214C - Lab 1 - Multiple Regression Write-Up

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# Introduction

Schools which include English Language Learners (ELLs; non-native English speakers) and schools comprised primarily of native English speakers may differ in academic performance based on socio-economic factors. This study utilizes a multiple regression model approach to investigate the effect of school diversity on test scores. Specifically, we investigate whether the relationship between 8th grade student test scores and school spending is moderated by schools diversity after controlling for parent income. School composition of *English Language Learners* (ELLs; I.e., non-native english speakers) is used as a proxy for *school diversity* due to availability of data. This study utilizes a public-use repository including school district-level educational data reported in 1998 from 220 school districts in Massachusetts. In this paper *school(s)* is used as shorthand to refer to *school-district(s)*. This paper includes the following sections: (1) Review of descriptive statistics, (2) Assessment of regression model assumptions, (3) Description of the regression model specification, and (4) Summary of the multiple regression results.

## Measures: Model Variables

Table 1 includes a description of each variable included in the multiple regression model. The variable english reporting the percent of ELL students in a school was transformed into a dichotomous variable due to the heavily skewed distribution and clustering of the data at zero (i.e., floor effect; see Figure 1). In the transformed variable, schools which included at least one percent of ELL students were labeled “ELL” schools and schools composed of less than one percent ELL students were labeled as “NO ELL” schools.

Table 1:

Description of Variables Included in the Regression Model.

| Name | Label |
| --- | --- |
| test\_score | Average test scores for 8th grader students (1998) |
| school\_spending | Total spending per-pupil (dollars) |
| english | School includes ELL students (0=NO ELL, 1=ELL) |
| income | Average parent income (scale unavailable) |

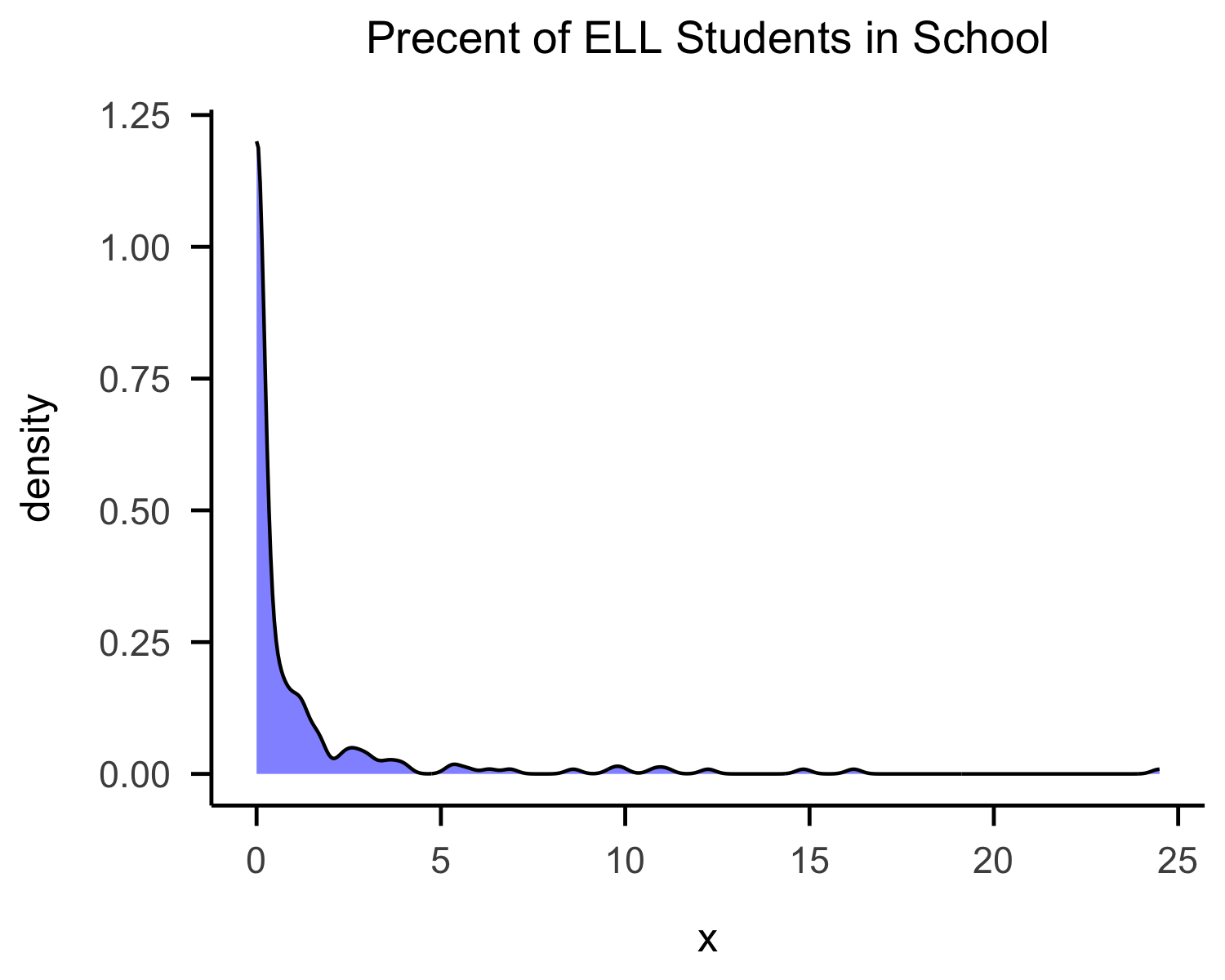


Figure 1: Distribution of percent of ELL students in school.

## Review of Descriptive Statistics

Table 2 presents the descriptive statistics for the variables included in the regression model. The outcome variable, schools’ average test\_scores has a mean and a standard deviation of . The distribution of test scores has minimal negative skew (as indicated by the similarity between mean and median values) and small negative kurtosis values. These shape statistics indicate that the outcome variable test scores is approximately normal. Test scores range from 641 to 747 points across schools in the sample. The predictor variable average school spending (school\_spending) has a mean of and a standard deviation . The distribution of school spending has moderate positive skew, indicating that the right tail of the distribution is long or that the sample includes schools which reported high spending (relative to the mean). The kurtosis value is also positive and moderately high in value indicating that more schools are clustered at each tail of the distribution compared to a normal distribution. School spending ranged from 3465 to 9868 across schools in the sample. The predictor variable average parent income (income) has a mean of and a standard deviation of . The distribution of parent income is positively skewed and kurtotic with a similar distribution shape to the school spending variable. The highest and lowest average parent incomes reported were 9.7 and 46.85 respectively. Finally, for the proportion of schools with ELL students (english), 24% of schools reported ELL students and 76% of schools reported no ELL students (Table 3).

Table 2:

Descriptive Statistics for the Massachusetts School Data

|  | mean | sd | median | min | max | skew | kurtosis |
| --- | --- | --- | --- | --- | --- | --- | --- |
| test\_score | 698.41 | 21.05 | 698.00 | 641.00 | 747.00 | -0.20 | -0.12 |
| school\_spending | 5,370.25 | 977.04 | 5,155.00 | 3,465.00 | 9,868.00 | 1.30 | 2.51 |
| income | 18.75 | 5.81 | 17.13 | 9.69 | 46.85 | 1.74 | 3.86 |

Table 3:

Counts for schools with ELL students & NO ELL students

| english | n | percent |
| --- | --- | --- |
| NO ELL | 167 | 0.76 |
| ELL | 53 | 0.24 |

## 

## Evaluation of Multiple Regression Assumptions

Prior to running a multiple linear regression, regression assumptions were evaluated including, linearity, normality, multicollinearity, and homoscedasticity.

Linearity was assessed using bivariate plots to assess the relationship between the two continuous predictors (school\_spending and parent\_income) and the outcome variable (test\_scores). The left panel of Figure 2 displays the bivariate relationship with test scores increasing slightly with increased school spending. This relationship is weak with high heterogeneity in test scores across the range of the school spending variable. The right panel of Figure 2, depicts a positive and moderately strong relationship between parent income and test scores. These plots provide sufficient evidence that the linearity assumption is satisfied for proceeding with the linear specification of these predictors.

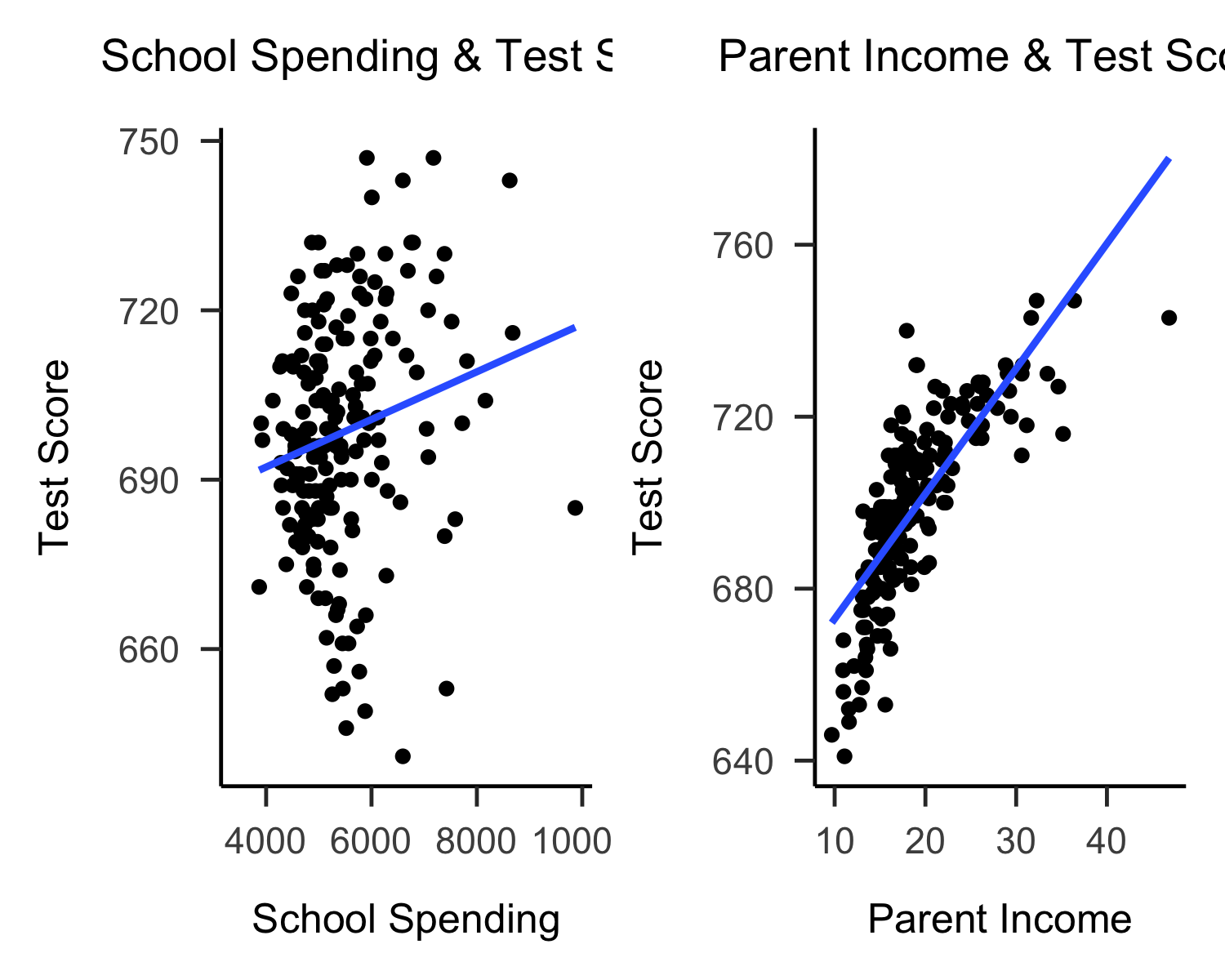


Figure 2: Bivariate scatterplots with fit line for continuous predictors by outcome variable.

Univariate normality was investigated using density plots to visualize the distribution of outcome and predictor variables (Figure 3). The outcome variable test scores on the left panel of Figure 1 can be seen to be approximately normal. The school spending and income predictor variable density plots reflect the positive skew and kurtosis values as reported previously in Table 2.

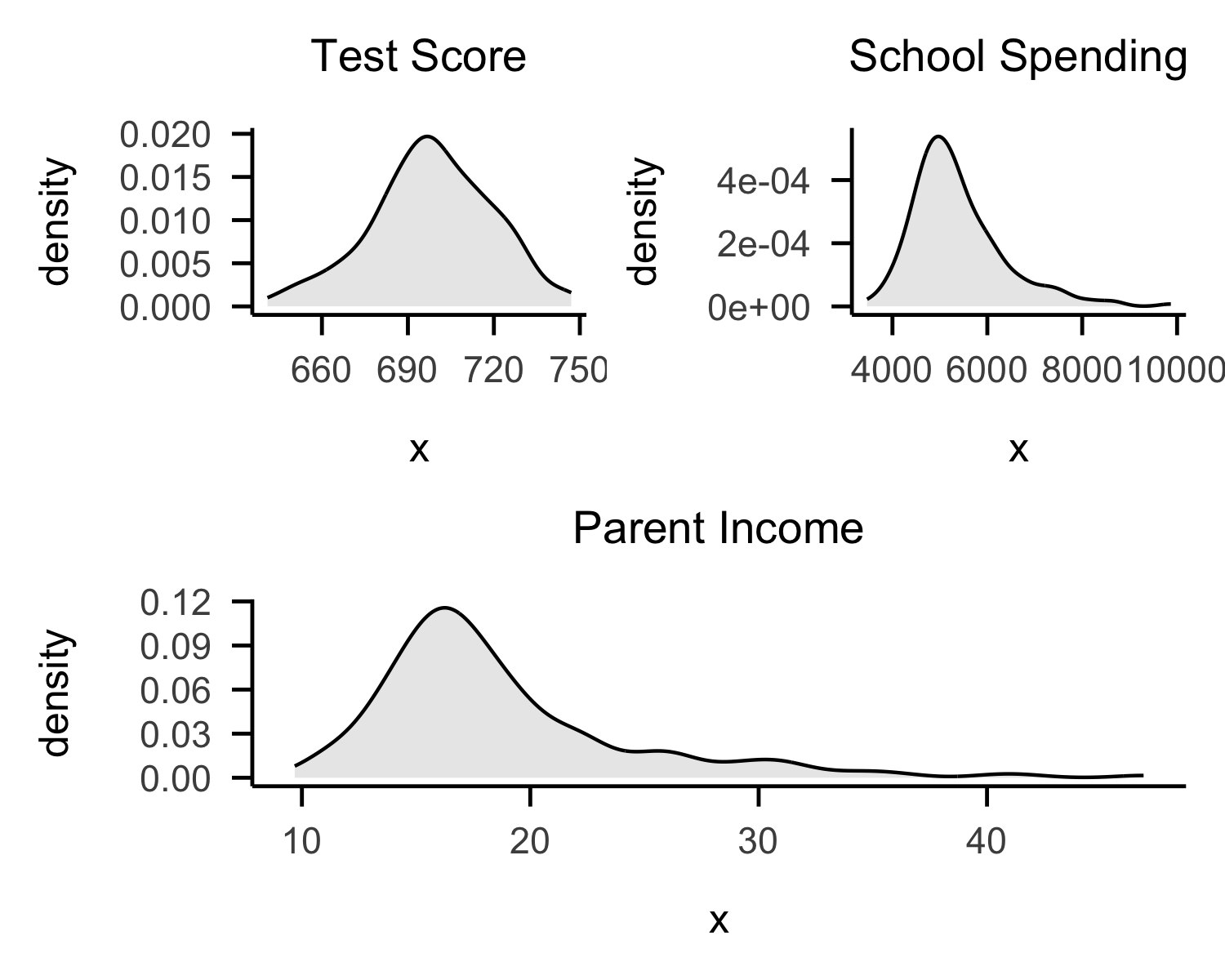


Figure 3: Density plot of the outcome and predictor variables.

The multivariate normality assumption can be assessed using QQ-plots of the standardized residuals (Figure 4). The QQ-plot shows that the residuals are approximately normal with negligible violation to normality indicated by the points at either end of the plot slightly deviating form the line. Only a single residual appears to be greater than a standard deviation from normality. This provides evidence that the mulitvariate normality assumption is sufficiently satisfied to proceed with the regression analysis.

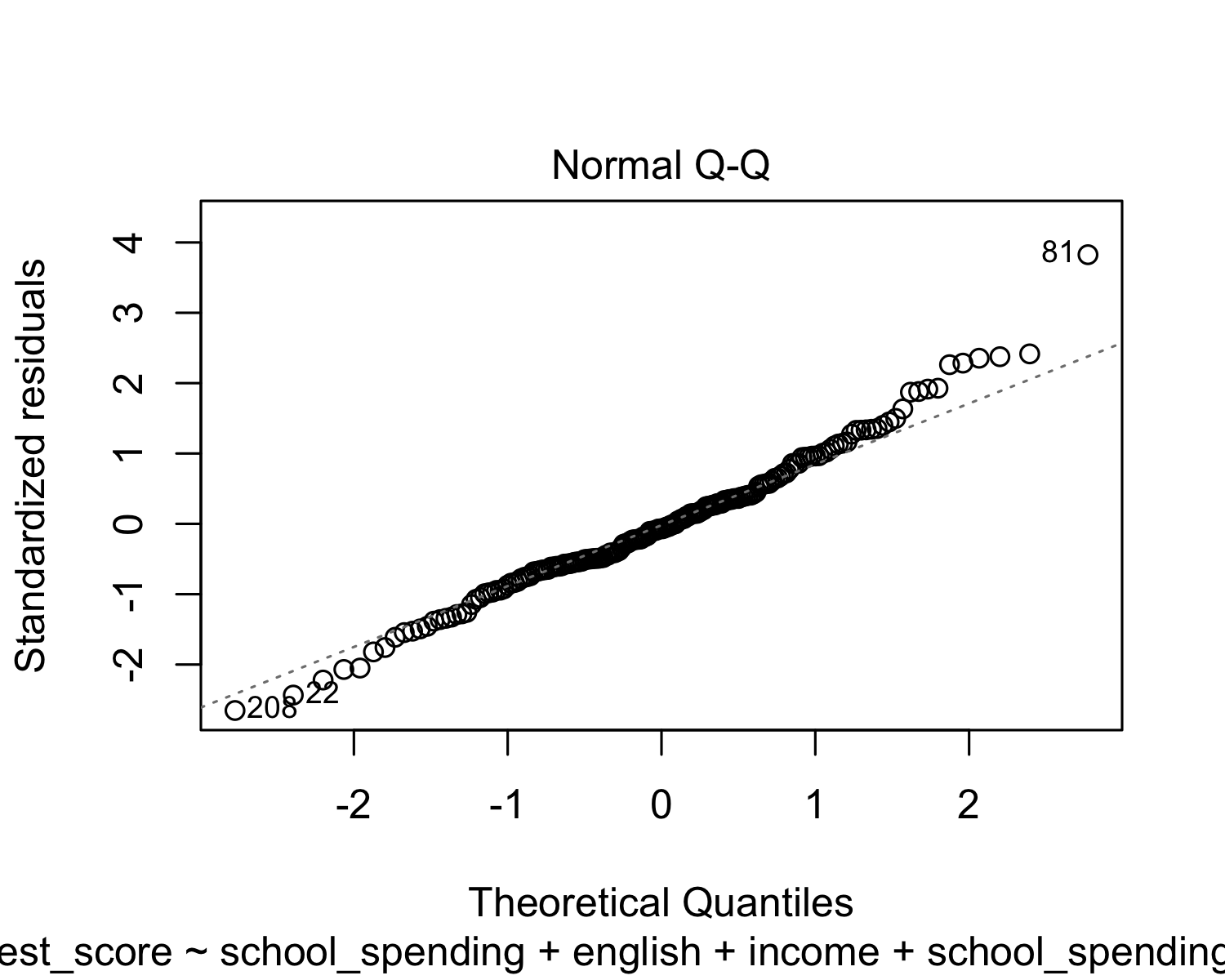


Figure 4: QQ-plot of standardized residuals

The multicollinearity assumption can be evaluated using a bivariate correlation table. The Pearson correlations shown in Table 4 are below the threshold indicating that no serious violations of multicollinearity are present. Furthermore, the variance inflation factor for the predictors are below the recommended threshold (VIF<5) indicating that only moderate levels of multicollinearity exist for predictors in the model (Table 5).

Table 4:

Means, standard deviations, and correlations with confidence intervals

| Variable | M | SD | 1 | 2 |
| --- | --- | --- | --- | --- |
| 1. test\_score | 698.41 | 21.05 |  |  |
|  |  |  |  |  |
| 2. school\_spending | 5370.25 | 977.04 | .19\*\* |  |
|  |  |  | [.05, .33] |  |
|  |  |  |  |  |
| 3. income | 18.75 | 5.81 | .78\*\* | .39\*\* |
|  |  |  | [.71, .83] | [.27, .50] |
|  |  |  |  |  |

*Note.* Note. M and SD are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). \* indicates p < .05. \*\* indicates p < .01.

Table 5.

*Variance inflation factor (VIF) estimates for predictors in model*.

## school\_spending income english   
## 1.557807 1.556551 1.274595

The Homoscedasticity assumption is evaluated using a plot of the standardized residuals. Figure 5 shows horizontal but slightly curved fit line for the standardized residuals indicating that no serious violations of the assumption are present. The distribution of points in the plot are spread relatively evenly across points on the x-axis with reduced coverage at the higher end of the test score distribution.

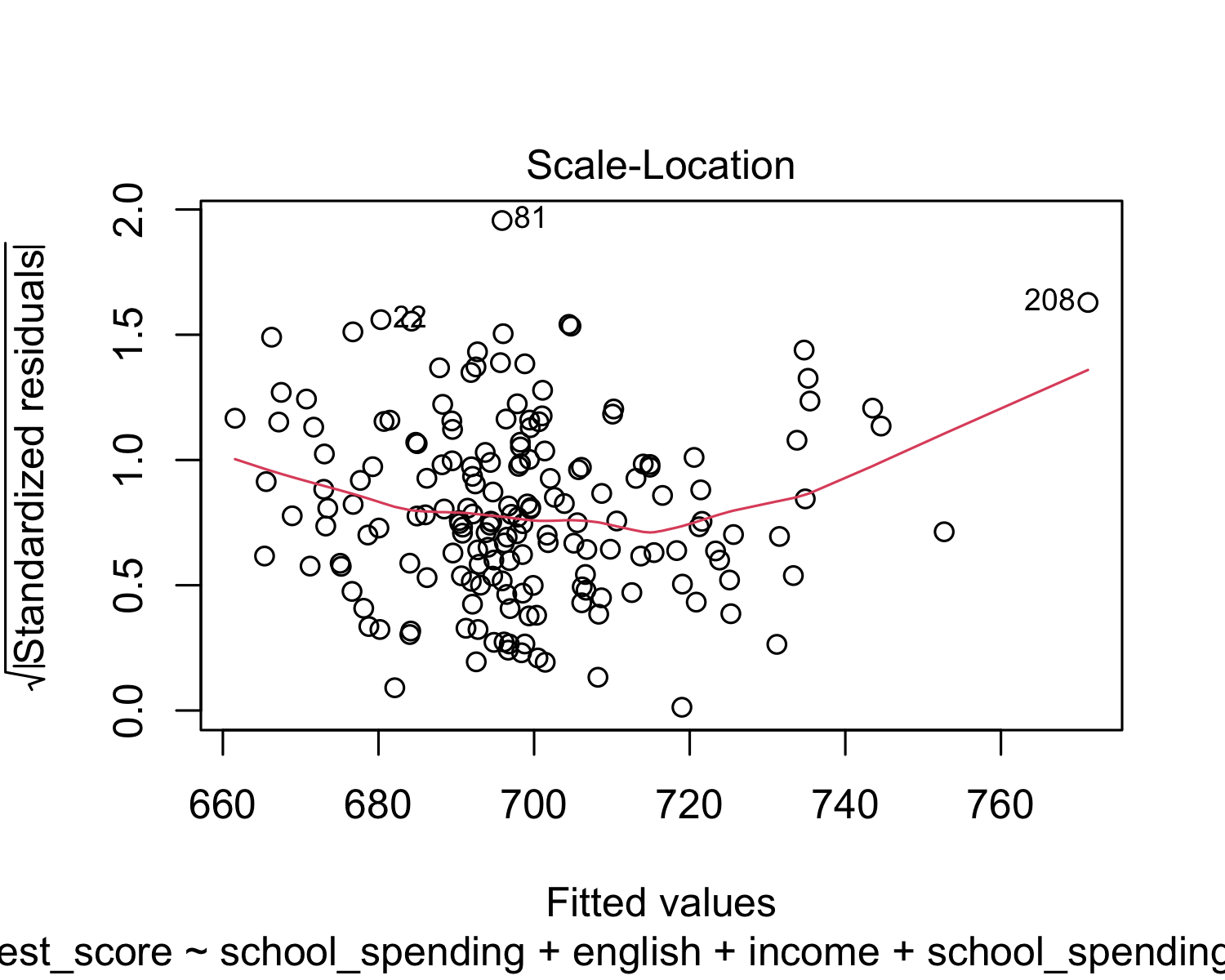


Figure 5: Standardized residual plot.

# Results

A multiple regression analysis was conducted to examine the relationship between test scores and school spending, parent income, and school diversity (presence of ELL students) in a sample of schools. Presence of ELL students (english) was hypothesized to moderate the relationship between school\_spending and test\_scores after controlling for parent income as shown in the linear regression equation below.

The multiple regression model with three predictors and interaction term was found to account for 70% of the variance in test\_scores, , , (see model equation predicted for study sample).

Presented in Table 6, the models main effects and interaction term were all found to significantly predict test scores. The main effects for school\_spending (, , ) and english (, , ) were both found to be significant after accounting for the interaction of school\_spending by english and controlling for parent income. The size of the main effect for english is a large negative effect (see standardized coefficients; Table 8), indicating that schools with ELL students had test scores 41 points lower on average than schools which reported no ELL students. In contrast, the main effect for school\_spending was relatively smaller and negative, indicating that for schools without ELL students a one unit increase in test scores was associated with a .005 decrease in school spending. The control variable parent income (income), was found to have a positive relationship with test scores (, , ). This means that every one unit increase in test scores was associated with schools with 3.05 units higher average parent income.

Table 6:

Regression Model Summary. Test Score predicted by School Spending, ELL (%), Parent Income

| Predictor |  | 95% CI |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Intercept | 670.99 | [658.65, 683.33] | 107.30 | 175 | < .001 |
| School spending | -.005 | [-0.01, 0.00] | -3.47 | 175 | .001 |
| EnglishELL | -41.16 | [-63.82, -18.51] | -3.59 | 175 | < .001 |
| Income | 3.05 | [2.66, 3.45] | 15.23 | 175 | < .001 |
| School spending EnglishELL | .005 | [0.00, 0.01] | 2.64 | 175 | .009 |

Table 7 presents the standardized regression coefficients which can be used to compare magnitudes across the coefficients using a common scale. Here we can see, for example, that the effect size for income () is nearly four times the magnitude of the main effect for school\_spending (). Similarly, the main effect for english () is twice the magnitude of the main effect for school\_spending. The standardized regression coefficient for the interaction term school\_spending:englishELL () is considered a small sized effect in education research. However, in the current research context, this moderation effect may be considered meaningful due to its implication regarding test score achievement for historically marginalized populations.

Table 7.

*Standardized coefficients for multiple regression model.*

## # Standardization method: refit  
##   
## Parameter | Std. Coef. | 95% CI  
## --------------------------------------------------------  
## (Intercept) | 0.12 | [ 0.02, 0.22]  
## school\_spending | -0.23 | [-0.36, -0.10]  
## englishELL | -0.56 | [-0.77, -0.35]  
## income | 0.82 | [ 0.71, 0.92]  
## school\_spending:englishELL | 0.25 | [ 0.06, 0.43]

The relationship between school spending and test scores was found to be moderated by school diversity (englishELL) after controlling for parent income. This is indicated by the signficant interaction estimated in the model for school\_spendingenglishELL (, , ). This means that for schools with ELL students the slope of school spending is .005 units higher relative to the slope for schools with no ELL students. This moderation effect is depicted below using a simple slopes plot (Figure 6). As seen in the plot (blue line), test scores decrease with increased school spending for schools with no ELL students after controlling for parent income and this slope is found to be statistically different from zero (i.e., no relationship; see Table 7). In contrast, the simple slope for schools with ELL students is slightly positive but this slope estimate was found not to be significantly different from zero (see Table 6).

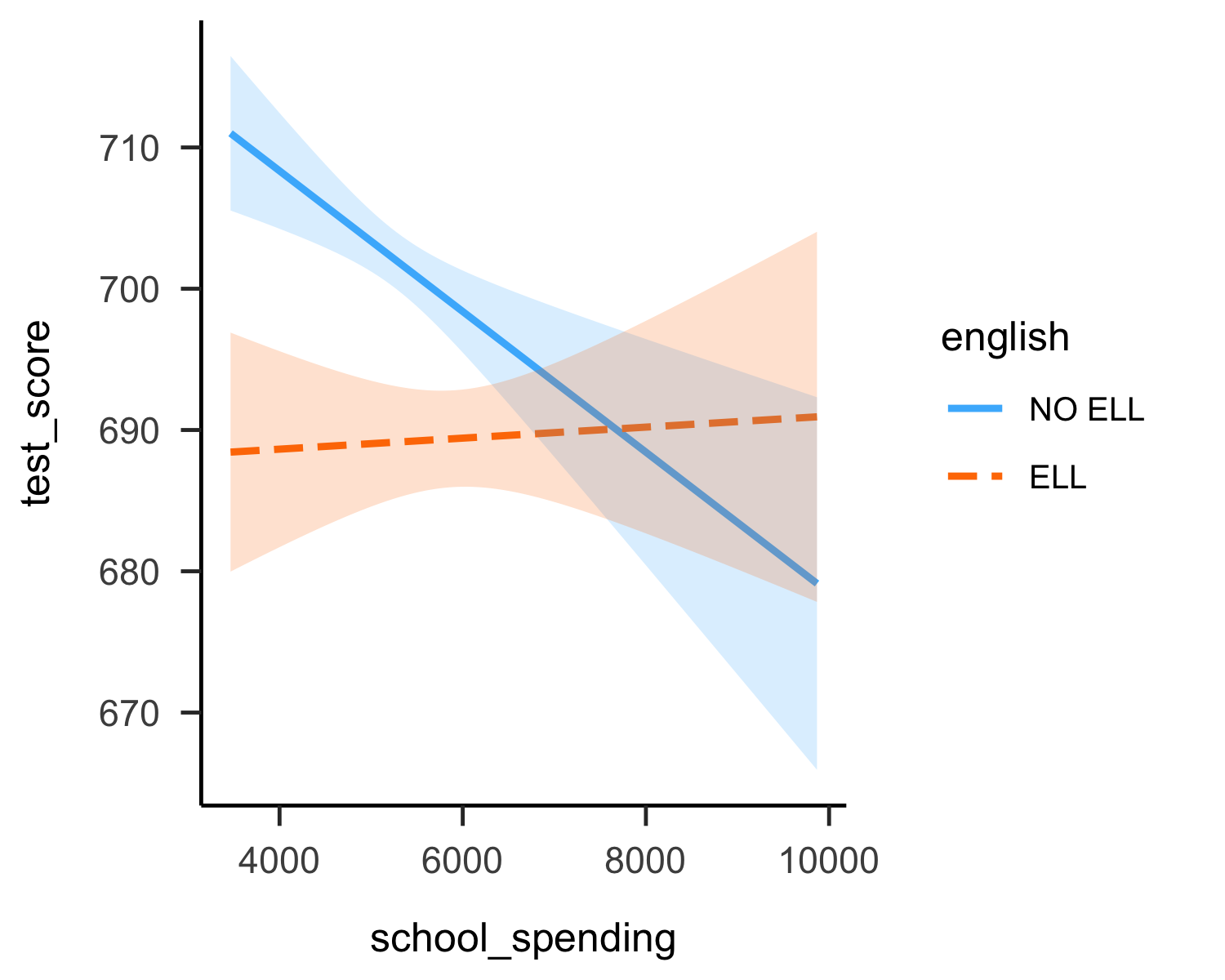


Figure 6: Simple slope plot of english moderating the relationship between school\_spending and test\_score.

Table 8.

*Simple slope estimates with significance tests.*

## SIMPLE SLOPES ANALYSIS   
## Slope of school\_spending when english = ELL:   
## Est. S.E. t val. p  
## ------ ------ -------- ------  
## 0.000 0.00 0.24 0.81  
## Slope of school\_spending when english = NO ELL:   
## Est. S.E. t val. p  
## ------- ------ -------- ------  
## -0.005 0.00 -3.47 0.00

The negative simple slope for schools with no ELL students is surprising because school spending would be expected to increase test scores regardless of population and it is possible that this effect (slope) is being suppressed or reduced by parent income. This theory can be tested by removing the variable income from the model and re-plotting the moderation effect. The simple slopes for school\_spending by english without controlling for parent income is shown in Figure 7. Here we can see that school spending now has a positive relationship with test scores for both schools with and without ELL students and the interaction term is no longer significant (, , ).

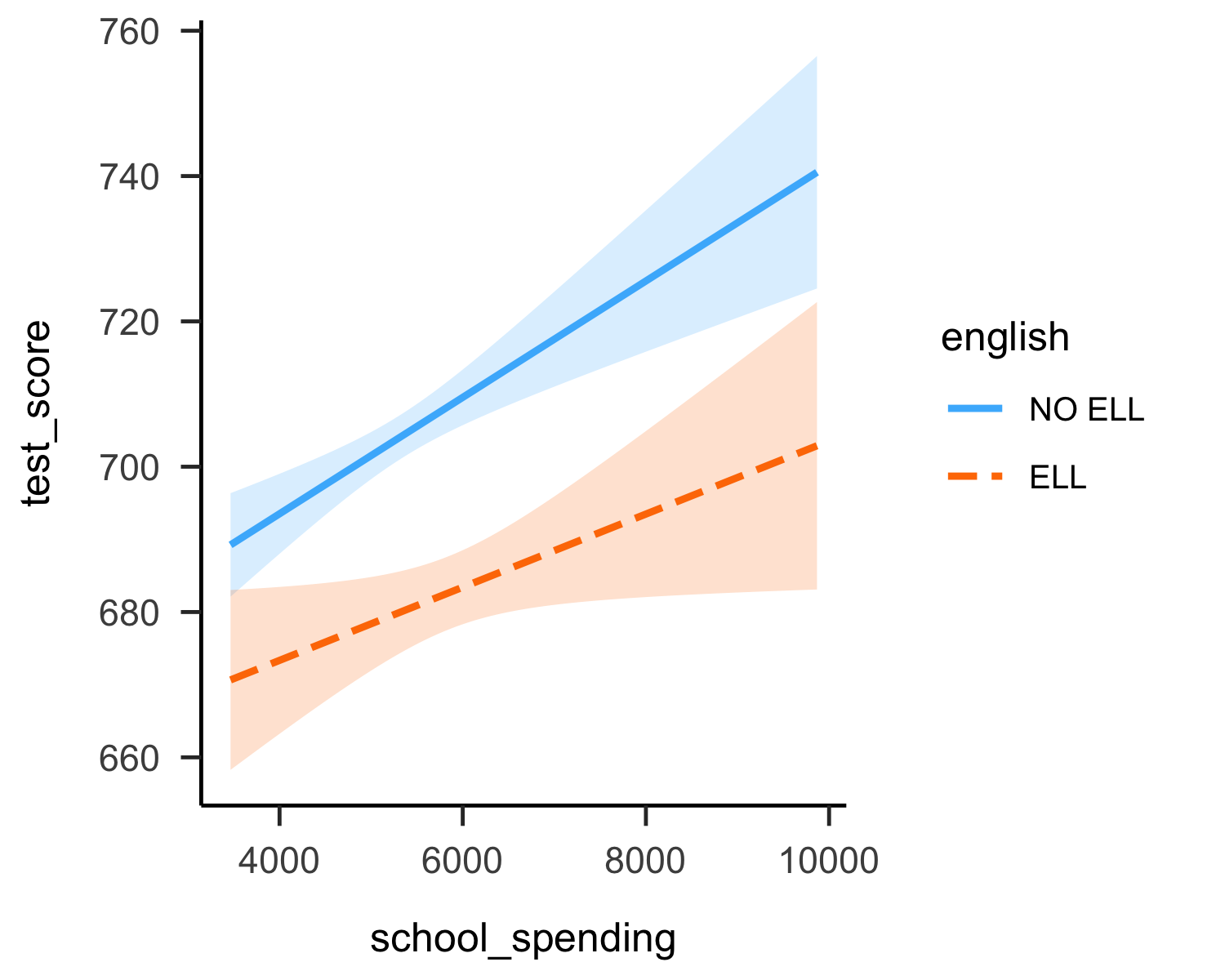


Figure 7: Simple slope plot presenting moderation result after removing the control variable parent income.

## Discussion

The current study provides a preliminary exploration of how school diversity relates to school spending and 8th grade test scores. The finding that school spending is negatively related to test scores for schools without ELL students after controlling for parent income is interesting. This seems to suggest that school spending may not be benefiting student who’s native language is not English in Massachusetts school districts. Further research is warranted to understand the reasons for this unexpected result. A theory which may explain this result, is that schools with higher spending (i.e., more affluent districts) may have school climates that have adverse effects for students who are non-native speakers (i.e., schools where discrimination is prevalent). To explore such a theory further research is warranted that includes school climate as a moderating and/or mediating variable in the model. Limitations of this analysis include small sample size (N=220), unavailability of exogenous variables potentially salient to the research question (e.g, school climate), and lack of experimental control which would permit the evaluation of causal inferences. An important contribution of this study is that it suggest directions for future research such as the investigation of how school climate relates to test scores and school spending for marginalized populations.

## References

Data Source: <https://search.r-project.org/CRAN/refmans/AER/html/MASchools.html>