click in the **R: Count Variable** box. This will bring up the variable selection window.
- Select **Response** from the list of variables and then click **Ok**.
- Double-click in the **X: Dose Variable** box. This will bring up the variable selection window.
- Select **Dose** from the list of variables and then click **Ok**.
- Double-click in the **N: Sample Size Variable** box. This will bring up the variable selection window.
- Select **Subjects** from the list of variables and then click **Ok**.

4 Run the procedure.

- From the Run menu, select **Run Procedure**. Alternatively, just click the green Run button.

Probit Estimation Section

Probit Estimation Section

Parameter	Estimate	Std. Error
Alpha	-4.545974	1.032341
Beta	4.901165	0.5483724
LD50	1.947695	1.304145E-02
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
						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

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.

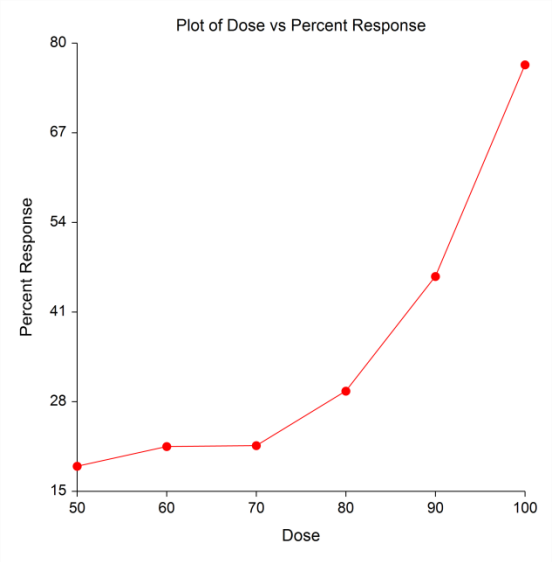
Dose

The dose level.

Std. Error Dose

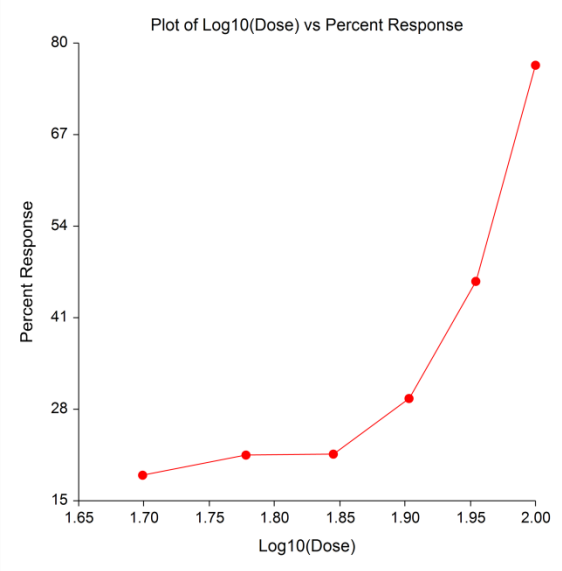
The standard error of the estimated dose level.

Dose-Response Plot



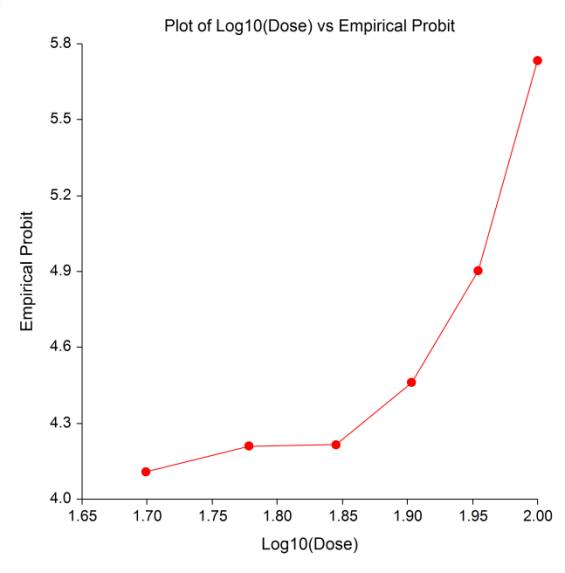
This plot lets you look at the relationship between percent response and dose. Usually, this plot will be nonlinear.

Log(Dose) - Response Plot



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

Log(Dose) - 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.