Course: INF2178
Assignment: Assignment 3
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Evaluating Kindergarten Student Score over time by Income Group

Introduction

The research seeks to explore the trajectory of kindergarten students' academic progress in reading and math, over the course of an academic year (Fall 1998 to Spring 1999), with a particular focus on the influence of household income. Utilizing data from an early childhood longitudinal study, the study examines approximately 11933 students' performance, parsed into three household income categories:

- Income group 1: Total Household Income below $40k
- Income group 2: Total Household Income between $40k and $70k
- Income group 3: Total Household Income above $70k

Research question:

1. How do students' reading, and math scores change by over time by income level after controlling for their general knowledge scores?
2. If the change in students' reading, and math scores over time differ by income group after controlling for their general knowledge scores?

Exploratory Data Analysis

The scatterplots from Figure 1 show a comparison between students score in reading, math, and general knowledge from Fall to Spring term, with data points color-coded by income group. All scatterplots show a positive correlation between Fall and Spring scores, suggesting students who score higher in Fall term tends to score higher in the Spring term. The score from income group 3 has a higher concentration in the upper range, especially for General knowledge score, which indicate that students from higher income group have more resources to education, hinting a potential income-related advantage.

Figure 1 Fall vs. Spring Reading/Math/General Knowledge Score

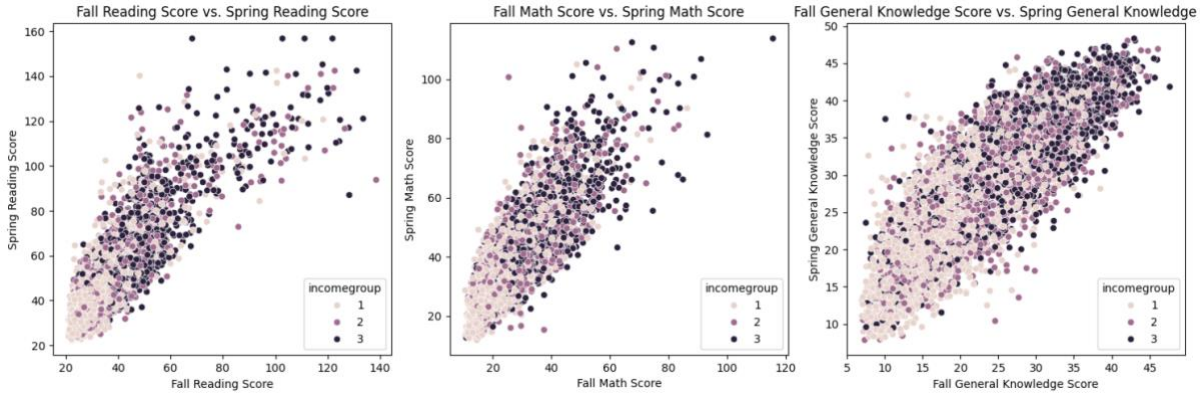
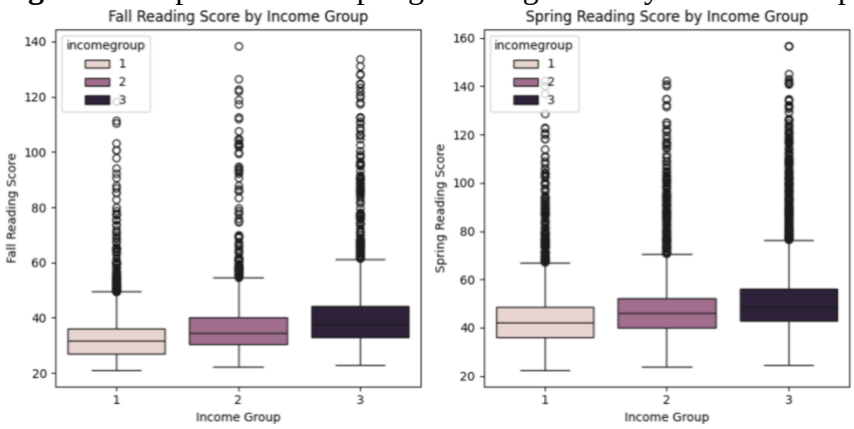
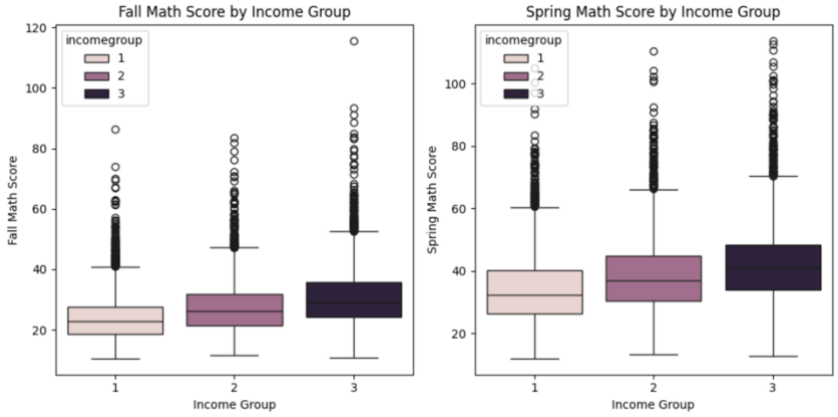


Figure 2 Boxplots of Fall/Spring Reading Score by Income Group



The boxplot shows that over both terms, the median Reading scores appear to increase with income group. There is also increase in scores from Fall to Spring terms across all income groups, suggesting overall improvement over the year.

Figure 3 Boxplots of Fall/Spring Math Score by Income Group



The box plot shows that the median score of Math is higher for higher income group over both terms. Similar as Reading score, Math score improve in general over terms across all income groups.

To delve into the dynamics of academic progression among kindergarten students, Figures 4 and 5 present an analysis of how reading and math scores evolve across terms for different income groups, and whether these changes vary according to income levels. The figures track the average scores for both subjects from Fall to Spring, calculating the mean difference between the terms. The analysis reveals academic growth across the board, with students from all income groups showing gains in both reading and math as the academic year progresses. Notably, students from higher-income brackets not only start off with stronger scores in the Fall but also exhibit marginally larger improvements by the Spring term. This pattern suggests that while all students are capable of academic growth, the magnitude of this growth may be somewhat affected by household income group.

Figure 4 Mean Reading Score over Fall and Spring Term by Income Group

Income Group	Fall Reading Score	Spring Reading Score	Diff (Spring – Fall)
1	32.78	43.67	10.89
2	36.29	48.01	11.72
3	39.89	52.21	12.32

Figure 5 Mean Math Score over Fall and Spring Term by Income Group			
Income Group	**Fall Math Score**	**Spring Math Score**	**Diff (Spring – Fall)**
1	23.92	33.88	9.96
2	27.57	38.46	10.89
3	31.01	42.41	11.4

The analysis encapsulates the academic performance trends of Kindergarten students across different income groups from Fall to Spring term. However, the observed score increases, documented in Figures 4 and 5, do not account for other influential factors such as students' general knowledge and baseline academic abilities as measured at the beginning of the Fall term. To isolate the impact of income group on Spring term scores while adjusting for these initial abilities, an ANCOVA will be conducted. This statistical approach will control for the potential confounding effects of Fall general knowledge scores and Fall academic scores in both reading and math, thereby allowing for a more nuanced exploration of how income levels may interact with students' academic progress by Spring term.

ANCOVA Test

Figure 6 and 7 illustrate the ANCOVA analysis using OSL regression, detailing the impact of income group, fall scores and fall general knowledge scores on Spring score for Reading and Math score individually.

ANCOVA Test - Reading

The models (Figure 6) return a R-squared value of 0.693 which indicate that approximately 69.3% of the variability of Spring reading scores is explained by the model. The coefficient for Fall reading scores, Fall general knowledge scores are significant (<0.001), showing a positive relationship with Spring reading scores. While the coefficient for income group (T.2 - Income group 1 vs. Income group 2) and income group (T.3 - Income group 1 vs. Income group 3) are not statistically significant ($p > 0.05$), implying that after controlling for fall reading and general knowledge scores, there are no significant impact of income groups on the changes of reading scores over fall to spring terms across income groups.

Figure 6 ANCOVA Table for Spring Reading Scores						
Dep. Variable:	springreadingscore					
No. observations	11933					
Df residuals:	11928					
Df model:	4					
R-squared:	0.693					
Adj. R-squared:	0.693					
Prob (F-statistic):	< 0.001					
	Coef	**Std err**	**t**	**P > |t|**	**[0.025**	**0.975]**
Intercept	5.606	0.289	19.365	< 0.001	5.039	6.174
C (incomegroup)[T.2]	0.109	0.179	0.614	0.539	-0.241	0.461
C (incomegroup)[T.3]	0.087	0.192	0.458	0.647	-0.288	0.463

fallreadingscore	1.105	0.008	138.019	< 0.001	1.090	1.121
fallgeneralknowledgescore	0.091	0.012	7.798	< 0.001	0.068	0.114

ANCOVA Test – Math

The model (Figure 7) returns a R-squared value of 0.691 which indicate that approximately 69.1% of the variability of Spring reading scores is explained by the model. The coefficient for income groups (T.2 and T.3) are not statistically significant (p-value > 0.05), indicating that after adjusting for the fall math score and fall general knowledge score, there is no statistically significant difference in spring math scores between the income group 1 and other groups. While the coefficient for fall math scores and fall general knowledge scores are significant, (p-value < 0.001), indicating that these are significant predictor of spring math scores.

Figure 7 ANCOVA Table for Spring Math Scores

Dep. Variable:	Springmathscore
No. observations	11933
Df residuals:	11928
Df model:	4
R-squared:	0.691
Adj. R-squared:	0.691
Prob (F-statistic):	< 0.001

	Coef	**Std err**	**t**	**P > |t|**	**[0.025**	**0.975]**
Intercept	6.192	0.220	28.174	< 0.001	5.761	6.623
C (incomegroup)[T.2]	0.171	0.151	1.134	0.257	-0.125	0.467
C (incomegroup)[T.3]	0.197	0.162	1.222	0.222	-0.119	0.515
fallreadingscore	0.979	0.009	115.029	< 0.001	0.962	0.996
fallgeneralknowledgescore	0.214	0.011	19.996	< 0.001	0.193	0.235

Both ANCOVA results suggest that, while income group does not have a statistically significant impact on both spring reading and math scores when controlling for fall reading/math scores and fall general knowledge scores, both covariant (fall reading/math scores and fall general knowledge scores) are significant predictor of spring reading/math scores, and returns a positive relationship between variables and the spring scores. While before making conclusions, we will first check the ANCOVA assumption to ensure that the results are valid.

ANCOVA Assumption Check

Assumption 1: Linearity and Homogeneity of regression slopes

The Figure 8 illustrates the regression lines for fall reading, fall math, fall general knowledge scores over spring scores, which each line represents one income group. In all three charts, the regression lines appear to be quite close, and with some parts intersect with each other, thus this assumption is violated which may lead to bias of the results.

Figure 8 Homogeneity of Regression Slope

Assumption 2: Homogeneity of variances

Figure 9 Levene's Test		
Levene's Test	**Reading**	**Math**
Statistic	26.60	29.45
P-value	< 0.001	< 0.001

Levene's test (Figure 9) yield a very low p-value for both Reading and Math score, indicates a significant violation of the homogeneity of variances assumption.

Assumption 3: Normality of residuals

To verify the normality of the residuals, we look to Q-Q plots of residuals (Figure 10). The Q-Q plot for both Reading (Left) and Math (Right) shows significant deviation of residuals from the line in the tails. Though the Shapiro Wilk test (Figure 11) returns a high statistics value, the low p-value (<0.001) indicate strong evidence against null hypothesis of normality. Both tests suggest that residuals do not follow a normal distribution for either set of scores.

Figure 10 Q-Q plot for Reading and Math Score

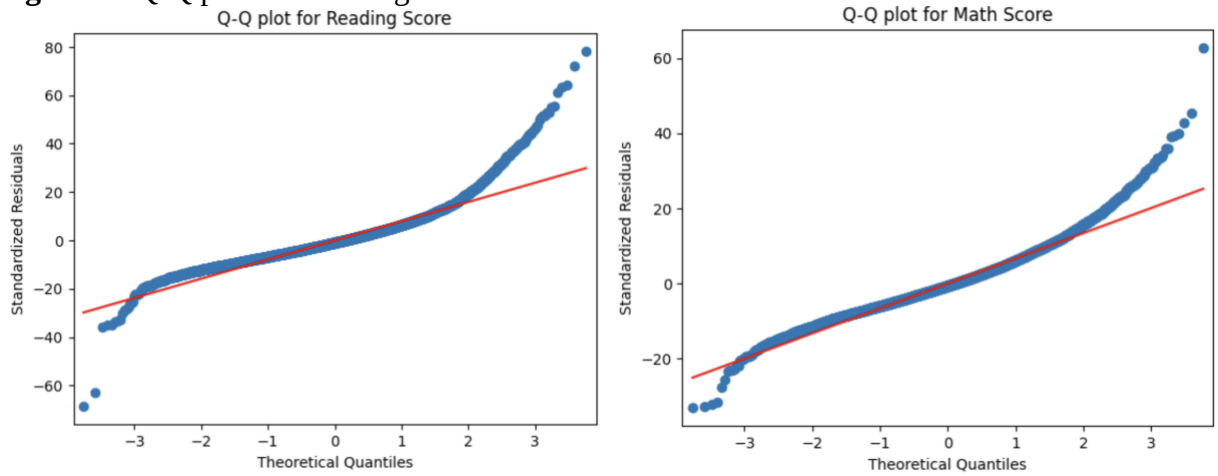


Figure 11 Shapiro Wilk test		
Shapiro Wilk test	**Reading**	**Math**
Statistic	0.91	0.96
P-value	< 0.001	< 0.001

The analysis of the ANCOVA assumptions suggests that the dataset does not fully meet the criteria for ANCOVA. Despite deviations from normality in the residuals and evidence of unequal variances across groups, the large sample size in this study allows for some flexibility. According to the central limit theorem, the distribution of sample means will approximate a normal distribution for large samples, making ANCOVA robust to violations of the normality assumption. Additionally, the equal sample sizes among groups can mitigate the impact of unequal variances. However, it is essential to note that the interpretation of the results should be approached with caution.

In summary, the ANCOVA results indicate that while students from higher income groups tend to have higher initial scores in the fall term, income group itself does not provide a statistically significant advantage in spring term math and reading outcomes when other variables are accounted for. This suggests that the baseline academic performance in the fall is more predictive of spring term success than income group. Both fall course scores and general knowledge scores are significant predictors of spring scores, establishing a positive relationship: students with higher scores in these areas during the fall are likely to carry this performance into the spring term. Therefore, while income may correlate with initial performance, it does not significantly influence the progression of academic scores from fall to spring when controlling for fall performance.