Assignment 2

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Q57 Suppose $r_{1.23}$ and $r_{1.234}$ are sample multiple correlation coefficients of X_1 on X_2, X_3 and X_1 on X_2, X_3, X_4 respectively. Which of the following is possible?

1. $r_{1.23} = -0.3$ and $r_{1.234} = 0.7$
2. $r_{1.23} = 0.7$ and $r_{1.234} = 0.3$
3. $r_{1.23} = 0.3$ and $r_{1.234} = 0.7$
4. $r_{1.23} = 0.7$ and $r_{1.234} = -0.3$

Sol Here, as given in the question X_2, X_3X_4 are independent random variables and X_1 is dependent variable.

$r_{1.23}$ is coefficient of multiple correlation of X_1 on X_2, X_3 and $r_1.234$ is coefficient of multiple correlation of X_1 on X_2, X_3, X_4.

The coefficient of multiple correlation, denoted R, is a scalar that is defined as the Pearson correlation coefficient between the predicted and the actual values of the dependent variable in a linear regression model that includes an intercept.

The coefficient of multiple correlation(R) is known as the square root of the coefficient of determination(R^2)

for any multi-linear regression model R^2 can be calculated using the formula given bellow

$$R^2 = 1 - \frac{sum squared regression(SSR)}{total sum of squares(SST)} \tag{1}$$

$$R^2 = 1 - \frac{\sum(y_i - \hat{y_i})^2}{\sum(y_i - \bar{y})^2} \tag{2}$$

where,

y_i is actual value,
$\hat{y_i}$ is predicted value,
and $\bar{y}$ is mean of actual y values.

So, in our case X_1 is actual value and $\bar{X_1}$ is mean of X_1 values. Here, values of X_1 variable can be predicted by using independent random variables X_2, X_3, X_4 by using multiple linear regression.

here, lets say $\hat{X_{123}}$ is predicted value of X_1 using X_2, X_3 and $\hat{X_{1234}}$ is predicted value of X_1 using X_2, X_3, X_4.
So

$$\hat{X_{123_i}} = \beta_2 x_2 + \beta_3 x_3 \tag{3}$$

and

$$\hat{X_{1234_i}} = \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 \tag{4}$$

So here,

$$r_{1.23}^2 = 1 - \frac{\Sigma(X_{1_i} - \hat{X_{123_i}})^2}{X_{1_i} - \bar{X_1}} \tag{5}$$

and

$$r_{1.234}^2 = 1 - \frac{\Sigma(X_{1_i} - \hat{X_{1234_i}})^2}{X_{1_i} - \bar{X_1}} \tag{6}$$

Here from equation 2 we can clearly see that coefficient of multiple correlation cannot be negative. Also, if we introduce more variables, the R^2 will always increase, it can never decrease. This follows mathematically from the observation that,

$$(y - \beta_0 - \beta_1 x_1 - \cdots - \beta_p x_p - \beta_{p+1} x_{p+1})^2 \leq (y - \beta_0 - \beta_1 x_1 - \cdots - \beta_p x_p)^2 \tag{7}$$

Hence, in our case $\Sigma(X_{1_i} - \hat{X_{1234_i}})^2 \leq \Sigma(X_{1_i} - \hat{X_{123_i}})^2$ is always true. Means, $r_{1.23} \leq r_{1.234}$ is always true.

Hence we can conclude 2 statements that,

- Coefficient of multiple correlation cannot be negative.
- if we introduce more variables, the R^2 will always increase, it can never decrease.

If we look at option 1 value of $r_{1.23}$ is negative and in option 4 value of $r_{1.234}$ is negative hence these options are not possible. In option 2, value of $r_{1.23}$ is grater than value of $r_{1.234}$ which is also not possible.

Only option 3($r_{1.23} = 0.3$ and $r_{1.234} = 0.7$) satisfy both the conditions hence option 3 is the correct answer