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The Methods Used in Nonparametric Covariance Analysis

Parametrik Olmayan Kovaryans Analizinde Kullanılan Metotlar

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ABSTRACT

Aim: Nonparametric covariance analysis (ANCOVA) methods are used when the assumptions of parametric ANCOVA are not met and/or the dependent variable has bivariate/ordinal scale. In the nonparametric ANCOVA methodology, Quade, Puri & Sen and McSweeney & Porter methods are known as Ranked ANCOVA methods. However, commonly used programs do not have module(s) for applying these methods. The objective of this study is to introduce the ranked ANCOVA methods, to apply it in a web-based program developed by the authors and to present the advantages of these methods.

Material and Methods: The theoretical features and application steps of the Ranked ANCOVA methods are defined and a web-based program for the application of each method has been established. The application of each method on this program with the help of simulated data taken from the health field study, where the effect of cigarette smoking on biochemical tests was examined has also been included.

Results: Although there is no specific module in the widely used statistical programs for the methods described in this study, it is shown on a clinical study constituted with simulated data that these methods can easily be applied and the results of the methods are given.

Conclusion: The use of parametric methods for factorial models leads to an increase in Type-I error rate and a decrease in test power in many studies, where the sample size is limited and/or the dependent variable does not have normal distribution. To reduce this error, we recommend using the methods suggested in the study. These methods are also expected to reach widespread use thanks to the web-based program.

Keywords: Ranked ANCOVA; covariance; nonparametric; Quade; Puri & Sen; McSweeney & Porter.

ÖZ

Amaç: Parametrik kovaryans analizi (ANCOVA) varsayımlarının sağlanamaması ve/veya bağımlı değişkenin iki değerli/sıralayıcı ölçekli olması durumunda, parametrik olmayan ANCOVA yaklaşımlarından yararlanılmaktadır. Parametrik olmayan ANCOVA metodolojisinde Quade, Puri & Sen ve McSweeney & Porter metotları, Ranklı ANCOVA yöntemleri olarak bilinmektedir. Ancak yaygın kullanılan programlarda, bu metotların uygulanmasına yönelik modül(ler) bulunmamaktadır. Bu çalışmanın amacı Ranklı ANCOVA yaklaşımlarını tanıtmak, yazarlar tarafından geliştirilen web tabanlı bir programda uygulamasını yapmak ve bu yaklaşımların avantajlarından bahsetmektedir.

Gereç ve Yöntemler: Ranklı ANCOVA yaklaşımlarının teorik özellikleri ve uygulama adımları tanımlanmış ve her bir yaklaşımın uygulanmasına yönelik web tabanlı bir program oluşturulmuştur. Sigara kullanma durumunun biyokimyasal tetkik sonuçları üzerindeki etkisinin incelendiği sağlık alanındaki bir çalışmadan simüle edilen veriler yardımıyla web tabanlı bir program üzerinde her bir yaklaşımın uygulamasına da yer verilmiştir.

Bulgular: Her ne kadar, bu çalışmada açıklanan yaklaşımlar için yaygın kullanılan istatistik programlarında özel bir modül olmasa da, bu yaklaşımların kolaylıkla uygulanabileceği simüle verilerle oluşturulmuş klinik bir çalışma üzerinde gösterilmiş, yaklaşımların sonuçları verilmiştir.

Sonuç: Birçok araştırmada örneklem genişliğinin kısıtlı olması ve/veya bağımlı değişkenin normal dağılım göstermemesi durumunda, faktöriyel modeller için parametrik yöntemlerin kullanılması, Tip I hata oranının artmasına ve testin gücünün azalmasına neden olmaktadır. Bu hatayı azaltmak için çalışmada önerilen yaklaşımların kullanılması tavsiye edilmektedir. Bu yaklaşımların, web tabanlı program sayesinde de yaygın kullanıma ulaşacağı düşünülmektedir.

Anahtar kelimeler: Ranklı ANCOVA; kovaryans; parametrik olmayan; Quade; Puri & Sen; McSweeney & Porter.

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INTRODUCTION

The analysis of covariance (ANCOVA) analyzes for differences in response variable among groups, taking into account the variability in the response variable explained by one or more covariates (1). ANCOVA is a statistical procedure widely used in many disciplines such as health, ecology, environmental science and psychological perspective (2-5). ANCOVA includes some additional assumptions as well, in addition to the standard assumptions (independence, variance equality and normality) of the analysis of variance (ANOVA). Additional assumptions of ANCOVA can be listed as (i) linear relationship between response variable and covariate, (ii) parallel regression slopes between groups, (iii) variability in response variable for each group is equal at each value of covariate, (iv) similarity of covariate values between groups, and (v) that covariate is a constant-effect variable and is measured without error (6). Violations of one or more of these assumptions may threaten the validity of the ANCOVA results (7).

It is quite difficult to achieve all of these assumptions in practice, especially in the health field researches. For this reason, nonparametric covariance analysis models or alternatives are used when the ANCOVA assumptions are not met and / or the dependent variable has bivariate / ordinal scale (1,8-10). If the normality assumption of the conditional distributions of the response variable is not satisfied, then Ranked ANCOVA methods including Quade, Puri & Sen, Conover & Inman, Rutherford and McSweeny & Porter, Burnett & Barr, Hettmansperger & Mckean, and Hettmansperger methods are used (11-17). However, there are no module(s) for the application of the Ranked ANCOVA methods in commonly used programs. It is observed that only Nakonezny and Shull (18) apply Hettmansperger & Mckean (16) test to the one-factor ANCOVA model with single-covariate by coding in SAS program.

The objective of this study is to introduce, first, the features of the parametric ANCOVA model, and then introduce the theoretical features of Quade, Puri & Sen and McSweeny & Porter Ranked ANCOVA models, to apply it in the web based program that we have developed to show its use in health-related researches and to present the advantages of these methods.

PARAMETRIC COVARIANCE ANALYSIS MODEL

ANCOVA is used to test for differences in response variable among groups, taking into account the variability in the response variable explained by one or more covariates. This analysis is a combination of linear regression methods and analysis of variance. ANCOVA model is obtained when regression term is added to ANOVA model. The ANCOVA model takes both between-groups and regression-variance as systematic (error-free) components. A single-factor statistical model for covariance analysis is given in Equation [1].

$$Y_{ij} = \mu + \tau_j + +\beta_1\left(X_{ij} - \bar{X}_{..}\right) + \varepsilon_{ij} \quad i=1,\ldots,k \quad j=1,\ldots,n_i \quad [1]$$

In Equation [1], Y_{ij} shows the response variable value of the i^{th} individual in the j^{th} factor level, μ is the overall population mean, τ_j shows the effect of the j^{th} factor, β_1 shows linear regression coefficient of Y variable over X, X_{ij} is the covariate value of the i^{th} individual in the j^{th} factor level, $\bar{X}_{..}$ shows the grand covariate mean and ε_{ij} is the error term for the i^{th} unit in the j^{th} factor level (1).

Covariance analysis is a very useful and robust statistical method when the assumptions are met. The assumptions of ANCOVA are listed below (1,19,20).

1. When X covariate is given, the conditional distribution of the Y response variable follows the normal distribution with mean zero and variance σ^2 ($f(Y|X) \sim N(0, \sigma^2)$).
2. The within-group regression slopes are homogeneous $(\beta_1^{group\ 1} = \beta_1^{group\ 2} = \cdots = \beta_1^{group\ I})$.
3. The conditional variances are homogeneous $\left(\sigma^2_{y_{1|x}} = \sigma^2_{y_{2|x}} = \cdots = \sigma^2_{y_{I|x}}\right)$.
4. Error term follows the normal distribution with mean zero and variance σ^2 ($\varepsilon_{ij} \sim N(0, \sigma^2)$).
5. The relationship between response variable and covariate must be linear.
6. The factor levels (or groups) must be independent of each other.
7. Covariate(s) must be constant variable and measured without error.
8. If more than one covariate is to be used, there should be no strong relationship between the covariates.

Hypotheses for the one-way ANCOVA model can be written as Equation [2] and the summary table for this model is given in Table 1 (1).

$$H_0: \mu_{1adj} = \mu_{2ad} = \cdots = \mu_{Iadj}$$
$$H_0: \beta_1^{group\ 1} = \beta_1^{group\ 2} = \cdots = \beta_1^{group\ I} \quad [2]$$

Table 1. The summary table for one-way ANCOVA

Source	Sum of Square and Sum of Products			Adjusted Sum of Square	df	Adjusted Mean Square	F
	XX	XY	YY				
Factor/Group	-	-	-	$M_{yy(adj)}$	*k-1*	$\frac{M_{yy(adj)}}{k-1}$	$\frac{MS(Factor)_{adj}}{MS(Error)_{adj}}$
Error	E_{xx}	E_{xy}	E_{yy}	$E_{yy(adj)}$	*N-k-1*	$\frac{E_{yy(adj)}}{N-k-1}$	
Total	T_{xx}	T_{xy}	T_{yy}	$T_{yy(adj)}$	*N-2*		
The Homogeneity of Regression Slopes	$F_{(\alpha,k-1,N-2k)} = \frac{\left(\sum_{i=1}^{k} b_{w_i}^2 E_{xx_i} - b_w^2 E_{xx}\right)/(k-1)}{\left(E_{yy} - \sum_{i=1}^{k} b_{w_i}^2 E_{xx_i}\right)/(N-2k)}$						
Adjusted Mean	$\bar{Y}_{(adj)}^{(k)} = \bar{Y}^{(k)} - b_w(\bar{X}^{(k)} - \bar{X})$						

$E_{xx} = \sum\sum\left(X_{ij} - \bar{X}_i\right)^2$

$E_{xy} = \sum\sum\left(X_{ij} - \bar{X}_i\right)\left(Y_{ij} - \bar{Y}_i\right)$

$E_{yy} = \sum\sum\left(Y_{ij} - \bar{Y}_i\right)^2$

$T_{xx} = \sum\sum\left(X_{ij} - \bar{X}\right)^2$

$T_{xy} = \sum\sum\left(X_{ij} - \bar{X}\right)\left(Y_{ij} - \bar{Y}\right)$

$T_{yy} = \sum\sum\left(Y_{ij} - \bar{Y}\right)^2$

$E_{yy(adj)} = E_{yy} - E_{xy}^2/E_{xx}$

$T_{yy(adj)} = T_{yy} - T_{xy}^2/T_{xx}$

$M_{yy(adj)} = T_{yy(adj)} - E_{yy(adj)}$

$b_w = E_{xy}/E_{xx}$

NONPARAMETRIC ANCOVA

In parametric ANCOVA, it is assumed that the conditional distribution of the response variable is normal. That is, when the covariate value is given, the values of the response variable are normally distributed. This assumption, as it is known, is examined by testing the residuals obtained from the Generalized Linear Modeling (GLM) procedure (1,6).

The hypothesis that the conditional distributions between groups are equal in nonparametric ANCOVA is tested with $H_0: f(Y_1|X) = f(Y_2|X) = \cdots = f(Y_l|X)$. In this hypothesis, $f(Y_l|X)$ shows the conditional distribution of Y response variable of i^{th} group, when the covariate value is given. Nonparametric ANCOVA assumes that the relationship between response variable and covariate is monotonic. The nonparametric ANCOVA methods that we will examine in this study are based on the ranked approach. These are the Quade method, the Puri & Sen method and the McSweeny & Porter method (1,6).

1. Quade Method

The Quade method is based on testing the equality of the residuals among groups obtained from the linear regression of the ranked response variable and the ranked covariate. This method is distribution-free and the test statistic shows asymptotically central F-distribution. The application steps of this method are given below (7,11).

Application Steps

<u>*Step 1:*</u> The response variable and the covariate are ranked separately ($Y \xrightarrow{Rank} RY$ and $X \xrightarrow{Rank} RX$).

<u>*Step 2:*</u> Residual values from the linear regression of the ranked covariate considered to have an effect on the ranked response variable are calculated ($RY = b_0 + b_1 RX \;\Rightarrow e_{ij}$).

<u>*Step 3:*</u> Whether the calculated residual values are different among groups is checked by considering the number of factors as well as the number of group.

<u>*Step 4:*</u> If the p-value of the test statistic is less than the specified level of significance, it is assumed that 'the conditional distributions of the response variables are not equal among the groups.' ($p<\alpha \rightarrow H_1: f(Y_h|X) \neq f(Y_v|X)$ at least one $for\ h \neq v$).

<u>*Step 5:*</u> When the null hypothesis is rejected, if the number of groups is more than 2, one of the multiple comparison methods is applied to investigate which group pair/pairs cause this difference.

2. Puri & Sen Method

The procedure developed by Puri and Sen (12) is more general than the Quade method with regards to the fact that it permits transformation of the ranked data or ranked data itself. The Puri & Sen method assumes that the relationship between the ranked response variable and ranked covariate is constant across groups. Residual values are calculated similar to the Quade procedure, as shown in the application steps the test statistic shows chi-square distribution. The application steps of this method are given below (7,12).

Application Steps

<u>*Step 1:*</u> The response variable and the covariate are ranked separately ($Y \xrightarrow{Rank} RY$ and $X \xrightarrow{Rank} RX$).

<u>*Step 2:*</u> The residual averages of the ranked values are then calculated as $R\bar{e}_j = \left(\bar{R}_{y,j} - \bar{R}\right) - r(\bar{R}_{x,j} - \bar{R})$. In this equation, $\bar{R}_{y,j}$ shows the mean of the ranked response variable for the j^{th} group, $\bar{R}_{x,j}$ is the mean of the ranked covariate for the j^{th} group and r shows the correlation coefficient of the relationship between the ranked response variable and the ranked covariate.

<u>*Step 3:*</u> Puri & Sen L test statistic is calculated for one-way ANCOVA model. This test statistic is distributed chi-square with (k-1) degrees of freedom.

$$L_{(k-1)} = \frac{\sum_{i=1}^{k} n_i \bar{e}_i^2}{s_Y^2} \sim \chi^2_{(k-1)} \quad [3]$$

Sum of squared error used in the calculation of the equation is given as the formulas of $SSE = \sum(y_i - \hat{y}_i)^2$ and $s_Y^2 = SSE/N$.

<u>*Step 4:*</u> When the null hypothesis is rejected ($H_1: f(Y_h|X) \neq f(Y_v|X)$ at least one $for\ h \neq v$); if the number of groups is more than 2, one of the multiple comparison methods is applied to investigate which group pair/pairs cause this difference.

3. McSweeny & Porter Method

The McSweeny & Porter method is quite similar to the Conover & Inman (15) method. It is known as the easiest among the ranked ANCOVA methods in terms of calculations. Ranked values can easily be obtained by applying parametric test methods. The advantage of this method is that it can test the homogeneity of the regression slopes. The test statistic obtained based on the ranked values has the F distribution. The application steps of this method are given below (7,13).

Application Steps

<u>*Step 1:*</u> The response variable and the covariate are ranked separately ($Y \xrightarrow{Rank} RY$ and $X \xrightarrow{Rank} RX$).

<u>*Step 2:*</u> Equality of regression slopes is tested with the GLM model $\left(H_0: \beta_1^{group\ 1} = \beta_1^{group\ 2} = \cdots = \beta_1^{group\ l}\right)$.

<u>*Step 3:*</u> $Y_{Rdependent} = X_{Rcovariate} + X_{factor}$ model is established. The equality of the regression slopes is checked by adding the interaction (ranked covariate × factor) effect together with the main effects to the general linear regression model. If the interaction is not significant, the hypothesis that the relationship between the covariate and the dependent variable is the same at each level of the factor is accepted.

<u>*Step 4:*</u> If the null hypothesis is rejected, it is assumed that 'the conditional distributions of the response variable are not equal among the groups ($H_1: f(Y_h|X) \neq f(Y_v|X)$ at least one $for\ h \neq v$).

<u>*Step 5:*</u> If the number of groups is more than 2, one of the multiple comparison methods is applied to investigate which group pair/pairs cause this difference.

MATERIAL AND METHODS

A web-based program has been developed for the Quade, Puri & Sen, and McSweeny & Porter ranked ANCOVA methods (post hoc Tukey-Kramer test) proposed in this study for one-factor covariance model with single-covariate. This web-based program is available at "www.masungur.com/nancova0.php". The interface of this program is given in Figure 1. This program is a free web-based program written in php programming language. The number of factor levels can be determined by the user in the program.

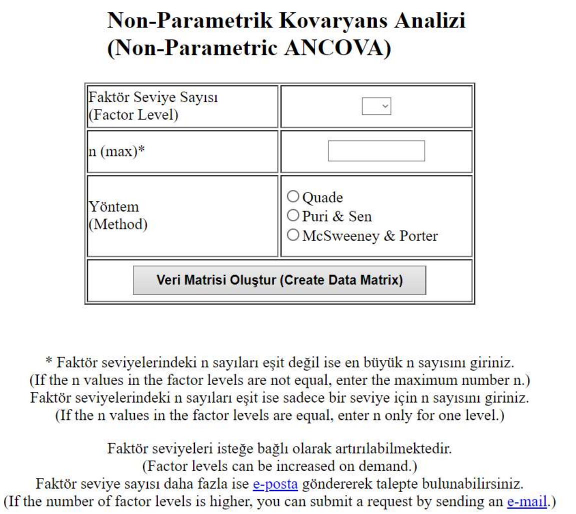

Figure 1. The interface of Nonparametric ANCOVA program

To demonstrate how these methods are implemented on the program, applications of the simulated data obtained from a clinical research are presented. The data of a total of 210 individuals were addressed in this study where the data were simulated from a real study investigating the effect of cigarette smoking on biochemical test results. It was determined that age is an important covariate within the scope of the relevant clinical study. It is desired to investigate whether there is a statistically significant difference in the adjusted mean values of hemoglobin (hb) according to smoking status (non-smoker, smoker, and ex-smoker) by eliminating the effect of age on hb values according to this information. Accordingly, the one-factor ANCOVA model with single-covariate will be discussed. In this study, Anderson-Darling normality test, Levene variance equality test as well as Pearson chi-square, Kruskal-Wallis (post hoc Dunn test) and Spearman correlation tests were also used to check the parametric ANCOVA assumptions. In case when the assumption/assumptions is/are not met, the ranked ANCOVA methods (post hoc Tukey-Kramer test) proposed in this study were applied respectively to the simulated data with the help of the web-based program freely available at web page given. The ranked one-factor ANCOVA model with single-covariate in the study is given in Equation [4].

$$Y_{(Rhb)ij} = \mu + \tau_{(group)j} + \beta_1\left(X_{(Rage)ij} - \bar{X}_{(Rage)..}\right) + \varepsilon_{ijk} \quad [4]$$

In Equation [4], $Y_{(Rhb)ij}$ shows the ranked hb value of the i^{th} individual in the j^{th} level of the group, μ is the overall mean of the ranked response variable, $\tau_{(group)j}$ shows the effect of the j^{h} level of the group, and $\beta_1\left(X_{(Rage)ij} - \bar{X}_{(Rage)..}\right)$ is the effect of the ranked age, $X_{(Rage)ij}$ shows the ranked age value for i^{th} individual in j^{th} group, $\bar{X}_{(Rage)..}$ is the grand ranked age mean and ε_{ij} shows the error term of the i^{th} individual in the j^{th} group.

Table 2. The results of Quade ranked ANCOVA method

Non-Parametric ANCOVA (Quade Method)

TANIMLAYICI İSTATİSTİKLER (DESCRIPTIVE STATISTICS)		Seviye 1 (Level 1)	Seviye 2 (Level 2)	Seviye 3 (Level 3)
X	n	70	70	70
	Ortalama (Mean)	33.586	29.529	38.471
	St.Sapma (St.Deviation)	13.841	4.409	12.642
Y	n	70	70	70
	Ortalama (Mean)	14.360	12.900	14.459
	St.Sapma (St.Deviation)	1.436	1.536	1.091
rX	n	70	70	70
	Ortalama (Mean)	99.664	88.814	128.021
	St.Sapma (St.Deviation)	73.476	30.266	63.416
rY	n	70	70	70
	Ortalama (Mean)	120.464	66.036	130.000
	St.Sapma (St.Deviation)	61.446	48.477	51.307
Artık (Residual)	n	70	70	70
	Ortalama (Mean).	16.298	-35.652	19.354
	St.Sapma (St.Deviation)	58.736	47.847	53.971

Non-Parametric ANCOVA (Quade Method)

VK (Source)	KT (SS)	sd (df)	KO (MS)	F	p
Seviye (Level)	133,787.362	2	66,893.681	23.195	0.000
Hata (Error)	596,993.117	207	2,884.025		
Genel (Total)	730,780.479	209			

	Seviye 1 (Level 1)	Seviye 2 (Level 3)	Seviye 3 (Level 3)
Seviye 1 (Level 1)		<0.05	>0.05
Seviye 2 (Level 2)	<0.05		<0.05
Seviye 3 (Level 3)	>0.05	<0.05	

RESULTS

Of the 210 individuals examined in this study, 46.7% of them were male, 53.3% of them were female and the median age was 31.5 (IQR=17.25). In this simulated data set, it was found that there was a significant difference according to smoking status (p=0.021) in terms of the median age (p<0.001). The median age of ex-smoker/non-smoker at the last six months group was found to be significantly higher than the median age values of the individuals in the other groups (respectively p=0.017, p<0.001). It was determined that there was a significant positive relationship between age and hb (r=0.228, p=0.001). First of all, it was examined whether the hb dependent variable in the model provides pre-conditions for parametric covariance analysis. As a result, hb dependent variable (Anderson-Darling test statistic=3.875, p<0.005) and the residuals (Anderson-Darling test statistic=1.210, p<0.005) did not fit to the normal distribution. When the variance equality assumption according to smoking status was tested, the variances were found to be equal (Levene test statistic=1.24, p=0.293). Since the dependent variable in the parametric covariance analysis did not satisfy the normal distribution condition, the nonparametric ANCOVA methods proposed this study were applied respectively.

The first technique used in the nonparametric ANCOVA is the ranked Quade ANCOVA method. The results of the ranked Quade ANCOVA method were given in Table 2.

Another one of the nonparametric ANCOVA methods is the Puri & Sen method. When the Puri & Sen method was applied to the one-factor covariance analysis model with single-covariate, the results were given in Table 3.

The last method we obtained the ranked ANCOVA model is McSweeny & Porter method. It was found that the regression slopes were homogeneous before establishing the relevant model (F=2.46, p=0.088). The results of the application of the McSweeny & Porter-ranked ANCOVA method were given in Table 4.

According to the results obtained by applying the three ranked methods, there was a significant difference among groups (i.e. smoking status) in terms of age-adjusted hb values (p<0.001, Table 2-4). According to the Tukey-Kramer post hoc test results of each method; the age-adjusted ranked hb value of smoker was significantly lower than the age-adjusted hb values of the non-smoker and ex-smoker (p<0.001). However, there was not a statistically significant difference between the age-adjusted ranked hb values of the non-smoker and ex-smoker groups (p>0.05).

DISCUSSION AND CONCLUSION

When parametric test assumptions are not satisfied, an increase in Type I error rate and a decrease in power of test are observed. It is known that the parametric ANCOVA method is generally robust against assumption violations at minor level when the sample sizes of groups are equal. Hamilton (19), Olejnik & Algina (8), Olejnik & Algina (9) and Rheinheimer & Penfield (7) compared the parametric ANCOVA and the nonparametric ANCOVA methods in terms of Type I error rates and power in simulation studies. They found that the nonparametric ANCOVA methods were stronger than the parametric ANCOVA when the violation of the normality assumption is at a serious level, especially when the relationship between response variable and covariate is weak. They found that the nonparametric ANCOVA methods are generally stronger than ANCOVA methods and that they better control the Type I error rates, in cases when the variances are heterogeneous and in unbalanced designs. Hamilton (19), however, showed that ANCOVA is more robust than the nonparametric ANCOVA methods in terms of power, when the regression slopes are not homogeneous and except the cases when the sample size is small.

Although there are no specific modules in the widely used statistical programs for the approaches described in this study, these methods have been shown to be easily implemented with the aid of the web-based program we have developed and their advantageous aspects have been presented. The use of parametric methods for factorial models leads to an increase in Type I error rate and a decrease in power of test in many studies, where the sample size is limited and / or the dependent variable does not have a normal distribution. It is recommended to use the methods suggested in the study in order to reduce this error. These methods are also expected to reach widespread use thanks to our web-based program.

Table 3. The results of Puri &Sen ranked ANCOVA method

Non-Parametric ANCOVA (Puri & Sen Method)

TANIMLAYICI İSTATİSTİKLER (DESCRIPTIVE STATISTICS)		Seviye 1 (Level 1)	Seviye 2 (Level 2)	Seviye 3 (Level 3)
X	n	70	70	70
	Ortalama (Mean)	33.586	29.529	38.471
	St.Sapma (St.Deviation)	13.841	4.409	12.642
Y	n	70	70	70
	Ortalama (Mean)	14.360	12.900	14.459
	St.Sapma (St.Deviation)	1.436	1.536	1.091
rX	n	70	70	70
	Ortalama (Mean)	99.664	88.814	128.021
	St.Sapma (St.Deviation)	73.476	30.266	63.416
rY	n	70	70	70
	Ortalama (Mean)	120.464	66.036	130.000
	St.Sapma (St.Deviation)	61.446	48.477	51.307
Artık (Residual)	n	70	70	70
	Ortalama (Mean).	16.298	-35.652	19.354
	St.Sapma (St.Deviation)	58.736	47.847	53.971

Non-Parametric ANCOVA (Puri & Sen Method)			
r_{rxry}	0.228		
Ortalama Rank (Mean Rank)	105.500		
	Seviye 1 (Level 1)	Seviye 2 (Level 2)	Seviye 3 (Level 3)
Ortalama rX (Mean rX)	99.664	88.814	128.021
Ortalama rY (Mean rY)	120.464	66.036	130.000
Ortalama Artık (Mean Residual)	16.297	-35.653	19.356
L		sd (df)	p
38.448		2	0.000

	Seviye 1 (Level 1)	Seviye 2 (Level 2)	Seviye 3 (Level 3)
Seviye 1 (Level 1)		<0.05	>0.05
Seviye 2 (Level 2)	<0.05		<0.05
Seviye 3 (Level 3)	>0.05	<0.05	

Table 4. The results of McSweeny & Porter ranked ANCOVA method

Non-Parametric ANCOVA (McSweeney & Porter Method)

TANIMLAYICI İSTATİSTİKLER (DESCRIPTIVE STATISTICS)		Seviye 1 (Level 1)	Seviye 2 (Level 2)	Seviye 3 (Level 3)
X	n	70	70	70
	Ortalama (Mean)	33.586	29.529	38.471
	St.Sapma (St.Deviation)	13.841	4.409	12.642
Y	n	70	70	70
	Ortalama (Mean)	14.360	12.900	14.459
	St.Sapma (St.Deviation)	1.436	1.536	1.091
rX	n	70	70	70
	Ortalama (Mean)	99.664	88.814	128.021
	St.Sapma (St.Deviation)	73.476	30.266	63.416
rY	n	70	70	70
	Ortalama (Mean)	120.464	66.036	130.000
	St.Sapma (St.Deviation)	61.446	48.477	51.307

Non-Parametrik ANCOVA (McSweeney & Porter Method)					
VK (Source)	KT (SS)	sd (df)	KO (MS)	F	p
Kovaryat (Covariate)	13,318.824	1	13,318.824	4.643	0.032
Seviye (Level)	139,801.982	2	69,900.991	24.366	0.000
Hata (Error)	590,978.497	206	2,868.828		
Genel (Total)	771,010.000	209			

	Seviye 1 (Level 1)	Seviye 2 (Level 2)	Seviye 3 (Level 3)
Seviye 1 (Level 1)		<0.05	>0.05
Seviye 2 (Level 2)	<0.05		<0.05
Seviye 3 (Level 3)	>0.05	<0.05	

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