

## Chapter 743

# Superiority by a Margin Tests for Simple Linear Regression

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### Introduction

This procedure computes power and sample size for superiority by a margin tests of the slope in simple linear regression. Simple linear regression is a commonly used procedure in statistical analysis to model a linear relationship between a dependent variable  $Y$  and an independent variable  $X$ .

The details of sample size calculation for simple linear regression are presented in the *Non-Zero Null Tests for Simple Linear Regression* chapter and they will not be duplicated here. This chapter only discusses those changes necessary for superiority by a margin tests.

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### Difference between Simple Linear Regression and Correlation

The correlation coefficient is used when  $X$  and  $Y$  are from a bivariate normal distribution. That is,  $X$  is assumed to be a random variable whose distribution is normal. The values of  $X$  will not be known until the study is completed. In the simple linear regression context, no statement is made about the distribution of  $X$ . In fact,  $X$  does not have to be a random variable. In this procedure the distribution of  $Y$  is conditioned on  $X$ .

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### Fixed or Random $X$

Gatsonis and Sampson (1989) present power analysis results for two approaches: *unconditional* and *conditional*. This procedure provides a calculation for the *conditional* (fixed  $X$ ) approach.

The *unconditional* approach assumes that  $X$  is normally distributed and is based on the correlation coefficient. The normality assumption might occasionally be met, but not frequently. Our impression is that usually, the values of  $X$  will not be known at the planning stage and they will not follow (even approximately) the normal distribution. Hence, the only option available is to proceed with the sample size calculation using the *conditional* approach and then estimate the standard deviation of the  $X$ 's as best you can.

## Technical Details

Suppose that the dependence of a variable  $Y$  on another variable  $X$  can be modeled using the simple linear equation

$$Y = A + BX$$

In this equation,  $A$  is the  $Y$ -intercept,  $B$  is the slope,  $Y$  is the dependent variable, and  $X$  is the independent variable.

The nature of the relationship between  $Y$  and  $X$  is studied using a sample of  $N$  observations. Each observation consists of a data pair: the  $X$  value and the  $Y$  value. The values of  $A$  and  $B$  are estimated from these observations using the method of least squares. Using these estimated values, each data pair may be modeled using the equation

$$Y_i = a + bX_i + e_i$$

Note that  $a$  and  $b$  are the least squares estimates of the population parameters  $A$  and  $B$ . The  $e$  values represent the discrepancies between the estimated values ( $a + bX$ ) and the actual values  $Y$ . They are called the errors or residuals.

If it is assumed that these  $e$  values are normally distributed, tests of hypotheses about  $A$  and  $B$  can be constructed. Specifically, we can employ a T-test to test the superiority of  $B$  compared to a superiority boundary  $B_0$ .

## Linear Regression Slope T-Test Statistic

It is anticipated that a one-sided  $t$ -test of a regression coefficient will be used to conduct the test. Hence, the formula of the test statistic is

$$t_{N-2} = \frac{b - B_0}{s_b}$$

where  $N$  is the sample size,  $b$  is the estimate of  $B$ , and  $s_b$  is the standard error of  $b$ .

## The Statistical Hypotheses

Non-inferiority and superiority tests are examples of directional (one-sided) tests and their power and sample size could be calculated using the *Simple Linear Regression with a Non-Zero Null* procedure. However, at the urging of our users, we have developed this procedure which provides the input and output options that are convenient for superiority by a margin tests. This section will review the specifics of superiority by a margin testing.

Remember that in the usual simple linear regression setting, the null ( $H_0$ ) and alternative ( $H_1$ ) hypotheses for one-sided upper-tail tests are defined as

$$H_0: B \leq B_0 \quad \text{versus} \quad H_1: B > B_0$$

Rejecting  $H_0$  implies that the slope is larger than the value  $B_0$ . This test is called an *upper-tail test* because  $H_0$  is rejected in samples in which the sample slope is larger than  $B_0$ .

The corresponding *lower-tail test* is

$$H_1: B \geq B_0 \quad \text{versus} \quad H_1: B < B_0$$

*Superiority by a margin* tests are special cases of the above directional tests. It will be convenient to adopt the following specialize notation for the discussion of these tests.

## Superiority by a Margin Tests for Simple Linear Regression

| <u>Parameter</u> | <u>Interpretation</u>  |  |
|------------------|--|--|
| B                | <i>Population slope.</i>                                     | This parameter will be estimated using the method of least squares.  |
| B1               | <i>Actual population slope at which power is calculated.</i> | This is the assumed population slope used in all calculations.   |
| B0               | <i>Superiority Slope.</i>                                    | This is the smallest (or largest) value of the slope for which the new treatment will still be considered superior to the current treatment.   |
| B <sub>R</sub>   | <i>Reference value.</i>                                      | Usually, this is the slope in the reference population.  |
| SM               | <i>Margin of superiority.</i>                                | This is a tolerance value that defines the magnitude of slope that is not of practical importance. This may be thought of as the largest difference from the reference value that is considered to be trivial. |

### Superiority by a Margin Tests

A *superiority test* tests that the slope is better than that of the baseline (reference) population by more than a small margin. The actual direction of the hypothesis depends on the whether higher values of the response are good or bad.

#### Case 1: High Values Good

In this case, higher values are better. The hypotheses are arranged so that rejecting the null hypothesis implies that the slope is greater than a small amount above the reference value. Equivalent sets of the null and alternative hypotheses are

$$\begin{array}{lll}
 H_0: B \leq B_0 & \text{versus} & H_1: B > B_0 \\
 H_0: B \leq B_R + SM & \text{versus} & H_1: B > B_R + SM
 \end{array}$$

#### Case 2: High Values Bad

In this case, lower values are better. The hypotheses are arranged so that rejecting the null hypothesis implies that the mean of the treatment group is no more than a small amount above the reference value. Equivalent sets of the null and alternative hypotheses are

$$\begin{array}{lll}
 H_0: B \geq B_0 & \text{versus} & H_1: B < B_0 \\
 H_0: B \geq B_R - SM & \text{versus} & H_1: B < B_R - SM
 \end{array}$$

## Power Calculation of the Superiority Test of the Regression Coefficient, B

The following presentation is based on the standard results for a t-test as shown by Neter, Wasserman, and Kutner (1983) pages 71 and 72.

The power for a superiority test in which higher values of B are better is calculated as follows for a one-tailed test in which the statistical hypotheses are  $H_0: B \leq B_0$  vs.  $H_1: B > B_0$ .

1. Find  $t_{1-\alpha}$  such that  $T_{df}(t_{1-\alpha}) = 1 - \alpha$ , where  $T_{df}(x)$  is the area under a central- $t$  curve to the left of  $x$  and  $df = N - 2$ .
2. Calculate:  $X_0 = (t_{1-\alpha})\sigma_e/\sqrt{N}$ .
3. Calculate the noncentrality parameter:  $\lambda = \sqrt{N}(B_1 - B_0)\sigma_X/\sigma_e$ , where  $\sigma_X$  is the standard deviation of the X values in the regression and  $B_1$  is the slope at which the power is to be calculated.
4. Calculate:  $t_1 = (X_0 - (B_1 - B_0)\sigma_X\sqrt{N}/\sigma_e) + \lambda$ .
5. Power =  $1 - T'_{df,\lambda}(t_1)$ , where  $T'_{df,\lambda}(x)$  is the area to the left of  $x$  under a noncentral- $t$  curve with degrees of freedom  $df$  and noncentrality parameter  $\lambda$ .

The power for the case in which lower values of B are better is calculated using a test in which  $H_1: B < B_0$ .

The sample size can be easily found using a binary search with this power formula.

### Calculation of $\sigma_X$

The above calculation requires the value of  $\sigma_X$ , the (population) standard deviation of the X values in the regression analysis. Except for the occasional experimental design that includes a specification of the X values (e.g., doses), the specific X values are unknown in the planning phase. Hence, a reasonable estimate must be found. PASS includes a special tool called the *Standard Deviation Estimator* that will aid in your search for accurate estimates of this parameter.

The following table provides examples of typical data configurations and their corresponding standard deviations.

| $\sigma_X$ | X Values | $\sigma_X$ | X Values | $\sigma_X$ | X Values     | $\sigma_X$ | X Values         |
|------------|----------|------------|----------|------------|--------------|------------|------------------|
| 0.500      | 1, 2     | 0.816      | 1, 2, 3  | 1.118      | 1, 2, 3, 4   | 1.414      | 1, 2, 3, 4, 5    |
| 1.000      | 1, 3     | 1.633      | 1, 3, 5  | 2.236      | 1, 3, 5, 7   | 2.828      | 1, 3, 5, 7, 9    |
| 1.500      | 1, 4     | 2.449      | 1, 4, 7  | 3.354      | 1, 4, 7, 10  | 4.243      | 1, 4, 7, 10, 13  |
| 2.000      | 1, 5     | 3.266      | 1, 5, 9  | 4.472      | 1, 5, 9, 13  | 5.657      | 1, 5, 9, 13, 17  |
| 4.000      | 1, 9     | 6.532      | 1, 9, 17 | 8.944      | 1, 9, 17, 25 | 11.314     | 1, 9, 17, 25, 33 |

Because of the direct impact on the power and sample size, it will be important to spend some time determining appropriate values for this parameter.

One final note: when a basic pattern is repeated, its population standard deviation remains the same. For example, the standard deviation of the values 1, 2, 1, 2, 1, 2, 1, 2 is 0.5. This is also the standard deviation of 1, 2 or 1, 2, 1, 2.

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## Procedure Options

This section describes the options that are specific to this procedure. These are located on the Design tab. For more information about the options of other tabs, go to the Procedure Window chapter.

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### Design Tab

The Design tab contains most of the parameters and options that you will be concerned with.

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#### Solve For

##### Solve For

This option specifies the parameter to be solved for from the other parameters. Under most situations, you will select either *Power* for a power analysis or *Sample Size* for sample size determination.

Select *Sample Size* when you want to calculate the sample size needed to achieve a given power and alpha level.

Select *Power* when you want to calculate the power of an experiment.

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#### Superiority by a Margin Test

##### Higher Slopes Are

Use this option to specify whether higher values of B (slope) are interpreted to be *better* or *worse* than lower values. This in turn determines the direction of the hypothesis test.

- **Better**

If  $B_2 > B_3$ , then B2 is better than B3. The higher, the better. The statistical hypothesis tested is  $H_0: B \leq B_0$  vs.  $H_1: B > B_0$ .

- **Worse**

If  $B_2 < B_3$ , then B2 is better than B3. The lower, the better. The statistical hypothesis tested is  $H_0: B \geq B_0$  vs.  $H_1: B < B_0$ .

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#### Power and Alpha

##### Power

This option specifies one or more values for power. Power is the probability of rejecting a false null hypothesis, and is equal to one minus Beta. Beta is the probability of a type-II error, which occurs when a false null hypothesis is not rejected.

Values must be between zero and one. Historically, the value of 0.80 (Beta = 0.20) was used for power. Now, 0.90 (Beta = 0.10) is commonly used.

A single value may be entered here or a range of values such as *0.8 to 0.95 by 0.05* may be entered.

##### Alpha

This option specifies one or more values for the probability of a type-I error (alpha). A type-I error occurs when you reject the null hypothesis when in fact it is true.

Values of alpha must be between zero and one. Historically, the value of 0.05 has been used for alpha. This means that about one test in twenty will falsely reject the null hypothesis. You should pick a value for alpha that represents the risk of a type-I error you are willing to take in your experimental situation.

You may enter a range of values such as *0.01 0.05 0.10* or *0.01 to 0.10 by 0.01*.

## Superiority by a Margin Tests for Simple Linear Regression

### Sample Size

#### N (Sample Size)

Enter one or more values for the number of observations (e.g., subjects) in the study.

### Effect Size – Slope

#### B0 (Superiority Slope) when Higher is Better

Enter one or more values for B0, the superiority boundary in the case when higher slope values are desired.

Suppose  $B_R$  is the reference slope value. The superiority by a margin test requires us to state how much greater than  $B_R$  a slope must be so that we are willing to conclude that the slope value is superior to  $B_R$ . In this case,  $B_0 = B_R + |SM|$  where SM is the superiority margin.

$B_0$  is set to a value greater than  $B_R$  and the alternative hypothesis is that  $B > B_0$ .

The statistical hypotheses tested is  $H_0: B \leq B_0$  vs.  $H_1: B > B_0$ .

Note that neither  $B_R$  or SM is actually entered in the analysis.

For example, suppose  $B_R = 10$ . We might set  $B_0$  to 12 or 15.

#### Range

$B_0$  can be any value, positive or negative, so long as  $B_0 > B_R$ .

This value must be in the same scale as  $\sigma_x$ .

#### B0 (Superiority Slope) when Higher is Worse

Enter one or more values for B0, the superiority boundary in the case when lower slope values are desired.

Suppose  $B_R$  is the reference slope value. The superiority by a margin test requires us to state how much lower than  $B_R$  a slope must be so that we are willing to conclude that the slope value is superior to  $B_R$ . In this case,  $B_0 = B_R - |SM|$  where SM is the superiority margin.

$B_0$  is set to a value slightly less than  $B_R$  and the alternative hypothesis is that  $B < B_0$ .

The statistical hypotheses tested is  $H_0: B \geq B_0$  vs.  $H_1: B < B_0$ .

Note that neither  $B_R$  or SM is entered in the analysis.

For example, suppose  $B_R = 10$ . We might set  $B_0$  to 8 or 5.

#### Range

$B_0$  can be any value, positive or negative, so long as  $B_0 < B_R$ .

#### B1 (Slope|H1) when Higher is Better

Enter one or more values of the slope assumed by the alternative hypothesis, B1. This represents the actual value of B at which the power is computed.

You should make sure than  $B_1 > B_0$ .

You can enter a single value such as '1' or a series of values such as '1 2 3' or '1 to 10 by 1'.

#### B1 (Slope|H1) when Higher is Worse

Enter one or more values of the slope assumed by the alternative hypothesis, B1. This represents the actual value of B at which the power is computed.

You should make sure than  $B_1 < B_0$ .

You can enter a single value such as '1' or a series of values such as '1 2 3' or '1 to 10 by 1'.

## Superiority by a Margin Tests for Simple Linear Regression

### Effect Size – Standard Deviation of X

#### $\sigma_X$ Input Type

Select the method you want to use to enter the value(s) of  $\sigma_X$ . Your choices are

- **$\sigma_X$  (Std Dev of X)**  
Enter one or more values for  $\sigma_X$  directly.
- **List of X Values**  
Enter a list of two or more numbers from which the standard deviation is to be calculated.

#### $\sigma_X$ (Standard Deviation of X)

Enter one or more values for  $\sigma_X$ , the *population* standard deviation of the X values that will occur in a sample.

Usually, the actual X values are not known at the planning stage. When they are not known, you will have to estimate this value. You can press the *Standard Deviation Estimator* button at the right to obtain help in determining appropriate values for this parameter. Just be sure to use the *population*, not the *sample*, formula. That is, divide the sum of squares by N, not N-1.

The individual numbers can be any numeric value: positive, negative, or zero.

#### Fixed Xs

Determine the standard deviation of a typical set of fixed Xs. For example, suppose the X values will be five -1's and five 1's. The population standard deviation of these values (dividing by N, not N - 1) is 1.0. This is the value of  $\sigma_X$ . Note that '1 2' will result in the same  $\sigma_X$  as '1 2 1 2', '1 1 1 2 2 2', '-1 -2', or '11 12'.

#### Random Xs

Estimate one or more values of  $\sigma_X$ , the standard deviation of X, from your knowledge of X. If nothing else is available, you can use the likely range divided by 4, 5, or 6.

#### List of X Values

Enter a list of values from which the value of  $\sigma_X$  will be calculated. For example, entering "1, 3" results in  $\sigma_X = 1.0$ . Note that this calculation assumes that the N observations are allocated equally among the X's.

### Effect Size – $\sigma_e$ (Standard Deviation of Residuals)

#### $\sigma_e$ Input Type

Select the method to use to enter  $\sigma_e$  (the standard deviation of the residuals).

- **$\sigma_e$  (Std Dev of Residuals)**  
Specify  $\sigma_e$  directly.
- **$\sigma_Y$  (Std Dev of Y)**  
Specify  $\sigma_Y$ . Calculate:  $\sigma_e^2 = \sigma_Y^2 - B1^2 (\sigma_X^2)$

#### $\sigma_e$ (Std Dev of Residuals)

Enter one or more values of the standard deviation of the residuals from the regression of Y on X. The possible range is  $0 < \sigma_e$ .

#### $\sigma_Y$ (Std Dev of Y)

Enter one or more values for the standard deviation of Y, ignoring the independent variable X. The value of  $\sigma_Y$  is converted to  $\sigma_e$  using the formula:  $\sigma_e^2 = \sigma_Y^2 - B1^2 (\sigma_X^2)$ . The allowable range is  $0 < |B1(\sigma_X)| < \sigma_Y$ .

## Superiority by a Margin Tests for Simple Linear Regression

### Example 1 – Calculating the Power

Suppose a power analysis is required for a simple linear regression study that will perform a superiority test the relationship between two variables,  $Y$  and  $X$ . Further suppose that in the past, the slope has been 1 and it will be advantageous to show that it is now at least 1.2.

The analysis will look at the power of several sample sizes between 50 and 250. A superiority test will be used with a significance level of 0.025. Based on previous studies,  $\sigma_e$  will be assumed to be 0.6. The value of  $\sigma_x$  will assume that  $X$  is binary with equally-likely values of 1 and 2. The power will be computed at  $B1 = 0.9, 1, 1.1, \text{ and } 1.2$ .

### Setup

This section presents the values of each of the parameters needed to run this example. First, from the PASS Home window, load the **Superiority by a Margin Tests for Simple Linear Regression** procedure window. You may then make the appropriate entries as listed below, or open **Example 1** by going to the **File** menu and choosing **Open Example Template**.

| Option                                  | Value   |
|---|---|
| <b>Design Tab</b>                       |   |
| Solve For .....                         | <b>Power</b>  |
| Higher Slopes Are.....                  | <b>Better (H1: B &gt; B0)</b>                       |
| Alpha.....                              | <b>0.025</b>  |
| N (Sample Size).....                    | <b>50 100 150 200 250</b>                           |
| B0 (Superiority Slope).....             | <b>1.2</b>  |
| B1 (Slope H1) .....                     | <b>1.3 1.4 1.5</b>                                  |
| $\sigma_x$ Input Type.....              | <b>List of X Values</b>                             |
| List of X Values.....                   | <b>1 2</b>  |
| $\sigma_e$ Input Type.....              | <b><math>\sigma_e</math> (Std Dev of Residuals)</b> |
| $\sigma_e$ (Std Dev of Residuals) ..... | <b>0.6</b>  |

### Annotated Output

Click the Calculate button to perform the calculations and generate the following output.

| Numeric Results                                  |               |                      |                 |                         |                         |                              |                |       |  |
|--|---------------|----------------------|-----------------|-------------------------|-------------------------|------------------------------|----------------|-------|--|
| Hypotheses: $H_0: B \leq B_0$ vs. $H_1: B > B_0$ |               |                      |                 |                         |                         |                              |                |       |  |
| Power  | Sample Size N | Superiority Slope B0 | Actual Slope B1 | Std Dev of X $\sigma_x$ | Std Dev of Y $\sigma_y$ | Std Dev of Resids $\sigma_e$ | R <sup>2</sup> | Alpha |  |
| 0.0834   | 50            | 1.200                | 1.300           | 0.500                   | 0.885                   | 0.600                        | 0.540          | 0.025 |  |
| 0.2104   | 50            | 1.200                | 1.400           | 0.500                   | 0.922                   | 0.600                        | 0.576          | 0.025 |  |
| 0.4100   | 50            | 1.200                | 1.500           | 0.500                   | 0.960                   | 0.600                        | 0.610          | 0.025 |  |
| 0.1282   | 100           | 1.200                | 1.300           | 0.500                   | 0.885                   | 0.600                        | 0.540          | 0.025 |  |
| 0.3784   | 100           | 1.200                | 1.400           | 0.500                   | 0.922                   | 0.600                        | 0.576          | 0.025 |  |
| 0.6969   | 100           | 1.200                | 1.500           | 0.500                   | 0.960                   | 0.600                        | 0.610          | 0.025 |  |
| 0.1721   | 150           | 1.200                | 1.300           | 0.500                   | 0.885                   | 0.600                        | 0.540          | 0.025 |  |
| 0.5271   | 150           | 1.200                | 1.400           | 0.500                   | 0.922                   | 0.600                        | 0.576          | 0.025 |  |
| 0.8604   | 150           | 1.200                | 1.500           | 0.500                   | 0.960                   | 0.600                        | 0.610          | 0.025 |  |
| 0.2156   | 200           | 1.200                | 1.300           | 0.500                   | 0.885                   | 0.600                        | 0.540          | 0.025 |  |
| 0.6501   | 200           | 1.200                | 1.400           | 0.500                   | 0.922                   | 0.600                        | 0.576          | 0.025 |  |
| 0.9404   | 200           | 1.200                | 1.500           | 0.500                   | 0.960                   | 0.600                        | 0.610          | 0.025 |  |
| 0.2587   | 250           | 1.200                | 1.300           | 0.500                   | 0.885                   | 0.600                        | 0.540          | 0.025 |  |
| 0.7470   | 250           | 1.200                | 1.400           | 0.500                   | 0.922                   | 0.600                        | 0.576          | 0.025 |  |
| 0.9760   | 250           | 1.200                | 1.500           | 0.500                   | 0.960                   | 0.600                        | 0.610          | 0.025 |  |

## Superiority by a Margin Tests for Simple Linear Regression

### References

- Dupont, W.D. and Plummer, W.D. Jr. 1998. 'Power and Sample Size Calculations for Studies Involving Linear Regression'. *Controlled Clinical Trials*, Vol. 19, Pages 589-601.
- Sampson, Allan R. 1974. 'A Tale of Two Regressions'. *JASA*, Vol. 69, No. 347, Pages 682-689.
- Neter, J., Wasserman, W., and Kutner, M. 1983. *Applied Linear Regression Models*. Richard D. Irwin, Inc. Chicago, Illinois.

### Report Definitions

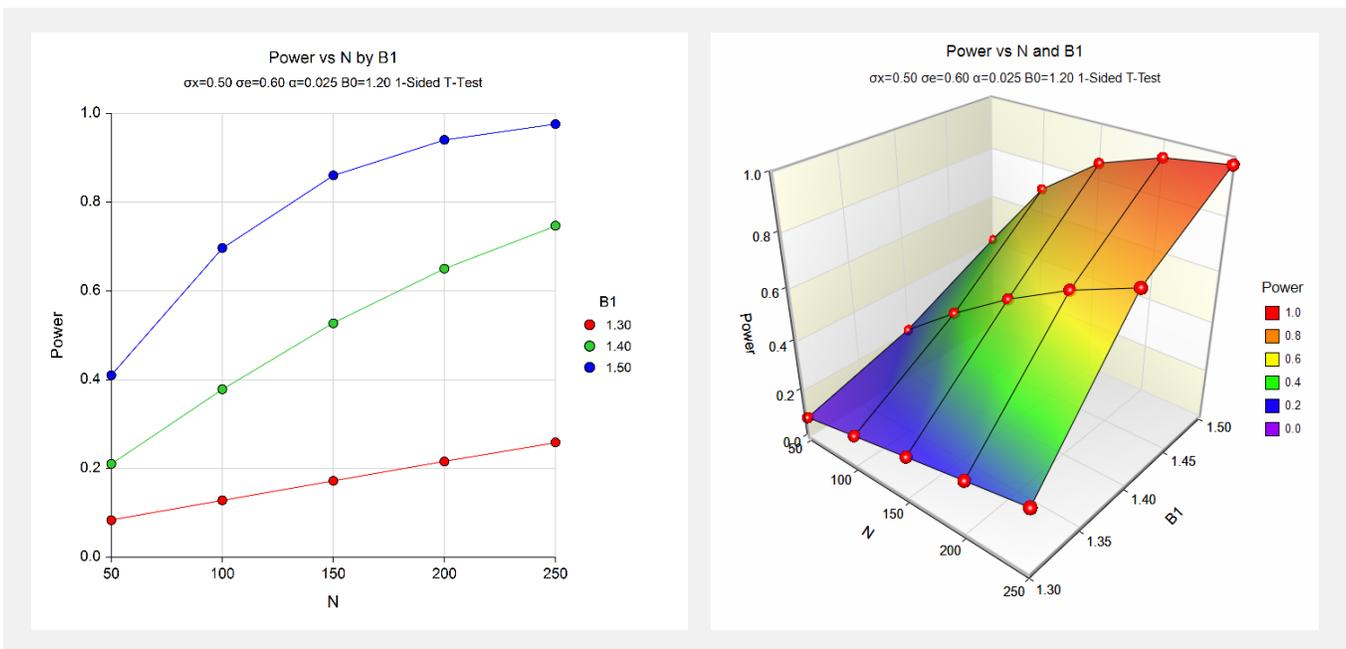
Power is the probability of rejecting a false null hypothesis. It should be close to one.  
 N is the size of the sample drawn from the population. To conserve resources, it should be small.  
 B0 is the superiority slope (boundary) in the case in which HIGHER slope values are desired.  
 B1 is the slope at which the power is calculated.  
 $\sigma_x$  is the standard deviation of the X values.  
 $\sigma_y$  is the standard deviation of Y (ignoring X).  
 $\sigma_e$  is the standard deviation of the residuals.  
 $R^2$  is the R-squared when Y is regressed on X.  
 Alpha is the probability of rejecting a true null hypothesis.

### Summary Statements

A superiority by a margin test is planned in which HIGHER slope values are desired. A sample size of 50 achieves 8% power to detect a change in slope from 1.200 under the null hypothesis to 1.300 under the alternative hypothesis when the statistical hypothesis is one-sided, the significance level is 0.025, the standard deviation of X is 0.500, the standard deviation of Y is 0.885, the standard deviation of residuals is 0.600, and  $R^2$  is 0.540.

This report shows the calculated power for each of the scenarios.

## Plots Section



These plots show the power versus the sample size for the three values of B1.

## Example 2 – Validation using Another PASS Procedure

We could not find a validation example for this procedure in the literature. But since this procedure was derived from the **Non-Zero Null Tests for Simple Linear Regression** procedure, we will use an example from that previously validated procedure to validate this procedure.

In the other procedure, set the *Solve For* parameter to Sample Size. Also, set the *Alternative Hypothesis* to One-Sided ( $H_1: B > B_0$ ). Also, set  $Power = 0.9, B_0 = 1.2, B_1 = 1.4, \alpha = 0.05, \sigma_X = 0.5, \sigma_e = 0.6$ .

The sample size is calculated as 310.

### Setup

This section presents the values of each of the parameters needed to run this example. First, from the PASS Home window, load the **Superiority by a Margin Tests for Simple Linear Regression** procedure window. You may then make the appropriate entries as listed below, or open **Example 2** by going to the **File** menu and choosing **Open Example Template**.

| <u>Option</u>                           | <u>Value</u>                      |
|---|-----------------------------------|
| <b>Design Tab</b>                       |                                   |
| Solve For .....                         | Sample Size                       |
| Higher Slopes Are.....                  | Better ( $H_1: B > B_0$ )         |
| Power.....                              | 0.90                              |
| Alpha.....                              | 0.05                              |
| $B_0$ (Superiority Slope).....          | 1.2                               |
| $B_1$ (Slope  $H_1$ ) .....             | 1.4                               |
| $\sigma_X$ Input Type.....              | $\sigma_X$ (Std Dev of X)         |
| $\sigma_X$ (Std Dev of X) .....         | 0.5                               |
| $\sigma_e$ Input Type.....              | $\sigma_e$ (Std Dev of Residuals) |
| $\sigma_e$ (Std Dev of Residuals) ..... | 0.6                               |

### Output

Click the Calculate button to perform the calculations and generate the following output.

| Numeric Results                                  |                     |                            |                       |                                  |                                  |  |                |       |  |
|--|---------------------|----------------------------|-----------------------|----------------------------------|----------------------------------|--|----------------|-------|--|
| Hypotheses: $H_0: B \leq B_0$ vs. $H_1: B > B_0$ |                     |                            |                       |                                  |                                  |  |                |       |  |
|  | Sample<br>Size<br>N | Superiority<br>Slope<br>B0 | Actual<br>Slope<br>B1 | Std<br>Dev<br>of X<br>$\sigma_X$ | Std<br>Dev<br>of Y<br>$\sigma_Y$ | Std<br>Dev<br>of<br>Resids<br>$\sigma_e$ | R <sup>2</sup> | Alpha |  |
| Power  | 310                 | 1.200                      | 1.400                 | 0.500                            | 0.922                            | 0.600                                    | 0.576          | 0.050 |  |

The sample size of 310 matches the result from the other procedure.