MULTIVARIATE ANALYSIS OF VARIANCE ON THE JAMB AND POST-JAMB SCORES OF STUDENTS (A CASE STUDY OF ABIA STATE UNIVERSITY, UTURU NIGERIA)

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ABSTRACT

This research work is on the multivariate analysis of variance on the academic performance of students enrolled into Abia State University, Uturu Nigeria through JAMB and Post-JAMB scores using their faculties (schools) and their academic sessions. The SPSS software package was used for the data analysis. The results of the analysis revealed the following; there was no interaction between the academic sessions and the faculties on the academic performance of the students enrolled in Abia State University, Uturu via their JAMB and Post JAMB scores. The vector means performed the same in the five academic sessions. It has been concluded that both the academic sessions and the faculties do not affect the performance of students in JAMB and Post JAMB scores.

Keywords: JAMB Scores, Post-JAMB Scores, Factor A (1) Effect, Factor B (2) Effect, Two-way MANOVA, Interaction Effect, Wilks' Lambda Simultaneous Confidence Intervals for Contrasts.

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BACKGROUND OF THE STUDY

Obviously the importance of research is to arouse, stimulate and develop student's skill so as to make the students become versatile in his school and at the same time make him or her fit politically, morally and socially in a given milieu.

In recent time's education as an international phenomenon has generated a lot of common to many individuals' scholars and groups. Education is the influence exercised by adult generations on those that are not yet ready for social life. The objectives are to stimulate and develop the child on certain number of physical, intellectual and moral status which is demanded of him by both political societies as a whole.

Generally, there has been a lot of controversy on the conduction of post U.M.E JAMB examination after taking the main JAMB exam, which they think is a strategy used in depriving the poor masses not to get admission. But this research has been made so that we can be sure and have the simple ideas why the Post UME JAMB was introduced.

SIGNIFICANCE OF THE STUDY

The need for selecting the right candidate for university education in Nigeria cannot be overemphasized, if the right candidates are selected and trained in the universities this will bring about the production of the right human resources who are the major factors of production. Students who are not suitable for university education based on their academic performance can go into technical education where they may excel well. This will bring about proper resource management and reduced waste of resource in training students who are not prepared for university education, whom after university education, tend to became unproductive.

Selection of best students for university education will also make teaching and learning easier as the best student is usually an individual who is focused and disciplined, the university management will find it much easier to manage the disciplined and focused students who always have set goals to achieve. This will go a long way in making the goal of education achieved effectively for economic growth and development into the various sectors of the nation.

Precisely, the significance of this study is based on:

1. Providing researched records on the effectiveness of the decision taken by Federal Government of Nigeria and the University Authorities to introduce Post-JAMB as means of sanitizing the University System.
2. The study will also inform the Federal Government to ascertain if Post-JAMB is the most suitable strategy in eradicating the decay in the quality of graduates produced by Nigerian Universities.
3. Students will be informed of the need for hard work which will earn one a chance into any university for undergraduate studies.

OBJECTIVES OF THE STUDY

The objective of the study aims at

1. Checking whether there is any significant interaction between the Academic sessions and the faculties.
2. Knowing whether there is any significant difference between the Academic sessions.
3. Knowing whether there is any significant difference between the faculties.

LIMITATION OF STUDY

There are many faculties that admitted students in Abia State University Uturu (ABSU), Nigeria but due to data collection, time and financial constraints, we limited our study to only three faculties. Simple random sampling was used to choose the three faculties.

Furthermore, in the three selected faculties, simple random sampling was also used to choose the JAMB scores of the candidates and their respective Post-JAMB scores in each of the three selected faculties. Finally, systematic random sampling was used to select 50 students from each faculty and five academic sessions was used for the research work.

STATEMENT OF PROBLEM

The performance of faculty of Humanities, Social Sciences and faculty of Business Administration students in JAMB and Post-JAMB examination have been a major concern of students and lecturers and even Government. The performance has led to slight rise and fall of scores of the students.

The performance of many students is very disheartening and poor; therefore, it is imperative that the cause and prevention of this failure must be investigated. Then with the aid of multivariate analysis of variance, we wish to know whether the students' performance is affected by the affect of faculty and whether there is or not significant difference between the three faculties.

STATEMENT OF HYPOTHESES

The following hypotheses shall be tested in this thesis work;

1. H_0: $\boldsymbol{\lambda_{11} = \lambda_{12} = \cdots = \lambda_{53}}$ (There is no interaction over the five levels in factor 1 and three levels in factor two)

   H_1: H_0 is false
2. H_0: $\boldsymbol{\alpha_i = 0}$; for all i, i = 1, …, 5. (There is no significant difference in the students' performance over the years)

   H_1: not all $\alpha_{i's}$ are equal to 0
3. H_0: $\boldsymbol{\beta_j = 0}$; for all j, j = 1, 2, 3. (There is no significant difference in the students' performance over the faculties)

   H_1: not all $\beta_{j's}$ are equal to 0

LITERATURE REVIEW

Ajayi, Opadare and Ariwola (1997) reported a study involving 480 students from 10 secondary schools in Ibadan municipality. They found that candidates got involved in examination malpractice due to laziness, poor teaching, inadequate supervision, and inadequate funds in schools, negative parental attitudes, desperation for certificate and the desire to obtain good grades without studying hard. The statistical technique used was the chi-square distribution test and the Hotellings T^2 distribution. Olayinka (1996) noted that passing examination to secure certificates is the main goal of education to many people and not acquisition of knowledge and skills through studying. Oluyeba (1996) identified the main causes of examination malpractice as agreed for financial or material benefits, lack of integrity and moral uprightness and poor teaching and learning situation. Other causes are unconducive environment for reading and learning process, intense competition for few vacancies in the next level of education and in employment market, too much premium on certificate and unwholesome societal values which place more premiums on wealth and affluence at the expense of merit, hard work and integrity.

Ubong (2009) carried out a M.Sc. seminar research work on the optimum conditions for extruding plastic film using an evolutionary operation. In the course of his study, three responses, tear resistance, gloss and opacity were measured at two levels of the factors, rate of extrusion and amount of an additive. The two-way multivariate analysis of variance was used to analyse the data with the help of a statistical software package known as SAS. The results showed that both the change in rate of extrusion and the amount of additive affect the responses and they do so in an additive manner.

Onwuatu (2009) carried out a research work on the performance of students from Biochemistry and Microbiology departments of Imo State University using Two-way multivariate analysis of variance (MANOVA). The effect of the departments and sessions on students in Imo State University, Owerri (IMSU) is measured by the JAMB score performance of male and female students for two academic sessions, 2005/2006 and 2006/2007. The result of the analysis showed that interaction is not significantly different from zero, session effect is not different from zero, and department effect is not significantly different from zero.

Anaike (2008) carried out a project work on Two-way multivariate analysis of variance (MANOVA) with interaction using two departments in physical science of Imo State University, Owerri as the case study. The result of the analysis showed that interaction is not significantly different from zero, session effect is significantly different from zero, and department effect is significantly different from zero. Thus, the effect of departments and sessions on students in Imo State University is measured by the student's performances in continuous assessment score and examination score in MAT 101.

In the article by Stefan van Aelst and Gert Willems published in the Journal of the American Statistical Association, they propose robust tests as alternatives to the classical Wilk's Lambda test for MANOVA. This suggests that Wilk's Lambda is not a statistic that is sufficiently robust. This is further agreed upon by the academic article by Valentin Todorov and Peter Filzmoser, published in Computational Statistics and Data Analysis (Todorov and Filzmoser. 2010, 37-48). They write that Wilk's Lambda, being based on multivariate normal theory, is generally highly sensitive to outliers. This would suggest that distributions that have many extreme values, such as skewed distributions or even distributions with heavy tails. The Exponential distribution is one such distribution that could adversely affect the MANOVA results.

Todorov has also done previous research into the robustness of MANOVA mainly dealing with the Wilk's Lambda statistic. In his article in 2007 published in *Statistical Methods and Applications* (Todorov 2007 395-407) he also evaluates the robustness of the Wilks MANOVA in terms of linear discriminant analysis, in which he concludes that Wilks is not a robust way of testing. It should be noted that Stefan van Aelst and Gert Willems also came to a similar solution, but with a particular focus on the effects of outliers (van Aelst and Willems, 106,494).

Both of these articles use Monte Carlo distributions in some degree, in which they identify a domain of parameters or possible inputs, generate the inputs randomly from a probability distribution and then perform computation. Others in the statistical community also use Monte Carlo Simulations to evaluate the robustness of MANOVA. This makes sense as mathematically computing the power of a MANOVA test in any given situation would be much more tedious and difficult. Taking this into consideration, the simulations done in this report will be of a Monte Carlo nature.

Lin and Butler (1990) Studied Cluster analyses for analyzing two-way classification data. The interaction of two-way classification data can often be identified if the data are stratified into homogeneous subsets. Four cluster methods, 2 new and 2 originally developed for investigating genotype x environment (GE) interactions, are proposed for this purpose. The 4 methods differ in the dissimilarity indices depending on whether the regression model or ANOVA model is used, and whether the similarity is specified with respect to the GE interaction alone or with respect to the genetic effect and GE interaction combined. The direct link between the cluster analysis and conventional ANOVA provides a convenient way of determining the cutoff point based on the F-ratio of the smallest dissimilarity index and the error estimate.

Goaszewski *et al.* (1998) studied the TDP method of seed yield component analysis in grain legume breeding. The results of plant breeding trials in Poland with populations of fodder pea (*Pisum sativum*) (12 strains and 3 cultivars) and broad bean (*Vicia faba*) (14 hybrids and 2 cultivars) were used as a basis for consideration of the interrelationships between some yield-related traits. Additionally, the interpretation of the results was supported by such standard statistical techniques as ANOVA. The main components affecting pea yield were plant height and the number of pods per plant. Among the analyzed characters of broad bean, the number of nodes with pods on the main stem, the major yield-contributing trait, was strongly affected by environmental conditions. The number of nodes with pods might be considered a criterion for selection of high-yielding broad bean genotypes.

Noureldin *et al.* (2000) a comparative study of some decision making procedures used in field crop experiments. Published data from 23 agricultural experiments in Egypt on yield and yield components of several crops (soya beans, faba beans, chickpea, triticale and sunflower), and on weed control in citrus were used for the comparative study of statistical procedures adopted in field crop trials. The relative magnitude of EMS for the analysis of covariance (ANCOVA) compared with the EMS for the analysis of variance (ANOVA), was >100% in general, which suggest that ANCOVA is a highly efficient tool for increasing the precision of ANOVA. Greater precision of results was obtained by combined analysis than by single analysis. This suggests that conclusions should be based on pooled error using combined analysis even if the variance is homogenous.

Alexandra *et al.* (2005) an experiment was conducted on Soil Electrical Conductivity as a Covariate to Improve the Efficiency of Field Experiments Soil ECa was used as a covariate in evaluating the effect of manure application on soil phosphorus (P) concentration.

Compared to a standard analysis of variance (ANOVA), an analysis of covariance (ANCOVA) with soil ECa as a covariate improved the accuracy of estimates of P concentrations for both treatment means and aeration tool tine position means within treatments. Standard errors for means with ECa as a covariate were smaller than those of the analysis without the covariate. Different conclusions were drawn regarding treatment effects with and without ECa as a covariate. For example, an ANOVA-based conclusion was that the control (no manure) treatment was not different from the surface applied manure treatment. The ANCOVA-based conclusion was that only in soils with low ECa values were the two treatments not different. In soils with medium and high ECa the control treatment had a significantly lower P concentration.

Tarakanovas and Sprainaitis (2006) Field experiments were conducted on Genotype x environment interaction and dry matter yield stability of white clover (*Trifolium repens* L.) cultivars and breeding populations to study the dry matter yield peculiarities in 6 cultivars (Suduviai, Bitunai, Atoliai, Nemuniai, Milo and Rivendel) and 4 breeding populations (Nos. 1123, 1124, 1421 and 1435) of white clover. ANOVA was employed to draw the conclusions. Results of the ANOVA analysis showed that dry matter yield was essentially influenced by the cuts, year of trials, cultivars and their interactions. Promising breeding lines1123 and 1124-combined high annual yield of dry matter with a low variance of stability (0.0593-0.0956).

Suneetha *et al.* (2006) Studied on heterosis for yield, quality and physiological characters in summer brinjal. The manifestation of hybrid vigour in 45 aubergine hybrids for yield, yield components, quality and physiological characters was investigated during the summer season in Gujarat, India. Hybrids were found to be high yielding, relatively late and tall with greater plant spread and leaf area per plant, compared to their parents. Existence of significant levels of heterobeltiosis and commercial heterosis for all the traits in the material studied was also observed from the significant mean squares recorded for parents vs. hybrids and control vs. hybrids components of variation in the ANOVA.

Ashalatha (1989) studied MANOVA for 17 genotypes with seven variables of Ragi at 15 locations. The results revealed that the genotype, location and GE-interactions were significant when tested against pooled error using wilk's L criteria.

Ledbetter and Palmquist (2002) studied collection of almond (*P. amygdalus* [*P. dulcis*]) selections from an almond breeding programme and several reference cultivars were evaluated for bloom characteristics during a four-year period (1996-99) in California, USA. Ten percent, fifty percent and full bloom dates, as well as date of petal fall, and the interval of bloom were scored for each of 27 almond accessions. K-means clustering analysis demonstrated the relative variability associated with each specific evaluated characteristic, and divided the almond collection and reference cultivars Mission, Nonpareil and Padre into four clusters. Multivariate analysis of variance (MANOVA) for the five bloom characteristic variables reinforced the K-means analysis showing that the almond collection should be divided into the four specific clusters based on data collected during the four years of
Observation. While F-ratios for bloom intervals were non significant during two of the four years of the study, all other evaluated characteristics during each of the four years were highly significant ($p<0.01$) in dividing the almond collection into the four clusters.

Mizuguti *et al.* (2002) reported two types of Imperata cylindrica from the Nohbi Plain in Japan. The early flowering type was named E-type and the late flowering type called Ctype. The biological characteristics of the E-type and C-type populations were compared, with reference to differences in seed germination characters considering the sib effect. Results of Nested MANOVA considering the sib effect showed the significant interaction between type and temperature fluctuation. C-type seeds were dormant but E-type seeds had very little dormancy. There were linear relationships between incubation temperature and germination speed in both types. But, there were clear differences in line segment and line slope between the two types. Line slopes of sibs in E-type were steeper than C-type.

Gupta *et al.* (2004) conducted Long Term Experiments on rice-wheat, maize-wheat and soyabean-wheat in the sequences for three consecutive years to complete a rotation and then the rotation is followed over time. Major objectives of these experiments are to monitor changes in soil properties and crop productivity as a result of continuous application of treatments and to identify the most suitable treatment. Data for each year is separately examined using univariate analysis of variance (ANOVA). Combined analysis of data over years is carried out using the procedure of groups of experiments or split plot analysis (taking years as sub plots). These analytical procedures have inherent problems and are not valid because the observations from the same plot may be correlated. Recently a M.Sc. thesis entitled of “Analytical Techniques of Long-Term Experiments” suggested the use of multivariate analysis of variance (MANOVA) in the analysis of data from long term fertilizer experiment. However, comparison of treatments after performing MANOVA is a problem. For comparison of treatments, ANOVA based on first principal component score is generally attempted. Generally, first principal component explains more than 75% of variation; sometimes it may not explain more than 75% of variation. Even if it explains 75% variation, about 25% remains unexplained. Inferences made on the partial variation of the population may be misleading. To tackle this problem, a multivariate treatment contrast analysis procedure based on Wilk's Lambda criterion has been developed. When long-term experiments are conducted with crop sequences, MANOVA may be performed on gross returns, calories, etc.

Doran *et al.* (2007) analyzed the total tract and rumen digestibility of mulberry foliage (*Morus alba*), alfalfa hay and oat hay in sheep. Foliage from mulberry trees, alfalfa hay and oat hay were fed to withers in two feeding trials to determine the whole tract digestibilities of main feed components, and the extent of rumen degradation and passage of dietary protein from these feeds. In Trial 1, each of five treatment diets was fed to five wethers (average 55 kg BW) to determine digestible energy (DE) and the digestibilities of the feeds and feed constituents using Cr2O3 as a feed marker. Intake was restricted to approximately 20 g DM/kg BW per day. The five diets consisted of alfalfa hay (AA), 1:1 alfalfa hay and oat hay mix (AO), dry mulberry foliage (MM), 1:1 mulberry foliage and oat hay mix (MO), and oat hay (OO). Each diet was fed individually to five withers in a completely randomized design. Univariate analyses (ANOVA) showed differences ($P<0.05$) among diets in digestible energy (DE), crude protein (CP) digestibility, and digestible crude protein (DCP). MM had DE and DCP values closer to AA than OO. Multivariate analyses (MANOVA) detected significant differences between all five diets ($P<0.0001$) primarily due to acid detergent fiber (ADF) and CP digestibility's and DE. Although all diets were significantly different from each other, MM was closer to AA than OO in multi-dimensional space.

In comparing the academic performance of first year students of 2004/2005 who were admitted by the last JAMB exercise and 2005/2006 students who were admitted by the first Post-JAMB test, Ifefili & Ifedili (2010), using Two-way multivariate analysis of variance, also observed that in 2004/2005 academic session examination in the University of Benin, the average percentage of successful candidates in their first year result was 14.23%, the carryover students was 66.94% while the probation students was 18.80%. These were the students admitted by the last JAMB result only. While the first year students in 2005/2006 session who were admitted by the first Post-JAMB, the average percentage of successful students were 39.65%, the carryover students were 53.80% while the probation students were 6.54%). From the analysis, it can be deduced that the students that were admitted by Post-JAMB performs much better than those admitted with JAMB scores. This is a clear manifestation of Post-JAMB being the ideal final screening process for University Admission. (Ifedili 2010) concluded that both the lecturer and administrators of the University of Benin agreed that Post-JAMB had brought a high positive change both in students' performance and in the discipline in the University. This is as a result of admitting focused and discipline students.

DATA COLLECTION/RESEARCH METHODOLOGY

DATA COLLECTION

The collection of relevant data is imperative and unavoidable before one can carry out a statistical research. Thus, the method adopted in this paper work is secondary data.

The data consist of JAMB and Post-JAMB scores of students enrolled into three different faculties of Abia State University, Uturu Nigeria for five different academic sessions. The faculties are Humanities, Social Sciences and Business Aministration, while the academic sessions are 2006/2007, 2007/2008, 2008/2009, 2009/2010 and 2010/2011. The results of 750 students were randomly selected from the faculties and thereafter, 50 students were randomly selected in the faculties of study. The same procedure was adopted for the other academic sections and the study data is presented in Table 3.1 (Appendix I).

PROBLEMS ENCOUNTERED

Some problems were encountered in the bid of data collection and they include “come later, come tomorrow syndrome”, “not on sit”, “not on duty”, etc. by some staff in admission unit. Much finance was involved going to and fro Abia State University during the data collection.

RELIABILITY OF THE STUDY

The reliability of any researchable data depends on the efficiency of the staff in keeping records. It is assumed in this research work that the data collected on students’ performance in JAMB and Post-JAMB examination in Abia State University Uturu, Nigeria can be relied upon. I strongly concur that the compilation of results of students enrolled in the various faculties were properly arranged.

METHOD OF ANALYSIS

This section shall discuss the statistical technique to be used in this research work. Based on the nature of data collected for this research work, we shall restrict our method to one-way multivariate analysis of variance and Two-way Multivariate Analysis of Variance (MANOVA) with interaction.

TWO-WAY MULTIVARIATE ANALYSIS OF VARIANCE

We assume that measurements are recorded at various levels of two factors. In some cases, these experimental conditions represent levels of a single treatment arranged within several blocks. The researchers shall, however, assume that observations at different combinations of experimental conditions are independent of one another.

Let the two sets of experiment conditions be the levels of, for instance, factor 1 and factor 2 respectively. Suppose there are ***r*** levels of factor 1, ***c*** levels of factor 2, and ***n*** independent observations at each level. Denoting the kth observation at level ***i*** of factor 1 and level ***j*** of factor 2 by $\boldsymbol{X_{ijk}}$, the univariate two-way model is

$$\boldsymbol{X_{ijk} = \mu + \alpha_i + \beta_j + \lambda_{ij} + e_{ijk}} \quad \ldots \quad (1)$$

$i = 1, 2, \ldots, r \quad j = 1, 2, \ldots, c \quad k = 1, 2, \ldots, n$

where $\sum_{i=1}^{r} \alpha_i = \sum_{j=1}^{c} \beta_j = \sum_{i=1}^{r} \sum_{j=1}^{c} \lambda_{ij} = 0$ and e_{ijk} are independent $N(0, \sigma^2)$ random variables. Here, μ represents an overall level, α_i represents the fixed effects of factor 1(A), β_j represents the fixed effect of factor 2(B), and λ_{ij} is the interaction between factor 1 and factor 2. The expected response at the $\boldsymbol{i}^{th}$ level of factor 1 and the j^{th} level of factor 2 is thus

$$\boldsymbol{E(X_{ijk}) = \mu + \alpha_i + \beta_j + \lambda_{ij}}$$

$$(\text{mean response}) = \begin{pmatrix}\text{overall}\\ \text{level}\end{pmatrix} + \begin{pmatrix}\text{effect of}\\ \text{factor 1}\end{pmatrix} + \begin{pmatrix}\text{effect of}\\ \text{factor 2}\end{pmatrix} + \begin{pmatrix}\text{factor 1} - \text{factor 2}\\ \text{interaction}\end{pmatrix} \quad \ldots \quad (2)$$

$\boldsymbol{i} = 1, 2, \ldots, r \quad \boldsymbol{j} = 1, 2, \ldots, c$

The presence of interaction, λ_{ij}, implies the factor effects are not additive.

The data layout for the design is as shown below

Treatment (factor 2) (j)

Treatment (factor 1) i	1	2	3	...	C
1	x_{111}	x_{121}	x_{131}	...	x_{1c1}
	x_{112}	x_{122}	x_{132}	...	x_{1c2}
	⋮	⋮	⋮	⋮	⋮
	x_{11n}	x_{12n}	x_{13n}	...	x_{1cn}
2	x_{211}	x_{221}	x_{231}	...	x_{2c1}
	x_{212}	x_{222}	x_{232}	...	x_{2c2}
	⋮	⋮	⋮	⋮	⋮
	x_{21n}	x_{22n}	x_{23n}	...	x_{2cn}
3	x_{311}	x_{321}	x_{331}	...	x_{3c1}
	x_{312}	x_{322}	x_{332}	...	x_{3c2}
	⋮	⋮	⋮	⋮	⋮
	x_{31n}	x_{32n}	x_{33n}	...	x_{3cn}
⋮	⋮	⋮	⋮	⋮	⋮
r	x_{r11}	x_{r12}	x_{r13}	...	x_{rc1}
	x_{r12}	x_{r22}	x_{r23}	...	x_{rc2}
	⋮	⋮	⋮	⋮	⋮
	x_{r1n}	x_{r2n}	x_{r3n}	...	x_{rcn}

Thus, we can estimate the parameters of (1) using the least squares method

$$e_{ijk} = X_{ijk} - \hat{X}_{ijk}$$

where $\hat{X}_{ijk} = \hat{\mu} + \hat{\alpha}_i + \hat{\beta}_j + \hat{\lambda}_{ij}$

$\therefore \quad e_{ijk} = X_{ijk} - \hat{\mu} - \hat{\alpha}_i - \hat{\beta}_j - \hat{\lambda}_{ij}$

Taking the sum of squares to get

$$\sum_{i=1}^{r}\sum_{j=1}^{c}\sum_{k=1}^{n} e_{ijk}^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\sum_{k=1}^{n} (X_{ijk} - \hat{\mu} - \hat{\alpha}_i - \hat{\beta}_j - \hat{\lambda}_{ij})^2$$

Let $\sum_{i=1}^{r}\sum_{j=1}^{c}\sum_{k=1}^{n} e_{ijk}^2 = Q$

$$\frac{\partial Q}{\partial \hat{\mu}} = -2\sum_{i=1}^{r}\sum_{j=1}^{c}\sum_{k=1}^{n} (X_{ijk} - \hat{\mu} - \hat{\alpha}_i - \hat{\beta}_j - \hat{\lambda}_{ij}) = 0$$

=

$$X_{...} - rcn\hat{\mu} - cn\sum_{i=1}^{r} \hat{\alpha}_i - rn\sum_{j=1}^{c} \hat{\beta}_j - n\sum_{i=1}^{r}\sum_{j=1}^{c} \hat{\lambda}_{ij} = 0$$

$$= X_{...} - rcn\hat{\mu} = 0$$

$$\therefore \quad \hat{\mu} = \frac{X_{...}}{rcn} = \overline{X}_{...} \qquad \ldots (3)$$

$$\frac{\partial Q}{\partial \hat{\alpha}_i} = -2\sum_{j=1}^{c}\sum_{k=1}^{n} (X_{ijk} - \hat{\mu} - \hat{\alpha}_i - \hat{\beta}_j - \hat{\lambda}_{ij}) = 0$$

$$\Rightarrow \Sigma\Sigma(X_{ijk} - \hat{\mu} - \hat{\alpha}_i - \hat{\beta}_j - \hat{\lambda}_{ij}) = 0$$

=>

$$X_{i..} - cn\hat{\mu} - cn\hat{\alpha}_i - n\sum_{j=1}^{c} \hat{\beta}_j - \sum_{j=1}^{c}\sum_{k=1}^{n} \hat{\lambda}_{ij} = 0$$

$$\Rightarrow X_{i..} - cn\hat{\mu} - cn\hat{\alpha}_i = 0$$

$$\therefore \quad \hat{\alpha}_i = \frac{X_{i..}}{cn} - \hat{\mu} = \overline{X}_{i..} - \overline{X}_{...} \qquad \ldots (4)$$

$$\frac{\partial Q}{\partial \hat{\beta}_j} = -2\sum_{i=1}^{r}\sum_{k=1}^{n} (X_{ijk} - \hat{\mu} - \hat{\alpha}_i - \hat{\beta}_j - \hat{\lambda}_{ij}) = 0$$

=>

$$\sum_{i=1}^{r}\sum_{k=1}^{n} (X_{ijk} - \hat{\mu} - \hat{\alpha}_i - \hat{\beta}_j - \hat{\lambda}_{ij}) = 0$$

=>

$$X_{.j.} - rn\hat{\mu} - n\sum_{i=1}^{r} \hat{\alpha}_i - rn\hat{\beta}_j - n\sum_{i=1}^{r} \hat{\lambda}_{ij} = 0$$

$$\Rightarrow X_{.j} - rn\hat{\mu} - rn\hat{\beta}_j = 0$$

$$\Rightarrow rn\hat{\beta}_j = X_{.j.} - rn\hat{\mu}$$

$$\therefore \quad \hat{\beta} = \frac{X_{.j.}}{rn} - \hat{\mu} = \overline{X}_{.j.} - \overline{X}\ldots \qquad \ldots (5)$$

$$\frac{\partial Q}{\partial \hat{\lambda}_{ij}} = -2\sum_{i=1}^{r} (X_{ijk} - \hat{\mu} - \hat{\alpha}_i - \hat{\beta}_j - \hat{\lambda}_{ij}) = 0$$

$$\sum_{k=1}^{n} (X_{ijk} - \hat{\mu} - \hat{\alpha}_i - \hat{\beta}_j - \hat{\lambda}_{ij}) = 0$$

$$X_{ij.} - n\hat{\mu} - n\hat{\alpha}_i - n\hat{\beta}_j - n\hat{\lambda}_{ij} = 0$$

$$n\hat{\lambda}_{ij} = X_{ij} - n\hat{\mu} - n\hat{\alpha}_i - n\hat{\beta}_j$$

$$\therefore \quad \hat{\lambda}_{ij} = \frac{X_{ij}}{n} - \hat{\mu} - \hat{\alpha}_i - \hat{\beta}_j$$

$$= \overline{X}_{ij.} - \overline{X}_{...} - \overline{X}_{i..} + \overline{X}_{...} - \overline{X}_{.j.} + \overline{X}_{...}$$

$$\therefore \quad \hat{\lambda}_{ij} = \overline{X}_{ij.} + \overline{X}_{i..} - \overline{X}_{.j.} + \overline{X}_{...} \qquad \ldots (6)$$

$$\hat{e}_{ijk} = X_{ijk} - \hat{\mu} - \hat{\alpha}_i - \hat{\beta}_j - \hat{\lambda}_{ij}$$

Substitute (3), (4), (5) and (6) into the above equation, we have

$$\hat{e}_{ijk} = X_{ijk} - \overline{X}_{...} + \overline{X}_{i..} + \overline{X}_{...} - \overline{X}_{.j.} + \overline{X}_{...} - \overline{X}_{ij.} + \overline{X}_{i..} + \overline{X}_{.j.} - \overline{X}_{...}$$

$$\hat{e}_{ijk} = X_{ijk} - \overline{X}_{ij.} \qquad \ldots (7)$$

In a manner analogous to (1), each observation can be decomposed as

$$X_{ijk} = \overline{X}_{...} + (\overline{X}_{i..} - \overline{X}_{...}) + (\overline{X}_{.j.} - \overline{X}_{...}) + (\overline{X}_{ij.} - \overline{X}_{i..} - \overline{X}_{.j.} + \overline{X}_{...}) + (\overline{X}_{ijk} - \overline{X}_{ij.}) \qquad \ldots (8)$$

where $\overline{X}_{...}$ is the overall average, $\overline{X}_{i..}$ is the average for the ith level of factor 1, $\overline{X}_{.j.}$ is the average for the jth level of factor 2, and $\overline{X}_{ij.}$ is the average for the i^{th} level of factor 1 and the jth level of factor 2. Squaring and summing the deviations ($x_{ijk} - \overline{X}_{...}$) gives:

$$\sum_{i=1}^{r}\sum_{j=1}^{c}\sum_{k=1}^{n} (X_{ijk} - \overline{X}_{...})^2$$

$$= cn\sum_{i=1}^{r} (X_{i..} - \overline{X}_{...})^2 + rn\sum_{j=1}^{c} (X_{.j.} - \overline{X}_{...})^2$$

$$n\sum_{i=1}^{r}\sum_{j=1}^{c}(X_{ij\cdot} - X_{i\cdot\cdot} - \overline{X}_{\cdot j\cdot} - \overline{X}_{\cdots})^2$$

$$+\sum_{i=1}^{r}\sum_{j=1}^{c}\sum_{k=1}^{n}(X_{ijk} - \overline{X}_{ij\cdot})^2 \quad \ldots \quad (9)$$

Or

$SS_{cor.} = SS_{foc1} + SS_{fac2} + SS_{int.} + SS_{res.}$

The corresponding degrees of freedom associated with the sums of squares in the breakup in (3.7) are

$$rcn - 1 = (r - 1) + (c - 1) + (r - 1)(c - 1) + rc(n - 1) \quad \ldots \quad (10)$$

The ANOVA table takes the following form.

Table 1: ANOVA Table for Comparing Effects of Two Factors and their Interaction

SV	Sum of Squares (SS)	Degrees of freedom (df)
Factor 1	$SS_{fac1} = cn\sum_{i=1}^{r}(\overline{X}_{i\cdot\cdot} - \overline{X}_{\cdots})^2$	r – 1
Factor 2	$SS_{fac2} = rn\sum_{j=1}^{r}(\overline{X}_{\cdot j\cdot} - \overline{X}_{\cdots})^2$	c – 1
Interaction	$SS_{int} = n\sum_{i=1}^{r}\sum_{j=1}^{c}(\overline{X}_{ij\cdot} - \overline{X}_{i\cdot\cdot} - \overline{X}_{\cdot j\cdot} + \overline{X}_{\cdots})^2$	(r – 1)(c – 1)
Residual (error)	$SS_{res} = \sum_{i=1}^{r}\sum_{j=1}^{c}\sum_{k=1}^{n}(\overline{X}_{ijk} - \overline{X}_{ij\cdot})^2$	rc(n – 1)
Total (corrected)	$SS_{cor} = \sum_{i=1}^{r}\sum_{j=1}^{c}\sum_{k=1}^{n}(\overline{X}_{ijk} - \overline{X}_{\cdots})^2$	rcn – 1

The F-ratios of the mean squares, $SS_{fac1}/(r - 1)$, $SS_{fac2}/(c - 1)$ and $SS_{int.}/(r - 1)(c - 1)$ to the mean square, $SS_{res}/[rc(n - 1)]$ can be used to test for the effects of factor 1, factor 2 and factor 1 – factor 2 interaction respectively.

MULTIVARIATE TWO-WAY FIXED-EFFECTS MODEL WITH INTERACTION

Proceeding by analogy, the two-way fixed effects model for a vector response consisting of p components is [see (1)].

$$\mathbf{X}_{ijk} = \boldsymbol{\mu} + \boldsymbol{\alpha}_i + \boldsymbol{\beta}_j + \boldsymbol{\lambda}_{ij} + \mathbf{e}_{ijk} \quad \ldots \quad (11)$$

i = 1, 2, …, r

j = 1, 2, …, c

k = 1, 2, …, n

where $\sum_{i=1}^{r}\boldsymbol{\alpha}_i = \sum_{j=1}^{c}\boldsymbol{\beta}_j = \sum_{k=1}^{r}\boldsymbol{\lambda}_{ij} = \sum_{j=1}^{c}\boldsymbol{\lambda}_{ij} = \mathbf{0}$. The vectors are all of order p ×1 and e_{ijk} is assumed to be an $N_p(0, \varepsilon)$ random vector. Thus, the responses consist of p measurements replicates n times at each of the possible combinations of levels of factors 1 and 2.

Following (8), the observation vectors $\mathbf{X}_{ijk}$ can be decomposed as

$$\mathbf{X}_{ijk} = \overline{\mathbf{X}}_{\cdots} + (\overline{\mathbf{X}}_{i\cdot\cdot} - \overline{\mathbf{X}}_{\cdots}) + (\overline{\mathbf{X}}_{\cdot j\cdot} - \overline{\mathbf{X}}_{\cdots}) + (\overline{\mathbf{X}}_{ij\cdot} - \overline{\mathbf{X}}_{i\cdot\cdot} - \overline{\mathbf{X}}_{\cdot j\cdot} + \overline{\mathbf{X}}_{\cdots}) + (\overline{\mathbf{X}}_{ijk} - \overline{\mathbf{X}}_{ij\cdot}) \quad \ldots \quad (12)$$

where $\overline{\mathbf{X}}_{\cdots}$ is the overall average of the observation vectors, $\overline{\mathbf{X}}_{i\cdot\cdot}$ is the average of observation vectors at the ith level of factor $\overline{\mathbf{X}}_{\cdot j\cdot}$ is the average of the observation vectors at the jth level of factor 2, and $\overline{\mathbf{X}}_{ij\cdot}$ is the average of the observation vectors at the ith level of factor 1 and the jth level of factor 2.

Straight forward generalizations of (9) and (10) give the breakups of the sum of squares cross-products and degrees of freedom.

$$\sum_{i=1}^{r}\sum_{j=1}^{c}\sum_{k=1}^{n}(\overline{X}_{ijk} - \overline{X}_{\cdots})(\overline{X}_{ijk} - \overline{X}_{\cdots})'$$

$$= cn\sum_{i=1}^{r}(\overline{X}_{i\cdot\cdot} - \overline{X}_{\cdots})(\overline{X}_{i\cdot\cdot} - \overline{X}_{\cdots})'$$

$$+ rn\sum_{j=1}^{c}(\overline{X}_{\cdot j\cdot} - \overline{X}_{\cdots})(\overline{X}_{\cdot j\cdot} - \overline{X}_{\cdots})'$$

$$+ n\sum_{i=1}^{r}\sum_{j=1}^{c}(\overline{X}_{ij\cdot} - \overline{X}_{i\cdot\cdot} - \overline{X}_{\cdot j\cdot} + \overline{X}_{\cdots})(\overline{X}_{ij\cdot} - \overline{X}_{i\cdot\cdot} - \overline{X}_{\cdot j\cdot} + \overline{X}_{\cdots})'$$

$$+\sum_{i=1}^{r}\sum_{j=1}^{c}\sum_{k=1}^{n}(\overline{\mathbf{X}}_{ijk} - \overline{\mathbf{X}}_{ij\cdot})(\overline{\mathbf{X}}_{ijk} - \overline{\mathbf{X}}_{ij\cdot})' \ldots \quad (13)$$

$$\mathbf{rcn - 1 = (r - 1)(c - 1) + (r - 1)(c - 1) + rc(n - 1)} \quad \ldots \quad (14)$$

Again, the generalization from the univariate to the multivariate analysis consists simply of replacing a scalar such as $(\bar{\mathbf{X}}_{i\cdot\cdot} - \bar{\mathbf{X}}_{\cdots})^2$ with the corresponding matrix $(\bar{\mathbf{X}}_{i\cdot\cdot} - \bar{\mathbf{X}}_{\cdots})(\bar{\mathbf{X}}_{i\cdot\cdot} - \bar{\mathbf{X}}_{\cdots})'$.

The MANOVA table is the following.

Table 2: MANOVA Table for Comparing Effects of Two Factors and their Interaction

SV	**Matrix of Sum of Squares and cross-product (SSP)**	**Degrees of freedom (df)**
Factor 1	$\mathbf{SSP_{fac1} = cn\sum_{i=1}^{r} (\bar{X}_{i\cdot\cdot} - \bar{X}_{\cdots})(\bar{X}_{i\cdot\cdot} - \bar{X}_{\cdots})'}$	**r – 1**
Factor 2	$\mathbf{SSP_{fac2} = rn\sum_{j=1}^{r} (\bar{X}_{\cdot j\cdot} - \bar{X}_{\cdots})(\bar{X}_{\cdot j\cdot} - \bar{X}_{\cdots})'}$	**c – 1**
Interaction	$\mathbf{SSP_{int} = n\sum_{i=1}^{r}\sum_{j=1}^{c} (\bar{X}_{ij\cdot} - \bar{X}_{i\cdot\cdot} - \bar{X}_{\cdot j\cdot} + \bar{X}_{\cdots})(\bar{X}_{ij\cdot} - \bar{X}_{i\cdot\cdot} - \bar{X}_{\cdot j\cdot} + \bar{X}_{\cdots})'}$	**(r – 1)(c – 1)**
Residual (error)	$\mathbf{SSP_{res} = \sum_{i=1}^{r}\sum_{j=1}^{c}\sum_{k=1}^{n} (X_{ijk} - \bar{X}_{ij\cdot})(X_{ijk} - \bar{X}_{ij\cdot})'}$	**rc(n – 1)**
Total (corrected)	$\mathbf{SSP_{cor} = \sum_{i=1}^{r}\sum_{j=1}^{c}\sum_{k=1}^{n} (X_{ijk} - \bar{X}_{\cdots})(X_{ijk} - \bar{X}_{\cdots})'}$	**rcn – 1**

3.6 TEST STATISTIC AND HYPOTHESES

A test (the likelihood ratio test) of

$H_1 : \boldsymbol{\lambda_{11}} = \boldsymbol{\lambda_{12}} = \cdots = \boldsymbol{\lambda_{rc}} = \mathbf{0}$ (no interaction effect) … (14)

Versus

H_1 : At least one $\boldsymbol{\lambda_{ij}} \neq \mathbf{0}$ is conducted by rejecting H_0 for small values of the ratio

$$\Lambda^* = \frac{|SSP_{res}|}{|SSP_{int} + SSP_{res}|} \quad \ldots \quad (15)$$

For large samples, Wilks Lambda Λ^*, can be referred to a chi-square percentile. Using Bartlett's multiplier to improve the chi-square approximation: Reject $H_0 : \boldsymbol{\lambda_{11}} = \boldsymbol{\lambda_{12}} = \cdots = \boldsymbol{\lambda_{rc}} = \mathbf{0}$ at α level if

$$\left[rc(n-1) - \frac{P+1(r-1)(c-1)}{2}\right]\ln\Lambda^* > \chi^2_{(r-1)(c-1)p(\alpha)} \quad \ldots \quad (16)$$

where Λ^* is given by (15) and $\chi^2_{(r-1)(c-1)p(\alpha)}$ is the upper (100α)th percentile of a chi-square distribution with (r – 1)(c – 1)p d.f.

Ordinarily, the test for interaction is carried out before the tests for main factor effects. If interaction effects exist, the factor effects do not have a clear interpretation. From a practical standpoint, it is not advisable to proceed with the additional multivariate tests. Instead, p univariate two-way analyses of variance (one for each variable) are often conducted to see if the interaction appears in some responses but not others. Those responses without interaction may be interpreted in terms of additive factor 1 and 2 effects, provided the latter effects exist.

In multivariate model, we test for factor 1 and factor 2 main effects as following first, consider the hypotheses.

$H_0 : \boldsymbol{\alpha_1} = \boldsymbol{\alpha_2} = \cdots = \boldsymbol{\alpha_r} = \mathbf{0}$ and

H_1: at least one $\boldsymbol{\alpha_i} \neq \mathbf{0}$. The hypotheses specify no factor 1 effects and some factor 1 effects respectively. Let

$$\Lambda^* = \frac{|SSP_{res}|}{|SSP_{fac1} + SSP_{res}|} \quad \ldots \quad (17)$$

So that small values of Λ^*, are consistent with H_1. Using Bartlett's correction, the likelihood ratio test is : Reject $H_0 : \boldsymbol{\alpha_1} = \boldsymbol{\alpha_2} = \cdots = \boldsymbol{\alpha_r} = \mathbf{0}$ (no factor 1 effect) at level α if.

$$\left[rc(n-1) - \frac{P+1(r-1)}{2}\right]\ln\Lambda^* > \chi^2_{(r-1)p(\alpha)} \quad \ldots \quad (18)$$

where Λ^* is given by (17) and $\chi^2_{(r-1)p(\alpha)}$ is the upper (100α)th percentile of a chi-square distribution with (r – 1)p d.f.

In a similar manner, factor 2 effects are tested by considering

$H_0 : \boldsymbol{\beta_1} = \boldsymbol{\beta_2} = \cdots = \boldsymbol{\beta_c} = \mathbf{0}$ and H_1 : at least one $\boldsymbol{\beta_j} \neq \mathbf{0}$. Small values of

$$\Lambda^* = \frac{|SSP_{res}|}{|SSP_{fac2} + SSP_{res}|} \quad \ldots \quad (19)$$

are consistent with H_1. Once again, for large samples and using Bartlett's correction: Reject $H_0 : \boldsymbol{\beta_1} = \boldsymbol{\beta_2} = \cdots = \boldsymbol{\beta_c} = \mathbf{0}$ (no factor 2 effect) at level α if.

$$\left[rc(n-1) - \frac{P+1(c-1)}{2}\right] \ln \Lambda^* > \chi^2_{(c-1)p(\alpha)} \quad \ldots \quad (20)$$

where $\boldsymbol{\Lambda^*}$ is given by (19) and $\boldsymbol{\chi^2_{(c-1)p(\alpha)}}$ is the upper (100α)th percentile of a chi-square distribution with (c – 1)p d.f.

SIMULTANEOUS CONFIDENCE INTERVALS FOR CONTRASTS

Simultaneous confidence intervals for contrasts in the model parameters can provide insight into the nature of the factor effects. When interaction effects are negligible, we may concentrate on contrasts in the factors 1 and factor 2 main effects. The Bonferoni approach applies to the components of the differences $\boldsymbol{\alpha_i - \alpha_m}$ of the factor 1 effects and the components of $\boldsymbol{\beta_j - \beta_q}$ of the factor 2 effects, respectively.

The 100(1 - α)% simultaneous confidence intervals for $\boldsymbol{\alpha_{ii'} - \alpha_{mi'}}$ are $\boldsymbol{\alpha_{ii'} - \alpha_{mi'}}$ belongs to $(\bar{\mathbf{X}}_{\mathbf{i..i'}} - \bar{\mathbf{X}}_{\mathbf{m..i'}}) \pm \mathbf{t}_v\left[\frac{\boldsymbol{\alpha}}{\mathbf{Pr(r-1)}}\right]$

$$\sqrt{\frac{E_{i'i'}}{v}\frac{2}{cn}} \quad \ldots \quad (21)$$

Where v = rc(n – 1), $E_{i'i'}$ is the i′th diagonal element of E = SSP_{res} and $\bar{\mathbf{X}}_{\mathbf{i..i'}} - \bar{\mathbf{X}}_{\mathbf{m..i'}}$ is the i′th component of $\bar{\mathbf{X}}_{\mathbf{i..}} - \bar{\mathbf{X}}_{\mathbf{m..}}$.

Similarly, the **100(1 - α)%** simultaneously confidence interval for $\boldsymbol{\beta_{ji'} - \beta_{qi'}}$ belongs to

$$(\bar{\mathbf{X}}_{\mathbf{i..i'}} - \bar{\mathbf{X}}_{\mathbf{m..i'}}) \pm \mathbf{t}_v\left[\frac{\boldsymbol{\alpha}}{\mathbf{Pc(c-1)}}\right]\sqrt{\frac{\mathbf{E}_{i'i'}}{\mathbf{v}}\frac{\mathbf{2}}{\mathbf{cn}}} \quad \ldots \quad (22)$$

where v and $\mathbf{E_{i'i'}}$ are defined above and $\bar{\mathbf{X}}_{\mathbf{\cdot j \cdot i'}} - \bar{\mathbf{X}}_{\mathbf{\cdot q \cdot i'}}$ the i′th component of $\bar{\mathbf{X}}_{\mathbf{\cdot j \cdot i'}} - \bar{\mathbf{X}}_{\mathbf{\cdot q \cdot i'}}$.

Comment: We have considered the multivariate two-way model with replications. That is, the model allows for n replications of the responses at each combination of factor levels. This enables us to examine the "interaction" of the factors.

DATA ANALYSIS

ANALYSIS OF APTNESS OF MODEL

We begin our analysis of the appropriateness of MANOVA model for the Data by considering the plot of the residuals e against the fitted values in Figures 1.2 and 2.2 in Appendix III. These plots do not suggest any systematic deviations from the response plane, nor that does the variance of the error terms vary with the level of $\hat{Y}$. These error variances are constant, since their residual plots showed about the same extent of scatter of the residuals around zero (0) for each factor. Plots of the residuals e are entirely consistent with the conclusions of good fit by the response function and constant variance of the error terms. Finally, Figures 1.1 and 2.1 (see Appendix III) contains a normal probability plot of the residuals. The pattern is reasonably linear, consistent with a normal distribution of the error terms.

The statistical method discussed in this study shall be implemented in this paper for the analysis. Due to the complicated nature of the data, a statistical software package known as SPSS version 15.0 was used for the analysis.

The matrices of the appropriate sum of squares and cross-products were calculated (see the SPSS statistical software output in Appendix II) leading to the matrices below as well as the MANOVA table:

$$SSP_{fac1} = \begin{pmatrix} 7482.435 & 5661.260 \\ 5661.260 & 7133.520 \end{pmatrix}$$

$$SSP_{fac2} = \begin{pmatrix} 1863.363 & -2452.147 \\ -2452.147 & 6186.115 \end{pmatrix}$$

$$SSP_{int} = \begin{pmatrix} 17095.237 & 5751.240 \\ 5751.240 & 6521.272 \end{pmatrix}$$

$$SSP_{res} = \begin{pmatrix} 766060.0 & 69545.207 \\ 69545.207 & 946061.454 \end{pmatrix}$$

Table 3: MANOVA Table

Source of variation	**SSP**	**d.f**
Factor 1: Academic sessions	$\begin{pmatrix} 7482.435 & 5661.260 \\ 5661.260 & 7133.520 \end{pmatrix}$	4

Factor 2: Faculties	$\begin{pmatrix} 1863.363 & -2452.147 \\ -2452.147 & 6186.115 \end{pmatrix}$	2
Interaction	$\begin{pmatrix} 17095.237 & 5751.240 \\ 5751.240 & 6521.272 \end{pmatrix}$	8
Residual	$\begin{pmatrix} 766060.0 & 69545.207 \\ 69545.207 & 946061.454 \end{pmatrix}$	735
Total (corrected)	$\begin{pmatrix} 792501.035 & 78505.56 \\ 78505.56 & 965902.361 \end{pmatrix}$	749

To test for interaction, we compute

$$\Lambda^* = \frac{|SSP_{res}|}{|SSP_{int} + SSP_{res}|} = 0.972$$

For (r – 1) (c – 1) = 8

Since we have large samples, we then use the Wilks'lambda, Λ^*

Using (16), we have

$$\left[5(3)(49) - \frac{2+1-(4)(2)}{2}\right]\ln 0.972 = 20.94$$

$$\chi^2_{(r-1)(c-1)p(\alpha)} = \chi^2_{4(2)(3)\alpha} = \chi^2_{16,0.05} = 26.30$$

Since $\left[rc(n-1) - \frac{P+1(r-1)(c-1)}{2}\right]\ln \Lambda^* = 20.94^2 <$ $\chi^2_{16,0.05} = 26.30$, we do not reject the hypothesis H_0 : $\boldsymbol{\lambda_{11} = \lambda_{12} = \lambda_{13} = \lambda_{21} = \lambda_{22} = \lambda_{23} = \lambda_{31} = \lambda_{32} = \lambda_{33} = \lambda_{41} = \lambda_{42} = \lambda_{43} = \lambda_{51} = \lambda_{52} = \lambda_{53} = 0}$ (no interaction effects).

To test for factor 1 and factor 2 effects, we require

$$\Lambda^* = \frac{|SSP_{res}|}{|SSP_{fac1} + SSP_{fac2}|} = 0.984$$

and

$$\Lambda^* = \frac{|SSP_{res}|}{|SSP_{fac2} + SSP_{res}|} = 0.991$$

Using (18), we have

$$\left[5(3)(49) - \frac{2+1-(4)}{2}\right]\ln 0.984 = 11.86$$

$$\chi^2_{(r-1)p(\alpha)} = \chi^2_{4(2)\alpha} = \chi^2_{8,0.05} = 15.51$$

Using (20), we have

$$\left[5(3)(49) - \frac{2+1-(2)}{2}\right]\ln 0.991 = 6.64$$

$$\chi^2_{(c-1)p(\alpha)} = \chi^2_{2(2)\alpha} = \chi^2_{4,0.05} = 9.49$$

From above, $-\left[rc(n-1) - \frac{p+1(r-1)}{2}\right]\ln \Lambda_1^* = 11.86$ $< \chi^2_{(r-1)p(\alpha)} = 15.51$, we do not reject the hypothesis H_0 : $\boldsymbol{\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0}$ (no factor 1 effects) at the 5% level. On the other hand, $-\left[rc(n-1) - \frac{p+1(c-1)}{2}\right]\ln \Lambda_2^* = 6.64$ < $\chi^2_{(c-1)p(\alpha)} = 9.49$, we do not reject H_0 : $\boldsymbol{\beta_1 = \beta_2 = \beta_3 = 0}$ (no factor 2 effect) at the 5% level.

SUMMARY, CONCLUSION AND RECOMMENDATION

SUMMARY

This study work is on the multivariate analysis of variance on the academic performance of students enrolled into Abia State University via their JAMB and Post-JAMB scores using three faculties of the university and five academic sessions. The statistical techniques for data analysis were explicitly explained prior to analysis of the data in details. The statistical software package used in this research work for data analysis is the SPSS. Thus, the results were well interpreted.

CONCLUSION

Having concluded the analysis in chapter four, the following conclusions can be observed:

1. There was no interaction between the academic sessions and the faculties on the academic performance of the students enrolled in Abia State University, Uturu Nigeria via their JAMB and Post JAMB scores.
2. The vector means performed the same in the five academic sessions.
3. It has been concluded that both the academic sessions and the faculties do not

affect the performance of students in JAMB and Post JAMB scores.

RECOMMENDATIONS

Having carried out this study work, the following recommendations are made:

i. Future researchers should carry out a similar research work with more than two interaction effects to compare the results.
ii. Future researchers should use other updated and advanced statistical software packages, such as SAS, SPSS version 19, E-views, Megastat, MATLAB e.t.c, for data analysis to enable the researcher get all the components needed.
iii. Future researchers should adopt some other multivariate methods on the similar research work, like Hotellings T^2 distribution, principal component analysis, discriminant analysis e.t.c to compare results.

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APPENDIX I
2006/2007 ACADEMIC SESSION

FOBA		FOH		FOSS	
JAMB	**POST-JAMB**	**JAMB**	**POST-JAMB**	**JAMB**	**POST-JAMB**
180.00	192.00	213.00	218.00	242.00	281.00
271.00	213.00	217.00	270.00	211.00	192.00
192.00	200.00	186.00	242.00	192.00	211.00
218.00	272.00	213.00	211.00	186.00	207.00
272.00	213.00	280.00	216.00	192.00	187.00
310.00	218.00	241.00	216.00	250.00	172.00
232.00	280.00	300.00	218.00	212.00	192.00
262.00	220.00	218.00	214.00	186.00	210.00
216.00	186.00	200.00	199.00	211.00	208.00
270.00	172.00	217.00	218.00	242.00	262.00
218.00	216.00	262.00	324.00	218.00	211.00
216.00	321.00	198.00	217.00	210.00	310.00
217.00	314.00	218.00	311.00	260.00	241.00
211.00	324.00	216.00	170.00	215.00	262.00
234.00	211.00	211.00	192.00	214.00	213.00
274.00	282.00	242.00	186.00	262.00	283.00
213.00	262.00	187.00	192.00	241.00	217.00
217.00	186.00	246.00	172.00	232.00	242.00
301.00	198.00	187.00	217.00	213.00	242.00
211.00	232.00	217.00	192.00	282.00	232.00
234.00	256.00	186.00	250.00	262.00	241.00
238.00	247.00	192.00	260.00	218.00	232.00
231.00	258.00	218.00	217.00	263.00	242.00
	218.00		264.00	236.00	214.00

321.00		300.00			
214.00	311.00	240.00	246.00	231.00	232.00
264.00	216.00	211.00	192.00	214.00	236.00
310.00	280.00	187.00	213.00	241.00	262.00
311.00	211.00	192.00	211.00	213.00	218.00
192.00	186.00	282.00	172.00	241.00	242.00
198.00	250.00	187.00	211.00	262.00	213.00
211.00	242.00	218.00	260.00	262.00	218.00
301.00	252.00	213.00	218.00	272.00	232.00
192.00	186.00	211.00	280.00	311.00	216.00
218.00	217.00	262.00	342.00	218.00	262.00
219.00	321.00	211.00	286.00	198.00	210.00
310.00	211.00	186.00	211.00	234.00	254.00
290.00	218.00	196.00	272.00	262.00	232.00
218.00	321.00	312.00	286.00	246.00	242.00
262.00	218.00	216.00	311.00	321.00	241.00
231.00	221.00	262.00	246.00	362.00	308.00
242.00	242.00	282.00	263.00	241.00	216.00
218.00	198.00	243.00	261.00	321.00	212.00
216.00	216.00	241.00	268.00	301.00	211.00
241.00	218.00	216.00	242.00	211.00	216.00
232.00	242.00	262.00	216.00	208.00	218.00
312.00	218.00	232.00	262.00	218.00	211.00
218.00	216.00	242.00	232.00	216.00	198.00
301.00	242.00	242.00	264.00	240.00	172.00
260.00	311.00	216.00	242.00	243.00	241.00
242.00	280.00	262.00	214.00	241.00	262.00

2007/2008 ACADEMIC SESSION

FOBA		FOH		FOSS	
JAMB	POST-JAMB	JAMB	POST-JAMB	JAMB	POST-JAMB
241.00	211.00	218.00	211.00	241.00	281.00
232.00	170.00	262.00	232.00	262.00	262.00
218.00	210.00	211.00	192.00	282.00	162.00
321.00	260.00	282.00	212.00	193.00	186.00
242.00	213.00	246.00	218.00	263.00	242.00
	216.00		232.00	242.00	232.00
311.00		286.00			
218.00	217.00	241.00	262.00	231.00	268.00
190.00	260.00	221.00	213.00	301.00	211.00
211.00	242.00	218.00	321.00	211.00	218.00
232.00	216.00	280.00	218.00	260.00	262.00
214.00	263.00	242.00	263.00	278.00	242.00
242.00	232.00	263.00	271.00	242.00	252.00
232.00	242.00	232.00	321.00	218.00	213.00
241.00	262.00	242.00	262.00	232.00	218.00
192.00	186.00	216.00	321.00	186.00	211.00
186.00	282.00	286.00	311.00	216.00	232.00
192.00	198.00	246.00	216.00	217.00	286.00
210.00	262.00	221.00	241.00	241.00	262.00
211.00	286.00	261.00	243.00	253.00	217.00
271.00	262.00	218.00	311.00	256.00	262.00
242.00	232.00	286.00	213.00	217.00	282.00
246.00	211.00	292.00	138.00	256.00	272.00
256.00	218.00	216.00	234.00	261.00	281.00
262.00	242.00	216.00	311.00	264.00	257.00
198.00	256.00	206.00	283.00	253.00	262.00
261.00	251.00	263.00	246.00	211.00	232.00
218.00	262.00	232.00	243.00	242.00	216.00
218.00	242.00	262.00	321.00	232.00	242.00
256.00	262.00	216.00	241.00	256.00	232.00
241.00	218.00	262.00	232.00	261.00	241.00
246.00	253.00	242.00	262.00	232.00	216.00
262.00	241.00	241.00	232.00	241.00	216.00
264.00	256.00	262.00	241.00	282.00	213.00
241.00	262.00	263.00	252.00	291.00	162.00
251.00	272.00	232.00	246.00	241.00	216.00
221.00	192.00	248.00	231.00	218.00	211.00
186.00	191.00	253.00	261.00	301.00	218.00
214.00	216.00	256.00	232.00	214.00	232.00
232.00	241.00	231.00	262.00	216.00	218.00
262.00	256.00	241.00	236.00	272.00	291.00
	256.00		231.00	241.00	261.00

241.00		253.00			
231.00	286.00	246.00	241.00	189.00	241.00
263.00	241.00	263.00	232.00	261.00	321.00
261.00	241.00	241.00	261.00	241.00	262.00
321.00	263.00	248.00	232.00	282.00	242.00
241.00	252.00	256.00	211.00	263.00	278.00
321.00	311.00	256.00	217.00	246.00	219.00
218.00	311.00	211.00	286.00	216.00	312.00
321.00	286.00	289.00	136.00	211.00	262.00
211.00	257.00	241.00	213.00	282.00	232.00

2008/2009 ACADEMIC SESSION

FOBA		**FOH**		**FOSS**	
JAMB	**POST-JAMB**	**JAMB**	**POST-JAMB**	**JAMB**	**POST-JAMB**
310.00	282.00	196.00	261.00	312.00	218.00
218.00	192.00	192.00	216.00	211.00	312.00
210.00	218.00	248.00	214.00	262.00	311.00
216.00	214.00	241.00	311.00	216.00	186.00
321.00	246.00	262.00	263.00	246.00	218.00
278.00	291.00	216.00	262.00	241.00	262.00
264.00	246.00	262.00	321.00	241.00	262.00
211.00	282.00	211.00	211.00	310.00	186.00
200.00	219.00	246.00	262.00	218.00	321.00
199.00	264.00	241.00	268.00	218.00	261.00
282.00	246.00	286.00	142.00	210.00	262.00
292.00	216.00	218.00	246.00	213.00	272.00
291.00	286.00	241.00	262.00	218.00	216.00
290.00	201.00	242.00	263.00	246.00	211.00
262.00	242.00	186.00	191.00	271.00	262.00
261.00	291.00	241.00	218.00	282.00	214.00
242.00	262.00	252.00	262.00	242.00	262.00
253.00	218.00	321.00	268.00	262.00	262.00
214.00	186.00	216.00	218.00	216.00	218.00
262.00	316.00	241.00	248.00	218.00	216.00
218.00	311.00	282.00	241.00	262.00	262.00
246.00	262.00	281.00	246.00	263.00	241.00
241.00	268.00	251.00	262.00	242.00	262.00
211.00	241.00	217.00	241.00	282.00	262.00
262.00	208.00	242.00	286.00	242.00	262.00
241.00	262.00	252.00	263.00	232.00	268.00
248.00	192.00	192.00	211.00	192.00	216.00
192.00	186.00	262.00	172.00	192.00	186.00
262.00	281.00	211.00	216.00	213.00	268.00
262.00	186.00	218.00	262.00	246.00	282.00
189.00	216.00	262.00	241.00	262.00	189.00
192.00	218.00	216.00	311.00	218.00	279.00
246.00	218.00	262.00	218.00	219.00	278.00
241.00	262.00	281.00	261.00	192.00	186.00
211.00	261.00	192.00	216.00	214.00	262.00
190.00	181.00	210.00	216.00	218.00	199.00
218.00	214.00	218.00	216.00	301.00	121.00
260.00	246.00	218.00	217.00	202.00	218.00
241.00	216.00	192.00	198.00	216.00	214.00
262.00	246.00	211.00	218.00	312.00	211.00
214.00	256.00	286.00	312.00	216.00	214.00
288.00	296.00	217.00	216.00	301.00	218.00
272.00	292.00	211.00	189.00	268.00	162.00
214.00	286.00	214.00	256.00	262.00	218.00
211.00	216.00	218.00	190.00	266.00	182.00
192.00	294.00	286.00	246.00	282.00	271.00
218.00	219.00	321.00	216.00	291.00	211.00
216.00	200.00	208.00	246.00	262.00	286.00
208.00	196.00	186.00	286.00	242.00	271.00
191.00	286.00	182.00	262.00	199.00	180.00

2009/2010 ACADEMIC SESSION

FOBA		**FOH**		**FOSS**	
JAMB	**POST-JAMB**	**JAMB**	**POST-JAMB**	**JAMB**	**POST-JAMB**
218.00	302.00	211.00	208.00	221.00	321.00
216.00	218.00	242.00	262.00	300.00	211.00

221.00	189.00	232.00	292.00	218.00	282.00
218.00	192.00	282.00	242.00	217.00	262.00
262.00	241.00	246.00	292.00	268.00	242.00
241.00	262.00	283.00	246.00	241.00	262.00
217.00	218.00	241.00	262.00	292.00	282.00
292.00	218.00	242.00	271.00	282.00	271.00
262.00	241.00	282.00	272.00	242.00	292.00
281.00	217.00	217.00	282.00	190.00	218.00
211.00	217.00	282.00	242.00	260.00	270.00
186.00	217.00	211.00	282.00	211.00	272.00
214.00	216.00	282.00	262.00	211.00	282.00
282.00	262.00	281.00	218.00	262.00	192.00
216.00	282.00	261.00	241.00	262.00	218.00
241.00	262.00	211.00	192.00	298.00	124.00
262.00	216.00	242.00	216.00	291.00	162.00
241.00	261.00	218.00	262.00	248.00	261.00
218.00	262.00	261.00	248.00	262.00	241.00
196.00	210.00	262.00	281.00	216.00	218.00
241.00	282.00	260.00	280.00	196.00	216.00
262.00	282.00	262.00	286.00	262.00	261.00
271.00	261.00	268.00	262.00	282.00	262.00
262.00	211.00	217.00	262.00	281.00	261.00
211.00	192.00	218.00	271.00	282.00	211.00
272.00	133.00	218.00	262.00	302.00	286.00
218.00	262.00	282.00	242.00	262.00	272.00
219.00	302.00	218.00	219.00	298.00	128.00
262.00	211.00	186.00	192.00	242.00	162.00
241.00	262.00	286.00	211.00	241.00	262.00
262.00	249.00	292.00	278.00	263.00	241.00
198.00	210.00	262.00	241.00	272.00	262.00
232.00	268.00	241.00	262.00	282.00	211.00
262.00	286.00	246.00	283.00	186.00	291.00
216.00	210.00	198.00	210.00	262.00	211.00
301.00	268.00	268.00	242.00	262.00	282.00
262.00	281.00	241.00	262.00	211.00	286.00
192.00	287.00	262.00	241.00	261.00	241.00
187.00	210.00	202.00	218.00	262.00	291.00
182.00	192.00	237.00	281.00	216.00	262.00
218.00	262.00	214.00	310.00	214.00	218.00
217.00	210.00	218.00	199.00	200.00	216.00
216.00	240.00	261.00	281.00	262.00	218.00
240.00	216.00	282.00	262.00	240.00	242.00
198.00	218.00	312.00	218.00	216.00	189.00
216.00	217.00	246.00	200.00	246.00	199.00
262.00	241.00	216.00	282.00	261.00	208.00
281.00	262.00	241.00	282.00	214.00	262.00
241.00	218.00	242.00	281.00	246.00	282.00
186.00	210.00	218.00	196.00	218.00	232.00

2010/2011 ACADEMIC SESSION

FOBA		FOH		FOSS	
JAMB	POST-JAMB	JAMB	POST-JAMB	JAMB	POST-JAMB
217.00	216.00	312.00	218.00	246.00	228.00
286.00	282.00	262.00	246.00	286.00	272.00
211.00	246.00	261.00	178.00	282.00	162.00
242.00	216.00	242.00	262.00	189.00	216.00
218.00	262.00	199.00	211.00	264.00	214.00
200.00	216.00	189.00	208.00	291.00	262.00
208.00	242.00	262.00	281.00	261.00	241.00
262.00	266.00	258.00	255.00	264.00	248.00
261.00	194.00	211.00	260.00	190.00	244.00
218.00	241.00	262.00	282.00	241.00	255.00
261.00	244.00	214.00	218.00	262.00	216.00
248.00	233.00	216.00	241.00	217.00	218.00
251.00	242.00	262.00	271.00	192.00	216.00
226.00	216.00	278.00	262.00	218.00	242.00
246.00	286.00	246.00	217.00	282.00	214.00
216.00	266.00	286.00	232.00	241.00	262.00
218.00	210.00	261.00	282.00	266.00	271.00
282.00	216.00	201.00	206.00	218.00	192.00
246.00	292.00	282.00	261.00	241.00	216.00

257.00	281.00	221.00	246.00	188.00	192.00
262.00	218.00	192.00	214.00	219.00	218.00
192.00	214.00	286.00	162.00	186.00	192.00
216.00	200.00	286.00	261.00	214.00	262.00
242.00	281.00	262.00	242.00	216.00	211.00
252.00	282.00	211.00	244.00	266.00	252.00
216.00	218.00	218.00	240.00	252.00	261.00
216.00	200.00	189.00	216.00	241.00	189.00
286.00	301.00	286.00	264.00	282.00	242.00
246.00	211.00	261.00	244.00	196.00	282.00
221.00	218.00	264.00	241.00	218.00	192.00
262.00	281.00	244.00	211.00	216.00	162.00
241.00	261.00	282.00	262.00	214.00	187.00
255.00	262.00	282.00	211.00	264.00	292.00
199.00	178.00	252.00	241.00	282.00	246.00
241.00	218.00	261.00	246.00	292.00	286.00
261.00	282.00	289.00	253.00	263.00	211.00
264.00	272.00	299.00	282.00	271.00	262.00
286.00	252.00	261.00	281.00	262.00	242.00
271.00	242.00	252.00	261.00	282.00	262.00
277.00	281.00	291.00	262.00	281.00	283.00
252.00	272.00	298.00	196.00	247.00	241.00
261.00	255.00	246.00	189.00	192.00	261.00
248.00	211.00	262.00	262.00	222.00	211.00
212.00	262.00	245.00	286.00	217.00	186.00
264.00	281.00	242.00	262.00	282.00	242.00
198.00	186.00	216.00	261.00	218.00	262.00
216.00	262.00	246.00	278.00	301.00	218.00
211.00	281.00	282.00	281.00	217.00	262.00
282.00	246.00	244.00	211.00	178.00	249.00
263.00	261.00	262.00	222.00	281.00	262.00

APPENDIX II
SPSS OUTPUT

Between-Subjects Factors

		N
FACTOR 1	1.00	150
	2.00	150
	3.00	150
	4.00	150
	5.00	150
FACTOR 2	1.00	250
	2.00	250
	3.00	250

Multivariate Tests[c]

Effect		Value	F	Hypothesis df
Intercepts	Pillai's Trace	958	8310.560[a]	2.00
	Wilks' Lambda	042	8310.560[a]	2.00
	Hotelling's Trace	22.675	8310.560[a]	2.00
	Roy's Largest Root	22.675	8310.560[a]	2.00
FACTOR 1FACTOR2	Pillai's Trace	.003	984[a]	2.00
	Wilks' Lambda	.997	984[a]	2.00
	Hotelling's Trace	.003	984[a]	2.00
	Roy's Largest Root	.003	984[a]	2.00
FACTOR1	Pillai's Trace	.016	1.492	8.000
	Wilks' Lambda	.984	1.493[a]	8.000
	Hotelling's Trace	.016	1.494	8.000
	Roy's Largest Root	.014	2.615[b]	4.000
FACTOR2	Pillai's Trace	.009	1.739	4.000
	Wilks' Lambda	.991	1.739[a]	4.000
	Hotelling's Trace	.010	1.739	4.000
	Roy's Largest Root	.014	3.162[b]	2.00
FACTOR1 FACTOR2	Pillai's Trace	.028	1.290	16.000
	Wilks' Lambda	.972	1.292[a]	16.000
	Hotelling's Trace	.028	1.294	16.000
	Roy's Largest Root	.024	2.174[b]	8.000

Multivariate Tests[c]

Effect		Error df	Sig.
Intercepts	Pillai's Trace	733.000	.000
	Wilks' Lambda	733.000	.000
	Hotelling's Trace	733.000	.000
	Roy's Largest Root	733.000	.000
FACTOR 1FACTOR2	Pillai's Trace	733.000	.374
	Wilks' Lambda	733.000	.374
	Hotelling's Trace	733.000	.374
	Roy's Largest Root	733.000	.374
FACTOR1	Pillai's Trace	1468.000	.155
	Wilks' Lambda	1466.000	.155
	Hotelling's Trace	1464.000	.154
	Roy's Largest Root	734.000	.034
FACTOR2	Pillai's Trace	1468.000	.139
	Wilks' Lambda	1466.000	.139
	Hotelling's Trace	1464.000	.139
	Roy's Largest Root	734.000	.043
FACTOR1 FACTOR2	Pillai's Trace	1468.000	.195
	Wilks' Lambda	1466.000	.193
	Hotelling's Trace	1464.000	.192
	Roy's Largest Root	734.000	.027

a. Exact statistic
b. The statistics is an upper bound on F that yields a lower bound on the significance level
c. Design: Intercepts + FACTOR1FACTOR2 + FACTOR1 + FACTOR2 + FACTOR1*FACTOR2

Levene's Test of Equality of Error Variances[a]

	f	df1	df2	Sig.
JAMB	1.923	14	735	.021
POSTJAMB	2.119	14	735	.009

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercepts + FACTOR1FACTOR2 + FACTOR1 + FACTOR2 + FACTOR1*FACTOR2

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	Df	Means Square
Corrected Model	JAMB	27906.980[a]	15	1860.465
	POSTJAMB	20764.413[b]	15	1384.294
Intercept	JAMB	10408321.473	1	10408321.473
	POSTJAMB	10338723.522	1	10338723.522
FACTOR1FACTOR2	JAMB	1465.945	1	1465.945
	POSTJAMB	923.506	1	923.506
FACTOR1	JAMB	7482.435	4	1870.609
	POSTJAMB	7133.520	4	1783.380
FACTOR2	JAMB	1863.363	2	931.681
	POSTJAMB	6186.115	2	3093.057
FACTOR1 FACTOR2	JAMB	17095.237	8	2136.905
	POSTJAMB	6521.272	8	815.159
Error	JAMB	44592667.000	750	
	POSTJAMB	44291716.000	750	
Corrected Total	JAMB	793966.936	749	
	POSTJAMB	966825.867	749	

Tests Between-Subjects Effects

Source	Dependent Variable	F	Sig.
Corrected Model	JAMB	1.783	.033
	POSTJAMB	1.074	.377
Intercept	JAMB	9972.729	.000
	POSTJAMB	8021.279	.000
FACTOR1FACTOR2	JAMB	1.405	.236
	POSTJAMB	.717	.398
FACTOR1	JAMB	1.792	.128
	POSTJAMB	1.384	.238
FACTOR2	JAMB	.893	.410
	POSTJAMB	2.400	.091
FACTOR1 FACTOR2	JAMB	2.047	.039
	POSTJAMB	.632	.751
Error	JAMB		
	POSTJAMB		
Corrected Total	JAMB		
	POSTJAMB		

a. R Squared = .035 (Adjusted R Squared = .015)
b. R Squared = .021 (Adjusted R Squared = .001)

Between-Subjects SSCP Matrix

			JAMB	POSTJAMB
Hypothesis	Intercept	JAMB	10408321	10373464.1
		POSTJAMB	10373464	10338723.5
	FACTOR1FACTOR2	JAMB	1465.945	1163.533
		POSTJAMB	1163.533	923.506
	FACTOR1	JAMB	7482.435	5661.260
		POSTJAMB	5661.260	7133.520
	FACTOR2	JAMB	1863.363	-2452.147
		POSTJAMB	-2452.147	6186.115
	FACTOR1* FACTOR2	JAMB	17095.237	5751.240
		POSTJAMB	5751.240	6521.272
Error		JAMB	766059.95	69545.207
		POSTJAMB	69545.207	946061.454

Based on Type III Sum of Squares

Residual SSCP Matrix

		JAMB	POSTJAMB
Sum-of-Squares and Cross-Product	JAMB	766059.95	69545.207
	POSTJAMB	69545.207	946061.454
Covariance	JAMB	1043.678	94.748
	POSTJAMB	94.748	1288.912
Correlation	JAMB	1.000	.082
	POSTJAMB	.082	1.000

Based on Type III Sum of Squares

APPENDIX III

Fig. 1

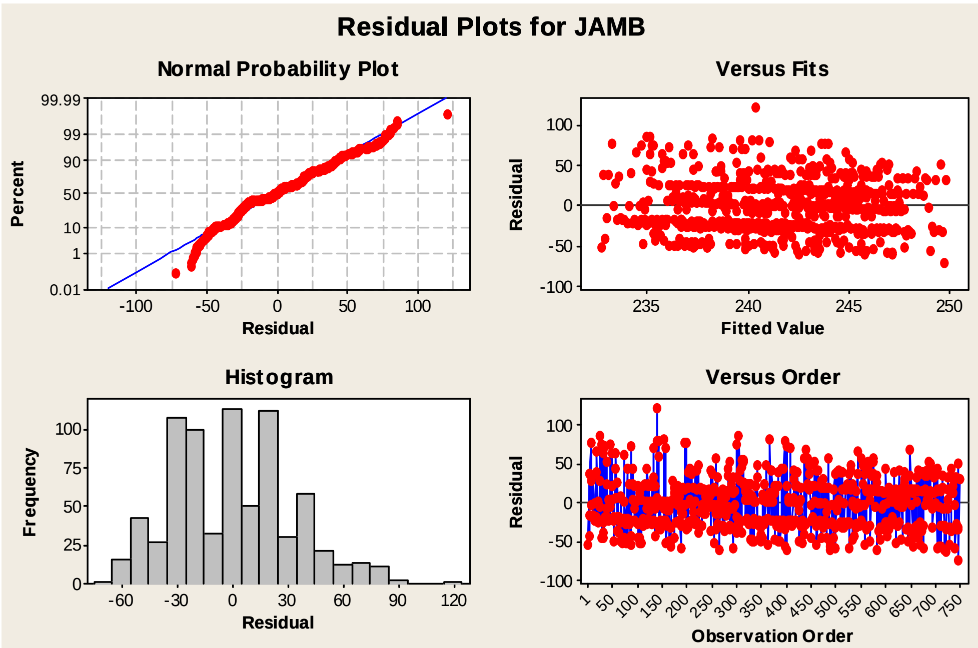
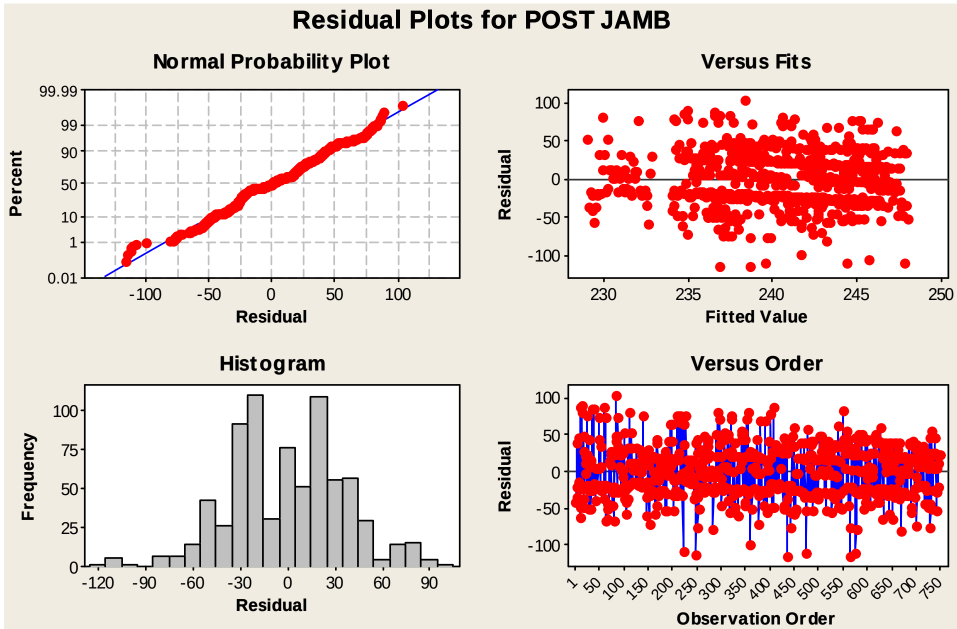


Fig.2


Residual Plots for POST JAMB
Normal Probability Plot
Percent
Residual
Versus Fits
Residual
Fitted Value
Histogram
Frequency
Residual
Versus Order
Residual
Observation Order