

**Final Report of
A Study of the Impact of
Graphing Calculator Use on State Assessments**

**Submitted to Texas Instruments
By**



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Executive Summary

In 1996, the Texas high school mathematics and science curricula began requiring the use of scientific and graphing calculators. In 2002, the state assessments in mathematics for ninth, tenth, and eleventh grade (Exit Level) also began requiring the use of graphing calculators. The purpose of this study was to determine if graphing calculators are used in high school mathematics classrooms and, if so, to investigate:

- how calculators are made available for student use,
- how frequently they are used,
- in what types of ways students use them, and
- for what purposes they are used.

In addition, this study sought to examine the relationships among the frequency, types, and purposes of use in Texas high schools and student achievement as measured by the Texas Assessment of Knowledge and Skills (TAKS) for high school students. SEDL researchers designed a cross-sectional survey of Texas high schools and selected a stratified random sample across rural, urban, and suburban schools. Of 509 schools contacted to request participation, 443 schools agreed to participate. Multiple data collection waves were implemented to maximize the response rate. Teachers had three vehicles for participation: mail, fax, and Internet surveys. At least 50% of the mathematics teachers on 260 of participating campuses responded to the survey. The overall response rate from schools that agreed to participate was 67%.

Almost all of the respondents (98%) stated that students use graphing calculators in their classrooms and that this use occurs on a daily basis. Respondents reported that students most often used graphing calculators for class work (99%), classroom tests (99%), and state assessments (99%). The least reported use was for homework (82%). Most of the respondents (98%) indicated that students used graphing calculators for the purpose of problem solving. Drill/practice was reported as the least often way graphing calculators were used (89%).

It was most commonly reported (96%) that students obtain access to graphing calculators through a classroom set of graphing calculators provided to teachers. Ninety-four percent of the respondents indicated that students were not required to provide their own calculator. Twenty-nine percent of the teachers reported that their schools provide each student with his/her own calculator, while 6% reported that the school requires students to provide their own calculators.

Data were analyzed in three ways: (1) a descriptive analysis of frequencies and percentages of responses, (2) a cross-tab analysis that compares responses across rural, urban, and suburban schools, and (3) linear regression analyses that determined what relationships, if any, were significant among the variables in the study with both 2004 TAKS mathematics scale scores (Models 1 – 3) and 2005 TAKS mathematics scale scores (Model 4).

Regression Model 1 accounted for 24% of the variance in 2004 TAKS mathematics scale scores. This analysis also revealed that there was a statistically significant positive relationship between several dependent variables and a school's average scale score on the TAKS mathematics test.

Holding all else constant, scale scores were 28 points higher in schools where teachers reported the use of graphing calculators for homework. A second significant positive correlation was found between scale scores and students supplying their own calculators. In schools where this was the case, the average scale scores were 36 points higher. In schools where teachers had a classroom set of calculators, average scale scores in mathematics were 19 points lower.

With regard to the difference among types of schools and grade levels of students, the regression analysis indicated that average scale scores in mathematics were highest in suburban schools followed by rural schools. The lowest average scale scores were in urban schools. In addition, average scale scores were the highest in the eleventh grade. There was no appreciable difference between ninth and tenth grade average scales scores, holding all else constant.

Regression Model 2 was constructed using complex interactions among the independent variables to more closely examine the relationships of a combination of variables to average scale scores on the TAKS test. This analysis revealed 14 of 45 variables had statistically significant relationships with mathematics scale scores. Model 2 accounted for 25% of the variance in 2004 TAKS mathematics achievement scale scores.

Some of the results of the interaction model indicate the particular uses of graphing calculators in one type of school or grade level resulted in a significant positive correlation, while the same use resulted in a significant negative correlation in another school or grade level. The results of this analysis are discussed in detail in the full report.

In Model 3, the base group was changed to ninth grade rural students. There were no significant changes in the main effects using this model. As a result, the researchers did not report the findings, although the parameter estimates are included in Appendix F.

Model 4 conducted the same analyses using 2005 TAKS data. This model accounted for 14% of the variance in the dependent variable (2005 TAKS mathematics scale scores). SEDL researchers found the parameters for student ownership of a graphing calculator, classroom sets of calculators, and use of calculators for homework to be consistent across both data sets. There was variation in the parameters estimates, however, the inferences were consistent. That is, schools that require students to provide their own calculator had higher TAKS scale scores than those schools where students have access to only a classroom set of calculators. Furthermore, schools in which calculators were used for homework typically had higher mathematics TAKS scale scores.

In addition, interaction effects were also included in the model to investigate possible differences between the levels of the independent variables. Four interaction effects had

similar parameter estimates across the data sets. Tenth grade rural scores were lower when teachers reported using graphing calculators for teaching operations. The second significant interaction effect indicated that 10th grade suburban scores were higher if teachers were provided with a set of classroom calculators. Thirdly, 10th grade suburban scores were lower if teachers used the graphing calculators for conceptual understanding. And, lastly 11th grade rural scores were significant lower if teachers reported using graphing calculators for teaching operations.

Under Regression Models 1, 2, and 4, the following main effects findings were consistent: (a) suburban schools had higher test scores, (b) schools that required students to provide their own graphing calculators had higher test scores, particularly in urban schools at the ninth grade level, (c) test scores were lower in urban schools where teachers had only a classroom set of calculators, and (d) use of graphing calculators for homework was positively correlated with a school's TAKS mathematics scale scores.

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Background

Over the course of the past ten years, several states across the United States began to allow or require the use of graphing calculators on statewide assessments in order to align those assessments to curriculum standards. Texas, North Carolina, Mississippi, Maryland, and New York are five such states. Based on information provided on the Web sites of the state departments of education in each of these states, the following are the requirements for use of graphing calculators on state tests:

- In Texas, the high school mathematics and science curricula implemented in 1996 required the use of scientific and graphing calculators. Beginning in 2002, the state assessments in mathematics for ninth, tenth, and eleventh grade (Exit level) required the use of graphing calculators. Districts must ensure that each student has a graphing calculator during the entire administration of the mathematics test. Any graphing calculator may be used except one with a typewriter-style keypad (known as QWERTY) or one that includes a computer algebra system (CAS). Handheld minicomputers, personal digital assistants, or laptop computers may not be used. All types of memory, including standard memory, ROM, and Flash ROM, must be cleared to factory default both before and after testing. In addition, any programs or applications must be removed prior to the test administration.
- In North Carolina, the use of graphing calculators on the High School Comprehensive Test for Mathematics and the End of Course Tests for Algebra I and Algebra II has been required since the 2000-2001 school year. Use of a graphing calculator on the High School Exit Exam in North Carolina began in Spring 2002.
- In Mississippi, graphing calculators are required for the statewide Algebra I end of course exam.
- In Maryland, the specifications for both the algebra and geometry end-of-course exams require that 10% of the test items require the use of graphing calculators and that graphing calculators will be beneficial for 40% of the items.
- In New York, graphing calculators are allowed on Math pretests, field tests, and the final Regents exams.

Because there is increasing use of graphing calculators during testing, research regarding the impact of use is needed. According to Ellington (2003), “most research involving use of calculators focused on changes to student achievement levels and attitudes toward mathematics” (p. 436). In her meta-analysis of 54 studies of the use of any type of calculator in the classroom, Ellington reports, “when calculators were included in testing and instruction, students in grades K-12 experienced improvement in operational skills as well as in paper-and-pencil skills and the skills necessary for understanding mathematical concepts” (p. 456). These findings were for classes of mixed ability students and were not sufficient to generalize to low or high ability classes. Use of calculators for longer periods of time (greater than 9 weeks) appeared to yield more positive effects. Ellington cautions that use of calculators with younger students should be done on an experimental basis as less than 20% of the studies she examined were with young students.

Other researchers both concur and disagree with these findings. The Education Commission of the States (2001) reported “Eighth graders whose teachers reported that they permitted unrestricted classroom use of calculators had higher achievement scores in 2000 than did students whose teachers restricted use.” On the other hand, Loveless (2004), based on his analysis of scores on identical items on the Long Term Trend NAEP that measured computation skills (addition, subtraction, multiplication, and division) both with and without calculators, concluded that when fourth graders used calculators the results were misleading “– misleading, that is, if one assumes that knowing how to compute means being able to make calculations without technological assistance” (p. 23). He notes that it is not known if the students taking these matched items actually used the calculators on the test, but calculators were available for use and student’s scores were much higher on identical items on the portion of the test in which calculators were allowed.

These results raise questions that warrant investigation regarding the impact of the use of calculators on student achievement, as well as on curriculum and teaching practices. Loveless’ analysis with younger students seems to be contradicted by The Education Commission of the States’ analysis of eighth graders. Ellington’s meta-analysis examined effects from K-12 studies of calculator use in general, not specifically graphing calculators. Thus, an examination of the relationships among frequency of use, types of use, and purposes of use of graphing calculators in the classroom and achievement scores on tests that require the use of graphing calculators contributes to the knowledge base regarding the use of graphing calculators on statewide assessments.

Purpose of Study

There are two purposes for this study:

1. Determine the frequency, types, and purpose of use of graphing calculators in high schools in Texas (e.g., are these calculators used for daily work in the classroom and on classroom assessments; is use unrestricted; for what types of mathematical processes are graphing calculators used?).
2. Examine the relationships among the frequency, types, and purposes of use of graphing calculators in Texas high schools and student achievement as measured by scores on the Texas statewide mathematics assessments for high school students that require the use of graphing calculators.

To meet these purposes, four research questions were developed.

Research Questions

1. Do students use graphing calculators in Texas High School classrooms?
2. How often, in what ways, and for what purposes are graphing calculators used in classrooms? When did calculator use begin?
3. Do schools that incorporate graphing calculators in the classroom demonstrate

- higher levels of achievement as measured by statewide assessments? Do schools that more frequently incorporate graphing calculators in the classroom demonstrate higher levels of achievement as measured by statewide assessments?
4. Which types of use, if any, appear more closely related to higher levels of achievement (e.g., unrestricted use by students; use on classroom tests)?

Method and Data Collection

SEDL designed a cross-sectional survey to gather data from Texas high school mathematics teachers. A seven-item questionnaire (see Appendix A) was created to measure how Texas high school mathematics teachers are using graphing calculators, how available calculators are for student use, how frequently they are used, the ways the graphing calculators are used, and purposes of use in the classroom.

For this study, the unit of analysis was a Texas high school. A representative number of high schools from subgroups were randomly selected in order to ensure that the proportion of rural, suburban, and urban, as well as small, medium, and large high schools in the sample represented the percentages of these type schools across the state. A stratified (rural, suburban, and urban) random sample of schools was selected from the Texas Education Agency's 2003-2004 PEIMS¹ directory. Only schools classified as "Regular Instructional" were included in the population from which the sample was drawn. This eliminated schools classified as JJAEP Instructional, Alternative Instructional, and DAEP Instructional.

A total of 509 schools were randomly selected. Agreement to participate by the school's administration was sought, and if the administration agreed to participate, teachers were mailed letters and surveys. The surveys were also faxed to school secretaries for distribution to teachers on campuses. Multiple mailings were implemented to maximize the response rate.

From the original sample, 59 schools declined participation, resulting in a sample of 443 schools. In spite of the administration's agreement to participate, no teachers responded from 50 of these schools. Of the 393 schools from which teacher responses were received, 163 were rural high schools with 725 mathematics teachers, 130 were suburban high schools with 1,664 mathematics teachers, and 100 were urban high schools that employed 1,330 mathematics teachers. The total number of teachers surveyed was 3,719.

To ensure a robust data set for each school, at least half of the mathematics faculty on a campus must have submitted a survey for the school to be included in the data analysis. Teachers had three vehicles for submitting a survey: mail, fax, and a Web-based form. The overall teacher response rate was 67%. As noted by Alreck and Settle (1995), "The single most serious limitation to direct mail data collection is the relatively low response rate. Mail surveys with response rates over 30 percent are rare" (p. 35).

¹ PEIMS is the Public Education Information Management System for Texas

Testing data for the Spring 2004 administration of the Texas Assessment of Knowledge and Skills (TAKS) for mathematics at the ninth grade, tenth grade, and eleventh grade (Exit) level were obtained from the accountability office at the Texas Education Agency for each of the schools included in the sample.

Teacher data were collected through January 8, 2005. These data were analyzed with SAS JMP. All analyses were calculated to reflect the final results of this study.

Table 1
Survey Distribution and Response Rates

Category	Number of schools responding	Number of teachers surveyed	Number of teachers responding	Teacher rate of return
Rural	163	725	489	67%
Suburban	130	1664	906	54%
Urban	100	1330	740	56%
Total	393	3179	2135	67%

Analysis & Results

A descriptive profile (frequencies, percentages, means, and standard deviations) was computed for each variable of inquiry. In addition, data was cross-tabulated, and correlated to understand the magnitude and relationship of the variables. A multiple linear regression model was used to test null hypothesis; namely, that the variables of inquiry do not contribute to mathematics achievement.

The multiple linear regression analysis tested hypotheses regarding the set of influence variables that best form a linear combination with achievement scale scores. Influence variables include: (a) availability of graphing calculators, (b) use of graphing calculators (c) length of use by teachers, (d) how often graphing calculators were used in the school, (e) ways in which graphing calculators were used in the school (e.g., for instruction, for classroom assessment, homework), (f) type of community in which the school was located (e.g., rural, suburban, urban), and (g) purposes of graphing calculators use in the school (e.g. operations, computations, conceptual understanding, problem solving).

The respondents included in the data analysis were teachers from 260 Texas high schools. Teaching experience ranged between .5 years to 28 years, with the greatest percentage of respondents teaching between 4 to 22 years. Survey respondents were asked seven questions to learn whether or not graphing calculators were being used, how available they were, the frequency of their use, the ways they were used, and purposes of use in the classroom. On some items on the survey, respondents failed to mark “yes” or “no” in response to a question. In those cases, no assumptions were made. For example, if a teacher marked “yes” on three types of mathematics courses taught and left three types blank, no data were entered for the non-responses. These variables were not coded “yes”

or “no.” Table 2 provides a summary of the responses of teachers from schools with at least 50% of teachers responding. Percentages do not include missing data; that is, these are valid percentages.

Table 2: Response Summary

	YES	NO
1. Do students use graphing calculators in your classes?	98%	2%
2. How are graphing calculators made available to the students in your classes?		
2a. Are students required to provide their own calculators?	6%	94%
2b. Does the school provide each student with his/her own calculator?	29%	70%
2c.. Does the school provide teachers with a classroom set of calculators?	96%	4%
3. What mathematics courses do you teach?		
3a. Algebra I	66%	34%
3b. Algebra II	62%	38%
3c. Geometry	44%	56%
3d. Trigonometry	21%	79%
3e. Pre-calculus or Calculus	61%	39%
3f. Other:	59%	41%
4. For how many years have you used graphing calculators with your classes?		
5 years or less	43%	
6 to 11 years	44%	
More than 11 years	13%	
(Mean = 7 years)		
5. How often do students use graphing calculators in your classes?		
Monthly	2%	
Weekly	17%	
Daily	81%	
6. In which of the following ways do students use calculators in your classes?		
6a.Homework	82%	18%
6b.Class Work	99%	1%
6c. Classroom Tests	99%	1%
6d. State Assessment Tests	99%	1%
7. For which of the following purposes do students use calculators in your classes?		
7a. Operations	96%	4%
7b. Drill/Practice	89%	11%
7c. Problem Solving	98%	2%
7d. Conceptual Understanding	94%	6%

In an attempt to answer the research questions for this study, the following sections present and overview the applied data analysis.

Research Question 1

Do students use graphing calculators in Texas High School classrooms?

As illustrated in Table 3, almost all of the teacher respondents (98%) reported that students use graphing calculators in their classrooms.

Table 3: Use and Availability of Graphing Calculators

	Yes	No
<i>Do students use graphing calculators in your classes?</i>	98%	2%
N=2134		

For each of the questions asked, responses were calculated and then cross-tabulated by location of the schools, that is, rural, urban, and suburban responses were compared to the overall responses for each variable. Cross-tabulation is the most common measure of association between variables. Cross-tabulation tables, or “cross-tabs,” indicate the relationship between two variables. The object of cross-tabulation is to show whether the distributions for one variable differ significantly for each value or level of the other variable. Cross-tabulation is a way to show how much the frequency or percentage distributions of one variable differ according to various levels of another variable.

Table 4 illustrates a comparison of the percentages of students using graphing calculators across the subcategories of the sample. Teachers in suburban schools reported that their students are using graphing calculators more than teachers in rural and urban schools. Location, however, did not appear to be related to the use of graphing calculators, as the differences were not appreciable.

Table 4: Cross Tab of Use of Graphing Calculators by Rural, Suburban, Urban schools

	Rural		Suburban		Urban		Total	
	Yes	No	Yes	No	Yes	No	Yes	No
<i>Do students use graphing calculators in your classes?</i> N=2134	98%	2%	99%	1%	98%	2%	98%	2%

Teachers were asked to indicate the course or courses they were teaching at the time they completed the survey. Table 6 illustrates the responses to this question: Algebra I (66%), Algebra II (62%), Geometry (61%), Trigonometry (21%), Pre-calculus/ Calculus (44%), and other (59%). Teachers were allowed to select more than one course. As many teachers indicated they were teaching courses in more than one category, the percentages do not total 100%.

Table 6: Mathematics Courses Taught

<i>Which mathematics courses do you teach?</i>	Yes	No
<i>Algebra I</i>	66%	34%
<i>Algebra II</i>	62%	38%
<i>Geometry</i>	61%	39%
<i>Trigonometry</i>	21%	79%
<i>Pre-calculus/ Calculus</i>	44%	56%
<i>Other</i>	59%	41%
<i>N =2138</i>		

As illustrated in Table 7, Algebra I was the course most often taught by teachers across all types of schools. Algebra II and Geometry followed as the next most often taught although the subjects vary by location of schools. Trigonometry was the least often mathematics course taught by respondents.

Table 7: Cross Tabs of Mathematics Courses Taught by Rural, Suburban, Urban schools

<i>What mathematics courses do you teach? N=2138</i>	Rural		Suburban		Urban		Total	
	<i>Yes</i>	<i>No</i>	<i>Yes</i>	<i>No</i>	<i>Yes</i>	<i>No</i>	<i>Yes</i>	<i>No</i>
<i>Algebra I</i>	73%	27%	62%	38%	66%	34%	66%	34%
<i>Algebra II</i>	68%	32%	57%	43%	65%	35%	62%	38%
<i>Geometry</i>	68%	32%	58%	42%	61%	39%	61%	39%
<i>Trigonometry</i>	27%	73%	19%	81%	21%	79%	21%	79%
<i>Pre-calculus/ Calculus</i>	52%	48%	40%	60%	45%	55%	45%	56%
<i>Other</i>	72%	29%	52%	48%	58%	42%	59%	41%

In addition to asking teachers if their students used graphing calculators in their mathematics courses, the study sought to learn more about the source of access to the graphing calculators used by students.

This variable of inquiry investigated the availability of graphing calculators to students and teachers by querying on three questions: (1) Are students required to provide their own calculators? (2) Does the school provide each student with his/her own calculator? (3) Does the school provide teachers with a classroom set of calculators? These categories were not mutually exclusive. That is, teachers could select more than one of these sources of access to graphing calculators.

Most of the respondents (94%) indicated that students are not required to provide their own calculators. Nearly one third (29%) of the schools do provide each student with

his/her own calculator. Teachers most commonly reported that their school provided them with a classroom set of calculators (96%). These data are illustrated in Table 8.

Table 8: Source of Graphing Calculators

<i>How are graphing calculators made available to the students?</i>	Yes	No
• <i>Students are required to provide their own calculators</i>	6%	94%
• <i>The school provides each student with his/her own calculator</i>	29%	71%
• <i>The school provides teachers with a classroom set of calculators</i>	96%	4%
• <i>Students required to provide their own calculators and school provides each student with his/her own calculator</i>	33%	67%
• <i>Students required to provide their own calculators and school provides class set</i>	96%	4%
• <i>School provides each student with his/her own calculator and school provides class set</i>	99%	1%

Because the number of positive responses to possible answers in the last category is so high, it may be that teachers interpreted these two questions similarly. That is, teachers with a classroom set may have also assumed that a classroom set was a means by which the school provided each student with his/her own calculator. It also appears that in a large number of instances, when students are required to provide his/her own calculator the school still provides teachers with a class set.

The cross-tab analysis revealed differences between the ways in which graphing calculators are made available to students. There was a slight difference in the percentages between rural, suburban, and urban schools with respect to whether they provide students with their own graphing calculators and/or provide teachers with classroom sets of graphing calculators. Table 9 illustrates these differences. Suburban schools had the most teachers (8%) who reported that students were required to supply their own graphing calculators and teachers in rural schools least often (3%) reported that their schools required students to supply their own graphing calculators.

**Table 9: Cross Tabs of Source of Graphing Calculators
by Rural, Suburban, Urban Schools**

How are graphing calculators made available to the students in your classes?	Rural		Suburban		Urban		Total	
	<i>Yes</i>	<i>No</i>	<i>Yes</i>	<i>No</i>	<i>Yes</i>	<i>No</i>	<i>Yes</i>	<i>No</i>
<i>Students required to provide their own calculator</i>	3%	97%	8%	92%	5%	95%	6%	94%
<i>The school provides students with his/her own calculator</i>	31%	70%	29%	71%	29%	71%	29%	71%
<i>The school provides teachers with a classroom set of calculators</i>	93%	7%	96%	4%	97%	3%	96%	4%

Summary

Do students use graphing calculators in Texas high school mathematics classrooms? The answer to this question appeared to be a resounding “Yes.” Most often, students had access to graphing calculators through a classroom set of calculators supplied to teachers by their schools. Only a few schools required students to provide their own calculators. While there was no appreciable difference among rural, urban, and suburban teachers’ responses regarding the use of graphing calculators in their classes, there was a significant difference overall with regard to how students gain access to graphing calculators.

Research Question 2

How often, in what ways, and for what purposes are graphing calculators used in classrooms? When did calculator use begin?

The survey questions designed to answer Question 2 included: 1) How often do students use graphing calculators in your classes? 2) In which of the following ways do students use graphing calculators? 3) For which of the following purposes do students use graphing calculators? 4) For how many years have you used graphing calculators with your classes?

Table 10 provides insight into teachers’ perceptions of the frequency of graphing calculator use in Texas high school mathematics classrooms. Most teachers (81%) reported that graphing calculators are used on a daily basis in their classrooms. Subsequently, seventeen percent (17%) indicated weekly use of the graphing calculator and a small percentage (2%) indicated at least monthly use of graphing calculators in the classroom.

Table 10: Frequency of Graphing Calculator Use in Classrooms

<i>How often do students use graphing calculators in your classes? N=2086</i>	f	%
Monthly	45	2%
Weekly	348	17%
Daily	1,693	81%

There was a reported difference in the percentages of frequency of graphing calculator use with regard to rural, suburban, and urban schools. That is, teachers in urban schools less often reported daily use and more often indicated weekly use than teachers from rural or suburban schools. Table 11 illustrates these differences.

Table 11: Cross Tabs of Frequency of Graphing Calculator use in Classrooms by Rural, Suburban, Urban Schools

How often do students use graphing calculators in your classes?	Rural	Suburban	Urban	Total
Monthly	3%	2%	2%	2%
Weekly	14%	16%	20%	17%
Daily	84%	82%	78%	81%
Total N=1428	100%	100%	100%	100%

Teachers were next asked in what ways students use graphing calculators in their classrooms: (a) homework, (b) class work, (c) classroom tests, (d) state assessment tests. Respondents reported students most often used graphing calculators for class work (99%), classroom tests (99%), and state assessments (99%). Homework was the least reported use (87%).

There was a small difference between rural, urban, and suburban schools in the ways students use calculators in classes. The overwhelming majority of teachers (99%) in all types of schools indicated that their students use graphing calculators on state assessments, classroom tests, and class work. Teachers in all types of schools reported that students use graphing calculators least for homework. Urban teachers ranked homework the lowest (77%).

Table 12: Cross Tabs of Ways Students use Graphing Calculator in Classrooms by Rural, Suburban, Urban Schools

<i>In which of the following ways do students use calculators in your classes? N=2045</i>	Rural		Suburban		Urban		Total	
	Yes	No	Yes	No	Yes	No	Yes	No
Homework	84%	16%	85%	15%	77%	23%	82%	18%
Class Work	99%	1%	99%	1%	99%	1%	99%	1%
Classroom Tests	99%	1%	99%	1%	99%	1%	99%	1%
State Assessment Tests	99%	1%	99%	1%	99%	1%	99%	1%

Ninety-eight percent of the respondents indicated that students use graphing calculators for the purpose of problem solving, followed by 96% of respondents who use graphing calculators to teach operations and 94 % to teach conceptual understanding. The least reported purpose of use of graphing calculators was drill/practice (89%). The percentages of purposes of use between rural, suburban, and urban schools were relatively similar as illustrated in Table 13.

**Table 13: Cross Tabs of Purposes of Student Use of Calculators
by Rural, Suburban, Urban Schools**

<i>For which of the following purposes do students use calculators in your classes?</i>	Rural		Suburban		Urban		Total	
	<i>Yes</i>	<i>No</i>	<i>Yes</i>	<i>No</i>	<i>Yes</i>	<i>No</i>	<i>Yes</i>	<i>No</i>
<i>Operations</i>	97%	3%	96%	4%	95%	5%	96%	4%
<i>Drill/Practice</i>	90%	10%	89%	11%	90%	10%	89%	11%
<i>Problem Solving</i>	99%	1%	98%	3%	98%	2%	98%	2%
<i>Conceptual Understanding</i>	94%	6%	94%	6%	95%	5%	94%	6%
<i>N=1993</i>								

As seen in Table 14, the cross-tab analysis revealed differences between the frequency of graphing use and ways in which graphing calculators are made available to students. There were appreciable differences in the percentages between monthly, weekly, and daily use with respect to whether students are required to provide their own graphing calculators.

Seventy-eight percent of the teachers reported that students use graphing calculators on a daily basis if they have their own calculator. Eighty-five percent of the teachers reported that students use calculators on a daily basis if the school provides them with a calculator. There were appreciable differences in the percentages between monthly (2%), weekly (16%), and daily (83%) use with respect to whether the schools provide teachers with a classroom set of graphing calculators. It is interesting to note that teachers reported that calculators are used more often on a daily basis if the school provides the students with calculators (85%) or if the school provides the teacher with a classroom set of graphing calculators (83%). In contrast, teachers reported that calculators are used more often on a weekly basis if the students are required to provide their own calculators (20%) or if the school provides the teacher with a classroom set of graphing calculators (16%). Monthly use held constant across all levels.

Table 14: Cross Tabs of Frequency of Graphing Calculator use in Classrooms by Source of Access

<i>How often do students use graphing calculators in your classes?</i>	<i>Students required to provide their own calculators</i>	<i>School provides students with his/her own calculator</i>	<i>School provides teacher a classroom set of calculators</i>
Monthly	2%	2%	2%
Weekly	20%	13%	16%
Daily	78%	85%	83%
Total	100%	100%	100%
N	2565	2555	2648

Texas high school mathematics teachers were also asked how many years they have used graphing calculators within their classrooms. The number of years ranged from 1 to 20 with a mean of 7 and standard deviation of 3.9. The distribution is positively skewed indicating more of the respondents have been using graphing calculators in their classrooms for a shorter time period. This result may be a function of the age of the teachers and/or the number of years teaching or as a result of the requirement to use graphing calculators on statewide assessments. There appeared to be little difference between years of graphing calculator use when comparing rural, suburban, and urban math teachers.

Table 15: Years of Graphing Calculator Use in Classroom

	0 to 5 years	6 to 11 years	Over 11 years	Mean	S.D.
<i>For how many years have you used graphing calculators with your classes?</i> <i>N=2025</i>	43%	44%	13%	7.0	.39
	Rural N=472	Suburban N=872	Urban N=649		
Average	6.9	6.9	7.2		

Summary

The vast majority of the teachers (81%) reported that graphing calculators are used on a daily basis in their classroom. Respondents reported that students most often used graphing calculators for class work (82%), classroom tests (81%), and state assessments (79%). The least often reported use was for homework (61%).

Most of the respondents indicated that students use graphing calculators for the purpose of problem solving (79%). The least used purpose was drill/practice (68%).

The cross-tab analysis revealed a difference in the percentages between rural, suburban, and urban schools with respect to the availability of graphing calculators. It was most commonly reported (77%) that schools provide teachers with a classroom set of graphing calculators. Twenty-five percent of the schools provide students with their own graphing calculator and 6% require students to provide their own calculator. There was a reported difference in the percentage between rural, suburban, and urban schools with regard to the frequency of graphing calculator use. There was also a difference among the three groups with regard to the ways students use graphing calculators in classes.

Regression Analysis

Applications of regression analysis exist in almost every field. In economics, the dependent variable might be a family's consumption expenditure and the independent variables might be the family's income, number of children in the family, and other factors that would affect the family's consumption patterns. In political science, the dependent variable might be a state's level of welfare spending and the independent variables might be measures of public opinion and institutional variables that would cause the state to have higher or lower levels of welfare spending. In sociology, the dependent variable might be a measure of the social status of various occupations and the independent variables characteristics of the occupations (pay, qualifications, etc.). In psychology, the dependent variable might be individual's racial tolerance as measured on a standard scale with indicators of social background as independent variables. In education, the dependent variable might be a student's score on an achievement test and the independent variables characteristics of the student's family, teachers, or school.

Multiple regression analysis is a technique used to identify a "best-fit" combination of independent (predictor) variables that are correlated with a dependent variable, and minimally correlated with other independent variables. A regression analysis identifies those variables that are most strongly related to the dependent variable. A multiple regression equation reveals a multiple correlation coefficient (r-squared) that represents the approximate amount of variability that the equation accounts for in the dependent variable. For example, if a multiple regression equation resulted in a multiple correlation coefficient (r-squared value) of .69, that would mean that the combination of variables in the multiple regression equation account for approximately 69% of the variability in the dependent variable.

2004 Mathematics Achievement Model Specification

For this study, researchers at SEDL proposed a multiple regression analysis to answer research questions three and four in order to determine if any relationships existed between mathematics achievement as measured by the Texas statewide assessment (TAKS) based on how available calculators are for student use, how graphing calculators are made available to students, how frequently they are used, the ways the graphing calculators are used, and the purposes of use in the classroom.

In applying the regression equation, researchers selected mathematics achievement

(campus level TAKS scale score) as the dependent variable (Y) to be predicted and explained by independent variables representing availability, frequency, ways, and purposes of use of graphing calculators in the classroom. Initially, researchers constructed a linear regression model with the following variables as independent variables:

- Rural
- Suburban
- Students required to provide own calculator (q2a)
- School provides teacher with a classroom set of calculators (q2c)
- 10th Grade
- 11th Grade
- Number years teacher has used graphing calculator in class (q4)
- Students use of calculators for homework (q6a)
- Calculators use for instructional purpose: operations (q7a)
- Calculators use for instructional purpose: drill/practice (q7b)
- Calculators use for instructional purpose: problem solving (q7c)
- Calculators use for instructional purpose: conceptual understanding (q7d)

Model 1.

$$04\text{MathScaleScore}_i = \beta_1 + \beta_2 10th_i + \beta_3 11th_i + \beta_4 Rural_i + \beta_5 Suburban_i + \beta_6 q2a_i + \beta_7 q2c_i + \beta_8 q4_i + \beta_9 q6a_i + \beta_{10} q6b_i + \beta_{11} q6c_i + \beta_{12} q6d_i + \beta_{13} q7a_i + \beta_{14} q7b_i + \beta_{15} q7c_i + \beta_{16} q7d_i + \varepsilon_i$$

The base group was 9th grade Urban Schools and the dependent variable was 2004 TAKS Math Scale scores. In Model 1, 6 of the 18 independent variables were statistically significant. Five of the variable indicated appreciable differences at the $p < 0.0001$ and one variable indicated appreciable difference at the $p < .05$ alpha level accounting for 24% of the variance in the dependent variable (2004 TAKS mathematics achievement scale score). See Table 16 for parameter estimates.

Table 16: 2004 Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	2104.2343	17.03781	123.50	0.0000
10 th	-1.127262	3.876852	-0.29	0.7713
11 th	59.050258	3.911518	15.10	<.0001
R	17.432463	4.175356	4.18	<.0001
S	45.881908	3.691946	12.43	<.0001
question.2a	35.765815	7.014633	5.10	<.0001
question.2c	-18.61164	7.630847	-2.44	0.0148
question.4.num	0.2632165	0.416102	0.63	0.5271
question.6a	28.320401	4.018937	7.05	<.0001

Term	Estimate	Std Error	t Ratio	Prob> t
question.7a	6.9438397	9.551968	0.73	0.4673
question.7b	-5.727902	5.69401	-1.01	0.3146
question.7c	-9.560154	12.1823	-0.78	0.4327
question.7d	-4.057416	6.575702	-0.62	0.5373

The researchers sought further clarification and included interactions terms in the model specification. Again, the 2004 TAKS scale scores were used as the dependent vector (Y). The independent variables included measures of availability, frequency, ways, and purposes of use of graphing calculators in the classroom. The base group (β_1) was ninth grade Urban Schools.

The following variables were included as independent variables:

- Grade (tenth)
- Grade (eleventh)
- Rural (r)
- Suburban (s)
- Students required to provide own calculator (q2a)
- School provides teacher with a classroom set of calculators (q2c)
- Number years teacher has used graphing calculator in class (q4)
- Students use of calculators for homework (q6a)
- Calculators use for instructional purpose: operations (q7a)
- Calculators use for instructional purpose: drill/practice (q7b)
- Calculators use for instructional purpose: problem solving (q7c)
- Calculators use for instructional purpose: conceptual understanding (q7d)
- Tenth grade rural students required to provide own calculator (10*r2a)
- Tenth grade rural school provides teacher with a classroom set of calculators (10*r2c)
- Number of years tenth grade rural teacher has used graphing calculator in class (10*rq4)
- Tenth grade rural students use of calculators for homework (10*rq6a)
- Tenth grade rural calculators use for instructional purpose: operations (10*rq7a)
- Tenth grade rural calculators use for instructional purpose: drill/practice (10*rq7b)
- Tenth grade rural calculators use for instructional purpose: problem solving (10*rq7c)
- Tenth grade rural calculators use for instructional purpose: conceptual understanding (10*rq7d)
- Tenth grade suburban school provides student with calculator (10*Sq2a)
- Tenth grade suburban school provides teacher with a classroom set of calculators (10*Sq2c)
- Tenth grade number of years suburban teacher has used graphing calculator in class (10*Sq4)
- Tenth grade suburban students use calculators for homework (10*Sq6a)

- Tenth grade suburban calculators use for instructional purpose: (10*Sq7a)
- Tenth grade suburban calculators use for instructional purpose: drill/practice (10*Sq7b)
- Tenth grade suburban calculators use for instructional purpose: problem solving (10*Sq7c)
- Tenth grade suburban calculators use for instructional purpose: conceptual understanding (10*Sq7d)
- Eleventh grade rural students required to provide own calculator (11*r2a)
- Eleventh grade rural school provides teacher with a classroom set of calculators (11*r2c)
- Number of years eleventh grade rural teacher has used graphing calculator in class (11*rq4)
- Eleventh grade rural students use of calculators for homework (11*rq6a)
- Eleventh grade rural calculators use for instructional purpose: operations (11*rq7a)
- Eleventh grade rural calculators use for instructional purpose: drill/practice (11*rq7b)
- Eleventh grade rural calculators use for instructional purpose: problem solving (11*rq7c)
- Eleventh grade rural calculators use for instructional purpose: conceptual understanding (11*rq7d)
- Eleventh grade suburban school provides student with calculator (11*Sq2a)
- Eleventh grade suburban school provides teacher with a classroom set of calculators (11*Sq2c)
- Eleventh grade number of years suburban teacher has used graphing calculator in class (11*Sq4)
- Eleventh grade suburban students use of calculators for homework (11*Sq6a)
- Eleventh grade suburban calculators use for instructional purpose: (11*Sq7a)
- Eleventh grade suburban calculators use for instructional purpose: drill/practice (11*Sq7b)
- Eleventh grade suburban calculators use for instructional purpose: problem solving (11*Sq7c)
- Eleventh grade suburban calculators use for instructional purpose: conceptual understanding (11*Sq7d)

The base group (β_1) in Model 2 was Ninth grade Urban schools and the dependent variable was 2004 TAKS mathematics scale score.

Model 2.

$$\begin{aligned}
 \text{MathScaleScore}_i = & \beta_1 + \beta_2 10th_i + \beta_3 11th_i + \beta_4 Rural_i + \beta_5 Suburban_i + \\
 & \beta_6 q2a_i + \beta_7 q2c_i + \beta_8 q4_i + \beta_8 q6a_i + \beta_{10} q7a_i + \beta_{11} q7b_i + \\
 & \beta_{12} q7c_i + \beta_{13} q7d_i + \beta_{14} 10 * r2a_i + \beta_{15} 10 * rq2c_i + \beta_{16} 10 * rq4_i + \\
 & \beta_{17} 10 * rq6a_i + \beta_{18} 10 * rq7a_i + \beta_{19} 10 * rq7b_i + \beta_{20} 10 * rq7c_i + \\
 & \beta_{21} 10 * rq7d_i + \beta_{22} 10 * sq2a_i + \beta_{23} 10 * sq2c_i + \beta_{24} 10 * sq4_i + \\
 & \beta_{25} 10 * sq6a_i + \beta_{26} 10 * sq7a_i + \beta_{27} 10 * sq7b_i + \beta_{28} 10 * sq7c_i + \\
 & \beta_{29} 10 * sq7d_i + \beta_{30} 11 * r2a_i + \beta_{31} 11 * rq2c_i + \beta_{32} 11 * rq4_i + \\
 & \beta_{33} 11 * rq6a_i + \beta_{34} 11 * rq7a_i + \beta_{35} 11 * rq7b_i + \beta_{36} 11 * rq7c_i + \\
 & \beta_{37} 11 * rq7d_i + \beta_{38} 11 * sq2a_i + \beta_{39} 11 * sq2c_i + \beta_{40} 11 * sq4_i + \\
 & \beta_{41} 11 * sq6a_i + \beta_{42} 11 * sq7a_i + \beta_{43} 11 * sq7b_i + \beta_{44} 11 * sq7c_i + \\
 & \beta_{45} 11 * sq7d_i + \varepsilon_i
 \end{aligned}$$

Ten of the 45 independent variables were statistically significant accounting for 25% of the variance in the dependent variable (2004 TAKS mathematics achievement scale score). See Table 17 for parameter estimates for Model 2. It should be note that all significant variables are highlighted.

Table 17: 2004 Parameter Estimates (Model 2 - Complex Interactions)

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	2086.0692	18.66201	111.78	0.0000
10th	6.1844055	6.579817	0.94	0.3474
11 th	71.969538	6.545357	11.00	<.0001
R	21.908109	7.031146	3.12	0.0019
S	58.936828	6.115822	9.64	<.0001
question.2a	35.188986	9.994013	3.52	0.0004
question.2c	-27.32304	10.77908	-2.53	0.0113
question.4.num	0.322856	0.5308	0.61	0.5431
question.6a	30.613096	4.864574	6.29	<.0001
question.7a	16.645986	13.14719	1.27	0.2056
question.7b	-1.664562	8.049109	-0.21	0.8362
question.7c	-21.04945	14.16485	-1.49	0.1374
question.7d	13.010039	8.743803	1.49	0.1369
10*r2a	-60.18676	36.98018	-1.63	0.1038
10*r2c	16.111599	19.01548	0.85	0.3969
10*r4	2.7462247	1.709517	1.61	0.1083
10*r6a	7.8277142	15.61423	0.50	0.6162
10*r7a	-66.51226	32.94513	-2.02	0.0436
10*r7b	1.9868815	20.03356	0.10	0.9210
10*r7c	41.933672	34.08305	1.23	0.2187
10*r7d	-17.73726	22.79011	-0.78	0.4365
10*s2a	1.5189483	19.83472	0.08	0.9390
10*s2c	59.220699	27.5272	2.15	0.0316
10*s4	-1.380986	1.332671	-1.04	0.3002
10*s6a	4.0191418	13.1187	0.31	0.7594
10*s7a	6.8503149	23.68859	0.29	0.7725
10*s7b	-11.1912	16.10526	-0.69	0.4872
10*s7c	-9.453188	32.6338	-0.29	0.7721
10*s7d	-62.38275	16.8671	-3.70	0.0002
11*r2a	-27.9046	28.92465	-0.96	0.3348
11*r2c	-8.097036	20.98861	-0.39	0.6997
11*r4	-0.026915	1.49767	-0.02	0.9857
11*r6a	-0.340615	16.00706	-0.02	0.9830
11*r7a	-67.69802	31.72725	-2.13	0.0330
11*r7b	13.837819	21.66577	0.64	0.5231
11*r7c	57.875571	39.53233	1.46	0.1434
11*r7d	-10.459	26.62878	-0.39	0.6945
11*s2a	23.940823	17.69355	1.35	0.1762
11*s2c	42.017497	22.89025	1.84	0.0666
11*s4	-0.90253	1.264189	-0.71	0.4754
11*s6a	-26.59394	15.18443	-1.75	0.0800
11*s7a	-16.67073	25.05901	-0.67	0.5060
11*s7b	-23.99737	16.72196	-1.44	0.1514
11*s7c	31.62786	33.45817	0.95	0.3446
11*s7d	-31.84255	24.95719	-1.28	0.2022

As a validity check, researchers changed the base group from 9th grade urban to 9th grade rural schools (Model 3). There were no significant changes in the main effects of the model. As a result, the researchers do not report the findings below, however, the parameter estimates are included in the Appendix F.

It should be again noted that Models 1, 2, and 3 used 2004 TAKS math scale scores; that is, the dependent variable was campus level data from the Spring 2004 school year and teacher data was collected during the 2004-2005 school year (Fall 2004 - Spring 2005). This regression was of teacher measures on lagged (Spring 2004) student scores at the campus level. In order to maximize the validity of the model, researchers at SEDL repeated the regression analysis with spring 2005 TAKS scores.

Table 18 illustrates the means and standard deviations for the 2004 and 2005 TAKS Scale Scores. Note that the 2005 mean score is higher than the 2004 mean score.

Table 18: Descriptive Statistics for 2004 and 2005 TAKS Scale Score

2004 and 2005 TAKS Scale Score	2004 n = 2640	2005 n = 2685
Mean	2140	2194
Std Dev	81	67

2005 Mathematics Achievement Model Specification

As in the analyses conducted with 2004 test data, researchers at SEDL continued to use multiple regression analysis to model the effects of the independent variables on the dependent variable. Researchers did not vary the model specification structurally, but simply included 2005 TAKS mathematics scale scores at the school level as the dependent variable (Y) in the analysis. The independent variables remained the same, which included measures of availability, frequency, ways, and purposes of use of graphing calculators in the classroom. The base group (β_1) was again ninth grade Urban Schools.

The following variables were included as independent variables:

- Grade (tenth)
- Grade (eleventh)
- Rural (r)
- Suburban (s)
- Students required to provide own calculator (q2a)
- School provides teacher with a classroom set of calculators (q2c)
- Number years teacher has used graphing calculator in class (q4)
- Students use of calculators for homework (q6a)
- Calculators use for instructional purpose: operations (q7a)
- Calculators use for instructional purpose: drill/practice (q7b)
- Calculators use for instructional purpose: problem solving (q7c)

- Calculators use for instructional purpose: conceptual understanding (q7d)
- Tenth grade rural students required to provide own calculator (10*r2a)
- Tenth grade rural school provides teacher with a classroom set of calculators (10*r2c)
- Number of years tenth grade rural teacher has used graphing calculator in class (10*rq4)
- Tenth grade rural students use of calculators for homework (10*rq6a)
- Tenth grade rural calculators use for instructional purpose: operations (10*rq7a)
- Tenth grade rural calculators use for instructional purpose: drill/practice (10*rq7b)
- Tenth grade rural calculators use for instructional purpose: problem solving (10*rq7c)
- Tenth grade rural calculators use for instructional purpose: conceptual understanding (10*rq7d)
- Tenth grade suburban school provides student with calculator (10*Sq2a)
- Tenth grade suburban school provides teacher with a classroom set of calculators (10*Sq2c)
- Tenth grade number of years suburban teacher has used graphing calculator in class (10*Sq4)
- Tenth grade suburban students use calculators for homework (10*Sq6a)
- Tenth grade suburban calculators use for instructional purpose: (10*Sq7a)
- Tenth grade suburban calculators use for instructional purpose: drill/practice (10*Sq7b)
- Tenth grade suburban calculators use for instructional purpose: problem solving (10*Sq7c)
- Tenth grade suburban calculators use for instructional purpose: conceptual understanding (10*Sq7d)
- Eleventh grade rural students required to provide own calculator (11*r2a)
- Eleventh grade rural school provides teacher with a classroom set of calculators (11*r2c)
- Number of years eleventh grade rural teacher has used graphing calculator in class (11*rq4)
- Eleventh grade rural students use of calculators for homework (11*rq6a)
- Eleventh grade rural calculators use for instructional purpose: operations (11*rq7a)
- Eleventh grade rural calculators use for instructional purpose: drill/practice (11*rq7b)
- Eleventh grade rural calculators use for instructional purpose: problem solving (11*rq7c)
- Eleventh grade rural calculators use for instructional purpose: conceptual understanding (11*rq7d)
- Eleventh grade suburban school provides student with calculator (11*Sq2a)
- Eleventh grade suburban school provides teacher with a classroom set of calculators (11*Sq2c)

- Eleventh grade number of years suburban teacher has used graphing calculator in class (11*Sq4)
- Eleventh grade suburban students use of calculators for homework (11*Sq6a)
- Eleventh grade suburban calculators use for instructional purpose: (11*Sq7a)
- Eleventh grade suburban calculators use for instructional purpose: drill/practice (11*Sq7b)
- Eleventh grade suburban calculators use for instructional purpose: problem solving (11*Sq7c)
- Eleventh grade suburban calculators use for instructional purpose: conceptual understanding (11*Sq7d)

Note that the base group (β_1) in the Model 4 was Ninth grade Urban schools and the dependent variable was the 2005 TAKS math scale score.

Model 4.

$$\begin{aligned}
 05\text{MathScaleScore}_i = & \beta_1 + \beta_2 10th_i + \beta_3 11th_i + \beta_4 Rural_i + \beta_5 Suburban_i + \\
 & \beta_6 q2a_i + \beta_7 q2c_i + \beta_8 q4_i + \beta_9 q6a_i + \beta_{10} q7a_i + \beta_{11} q7b_i + \\
 & \beta_{12} q7c_i + \beta_{13} q7d_i + \beta_{14} 10 * r2a_i + \beta_{15} 10 * rq2c_i + \beta_{16} 10 * rq4_i + \\
 & \beta_{17} 10 * rq6a_i + \beta_{18} 10 * rq7a_i + \beta_{19} 10 * rq7b_i + \beta_{20} 10 * rq7c_i + \\
 & \beta_{21} 10 * rq7d_i + \beta_{22} 10 * sq2a_i + \beta_{23} 10 * sq2c_i + \beta_{24} 10 * sq4_i + \\
 & \beta_{25} 10 * sq6a_i + \beta_{26} 10 * sq7a_i + \beta_{27} 10 * sq7b_i + \beta_{28} 10 * sq7c_i + \\
 & \beta_{29} 10 * sq7d_i + \beta_{30} 11 * r2a_i + \beta_{31} 11 * rq2c_i + \beta_{32} 11 * rq4_i + \\
 & \beta_{33} 11 * rq6a_i + \beta_{34} 11 * rq7a_i + \beta_{35} 11 * rq7b_i + \beta_{36} 11 * rq7c_i + \\
 & \beta_{37} 11 * rq7d_i + \beta_{38} 11 * sq2a_i + \beta_{39} 11 * sq2c_i + \beta_{40} 11 * sq4_i + \\
 & \beta_{41} 11 * sq6a_i + \beta_{42} 11 * sq7a_i + \beta_{43} 11 * sq7b_i + \beta_{44} 11 * sq7c_i + \\
 & \beta_{45} 11 * sq7d_i + \varepsilon_i
 \end{aligned}$$

Eleven of the 45 independent variables were statistically significant accounting for 14% of the variance in the dependent variable (2005 TAKS mathematics scale scores). Four main effects were found to be statistically significant.

Suburban schools was statistically significant ($t = 6.65, p < .0001$). That is, ninth grade TAKS math scale scores in suburban schools were 36 points higher than urban schools' scores ($\beta_1 + \beta_5$).

The variable q2a (Students required to provide their own calculator) was statistically significant ($t = 3.13, p < .0018$). That is, urban schools where 9th grade students reportedly supplied their own calculators had TAKS scale scores that were 28 points higher, holding all else constant.

The variable q2c (School provides teacher with a classroom set of calculators) was also statistically significant ($t = -2.75, p < .0060$). If urban teachers reported that their school

provided them with a classroom set of graphing calculators, ninth grade TAKS math scale scores were lower by 25 points, holding all else constant.

Finally, the variable q6a (Homework) was statistically significant ($t = 4.90, p < .0001$). In schools where teachers reported student use of a graphing calculator for homework assignments, 2005 TAKS math scale scores were 21 points higher, holding all else constant.

Interaction effects were also included in the model to investigate possible differences between the different independent variables. Seven of these interactions were statistically significant as illustrate in Table 19.

Table 19: Model 4 Statistically Significant Interactions

Variables	Level of significance	Impact on school's average scale scores, holding all else constant
10*r7a - Rural 10 th grade students/ operations	($t = -2.26, p < .0242$)	Rural 10th grade 66 points lower
10*s2c - Suburban 10 th grade teachers/classroom set of calculators	($t = 2.57, p < .0102$)	Suburban 10th grade 60 points higher
10*s7d Suburban 10 th grade students/conceptual understanding	($t = -2.77, p < .0056$).	Suburban 10th grade 42 points lower
11*r7a - Rural 11 th grade students/operations)	($t = -3.92, p < .0001$)	Rural 11th grade 111 points lower
11*r7c - Rural 11 th grade students/ problem solving	($t = 2.19, p < .0288$)	Rural 11 th grade 76 points higher
11*s2c - Suburban 11 th grade/classroom set of calculators	($t = 2.93, p < .0034$)	Suburban 11 th grade 40 points higher
11*s7b - Suburban 11 th grade/drill and practice)	($t = -1.95, p < .0509$)	suburban 11 th grade 28 points lower

Table 20 illustrates the parameter estimates for all variables in Model 4.

Table 20: 2005 Parameter Estimates (Model 4 - Complex Interactions Model)

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	2189.1272	16.41422	133.37	0.0000
10th	-1.656556	5.887724	-0.28	0.7785
11th	0.6017716	5.830517	0.10	0.9178
R	10.106281	6.293443	1.61	0.1085
S	36.22885	5.451635	6.65	<.0001
question.2a	27.881034	8.896679	3.13	0.0018
question.2c	-25.41183	9.232396	-2.75	0.0060
question.4.num	-0.037337	0.461632	-0.08	0.9355
question.6a	21.389227	4.362145	4.90	<.0001
question.7a	12.607366	11.53463	1.09	0.2745
question.7b	0.8755138	7.078557	0.12	0.9016
question.7c	-18.52358	12.85002	-1.44	0.1496
question.7d	-1.04608	7.853929	-0.13	0.8941
10*r2a	2.9840042	33.10547	0.09	0.9282
10*r2c	13.292754	16.91508	0.79	0.4320
10*r4	2.1356552	1.384011	1.54	0.1230
10*r6a	16.761102	14.10849	1.19	0.2350
10*r7a	-66.39963	29.44299	-2.26	0.0242
10*r7b	9.7988802	17.47605	0.56	0.5751
10*r7c	27.47185	30.71178	0.89	0.3712
10*r7d	-6.922185	20.22778	-0.34	0.7322
10*s2a	14.320696	17.73613	0.81	0.4195
10*s2c	59.62926	23.20304	2.57	0.0102
10*s4	-0.624924	1.07788	-0.58	0.5621
10*s6a	13.87473	11.5912	1.20	0.2314
10*s7a	9.4302369	20.82326	0.45	0.6507
10*s7b	-7.977122	14.15985	-0.56	0.5733
10*s7c	-26.06913	28.23742	-0.92	0.3560
10*s7d	-41.64429	15.03054	-2.77	0.0056
11*r2a	-18.62723	25.83677	-0.72	0.4710
11*r2c	-11.5587	18.65481	-0.62	0.5356
11*r4	1.5824822	1.207743	1.31	0.1903
11*r6a	-7.212387	14.27188	-0.51	0.6134
11*r7a	-111.3216	28.41296	-3.92	<.0001
11*r7b	21.927825	19.32725	1.13	0.2567
11*r7c	75.826174	34.65471	2.19	0.0288
11*r7d	14.858492	22.81668	0.65	0.5150
11*s2a	23.914234	15.79844	1.51	0.1303
11*s2c	40.495713	19.6385	2.06	0.0393
11*s4	-0.4388	1.032325	-0.43	0.6708
11*s6a	-10.40621	13.54292	-0.77	0.4423
11*s7a	-7.074707	21.77807	-0.32	0.7453
11*s7b	-28.26282	14.46457	-1.95	0.0509
11*s7c	24.59003	29.77694	0.83	0.4090
11*s7d	-19.63099	22.41222	-0.88	0.3812

Research Question 3

Do schools that incorporate graphing calculators in the classroom demonstrate high levels of achievement as measured by statewide assessments? Do schools that more frequently incorporate graphing calculators in the classroom demonstrate high levels of achievement as measured by statewide assessments?

Use vs. Non-Use

As noted earlier, 98% of the teachers indicated they were using graphing calculators in their classrooms, whereas only 2% indicated they were not. Because the two groups have unequal variances, mean difference estimates would be biased and inefficient if calculated on these variances. Therefore, a random sample from the use group (n=34) was selected to compare to the non-use group (n=34). As seen in Table 21, there was a difference in mathematics achievement scale scores between the two groups. That is, the use group's TAKS average scale score was 29 points higher than the non-use group. The mean difference was statistically significant at the .10 alpha level. While this is a lower alpha level than normally accepted, these findings are consistent with results on the National Assessment of Educational Progress. In 2000, eighth- and twelfth-graders who used graphing calculators in class had higher average NAEP scores than did non-users (NCES, 2001). Solyts (2004) also found that when students used graphing calculators they displayed significantly higher levels of achievement on the Pennsylvania standards-based mathematics assessment than students who used scientific or four-function calculators.

Table 21: Means for graphing calculator use

Group	N	Mean	Std. Deviation
Non - Use	34	2183	82.25
Use	34	2212	73.67
* Significant at the .10 alpha level			

Frequency of Use

Results related to how often graphing calculators are used in the classroom were so mixed that it was determined that this variable should be eliminated from the analysis. Results appeared to cancel one another out, appearing to create an identity, with no clear findings. Other studies, however, have demonstrated that more use of graphing calculators are related to higher test scores. For example, on the National Assessment of Educational Progress (NAEP) administered in 2000, more frequent calculator usage by eighth- and twelfth-graders was associated with higher scores. In addition, results from the Trends in International Mathematics and Science Study (Mullis, Martin, Gonzalez, & Chrstowski, 2003) appear to indicate that in those countries that demonstrated higher scores on the eighth grade assessment, students are allowed frequent access to calculators. Singapore, the highest scoring nation, had no teachers reporting that calculators were not allowed. Singapore teachers reported that their students used

calculators on half or more of lessons for the purpose of checking answers, routine computations, and solving complex problems. Teachers in both Hong Kong and Belgium, two of the other top performing countries, also reported almost unrestricted use of calculators by eighth graders, with only 2% and 3% respectively of teachers reporting students were not allowed to use calculators. Allowing the use of calculators in the other top scoring countries (Korea, Chinese Taipei, and Japan) ranged from 63% to 66% of teachers whose students used calculators in the classroom.

Access to Graphing Calculators

Students provide their own calculators. In Model 1, there was a statistically significant relationship between scale scores and students providing their own calculators. That is, if teachers reported that students were required to supply their own calculators, the math scale scores at that school were higher by 36 points, holding all else constant. Looking more closely at this relationship under Model 2, the relationship continued to be positive for ninth grade mathematics scores in urban schools, which were 35 points higher when students supplied their own calculators. Model 3 was constructed to investigate the stability of the parameter estimates and model validity. The base group was changed to rural schools. Researchers still found a positive relationship between students providing their own calculator and mathematics scores, which were 32 points higher, holding all else constant, in these rural schools. In model 4, this finding was again consistent. That is, if 9th grade urban students supplied their own calculator, then math scale scores were 28 points higher for that school, holding all else constant. There was variation in the parameters estimate for this variable across the samples; yet, the inference was consistent. That is, when schools required students to provide their own calculator the school's average TAKS scale scores were higher.

A classroom set of calculators. Under Model 1, a significant negative relationship between schools supplying teachers with a classroom set of calculators and TAKS math scale scores. That is, if the school provided teachers with a set of classroom calculators, then the school's math scale scores were 19 points lower, holding all else constant. In Model 2 and 3, researchers found similar findings except TAKS math scale scores were lower by 27 points, holding all else constant. And, in Model 4, TAKS math scale scores were lower by 25 points, holding all else constant.

In contrast, the interaction effects in Model 2 revealed that in suburban schools where teachers reported that the school provided them a classroom set of graphing calculators, tenth grade scores were 60 points higher. Strikingly similar results were also found in Model 3 and 4. In Model 3, data indicated that suburban schools that provided 11th grade teachers with a classroom set of calculators, had higher 11th grade TAKS math scale scores (44 points higher), holding all else constant. Furthermore, in Model 4, 11th grade suburban schools TAKS math scale scores were 40 points, holding all else constant, when 11th grade teachers were provided with a classroom set of calculators.

These results indicate great variation for suburban schools over all schools in general. Further study is needed to determine the potential relationships between having a

classroom set of graphing calculators and student outcomes.

Research Question 4

Which types of use, if any, appear more closely related to higher levels of achievement?

To answer this question, researchers looked for relationships between TAKS mathematics scale scores and the ways in which teachers reported their students were using graphing calculators. That is, were they using graphing calculators for homework, class work, or classroom tests? In addition, the purposes of use (operations, drill and practice, problem solving, and conceptual understanding) were examined for any relationships to test scores.

Homework

In the initial linear regression analysis, Model 1, the use of graphing calculators for homework was statistically significant. That is, in schools where teachers reported use of graphing calculators for homework assignments, average TAKS math scale scores were 28 points higher, holding all else constant. This relationship was also a significant positive relationship under Model 2 for ninth grade scale scores in urban schools. In this case, these scores were 31 points higher when graphing calculators were reportedly used for homework. Similar results were found in Model 3, where rural schools that reported use of a graphing calculator for homework had 9th grade TAKS math scale scores that were 34 points higher, holding all else constant. This finding was also consistent in Model 4 where rural 9th grade TAKS math scale scores were 21 points higher.

Operations

For rural schools in Model 1, 10th grade TAKS mathematics scale scores were 67 points lower and 11th grade scale scores were 68 points lower than the base group when graphing calculators were reportedly used for operations. In Model 4, similar results were found. Tenth grade rural TAKS math scale scores were 66 points lower when graphing calculators were reportedly used for operations. In addition, if teachers reported using graphing calculators to teach operations in 11th grade rural math classes, then 11th grade rural TAKS math scale scores were 111 points lower on average, holding all else constant.

Conceptual understanding

It is interesting that in Model 2, suburban schools where teachers reported using graphing calculators to teach conceptual understanding, tenth grade TAKS mathematics scores were 62 points lower, holding all else constant. This result was repeated in Model 4 when 10th grade suburban teachers reported that they used graphing calculators to teach conceptual understanding. In those schools, 10th grade TAKS math scale scores were 42 points lower on average.

Problem solving

Researchers found a positive relationship in Model 4 between use of graphing calculators for problem solving and Rural 11th grade TAKS math scale scores. If rural teachers reported using graphing calculators for problem solving in math classes, then 11th grade TAKS math scale scores in those rural schools were 76 points higher, holding all else constant.

Drill and practice

Finally, in Model 4, if teachers reported using graphing calculators for drill and practice in suburban schools, then suburban 11th grade TAKS math scale scores were 25 points lower on average, holding all else constant.

Comparing 2004 and 2005 analyses.

In Table 22, significant variables from the 2004 and 2005 analyses have been highlighted side-by-side. Both rural and suburban schools have higher scores than urban schools for both 9th and 11th grade in 2004 but in 2005 only 9th grade scores in suburban schools were significantly different from 9th grade scores in urban schools.

The results of this study indicate that the parameters estimates for question 2a, question 2c, and question 6a appear to be consistent across both data sets. There was variation in the parameters estimates for these three variables, but the inferences were consistent. That is, schools that require students to provide their own calculator had higher TAKS scale scores than those schools where students had access to a classroom set of calculators. Furthermore, schools in which teachers reported that students used calculators for homework typically had higher mathematics TAKS scale scores.

In addition, interaction effects were also included in the model to investigate possible differences between the levels of the independent variables. Four interaction effects had similar parameter estimates across the data sets. Rural schools' tenth grade scores were lower when teachers reported using graphing calculators for teaching operations. The second significant interaction effect indicated that suburban schools' tenth grade scores were higher if teachers were provided with a set of classroom calculators. Third, suburban schools' tenth grade scores were lower if teachers reported that they used graphing calculators to teach conceptual understanding. Finally, rural schools' 11th grade scores were significantly lower if teachers reported using graphing calculators for teaching operations.

Three other interaction effects were also determined to be significant in the 2005 analysis. The analyses indicated if graphing calculators were used for problem solving in 11th grade rural math classes, then associated TAKS math scale scores were higher. It was also revealed that if suburban schools provided a set of classroom calculators, then 11th grade TAKS scale scores were higher. Finally, the reported use of a graphing

calculator for drill and practice in suburban 11th grade math classes was inversely related with TAKS math scale scores for those schools.

Table 22: A comparison of parameter estimates

Term	2004 Estimate	Prob> t	2005 Estimate	Prob> t
9 th grade Urban	2086.0692	.0001	2189.1272	0.0000
10 th	6.1844055	0.3474	-1.656556	0.7785
11 th	71.969538	<.0001	0.6017716	0.9178
R	21.908109	0.0019	10.106281	0.1085
S	58.936828	<.0001	36.22885	<.0001
question.2a	35.188986	0.0004	27.881034	0.0018
question.2c	-27.32304	0.0113	-25.41183	0.0060
question.4.num	0.322856	0.5431	-0.037337	0.9355
question.6a	30.613096	<.0001	21.389227	<.0001
question.7a	16.645986	0.2056	12.607366	0.2745
question.7b	-1.664562	0.8362	0.8755138	0.9016
question.7c	-21.04945	0.1374	-18.52358	0.1496
question.7d	13.010039	0.1369	-1.04608	0.8941
10*r2a	-60.18676	0.1038	2.9840042	0.9282
10*r2c	16.111599	0.3969	13.292754	0.4320
10*r4	2.7462247	0.1083	2.1356552	0.1230
10*r6a	7.8277142	0.6162	16.761102	0.2350
10*r7a	-66.51226	0.0436	-66.39963	0.0242
10*r7b	1.9868815	0.921	9.7988802	0.5751
10*r7c	41.933672	0.2187	27.47185	0.3712
10*r7d	-17.73726	0.4365	-6.922185	0.7322
10*s2a	1.5189483	0.939	14.320696	0.4195
10*s2c	59.220699	0.0316	59.62926	0.0102
10*s4	-1.380986	0.3002	-0.624924	0.5621
10*s6a	4.0191418	0.7594	13.87473	0.2314
10*s7a	6.8503149	0.7725	9.4302369	0.6507
10*s7b	-11.1912	0.4872	-7.977122	0.5733
10*s7c	-9.453188	0.7721	-26.06913	0.3560
10*s7d	-62.38275	0.0002	-41.64429	0.0056
11*r2a	-27.9046	0.3348	-18.62723	0.4710
11*r2c	-8.097036	0.6997	-11.5587	0.5356
11*r4	-0.026915	0.9857	1.5824822	0.1903
11*r6a	-0.340615	0.983	-7.212387	0.6134
11*r7a	-67.69802	0.033	-111.3216	<.0001
11*r7b	13.837819	0.5231	21.927825	0.2567
11*r7c	57.875571	0.1434	75.826174	0.0288
11*r7d	-10.459	0.6945	14.858492	0.5150
11*s2a	23.940823	0.1762	23.914234	0.1303

11*s2c	42.017497	0.0666	40.495713	0.0393
11*s4	-0.90253	0.4754	-0.4388	0.6708
11*s6a	-26.59394	0.08	-10.40621	0.4423
11*s7a	-16.67073	0.506	-7.074707	0.7453
11*s7b	-23.99737	0.1514	-28.26282	0.0509
11*s7c	31.62786	0.3446	24.59003	0.4090
11*s7d	-31.84255	0.2022	-19.63099	0.3812

While the interaction findings are revealing, conclusions drawn from these interactions must be weighed carefully. The four interaction effects with similar parameter estimates across the data sets suggest probable conclusions. Careful examination of these results, however, demonstrate that three of the four pertain only to 10th grade scores and grade ten scores were typically lower across both tests. Other factors, rather than any real differences or relationships among the independent variables may be at play.

Discussion

The purpose of this study was to examine the impact of the use of graphing calculators on student achievement as measured by a statewide-standardized assessment in Texas. To examine this impact, the researchers sought to determine whether graphing calculators were being used in high schools in Texas, how often they were being used, and for what purposes. In addition, the study examined the relationships among the frequency, types, and purposes of use of graphing calculators in Texas high schools and student achievement as measured by scores on the Texas statewide mathematics assessments for high school students that require the use of graphing calculators.

Prior to the requirement to use graphing calculators on the Texas standardized mathematics assessments for high school students, a previous standardized test, the Texas Assessment of Academic Skills (TAAS) was administered to all students at the tenth grade level. This test did not require the use of graphing calculators. One model to determine the impact of requiring the use of graphing calculators on standardized assessments would be the examination of test scores both before and after this requirement.

Initially, the researchers explored the possibility of comparing student scores on the TAAS to the mathematics scores on new TAKS. A report prepared Pearson Educational Measurement for the Texas Education Agency indicated the two tests were too different to be equated. Any analysis would result in unreliable findings (Miller, 2005). Therefore, this study did not attempt to look at differences between the TAAS and TAKS mathematics scores. Rather, data was collected from high school mathematics teachers to answer four research questions:

1. Do students use graphing calculators in Texas high school classrooms?
2. How often, in what ways, and for what purposes are graphing calculators used in classrooms? When did calculator use begin?

3. Do schools that incorporate graphing calculators in the classroom demonstrate higher levels of achievement as measured by statewide assessments? Do schools that more frequently incorporate graphing calculators in the classroom demonstrate higher levels of achievement as measured by statewide assessments?
4. Which types of use, if any, appear more closely related to higher levels of achievement (e.g., unrestricted use by students; use on classroom tests)?

The overwhelming majority of the respondents stated that students are using graphing calculators in Texas high school mathematics classrooms. Eighty-one percent of the teachers reported that graphing calculators are used on a daily basis in their classroom. In urban schools, less daily use was reported (78%) than in suburban (80%) and rural (84%) schools. Most of the respondents indicated that students are using graphing calculators for the purpose of problem solving, operations, and conceptual understanding. The least often purpose of use of graphing calculators was for drill/practice. This was an area in which there were mixed results depending on grade level.

Two factors may have bearing on these findings. First, no definitions for the terms conceptual understanding, problem solving, operations, and drill/practice were provided on the survey instrument. Individual teachers may well have interpreted these terms differently. Secondly, the TAKS test itself becomes more application oriented and less focused on operations as students progress from grade 9 to grade 11. Less items related to operations may have appeared on the tenth and eleventh grade tests.

Forty-three percent of the teachers indicated they have been using graphing calculators from 1 to 5 years, while the rest reported use of graphing calculators for six or more years. There was no significant correlation between the length of time teachers had been using graphing calculators and mathematics test scores.

Under Regression Models 1, 2, and 4, the following main effects findings were consistent: (a) suburban schools had higher test scores, (b) schools in which teachers reported that students were required to provide their own graphing calculators had higher test scores, particularly in urban schools at the ninth grade level, (c) test scores were lower in urban schools where teachers had a classroom set of calculators, and (d) use of graphing calculators for homework was positively correlated with higher TAKS mathematics scale scores.

Limitations

With the exception of surveys based on a search of records, surveys are dependent on direct communication with persons having characteristics, behaviors, attitudes and other relevant information appropriate for a specific investigation. This makes them reactive in nature; that is, they directly involve the respondent in the assessment process by eliciting a reaction. Direct interactions are, however, often the most cost-effective, efficient, and credible means of collecting data because the respondents are usually in best position to speak for themselves and “tell it like it is.” Reactive methods run many risks of

generating misleading information. Isaac and Michael (1997) note some of these risks as the following:

1. Surveys only tap respondents who are accessible and cooperative.
2. Surveys often make the respondent feel special or unnatural and, thus, produce responses that are artificial or slanted.
3. Surveys arouse “response sets” such as acquiescence or a proneness to agree with positive statements or questions.
4. Surveys are vulnerable to over-rater or under-rater bias – the tendency for some respondents to give consistently high or low ratings (p. 137).

Attempts to establish causation in cross-sectional surveys are fraught with problems. Generally, survey data consist of observations made in natural settings where no attempt has been made to exercise experimental control. Therefore, establishing causation is not possible.

Although one question asked teachers to report whether the school required students to furnish their own calculators, additional data regarding the type of students who have their own calculators may contribute to the relationship between this variable and the results on the TAKS test. Level of student income, participation in advanced courses, or other student characteristics beyond supplying their own calculator may be possible confounding variables in this relationship.

Directions for Future Research

While this study indicated that there was a significant positive relationship between the use of calculators for homework and scores on a statewide assessment, this is not a cause-effect relationship. Similarly, requiring students to supply their own calculators was positively related to higher test scores for some students and providing teachers a classroom set of calculators had both positive and negative correlations under particular circumstances. These relationships warrant further study under experimental conditions in order to determine whether causal relationships exist.

Such a study might establish randomly selected treatment and control groups in which the students in the treatment group are provided with their own graphing calculators and required to use these calculators on homework assignments, while control groups have access only to a classroom set of graphing calculators and are not required to use the graphing calculators for homework. A third comparison group would include students who were supplied with their own calculators and were not required to use these calculators on homework assignments.

Other treatment and control group conditions might also examine the purposes of graphing calculator use. Clearly defined methods of using graphing calculators to teacher problem solving, operations, and conceptual understanding could be tested in such a study.

Lessons Learned

A mail, e-mail, and Internet survey methodology is an effective vehicle for data collection, yielding a response rate of 67%, which is well above the 30% level indicated as a high response rate for surveys. Multiple mailings and contacts with schools were necessary to obtain such a response rate.

Initially, we anticipated that we could interview teachers during the school day. We learned quickly in seeking to reach principals to secure permission to include their schools in the study sample, it was extremely difficult to reach school personnel by phone during the school day. By working with school secretaries, SEDL was able to obtain permission from principals as well as assistance in distributing surveys to teachers in some cases.

Another lesson learned during the course of conducting this study is that a number of school districts have internal research review processes that must be completed before schools in those districts are allowed to participate in research studies. Because these review processes take a number of weeks in most cases, additional time should be factored into the time frame for such a study to allow for approvals from these districts. Most of the largest districts in the state, which include a large number of the high schools in urban areas, have such procedures. Failing to include those schools would negatively impact the results of the study.

Another element that added to the time needed to conduct the study was the quality of data regarding the teachers currently employed in each school. Because we sought to obtain responses from at least 50% of the teachers (initially we sought to obtain 75% of the teachers) on a given campus, it was important that we knew exactly how many teachers were employed on each campus. Verifying the master teacher list obtained from the Texas Education Agency was more time consuming than estimated. A number of teachers had left their designated schools, resulting in the need to add or delete teachers from each individual school.

Finally, timing is crucial. The study began at the beginning of the school year. Consequently, when calls were made to follow up with principals regarding the letters sent requesting their permission to participate, many of the principals did not recall seeing the letters. Beginning a study such as this one after several weeks of the school year have passed may reduce the amount of follow-up required to obtain such permission. Working with the school secretaries to get the requests to the principals was a key to overcoming this timing problem.

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Appendixes

Appendix A: Graphing Calculator Survey

Teacher Name: _____ School: _____

1. Do students use graphing calculators in your classes?
___ YES ___ NO

If NO, survey is complete. If YES, continue:

2. How are graphing calculators made available to the students in your classes?
- 2a. Are students required to provide their own calculators?
___ YES ___ NO
- 2b. Does the school provide each student with his/her own calculator?
___ YES ___ NO
- 2c. Does the school provide teachers with a classroom set of calculators?
___ YES ___ NO

3. What mathematics courses do you teach?
- | | |
|----------------|------------------------------|
| 3a. Algebra I | 3d. Trigonometry |
| ___ YES ___ NO | ___ YES ___ NO |
| 3b. Algebra II | 3e. Pre-calculus or Calculus |
| ___ YES ___ NO | ___ YES ___ NO |
| 3c. Geometry | 3f. Other: _____ |
| ___ YES ___ NO | ___ YES ___ NO |

4. For how many years have you used graphing calculators with your classes?
_____ years

5. How often do students use graphing calculators in your classes?
___ Monthly ___ Weekly ___ Daily

6. In which of the following ways do students use calculators in your classes?

- | | |
|----------------|----------------------------|
| 6a. Homework | 6c. Classroom Tests |
| ___ YES ___ NO | ___ YES ___ NO |
| 6b. Class Work | 6d. State Assessment Tests |
| ___ YES ___ NO | ___ YES ___ NO |

7. For which of the following purposes do students use calculators in your classes?

- | | |
|--------------------|------------------------------|
| 7a. Operations | 7c. Problem Solving |
| ___ YES ___ NO | ___ YES ___ NO |
| 7b. Drill/Practice | 7d. Conceptual Understanding |
| ___ YES ___ NO | ___ YES ___ NO |

Please return to: Vicki Dimock, c/o SEDL, 211 East 7th Street, Austin, TX 78701 or fax to (512) 476-2286.

Appendix B: Model 1 -Linear Regression Model Analysis

Parameter Interpretation

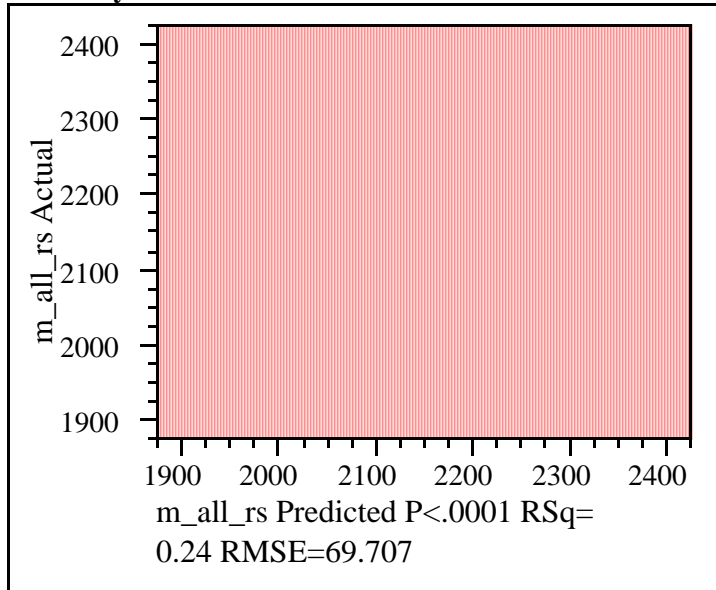
- The base group in this analysis was Urban Schools (β_1). The autonomous average mathematics scale score for Urban schools was 2104.
- The 11th variable was statistically significant ($t = 15.10, p < .0001$). In other words, the 11th grade **urban math scale scores** were **59 points higher** than **urban 9th scores** ($\beta_1 + \beta_3$).
- The R variable (Rural Schools) was statistically significant ($t = 4.18, p < .0001$). That is, 9th grade **rural math scale scores** were **17 points higher** than **Urban scores** ($\beta_1 + \beta_4$).
- The Suburban variable was statistically significant ($t = 12.43, p < .0001$). In other words, **Suburban math scale scores** were **46 points higher** than **Urban scores** ($\beta_1 + \beta_3$).
- The variable q2a (Students required to provide their own calculator) was statistically significant ($t = 5.10, p < .0001$). That is, if **students reportedly supplied their own calculator, their math scale score was higher by 36 points**, holding all else constant.
- The variable q2c (School provides teacher with a classroom set of calculators) was statistically significant ($t = -5.13, p < .0001$). That is, if the teacher reported that the school provided **them with a set of classroom calculators, student math scale scores were 19 points lower**, holding all else constant.
- The variable q6a (Homework) was statistically significant ($t = 7.05, p < .0001$). That is, if Texas High School students reportedly **use a graphing calculator with Homework** assignments, their TAKS **math scale scores were 28 points higher**, holding all else constant.

Appendix C: Model 1 – Initial Linear Regression Analysis and Plots

Response m_all_rs

Whole Model

Actual by Predicted Plot



Summary of Fit

RSquare	0.241234
RSquare Adj	0.236558
Root Mean Square Error	69.70652
Mean of Response	2143.104
Observations (or Sum Wgts)	1960

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	12	3007764	250647	51.5841
Error	1947	9460471	4859	Prob > F
C. Total	1959	12468235		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	619	3133379.3	5062.00	1.0625
Pure Error	1328	6327091.7	4764.38	Prob > F
Total Error	1947	9460471.0		0.1863
				Max RSq
				0.4925

Parameter Estimates

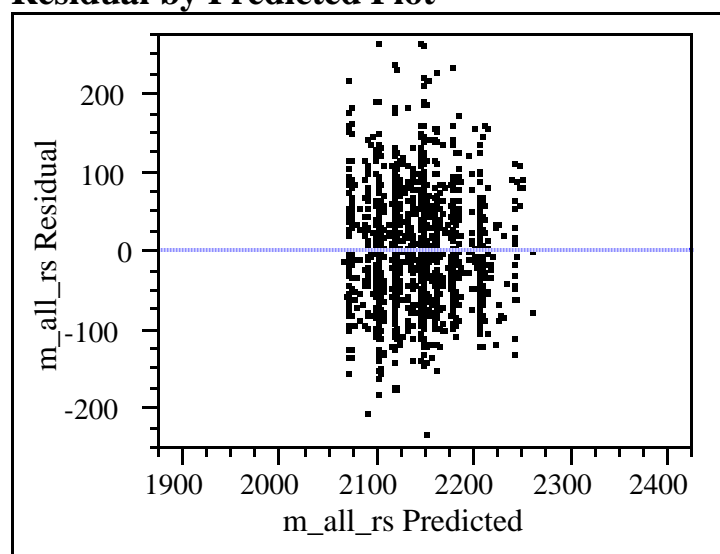
Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	2104.2343	17.03781	123.50	0.0000
10th	-1.127262	3.876852	-0.29	0.7713

Term	Estimate	Std Error	t Ratio	Prob> t
11th	59.050258	3.911518	15.10	<.0001
R	17.432463	4.175356	4.18	<.0001
S	45.881908	3.691946	12.43	<.0001
question.2a	35.765815	7.014633	5.10	<.0001
question.2c	-18.61164	7.630847	-2.44	0.0148
question.4.num	0.2632165	0.416102	0.63	0.5271
question.6a	28.320401	4.018937	7.05	<.0001
question.7a	6.9438397	9.551968	0.73	0.4673
question.7b	-5.727902	5.69401	-1.01	0.3146
question.7c	-9.560154	12.1823	-0.78	0.4327
question.7d	-4.057416	6.575702	-0.62	0.5373

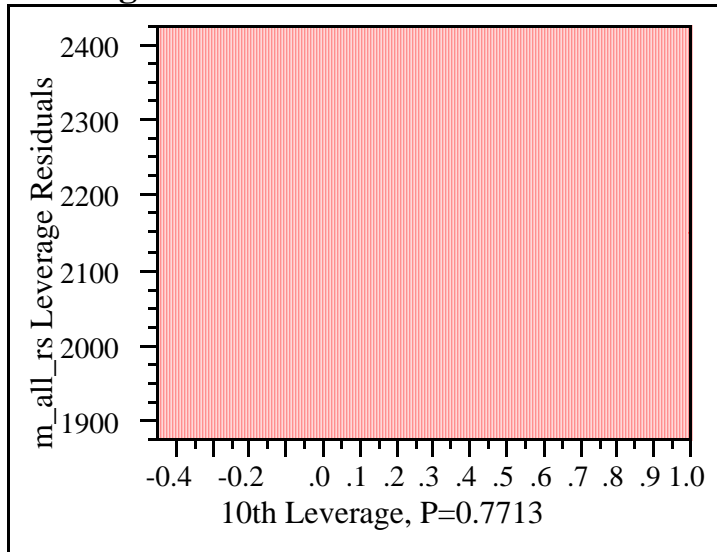
Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
10th	1	1	410.8	0.0845	0.7713
11th	1	1	1107388.0	227.9046	<.0001
R	1	1	84698.8	17.4313	<.0001
S	1	1	750445.2	154.4444	<.0001
question.2a	1	1	126320.3	25.9972	<.0001
question.2c	1	1	28904.8	5.9487	0.0148
question.4.num	1	1	1944.3	0.4002	0.5271
question.6a	1	1	241281.0	49.6565	<.0001
question.7a	1	1	2567.8	0.5285	0.4673
question.7b	1	1	4917.0	1.0119	0.3146
question.7c	1	1	2992.4	0.6158	0.4327
question.7d	1	1	1850.0	0.3807	0.5373

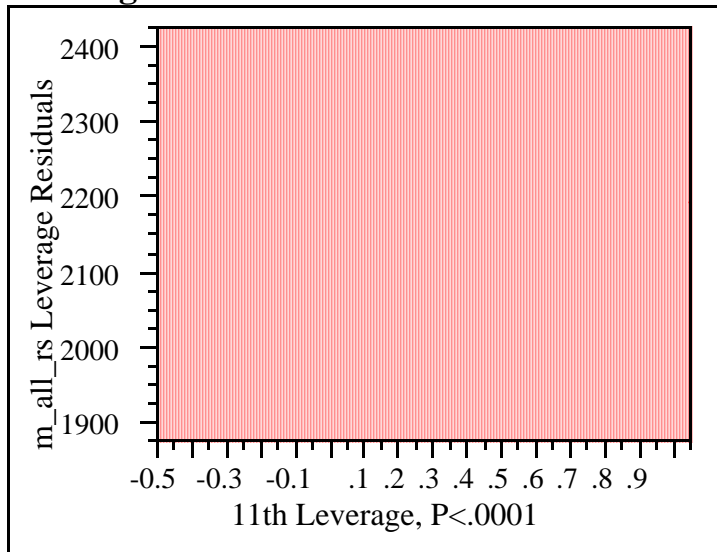
Residual by Predicted Plot



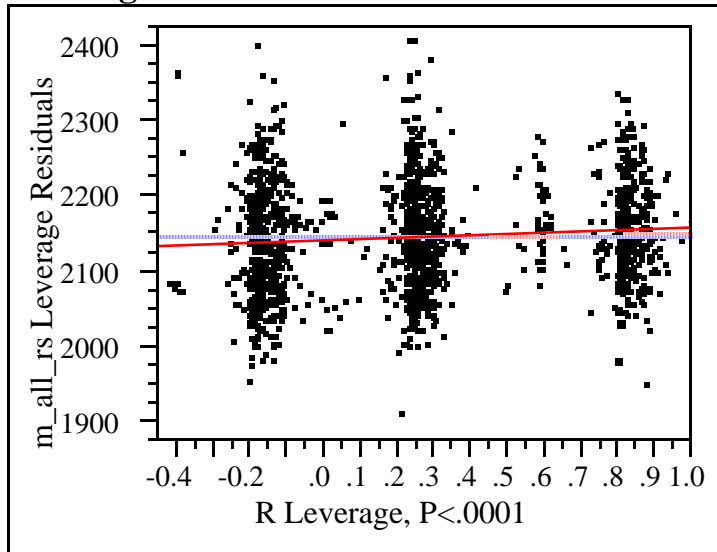
10th Leverage Plot



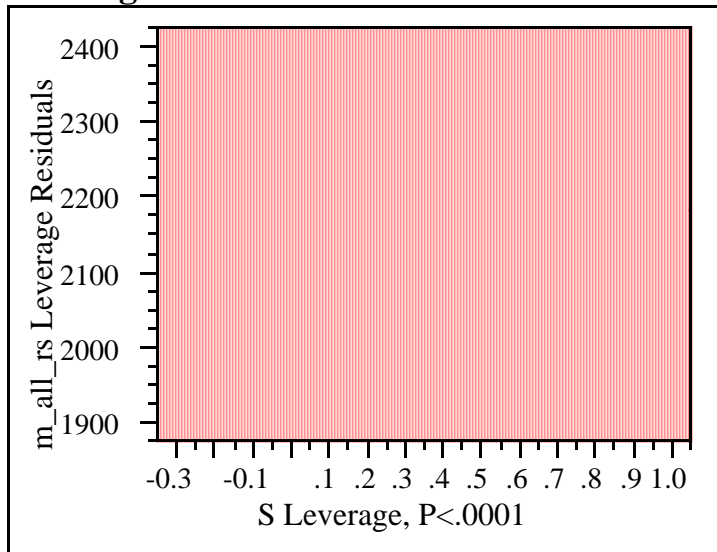
11th Leverage Plot



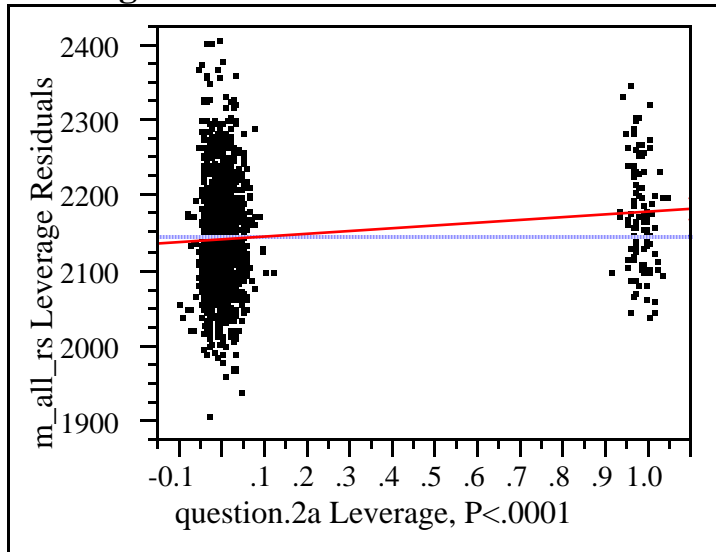
R Leverage Plot



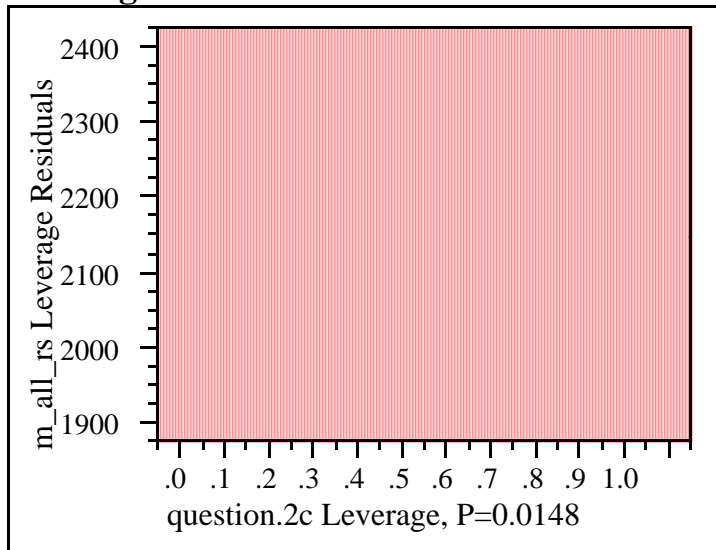
S Leverage Plot



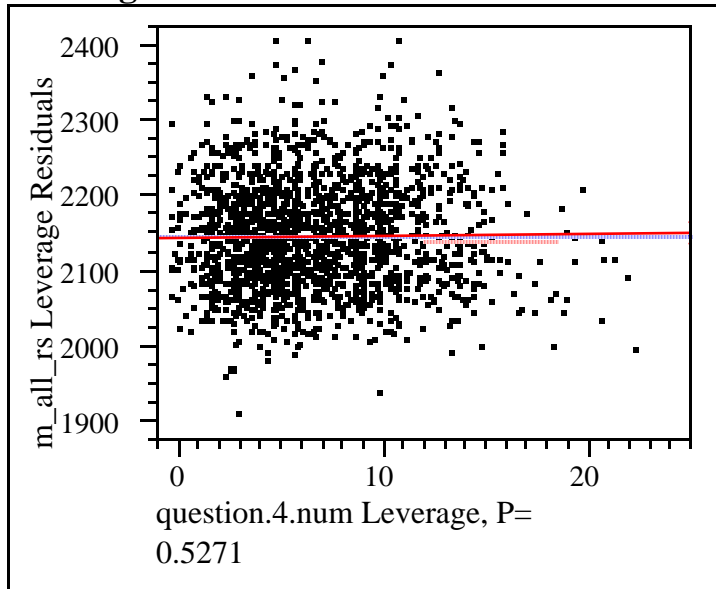
question.2a
Leverage Plot



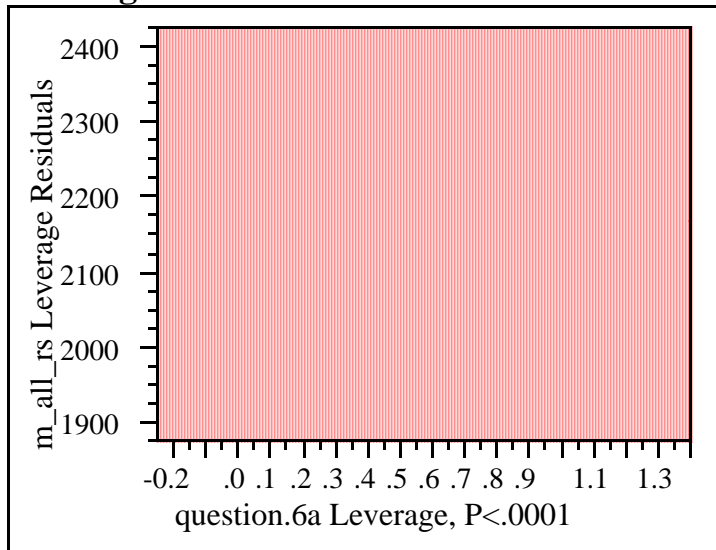
question.2c
Leverage Plot



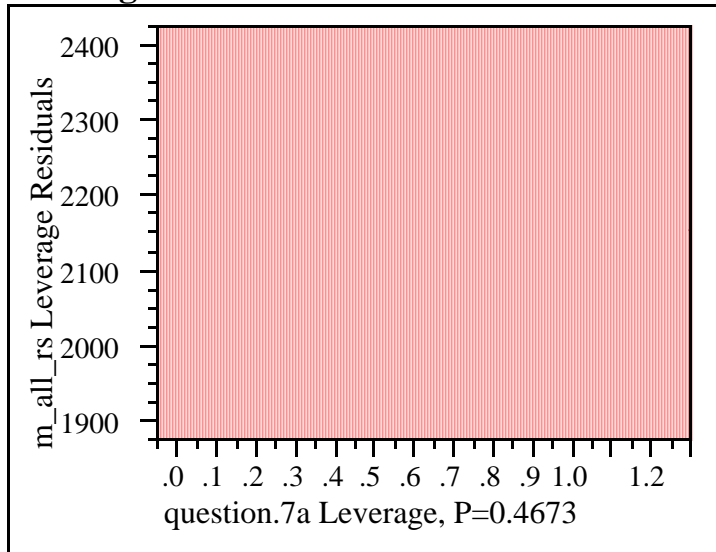
question.4.num
Leverage Plot



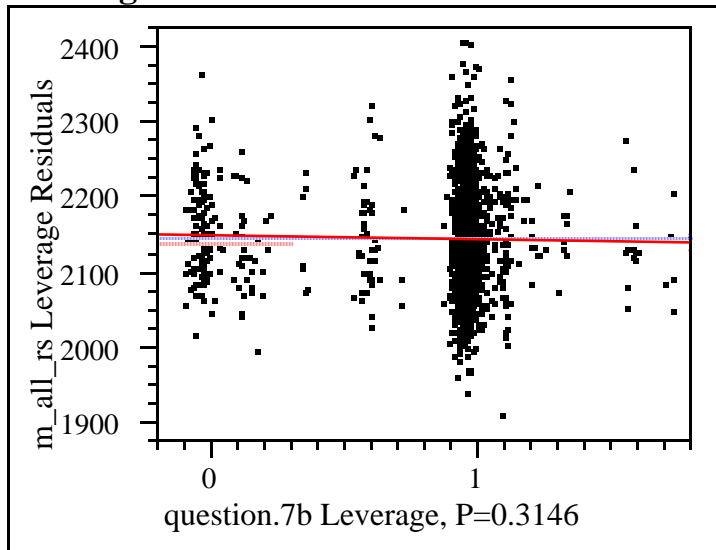
question.6a
Leverage Plot



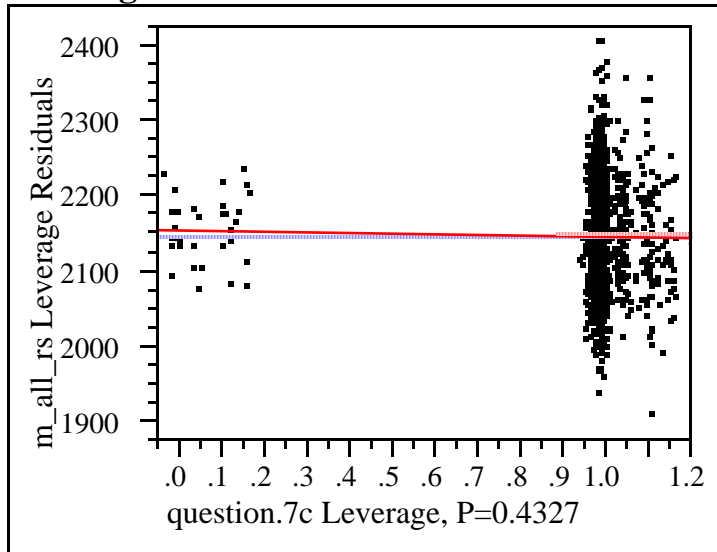
question.7a
Leverage Plot



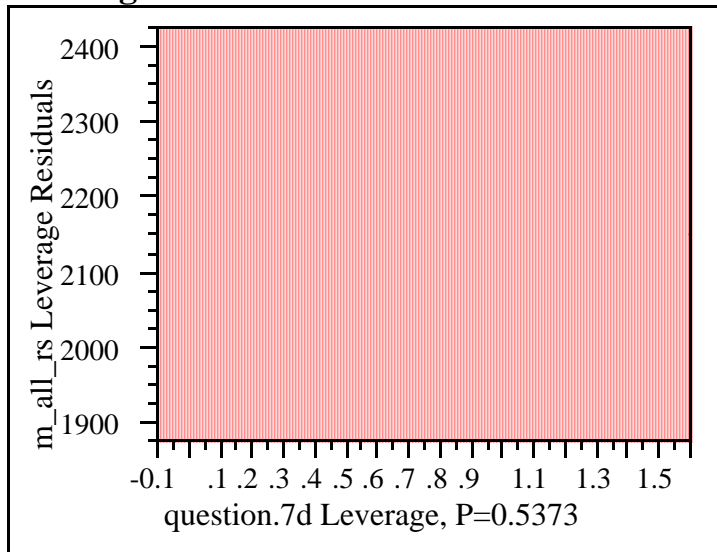
question.7b
Leverage Plot



question.7c
Leverage Plot



question.7d
Leverage Plot



Appendix D: Model 2 - Complex Interaction Model Analysis

Parameter Interpretation

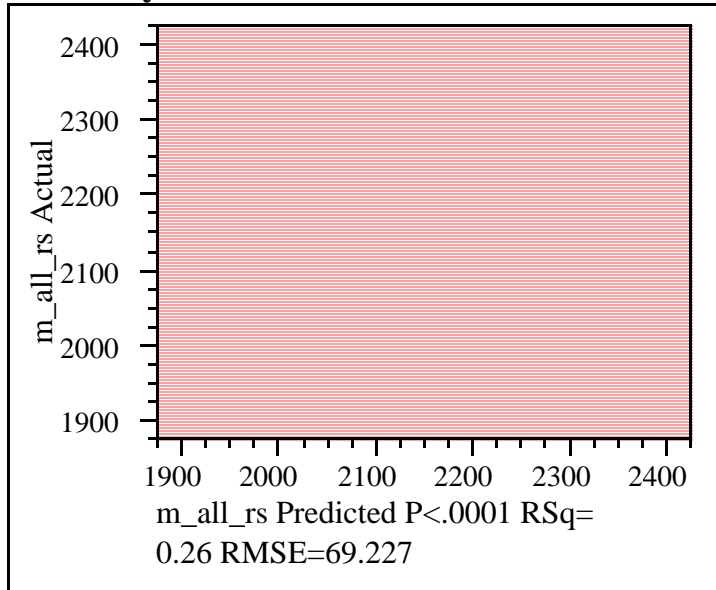
- The base group in this analysis was 9th grade Urban Schools (β_1). The autonomous average mathematics scale score for 9th grade urban schools was 2086.
- The 11th variable was statistically significant ($t = 11.00, p < .0001$). In other words, the 11th grade **urban math scale scores** were **72 points higher** than **urban 9th scores** ($\beta_1 + \beta_3$).
- The R variable (Rural Schools) was statistically significant ($t = 2.70, p < .0019$). That is, 9th grade **rural math scale scores** were **22 points higher** than **Urban scores** ($\beta_1 + \beta_4$).
- The S variable (Suburban schools) was statistically significant ($t = 9.64, p < .0001$). In other words, 9th grade **Suburban TAKS math scale scores** were **59 points higher** than **Urban scores** ($\beta_1 + \beta_5$).
- The variable q2a (Students required to provide their own calculator) was statistically significant ($t = 3.52, p < .0004$). That is, if 9th grade urban **students supplied their own calculator, math scale scores were 35 points higher**, holding all else constant.
- The variable q2c (School provides teacher with a classroom set of calculators) was statistically significant ($t = -2.53, p < .0113$). That is, if the teacher reported that their school only provided **a set of classroom calculators, then 9th grade urban student TAKS math scale scores were lower by 27 points**, holding all else constant.
- The variable q6a (Homework) was statistically significant ($t = 6.29, p < .0001$). That is, reported **use of a graphing calculator with Homework** assignments, relates to a **TAKS math scale scores were 31 points higher for 9th grade urban schools**, holding all else constant.
- The variable 10*r7a (Rural 10th grade students use graphing calculators for operations) was statistically significant ($t = -2.02, p < .0436$). If graphing calculators were used to **teach operations in Rural schools, 10th grade TAKS math scale scores were on average 66 points lower**, holding all else constant.
- The variable 10*s2c (Suburban School provides 10th grade teachers with a classroom set of calculators) was statistically significant ($t = 2.15, p < .0316$). That is, if the teacher reported that the school provided **teachers with a set of classroom calculators, then 10th grade suburban student TAKS math scale scores were 60 points higher**, holding all else constant.
- The variable 10*s7d (Suburban 10th grade students use graphing calculators for conceptual understanding) was statistically significant ($t = -3.70, p < .0002$). If graphing calculators are used to **teach conceptual understanding in suburban schools 10th grade TAKS math scale scores were 62 points lower on average**, holding all else constant.
- The variable 11*r7a (Rural 11th grade students use graphing calculators for operations) was statistically significant ($t = -2.13, p < .0330$). If graphing calculators are used to **teach operations in Rural math classes 11th grade TAKS math scale scores were 68 points lower on average**, holding all else constant.

Appendix E: Regression Analysis and Plots: Complex Interaction Model

Response m_all_rs

Whole Model

Actual by Predicted Plot



Summary of Fit

RSquare	0.263935
RSquare Adj	0.247023
Root Mean Square Error	69.22711
Mean of Response	2143.104
Observations (or Sum Wgts)	1960

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	44	3290802	74791.0	15.6062
Error	1915	9177433	4792.4	Prob > F
C. Total	1959	12468235		<.0001

Lack Of Fit

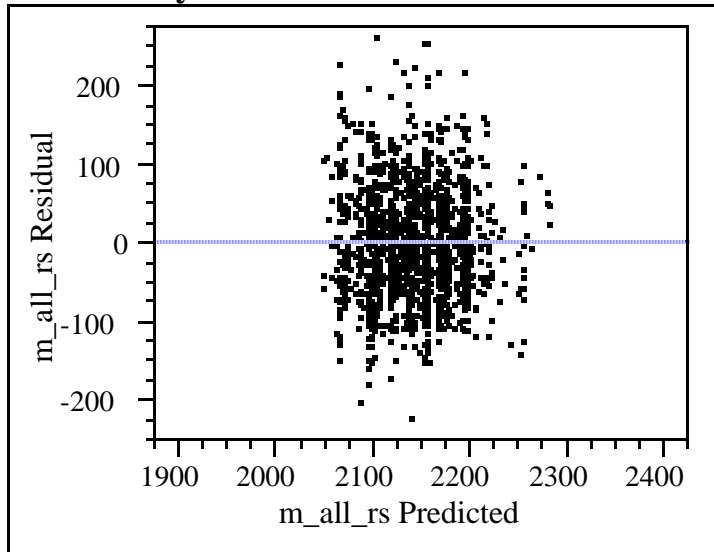
Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	587	2850341.0	4855.78	1.0192
Pure Error	1328	6327091.7	4764.38	Prob > F
Total Error	1915	9177432.7		0.3896
				Max RSq
				0.4925

Parameter Estimates

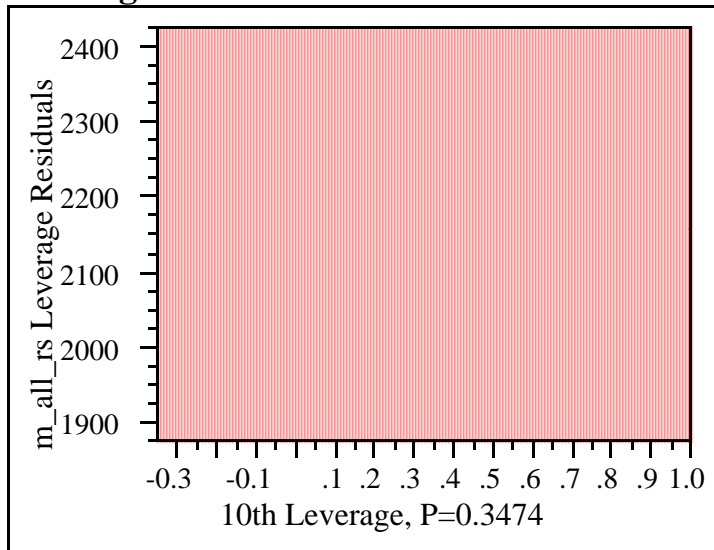
Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	2086.0692	18.66201	111.78	0.0000
10th	6.1844055	6.579817	0.94	0.3474

Term	Estimate	Std Error	t Ratio	Prob> t
11th	71.969538	6.545357	11.00	<.0001
R	21.908109	7.031146	3.12	0.0019
S	58.936828	6.115822	9.64	<.0001
question.2a	35.188986	9.994013	3.52	0.0004
question.2c	-27.32304	10.77908	-2.53	0.0113
question.4.num	0.322856	0.5308	0.61	0.5431
question.6a	30.613096	4.864574	6.29	<.0001
question.7a	16.645986	13.14719	1.27	0.2056
question.7b	-1.664562	8.049109	-0.21	0.8362
question.7c	-21.04945	14.16485	-1.49	0.1374
question.7d	13.010039	8.743803	1.49	0.1369
10*r2a	-60.18676	36.98018	-1.63	0.1038
10*r2c	16.111599	19.01548	0.85	0.3969
10*r4	2.7462247	1.709517	1.61	0.1083
10*r6a	7.8277142	15.61423	0.50	0.6162
10*r7a	-66.51226	32.94513	-2.02	0.0436
10*r7b	1.9868815	20.03356	0.10	0.9210
10*r7c	41.933672	34.08305	1.23	0.2187
10*r7d	-17.73726	22.79011	-0.78	0.4365
10*s2a	1.5189483	19.83472	0.08	0.9390
10*s2c	59.220699	27.5272	2.15	0.0316
10*s4	-1.380986	1.332671	-1.04	0.3002
10*s6a	4.0191418	13.1187	0.31	0.7594
10*s7a	6.8503149	23.68859	0.29	0.7725
10*s7b	-11.1912	16.10526	-0.69	0.4872
10*s7c	-9.453188	32.6338	-0.29	0.7721
10*s7d	-62.38275	16.8671	-3.70	0.0002
11*r2a	-27.9046	28.92465	-0.96	0.3348
11*r2c	-8.097036	20.98861	-0.39	0.6997
11*r4	-0.026915	1.49767	-0.02	0.9857
11*r6a	-0.340615	16.00706	-0.02	0.9830
11*r7a	-67.69802	31.72725	-2.13	0.0330
11*r7b	13.837819	21.66577	0.64	0.5231
11*r7c	57.875571	39.53233	1.46	0.1434
11*r7d	-10.459	26.62878	-0.39	0.6945
11*s2a	23.940823	17.69355	1.35	0.1762
11*s2c	42.017497	22.89025	1.84	0.0666
11*s4	-0.90253	1.264189	-0.71	0.4754
11*s6a	-26.59394	15.18443	-1.75	0.0800
11*s7a	-16.67073	25.05901	-0.67	0.5060
11*s7b	-23.99737	16.72196	-1.44	0.1514
11*s7c	31.62786	33.45817	0.95	0.3446
11*s7d	-31.84255	24.95719	-1.28	0.2022

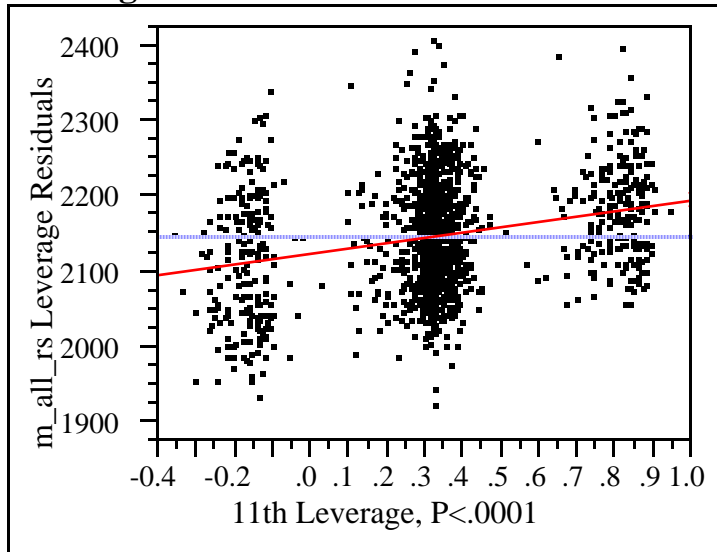
Residual by Predicted Plot



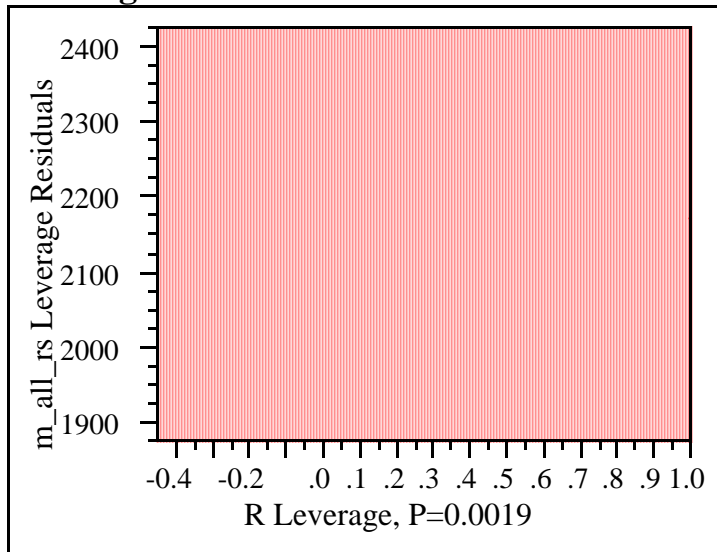
**10th
Leverage Plot**



11th Leverage Plot

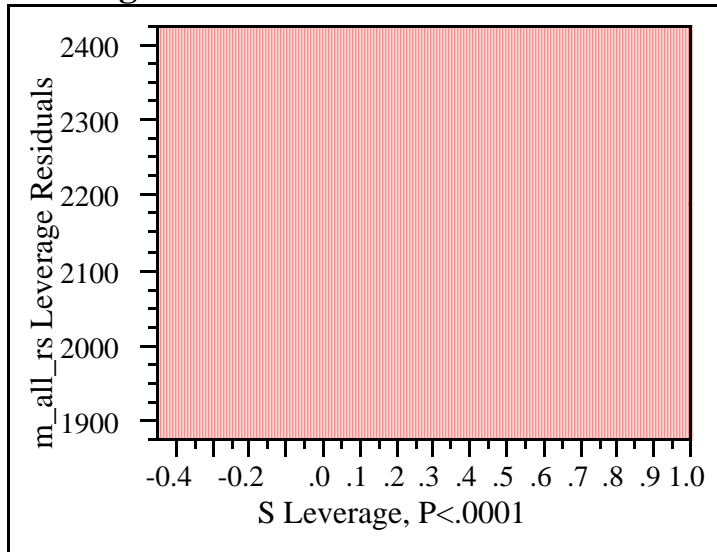


R Leverage Plot



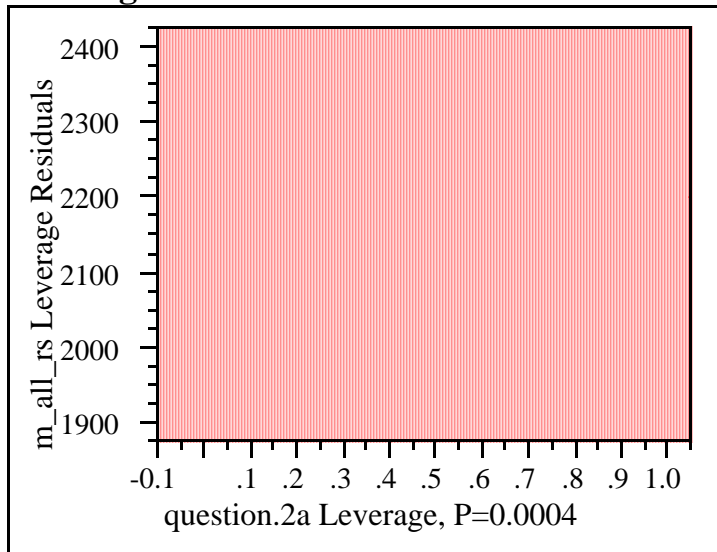
S

Leverage Plot

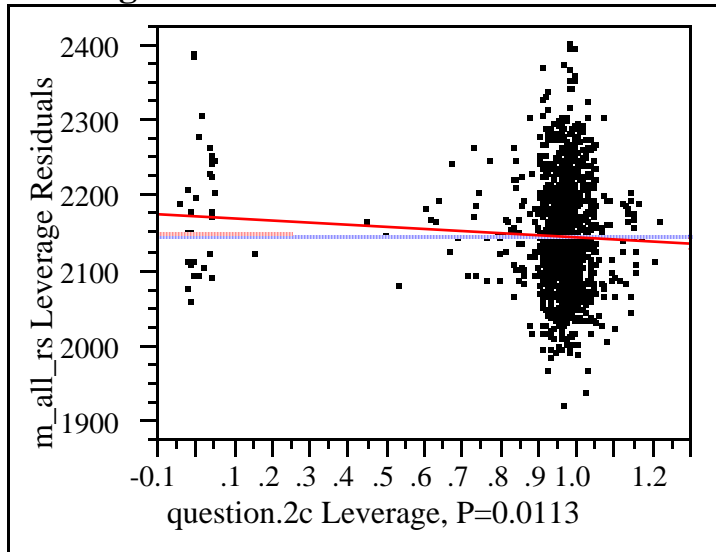


question.2a

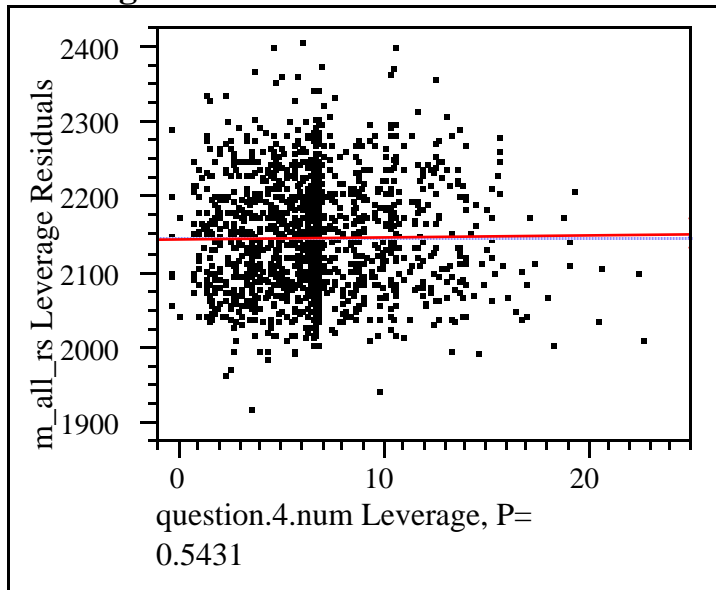
Leverage Plot



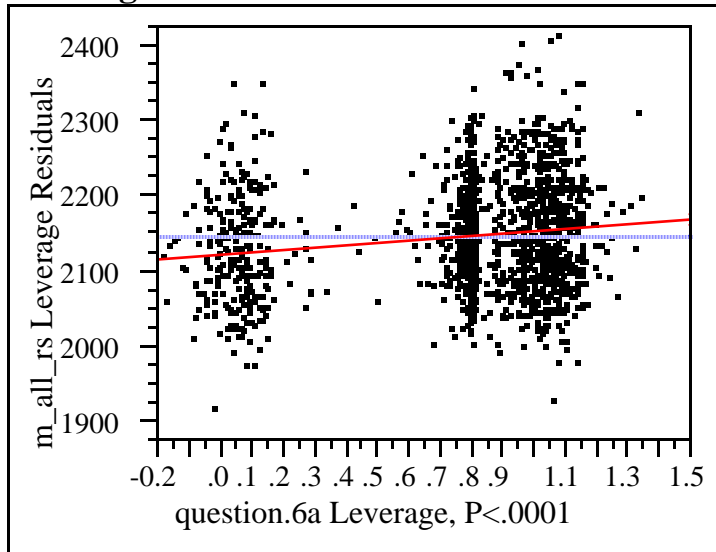
question.2c
Leverage Plot



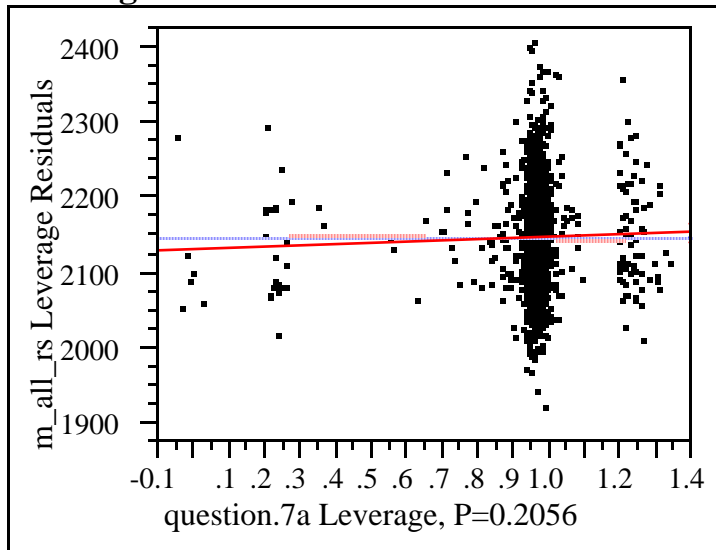
question.4.num
Leverage Plot



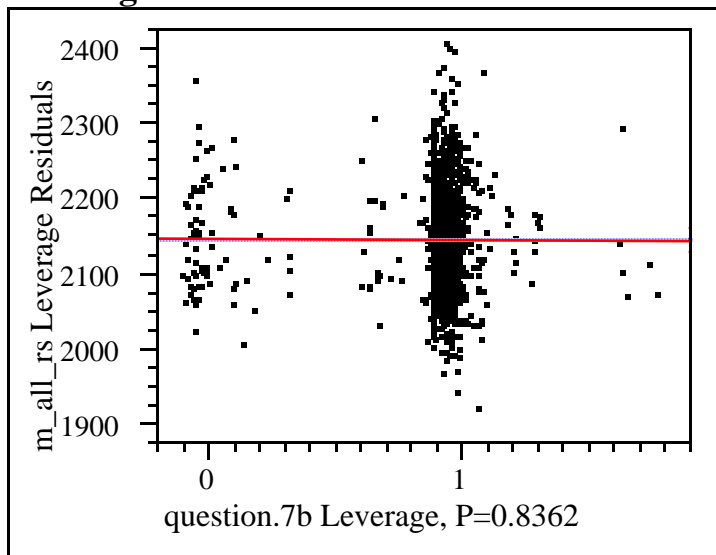
question.6a
Leverage Plot



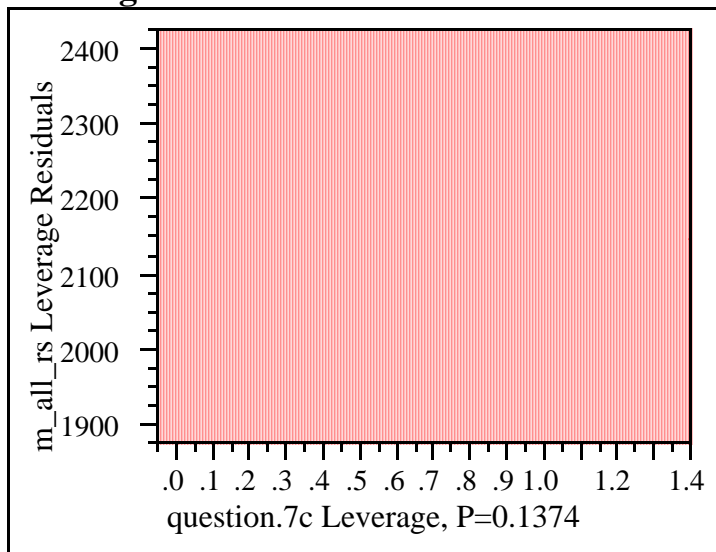
question.7a
Leverage Plot



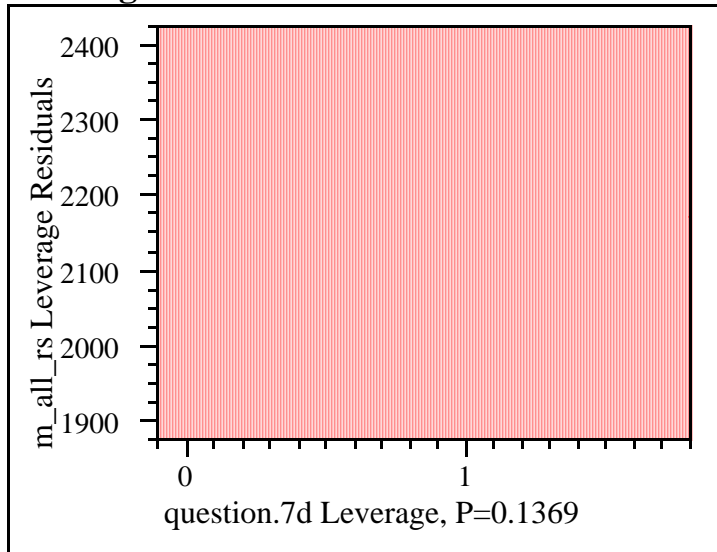
question.7b
Leverage Plot



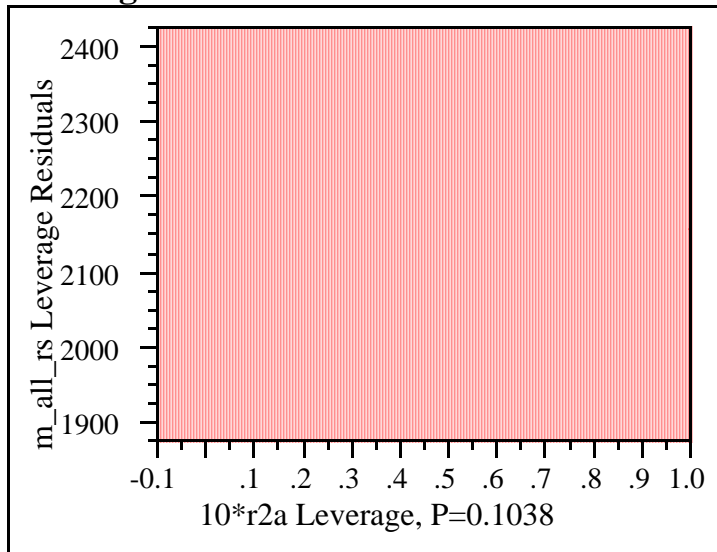
question.7c
Leverage Plot



question.7d
Leverage Plot

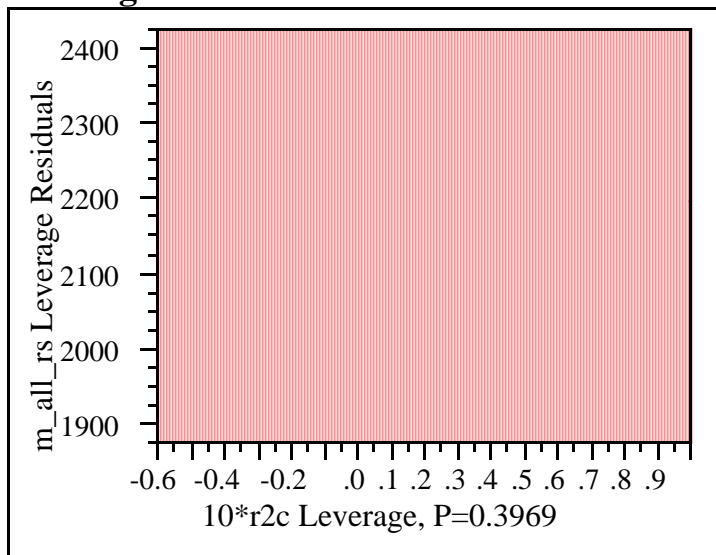


10*r2a
Leverage Plot



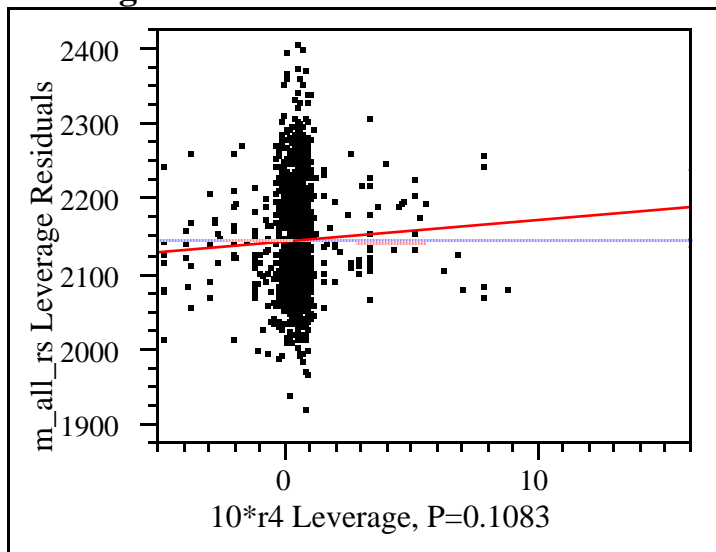
10*r2c

Leverage Plot



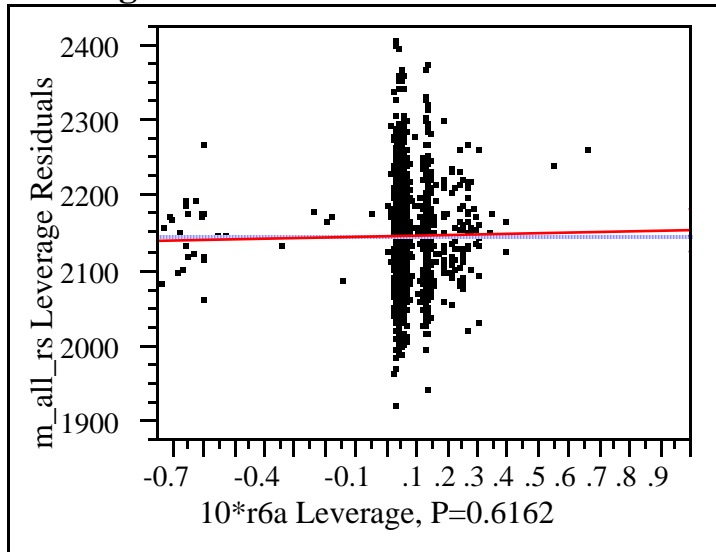
10*r4

Leverage Plot



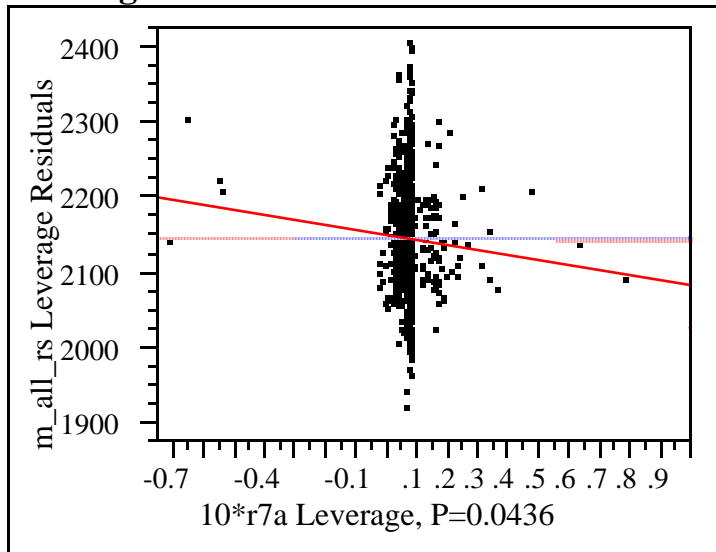
10*r6a

Leverage Plot



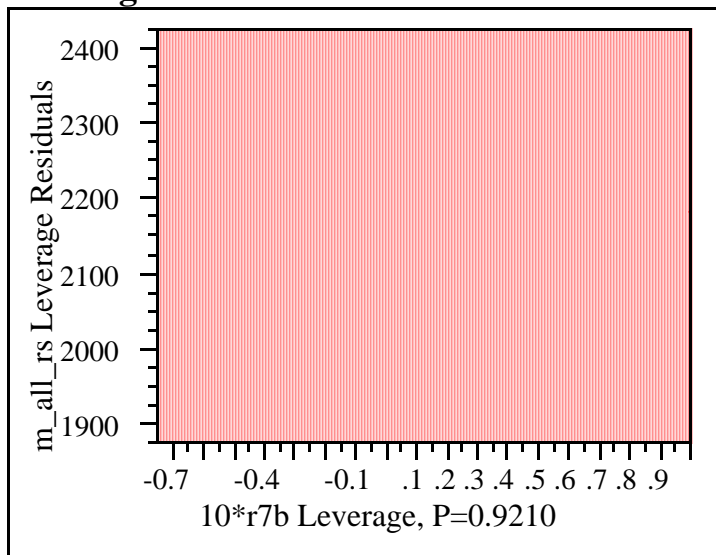
10*r7a

Leverage Plot



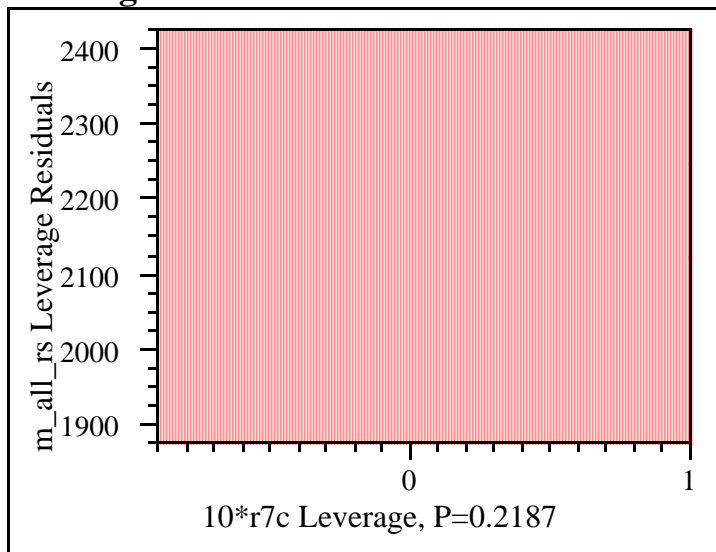
10*r7b

Leverage Plot



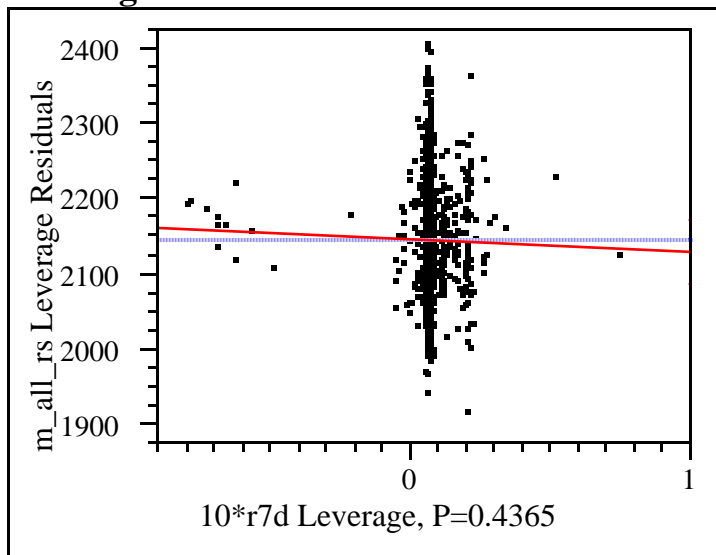
10*r7c

Leverage Plot



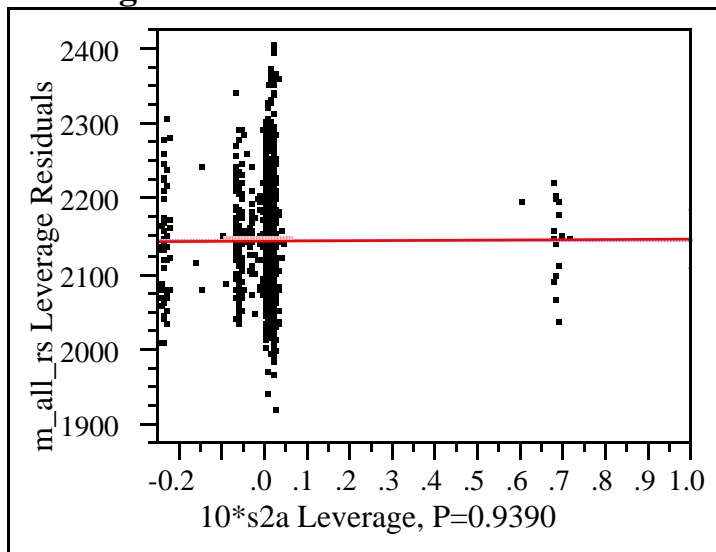
10*r7d

Leverage Plot



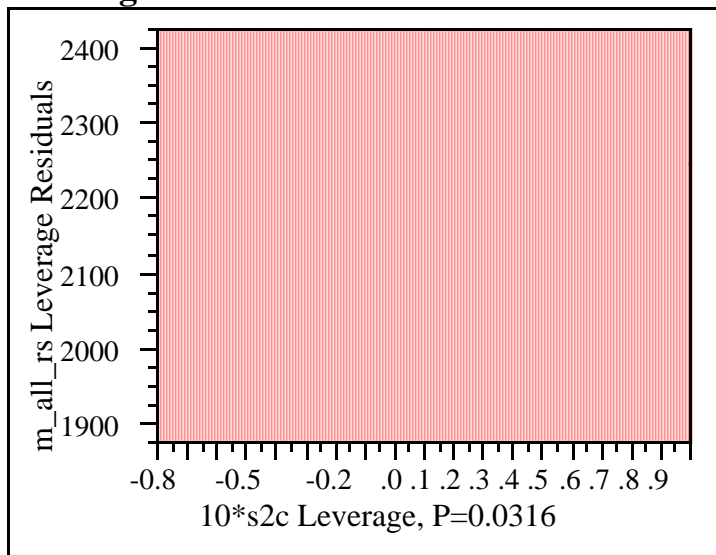
10*s2a

Leverage Plot



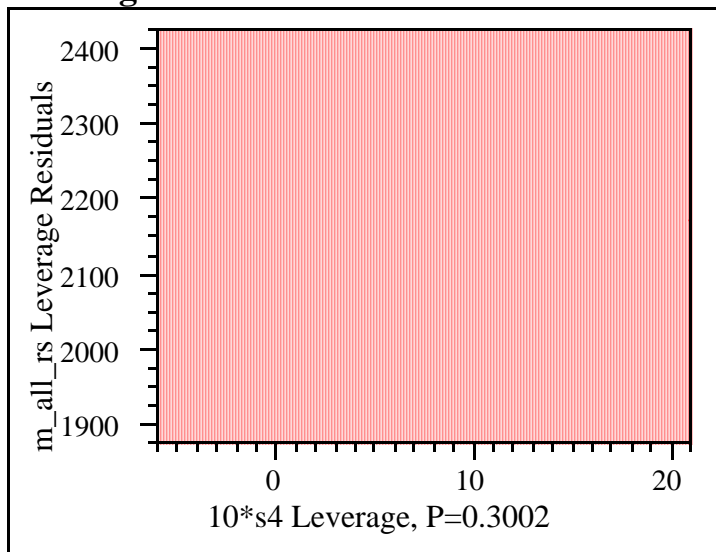
10*s2c

Leverage Plot



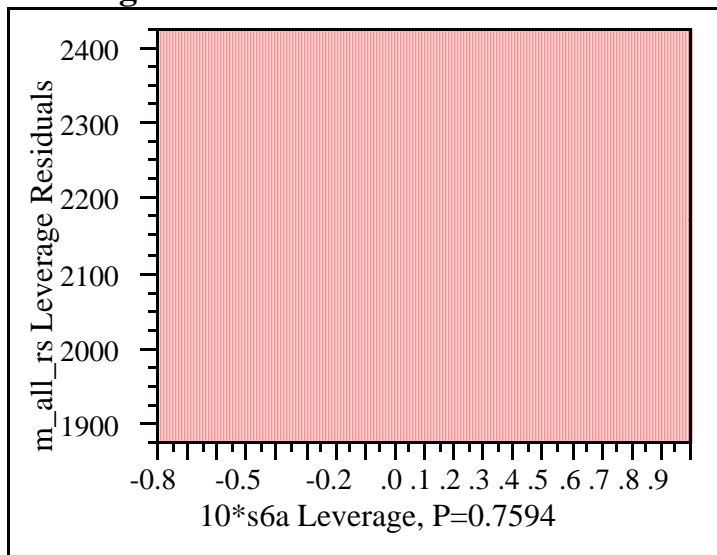
10*s4

Leverage Plot



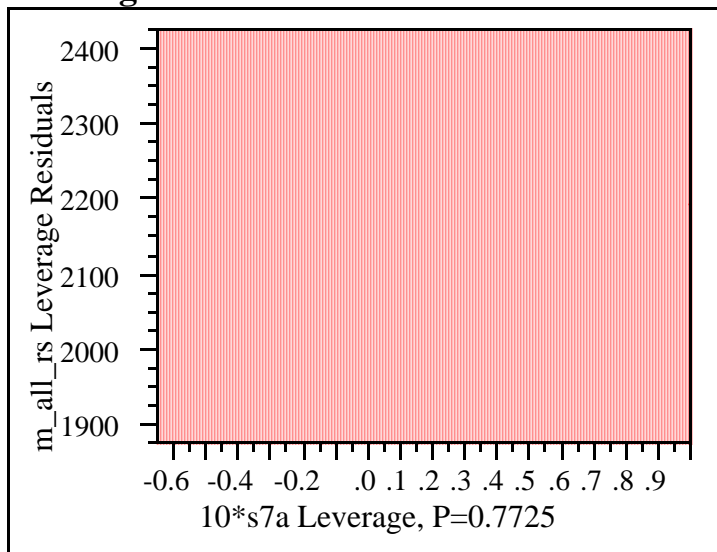
10*s6a

Leverage Plot



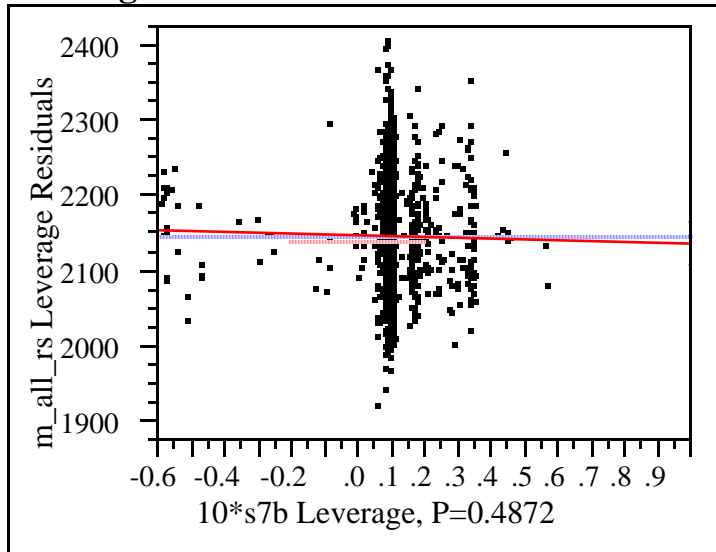
10*s7a

Leverage Plot



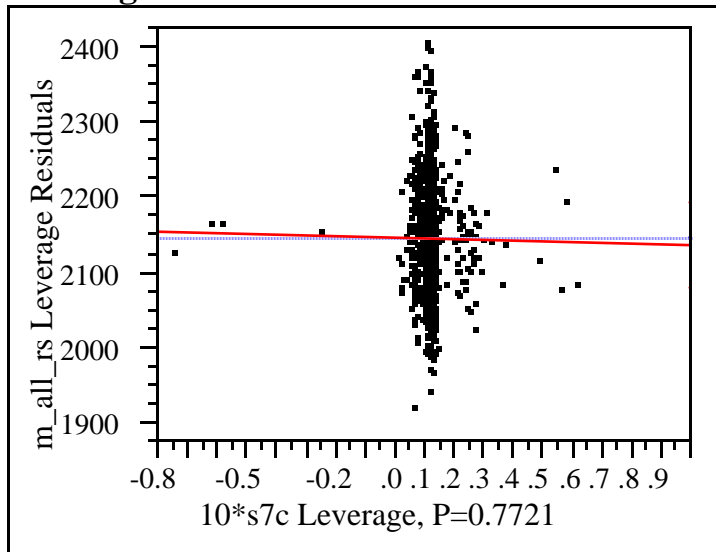
10*s7b

Leverage Plot



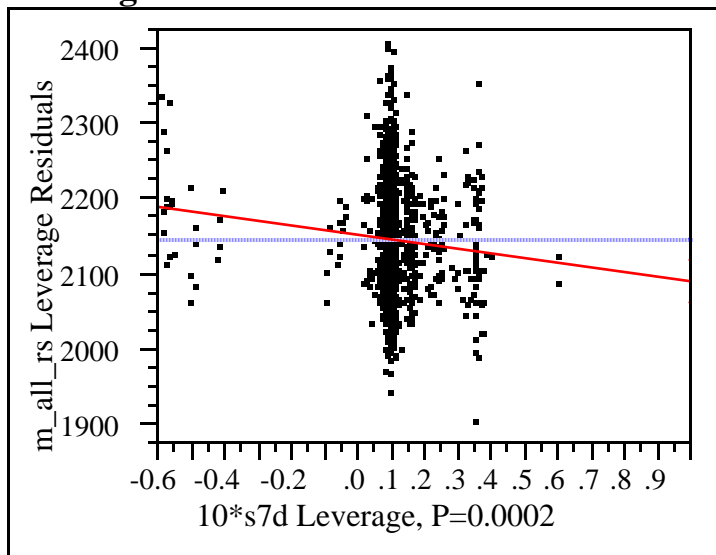
10*s7c

Leverage Plot



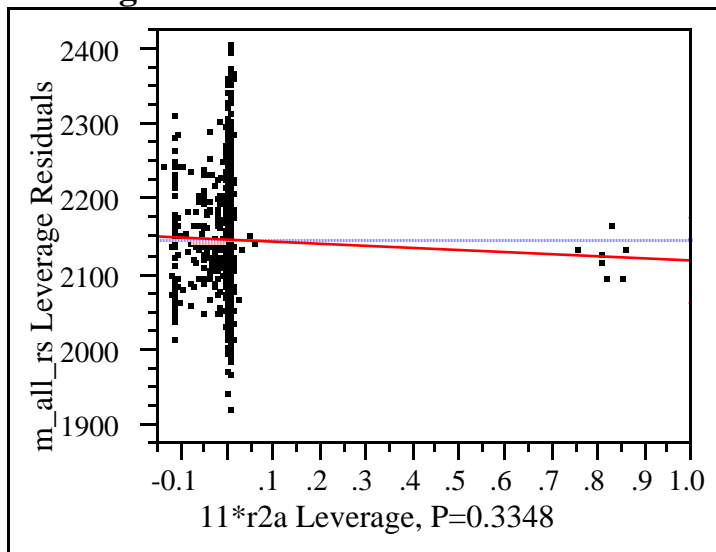
10*s7d

Leverage Plot



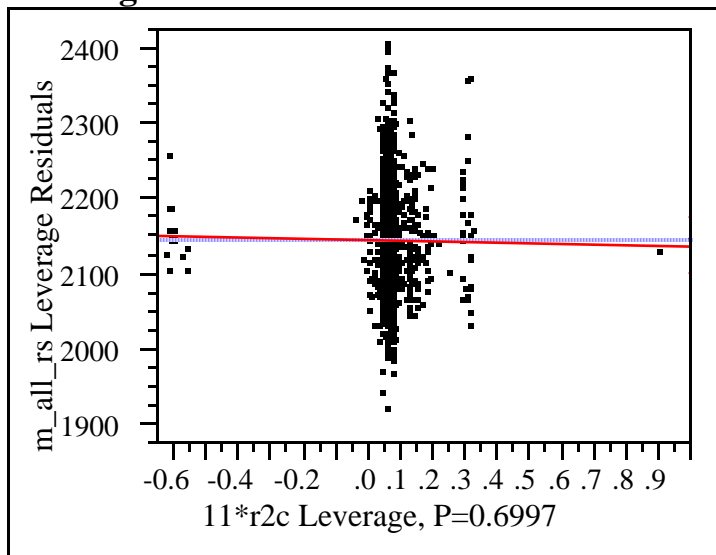
11*r2a

Leverage Plot



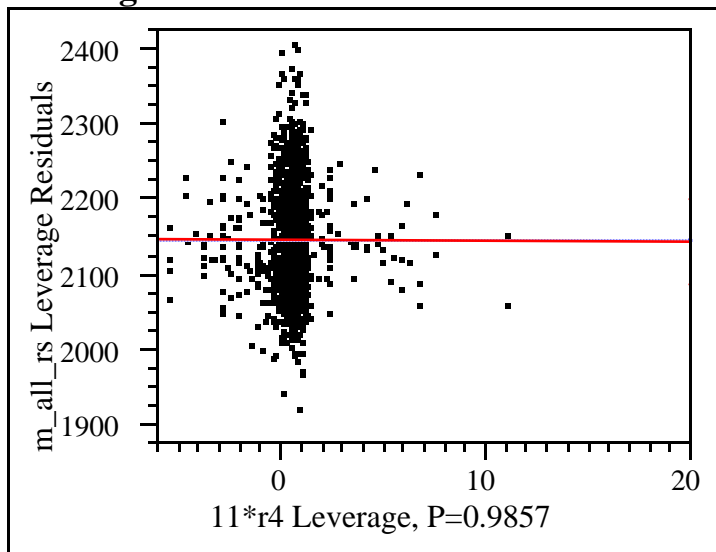
11*r2c

Leverage Plot



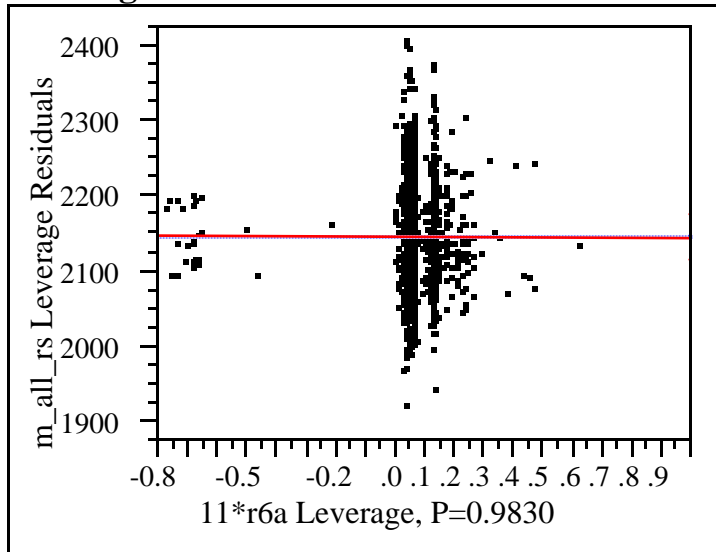
11*r4

Leverage Plot



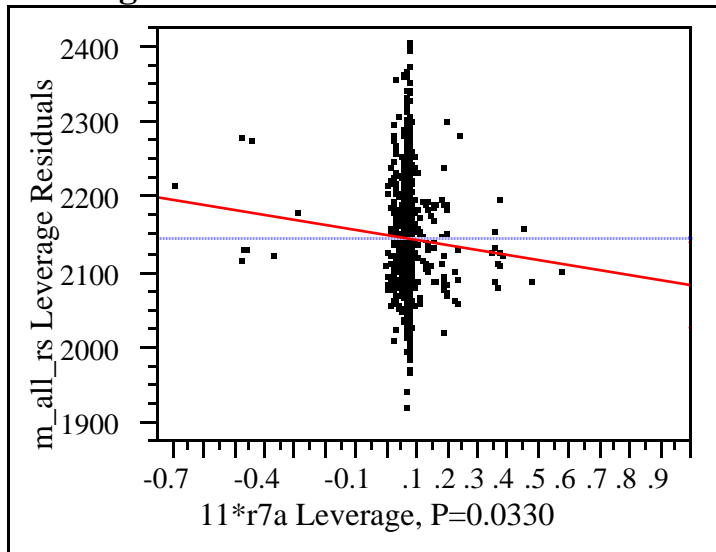
11*r6a

Leverage Plot



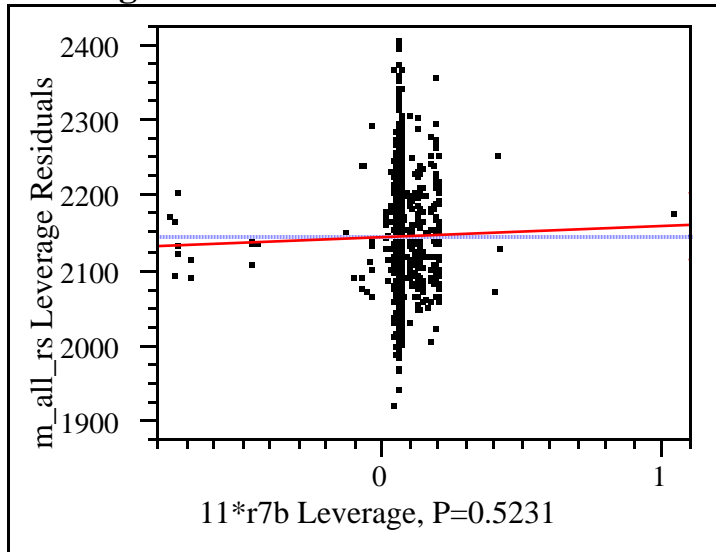
11*r7a

Leverage Plot



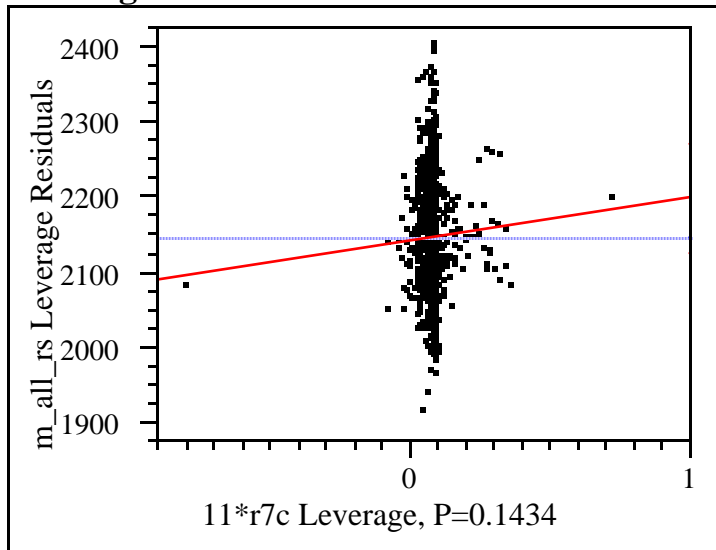
11*r7b

Leverage Plot



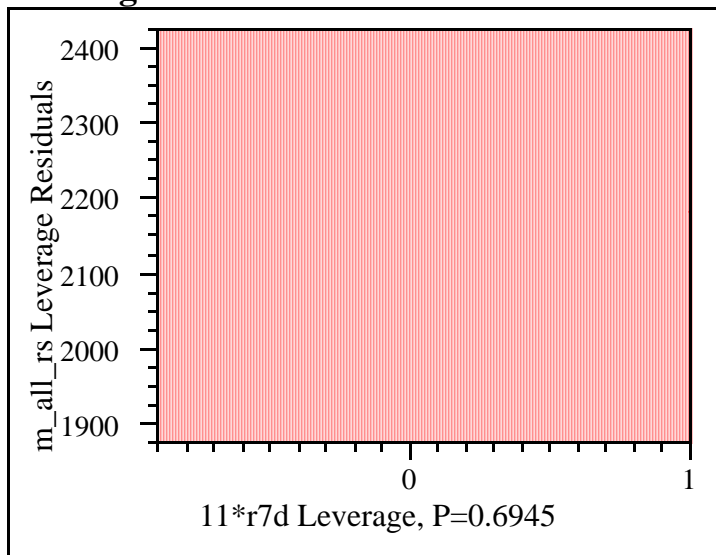
11*r7c

Leverage Plot



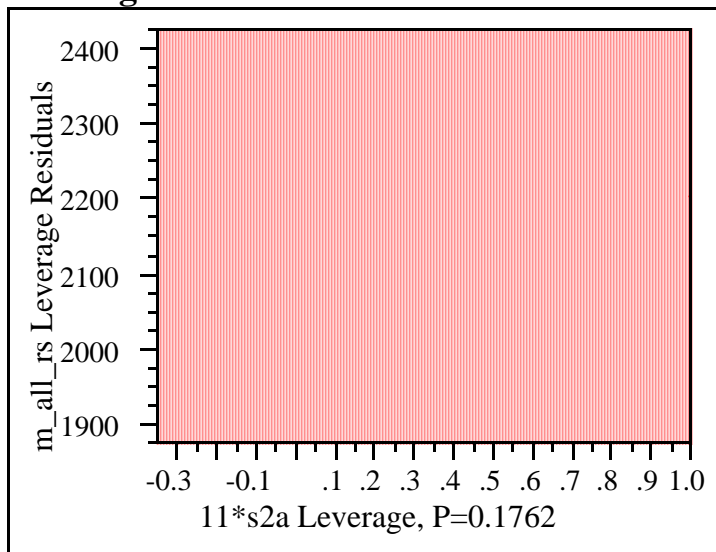
11*r7d

Leverage Plot



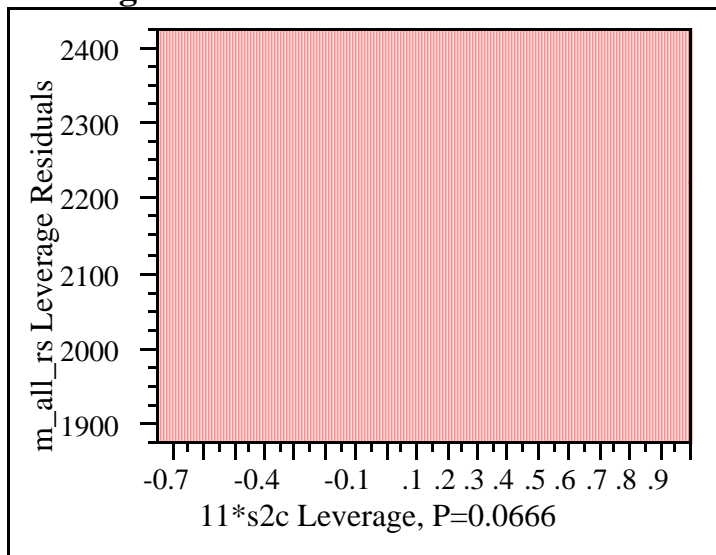
11*s2a

Leverage Plot



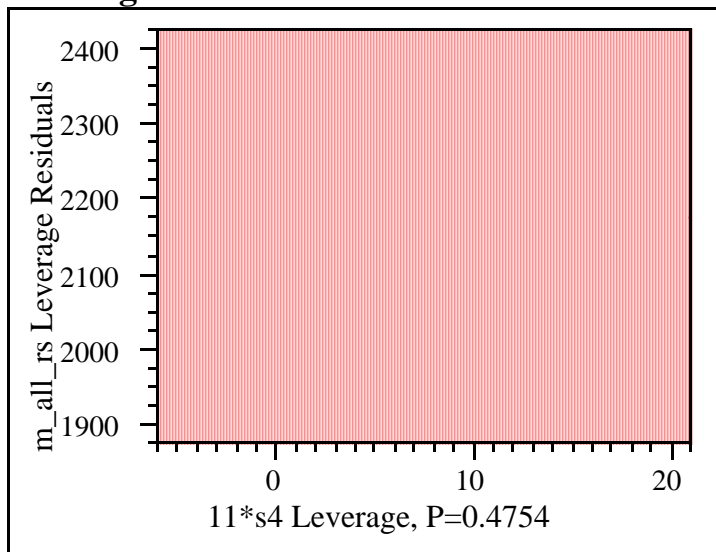
11*s2c

Leverage Plot



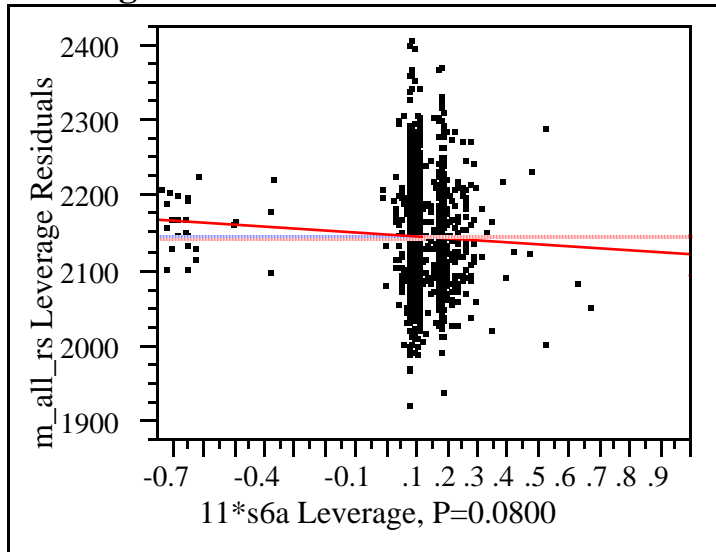
11*s4

Leverage Plot



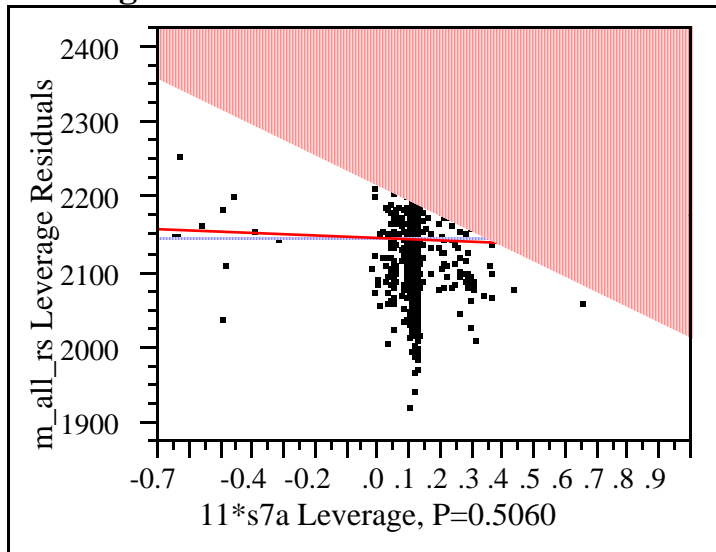
11*s6a

Leverage Plot



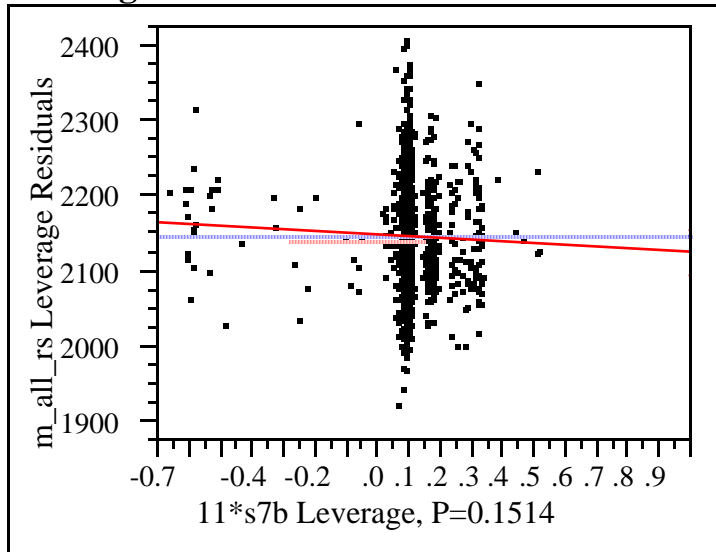
11*s7a

Leverage Plot



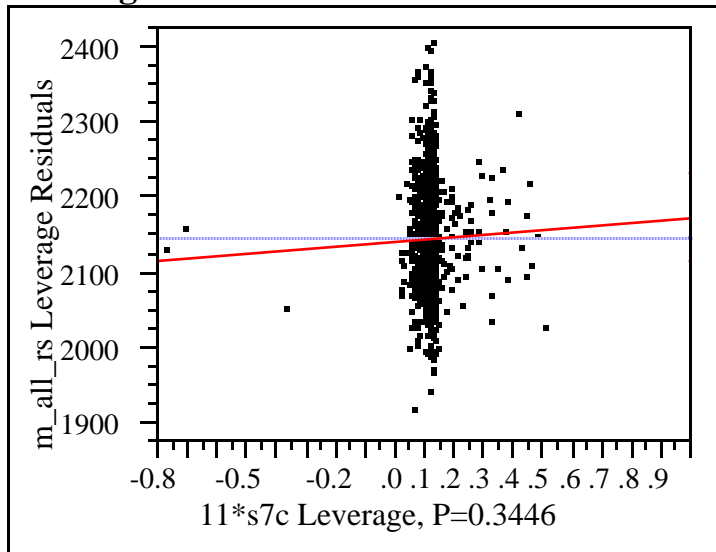
11*s7b

Leverage Plot



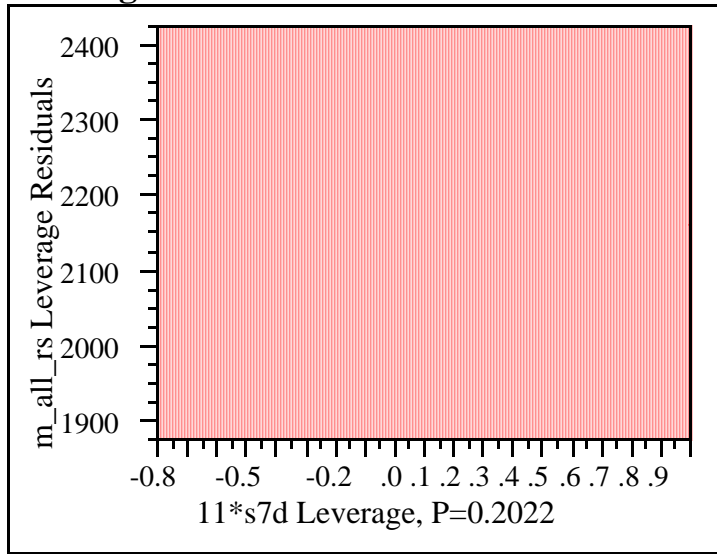
11*s7c

Leverage Plot



11*s7d

Leverage Plot



Appendix F: Model 3 - Complex Interaction Model Analysis Base Group Rural 9th grade Parameter Interpretation

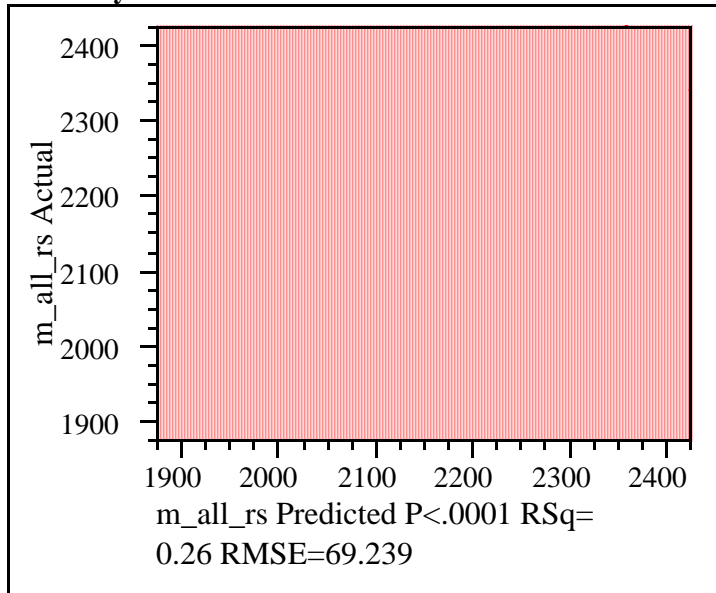
- The base group in this analysis was 9th grade Rural Schools (β_1). The autonomous average mathematics scale score for 9th grade urban schools was 2113.
- The 11th variable was statistically significant ($t = 7.36, p < .0001$). In other words, the 11th grade **urban math scale scores** were **56 points higher** than **urban 9th scores** ($\beta_1 + \beta_3$).
- The U variable (Urban Schools) was statistically significant ($t = -3.15, p < .0016$). That is, 9th grade **rural math scale scores** were **22 points lower** than **Rural scores** ($\beta_1 + \beta_4$).
- The S variable (Suburban schools) was statistically significant ($t = 5.76, p < .0001$). In other words, 9th grade **Suburban TAKS math scale scores** were **38 points higher** than **Rural scores** ($\beta_1 + \beta_5$).
- The variable q2a (Students required to provide their own calculator) was statistically significant ($t = 3.00, p < .0027$). That is, if 9th grade urban **students supplied their own calculator, math scale scores were 32 points higher**, holding all else constant.
- The variable q2c (School provides teacher with a classroom set of calculators) was statistically significant ($t = -3.03, p < .0025$). That is, if the teacher reported that their school provides **a set of classroom calculators, then 9th grade Rural student TAKS math scale scores were lower by 27 points**, holding all else constant.
- The variable q6a (Homework) was statistically significant ($t = 6.50, p < .0001$). That is, reported **use of a graphing calculator with Homework** assignments, relates to a **TAKS math scale scores were 34 points higher for 9th grade Rural schools**, holding all else constant.
- The variable 10*s2c (Suburban School provides 10th grade teachers with a classroom set of calculators) was statistically significant ($t = 2.11, p < .0353$). That is, if the teacher reported that the school provided **teachers with a set of classroom calculators, then 10th grade suburban student TAKS math scale scores were 60 points higher**, holding all else constant.
- The variable 10*s7d (Suburban 10th grade students use graphing calculators for conceptual understanding) was statistically significant ($t = -3.45, p < .0006$). If graphing calculators are used to **teach conceptual understanding in suburban schools 10th grade TAKS math scale scores were 59 points lower on average**, holding all else constant.
- The variable 11*s2c (Suburban School provides 11th grade teachers with a classroom set of calculators) was statistically significant ($t = 1.97, p < .0495$). That is, if the teacher reported that the school provided **teachers with a set of classroom calculators, then 11th grade suburban student TAKS math scale scores were 44 points higher**, holding all else constant.
- The variable 11*s6a (Suburban 11th grade students use graphing calculators for homework) was statistically significant ($t = -1.97, p < .0486$). That is, reported **use of a graphing calculator with Homework** assignments is inversely related to **TAKS math scale scores. Eleventh grade Suburban scores were 30 points lower if report homework use**, all else constant.

Appendix G: Model 3 -Regression Analysis and Plots: **Complex Interaction Model** **Base Group 9th Grade Rural**

Response m_all_rs

Whole Model

Actual by Predicted Plot



Summary of Fit

RSquare	0.263676
RSquare Adj	0.246758
Root Mean Square Error	69.23929
Mean of Response	2143.104
Observations (or Sum Wgts)	1960

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	44	3287573	74717.6	15.5854
Error	1915	9180661	4794.1	Prob > F
C. Total	1959	12468235		<.0001

Lack Of Fit

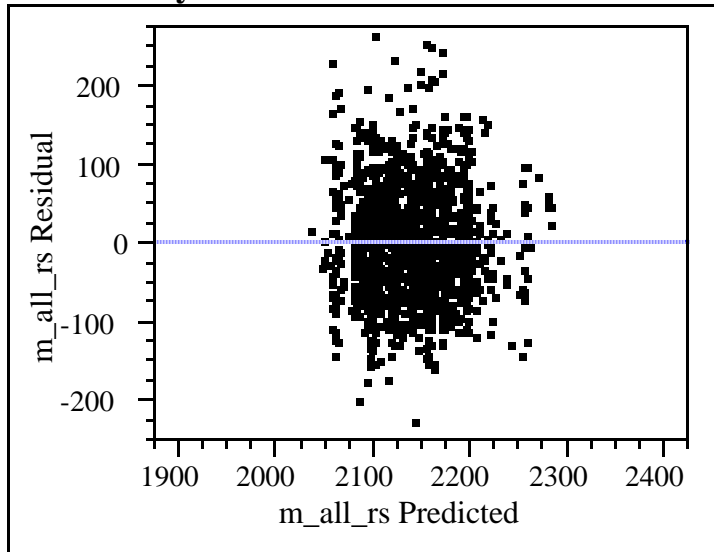
Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	587	2853569.7	4861.28	1.0203
Pure Error	1328	6327091.7	4764.38	Prob > F
Total Error	1915	9180661.4		0.3834
				Max RSq
				0.4925

Parameter Estimates

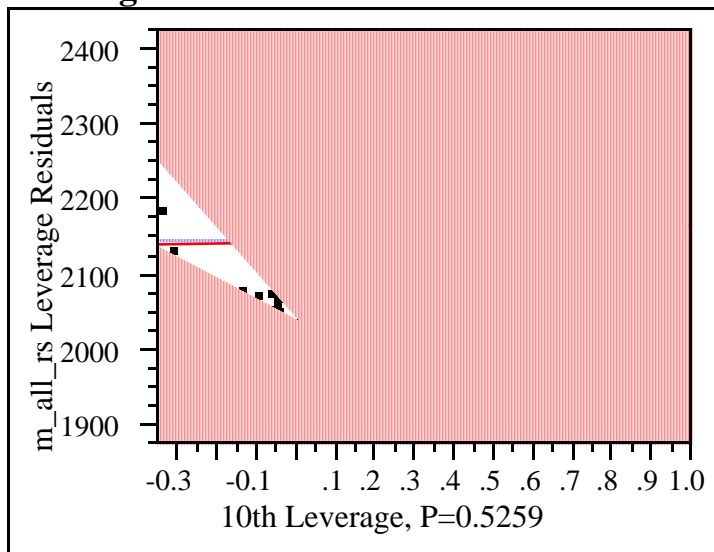
Term	Estimate	Std Error	t Ratio	Prob> t
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Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	2113.6975	19.03578	111.04	0.0000
10th	6.4781861	10.2121	0.63	0.5259
11 th ***	55.539479	7.542841	7.36	<.0001
U*	-22.02227	6.986267	-3.15	0.0016
S***	38.00529	6.601759	5.76	<.0001
question.2a*	32.284357	10.74806	3.00	0.0027
question.2c*	-27.65817	9.130815	-3.03	0.0025
question.4.num	0.7765512	0.637684	1.22	0.2235
question.6a***	34.786642	5.354508	6.50	<.0001
question.7a	-14.24092	13.5195	-1.05	0.2923
question.7b	-2.826316	8.063712	-0.35	0.7260
question.7c	2.6713351	15.39522	0.17	0.8623
question.7d	9.3210472	9.226194	1.01	0.3125
10*u2a	-12.92661	23.36495	-0.55	0.5802
10*u2c	-16.95888	27.98517	-0.61	0.5446
10*u4	-0.235528	1.09951	-0.21	0.8304
10u6a	-16.00055	11.98311	-1.34	0.1820
10u7a	49.101817	33.59793	1.46	0.1441
10u7b	21.484478	20.8368	1.03	0.3026
10u7c	-41.2687	33.23633	-1.24	0.2145
10u7d	2.5350885	20.66045	0.12	0.9024
10*s2a	4.4784652	20.22795	0.22	0.8248
10*s2c*	57.484288	27.29184	2.11	0.0353
10*s4	-1.628397	1.512584	-1.08	0.2818
10*s6a	-0.316468	13.31188	-0.02	0.9810
10*s7a	36.431137	23.94005	1.52	0.1282
10*s7b	-10.21567	16.12198	-0.63	0.5264
10*s7c	-36.14572	32.97862	-1.10	0.2732
10*s7d**	-58.97664	17.10568	-3.45	0.0006
11*u2a	-15.42368	30.89582	-0.50	0.6177
11*u2c	28.611487	20.09198	1.42	0.1546
11*U4	-0.604885	1.269344	-0.48	0.6337
11*U6a	-5.561178	12.44961	-0.45	0.6551
11*U7a	48.482851	28.92266	1.68	0.0938
11*u7b	-4.124363	21.20891	-0.19	0.8458
11*u7c	-44.38346	30.99296	-1.43	0.1523
11*u7d	-1.403288	23.5805	-0.06	0.9526
11*s2a	26.902084	18.13068	1.48	0.1380
11*s2c*	43.971348	22.3744	1.97	0.0495
11*s4	-1.321436	1.310818	-1.01	0.3135
11*s6a*	-30.31492	15.35993	-1.97	0.0486
11*s7a	15.815464	25.28204	0.63	0.5317
11*s7b	-23.09065	16.72583	-1.38	0.1676
11*s7c	12.852589	33.73636	0.38	0.7033
11*s7d	-26.85628	25.09904	-1.07	0.2847

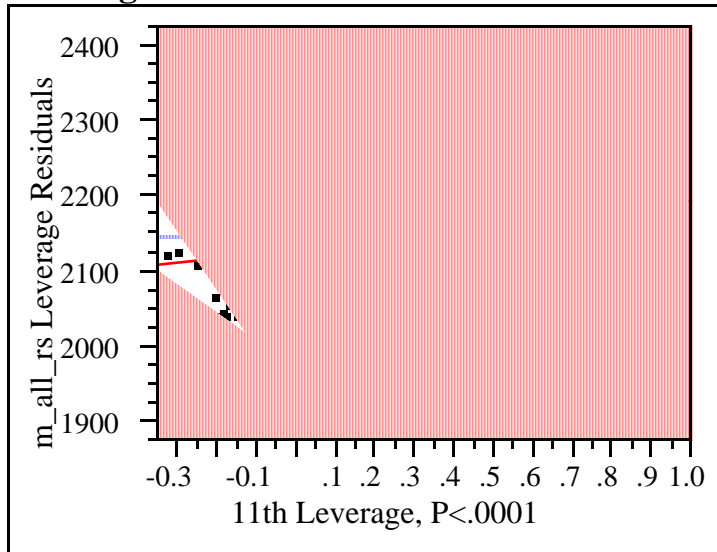
Residual by Predicted Plot



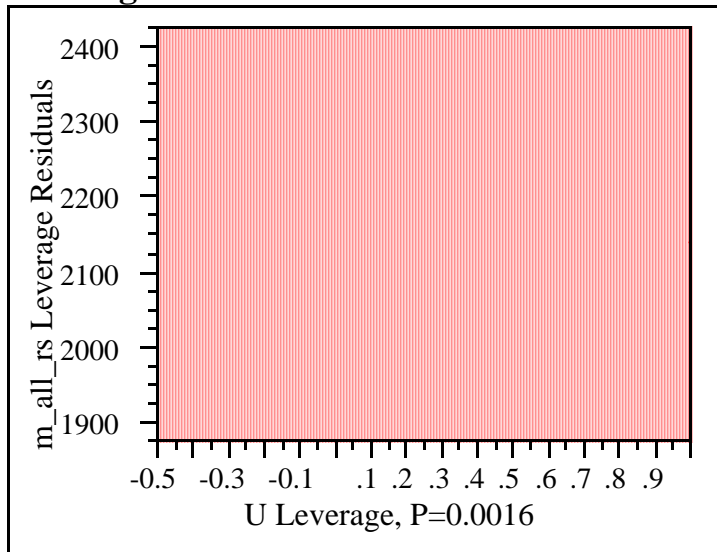
**10th
Leverage Plot**



11th Leverage Plot

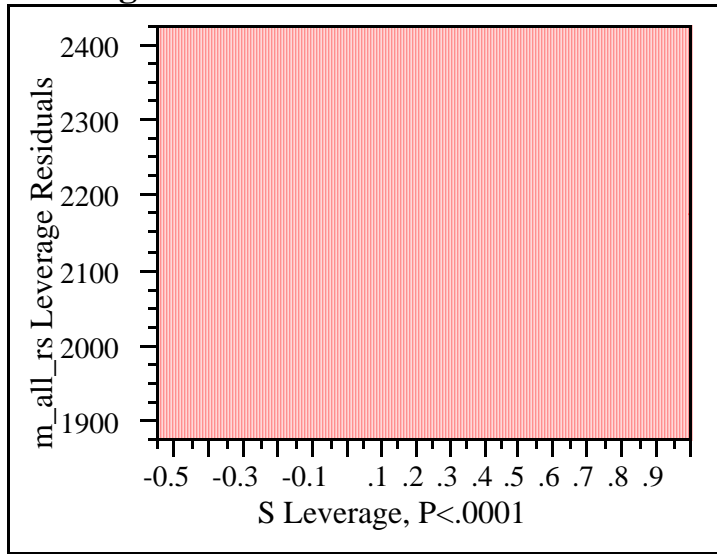


U Leverage Plot



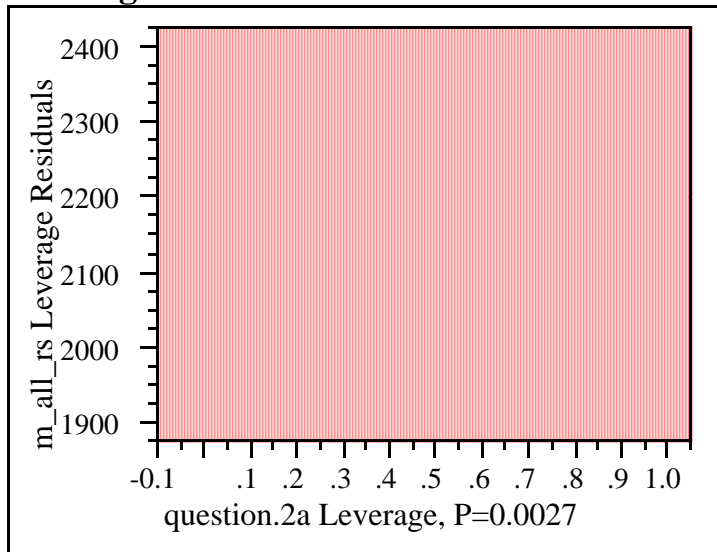
S

Leverage Plot

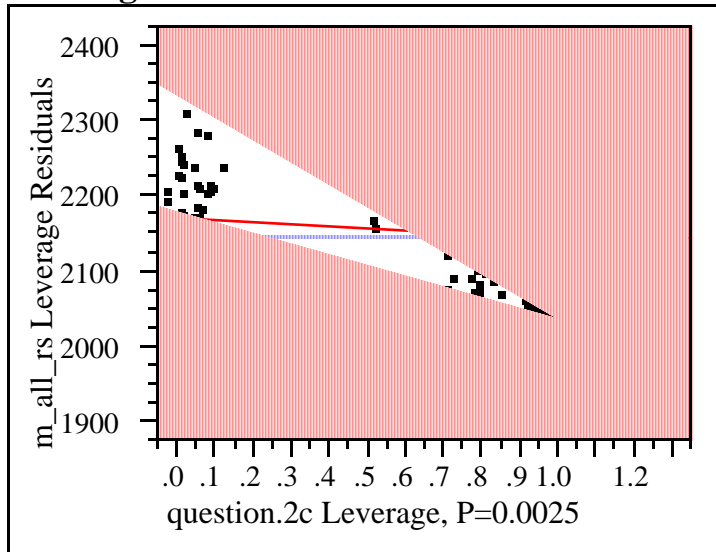


question.2a

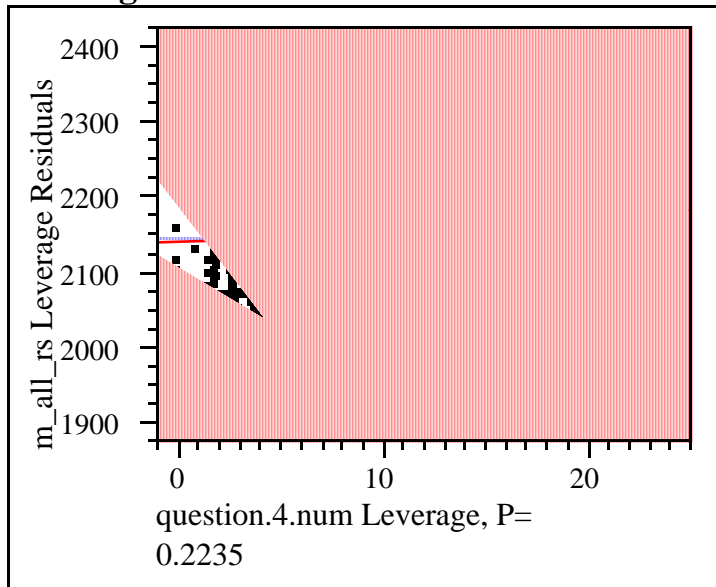
Leverage Plot



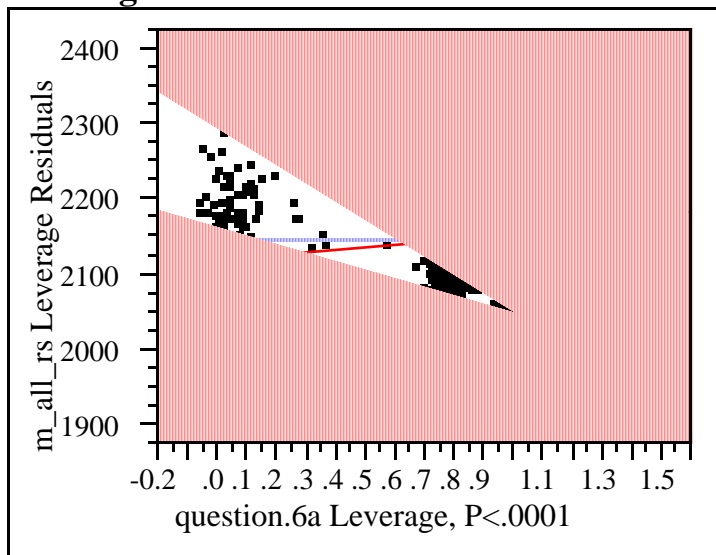
question.2c
Leverage Plot



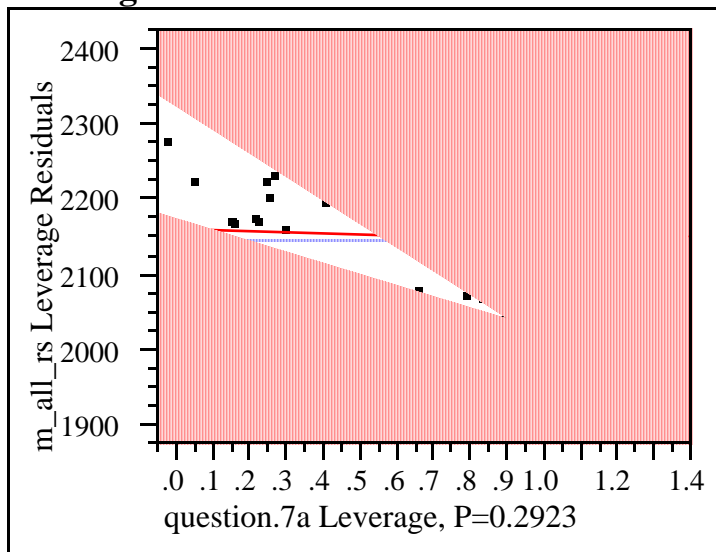
question.4.num
Leverage Plot



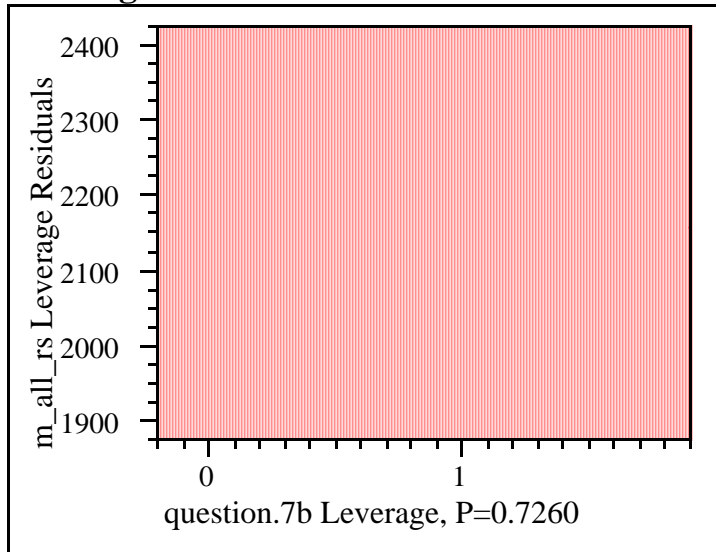
question.6a
Leverage Plot



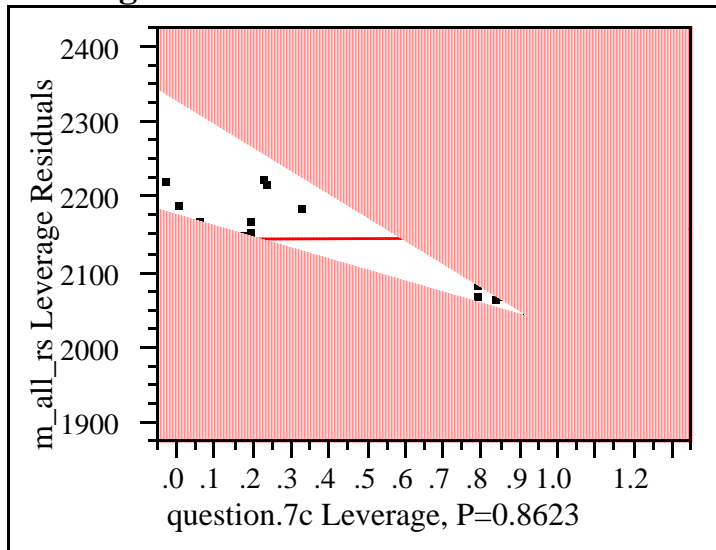
question.7a
Leverage Plot



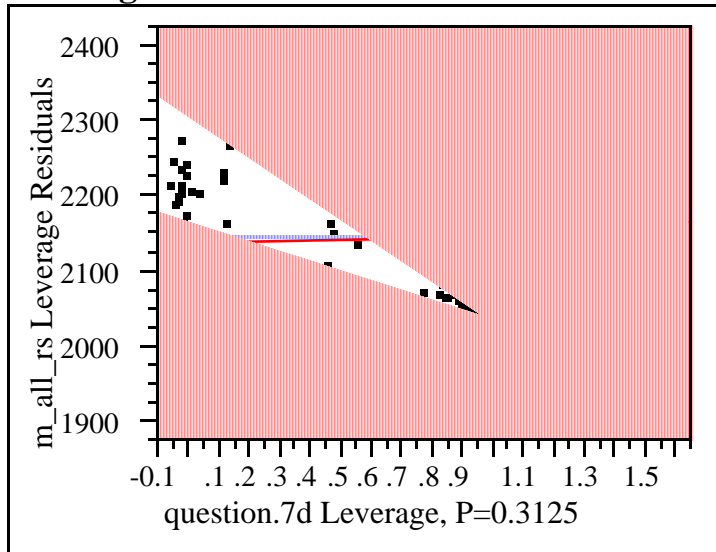
question.7b
Leverage Plot



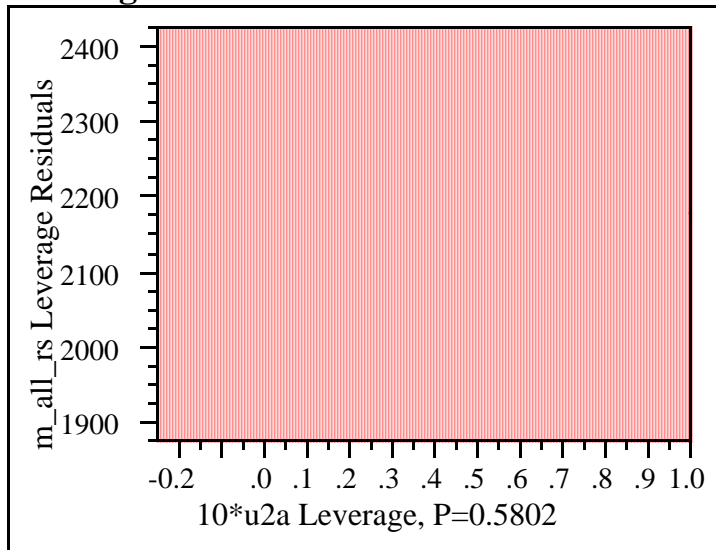
question.7c
Leverage Plot



question.7d
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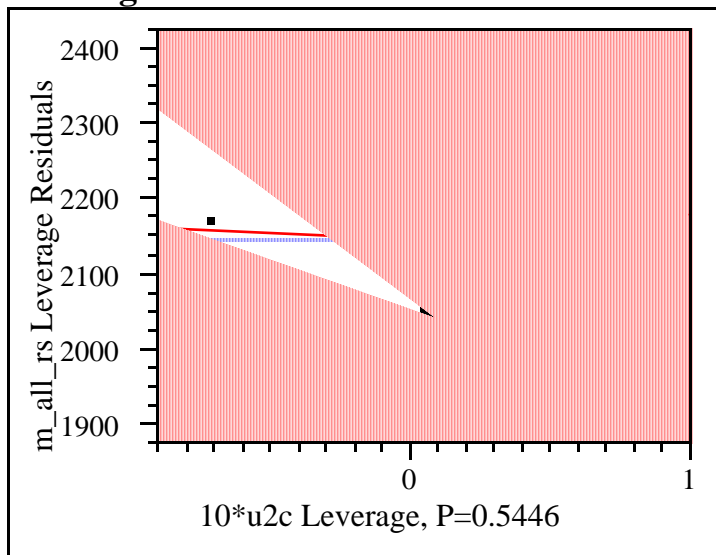


10*u2a
Leverage Plot



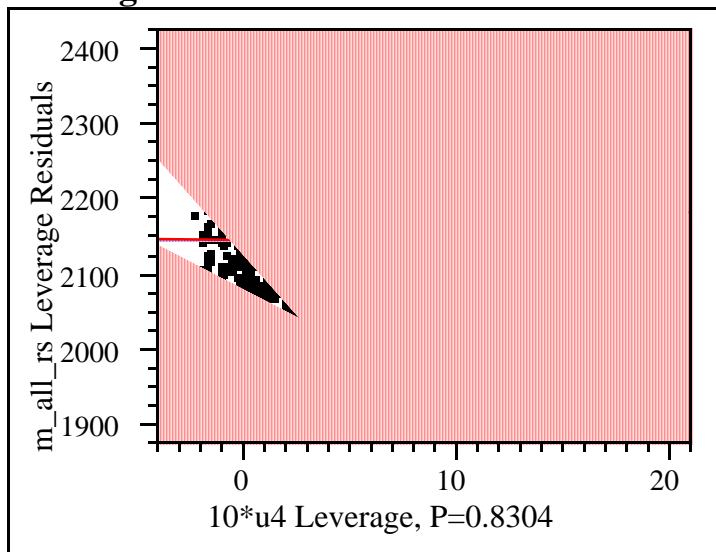
10*u2c

Leverage Plot



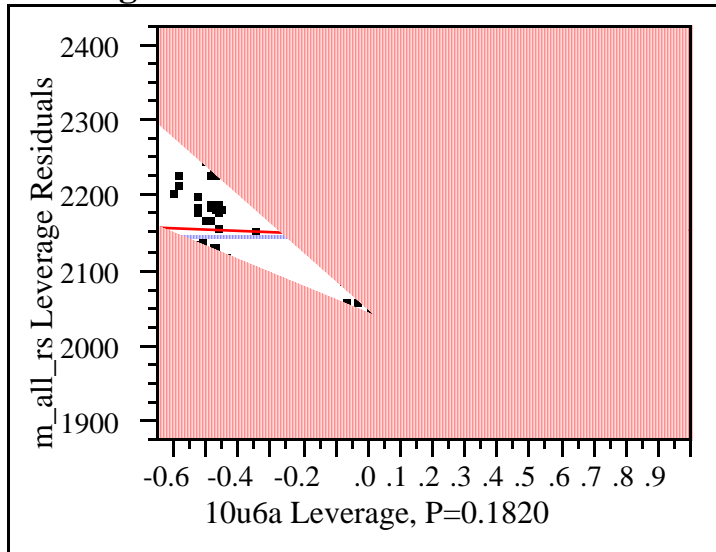
10*u4

Leverage Plot



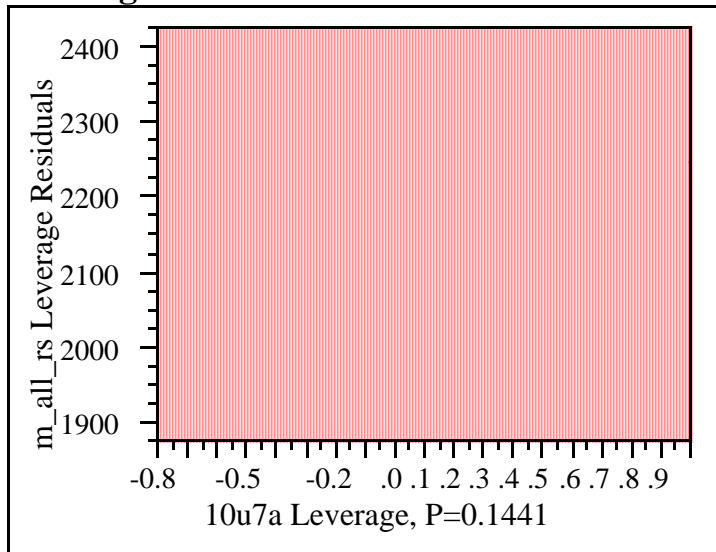
10u6a

Leverage Plot



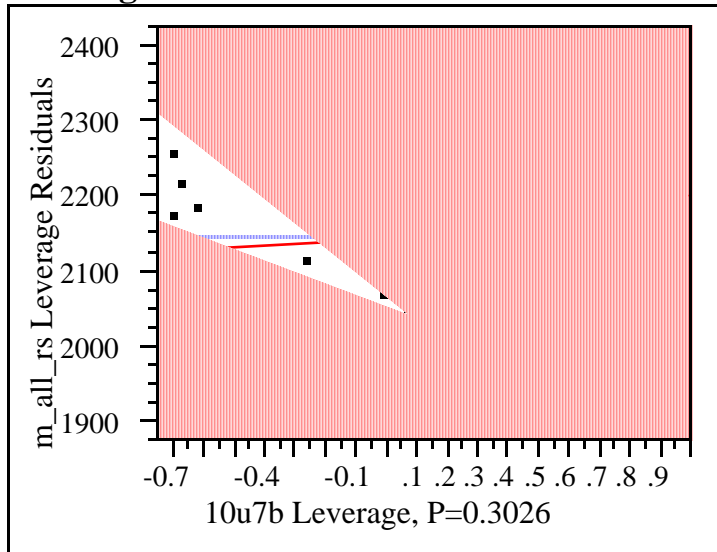
10u7a

Leverage Plot



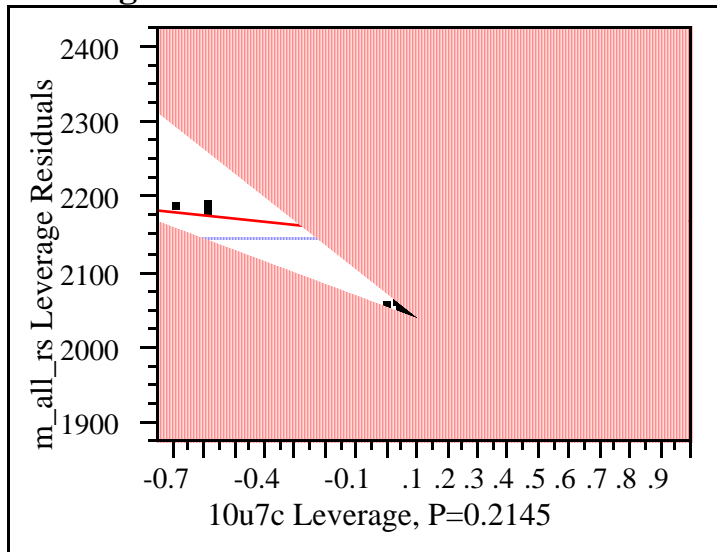
10u7b

Leverage Plot



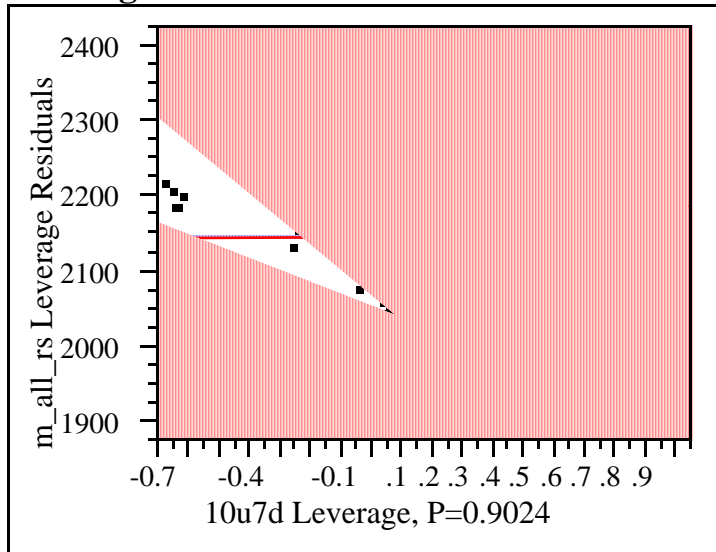
10u7c

Leverage Plot



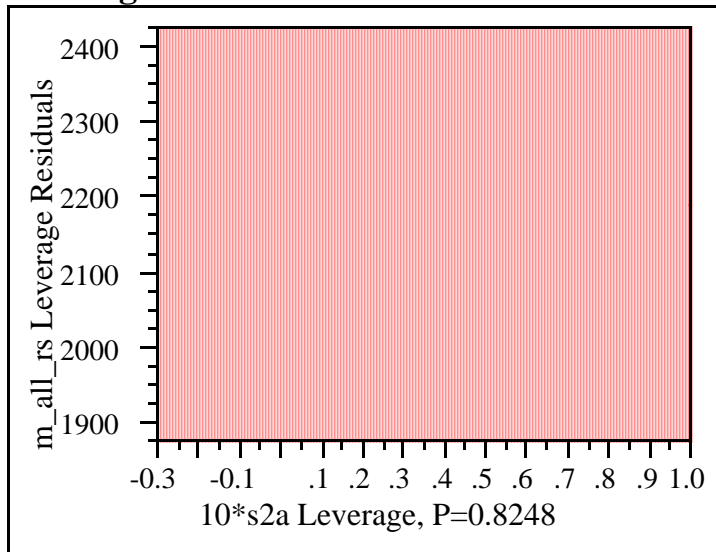
10u7d

Leverage Plot



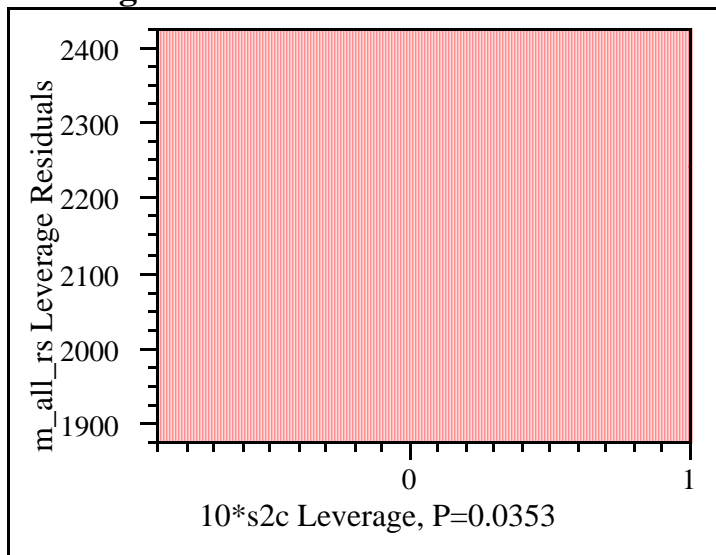
10*s2a

Leverage Plot



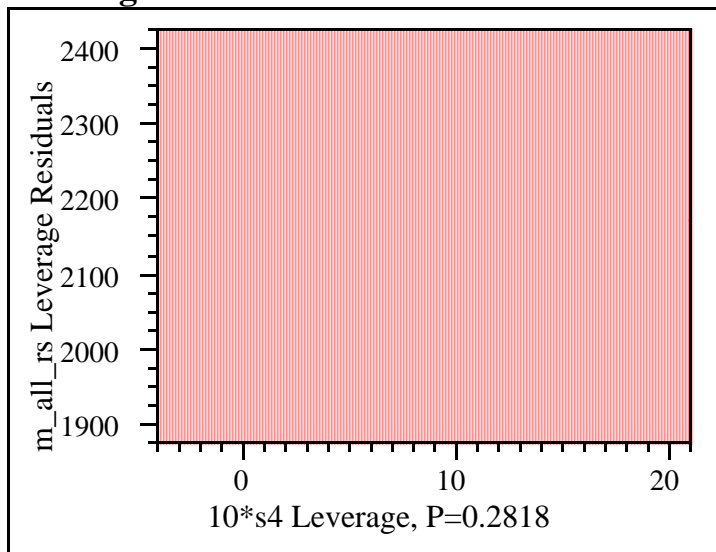
10*s2c

Leverage Plot



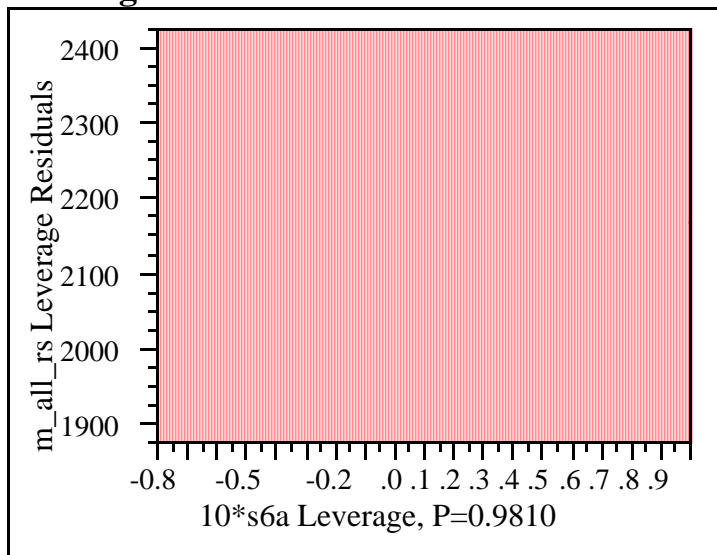
10*s4

Leverage Plot



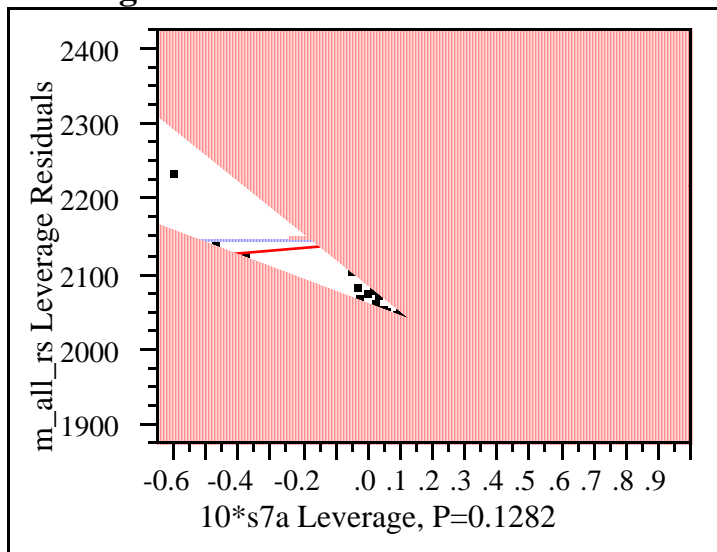
10*s6a

Leverage Plot



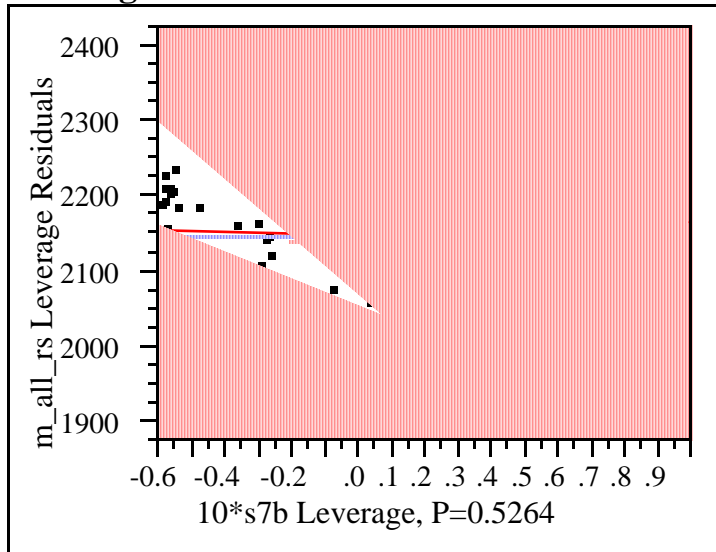
10*s7a

Leverage Plot



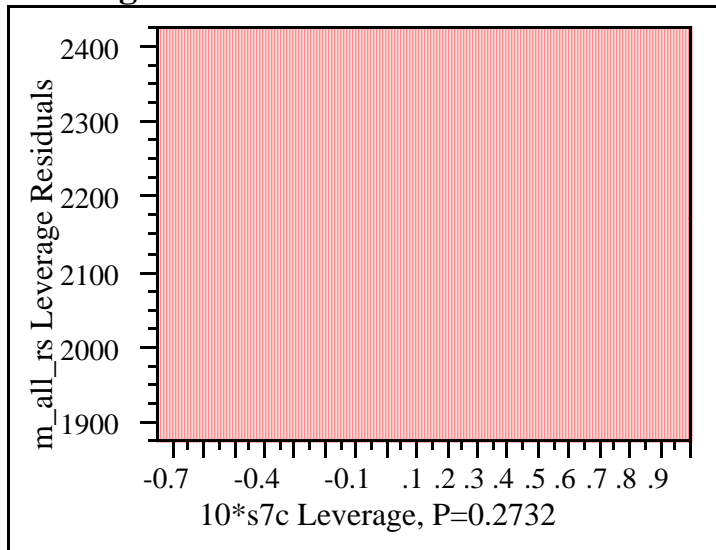
10*s7b

Leverage Plot



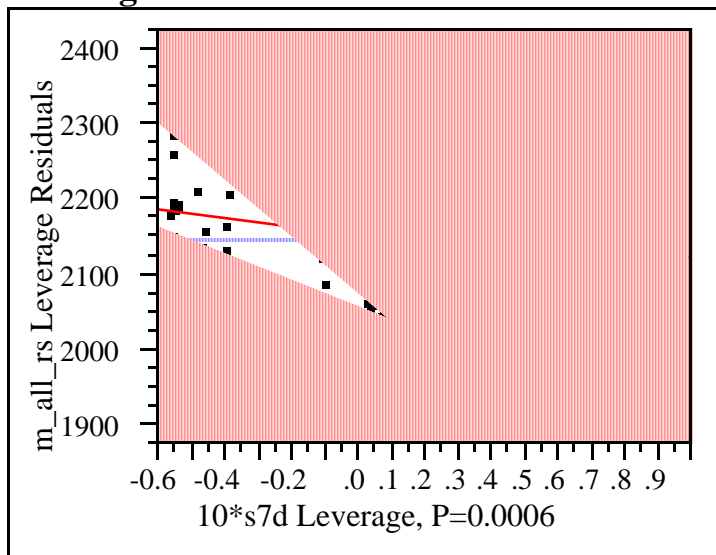
10*s7c

Leverage Plot



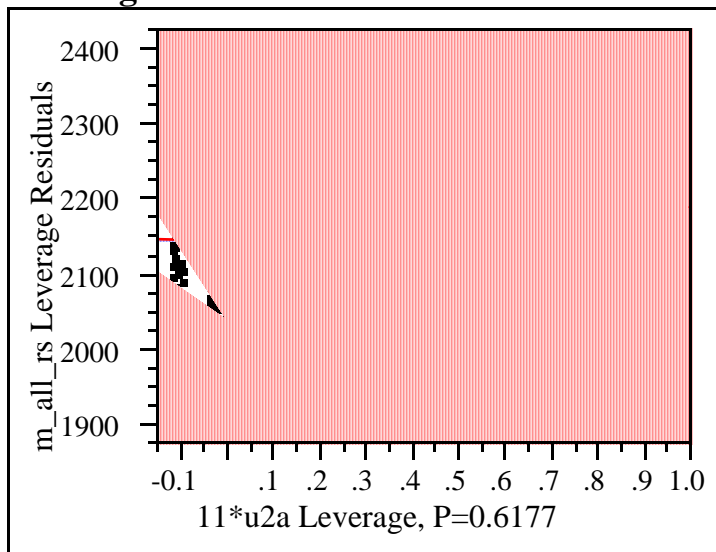
10*s7d

Leverage Plot



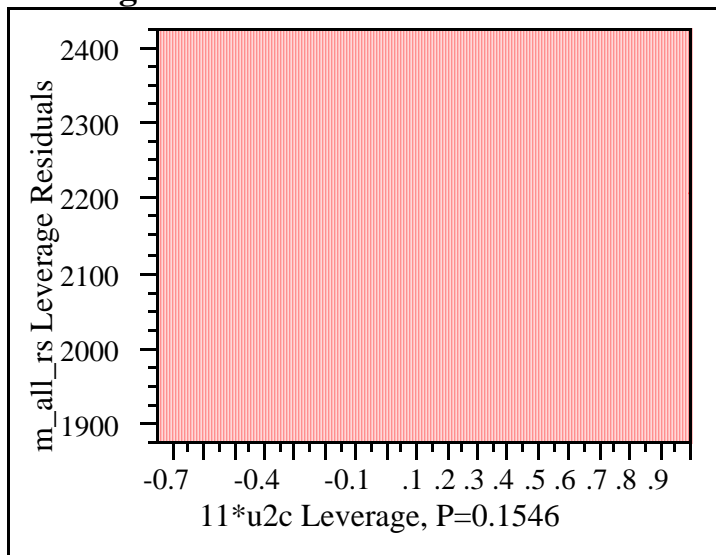
11*u2a

Leverage Plot



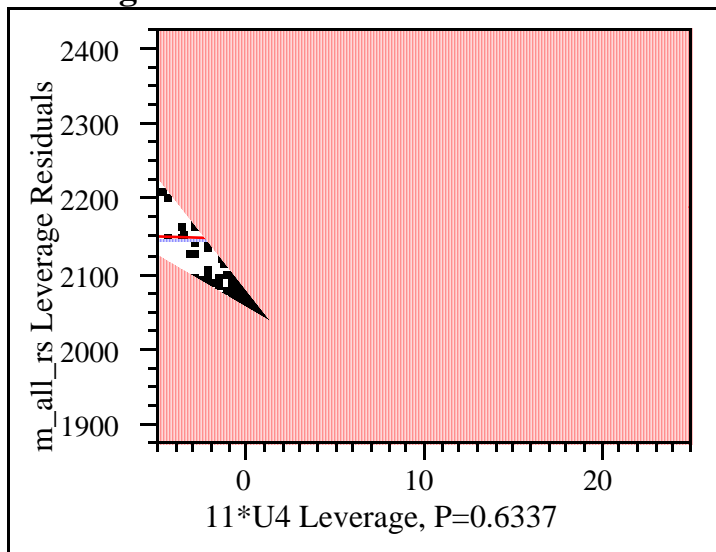
11*u2c

Leverage Plot



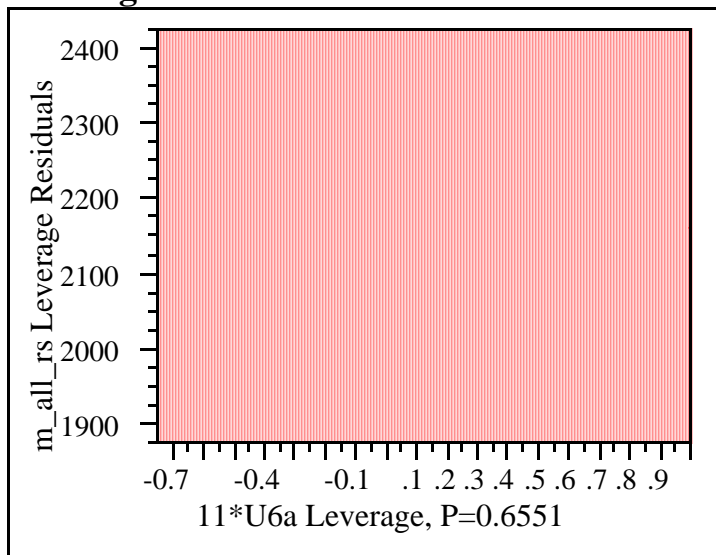
11*U4

Leverage Plot



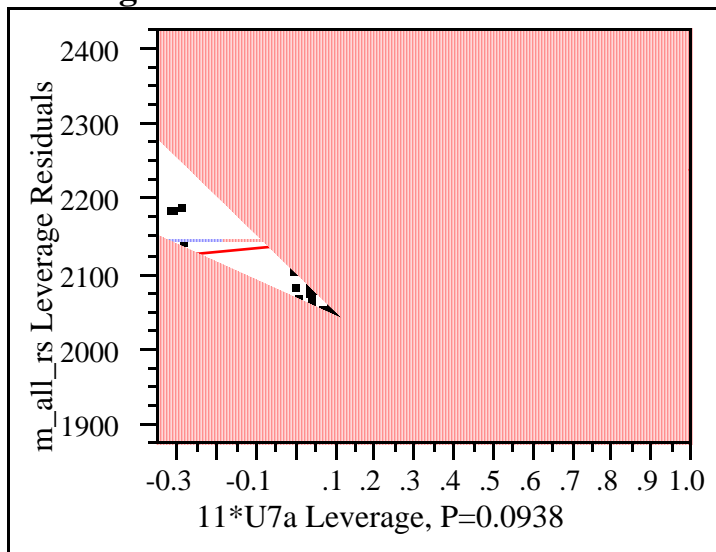
11*U6a

Leverage Plot



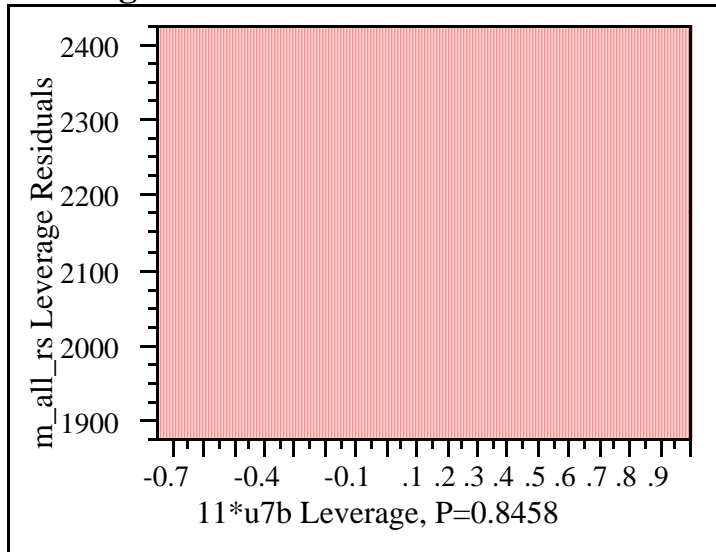
11*U7a

Leverage Plot



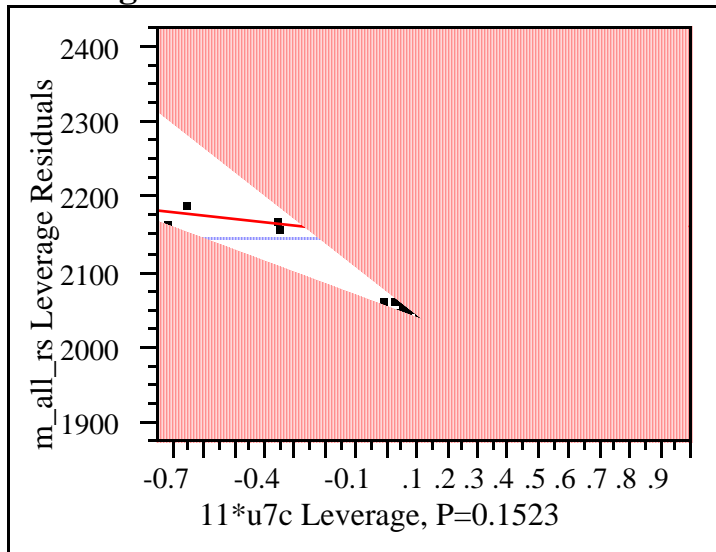
11*u7b

Leverage Plot



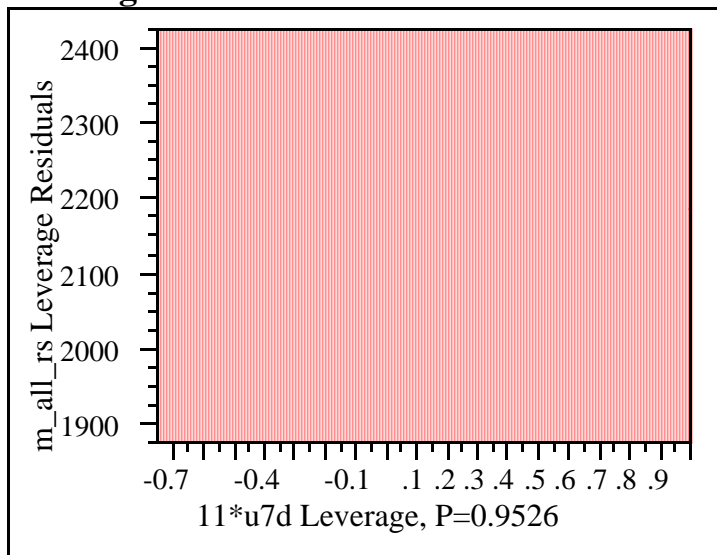
11*u7c

Leverage Plot



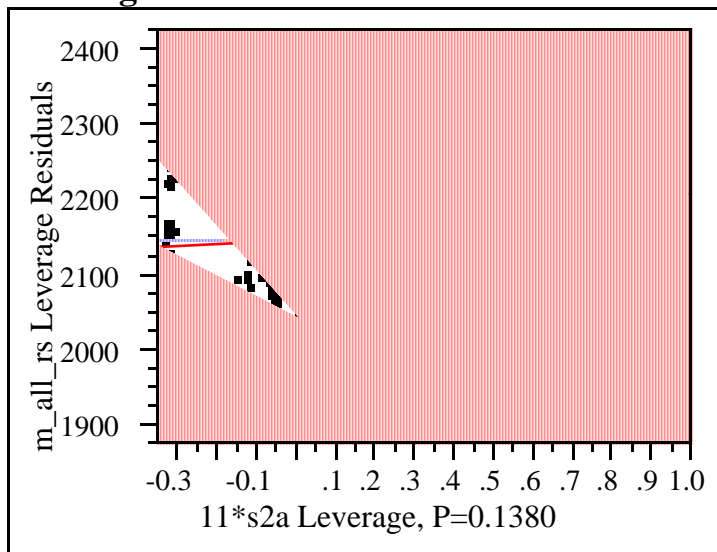
11*u7d

Leverage Plot



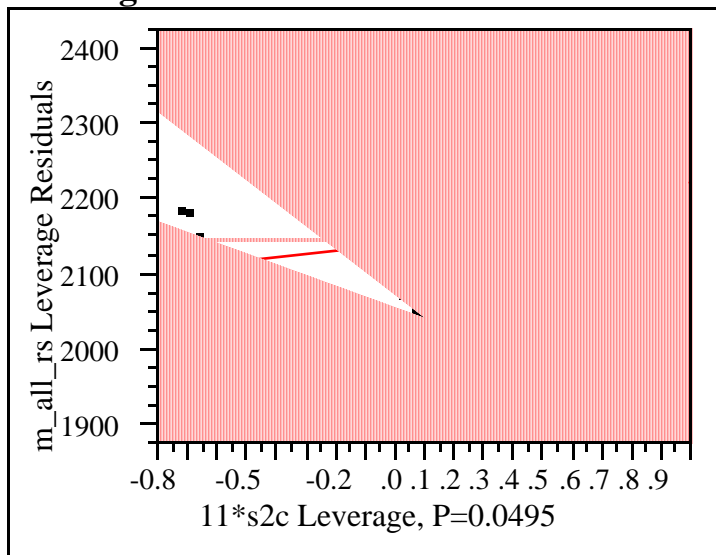
11*s2a

Leverage Plot



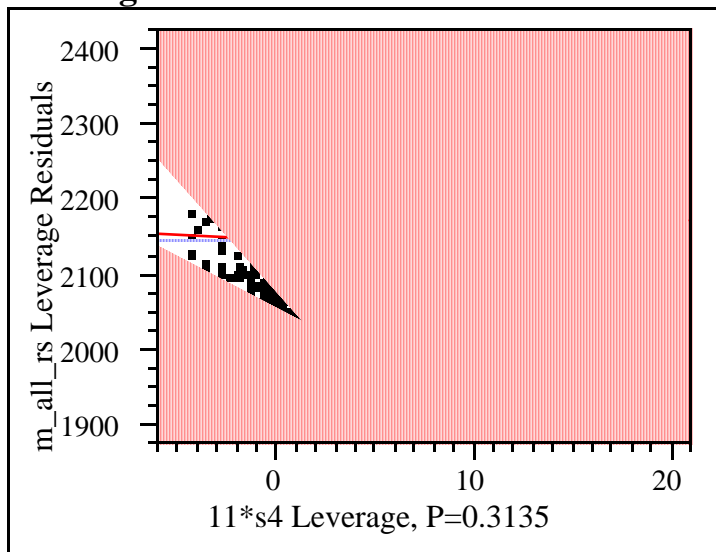
11*s2c

Leverage Plot



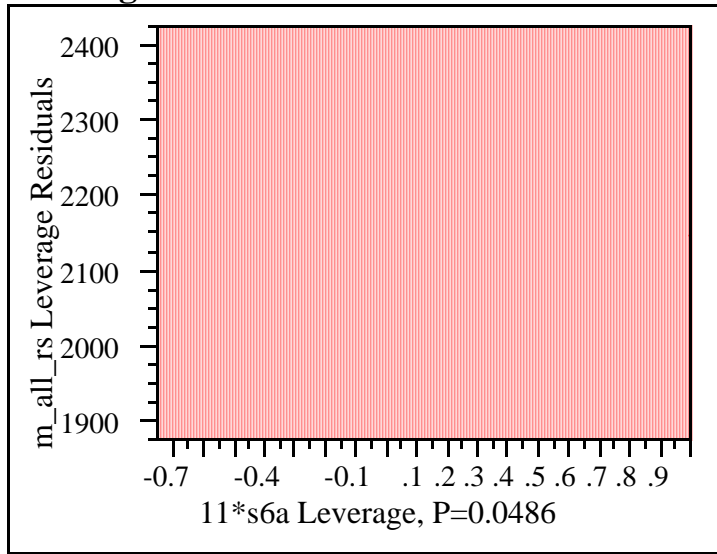
11*s4

Leverage Plot



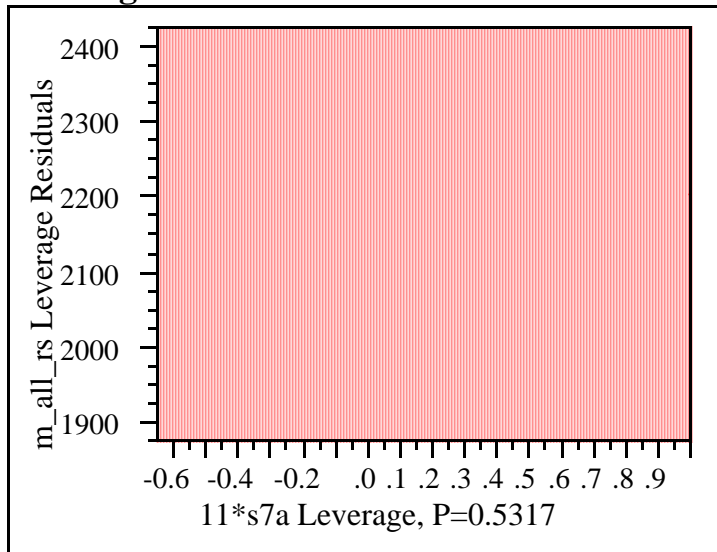
11*s6a

Leverage Plot



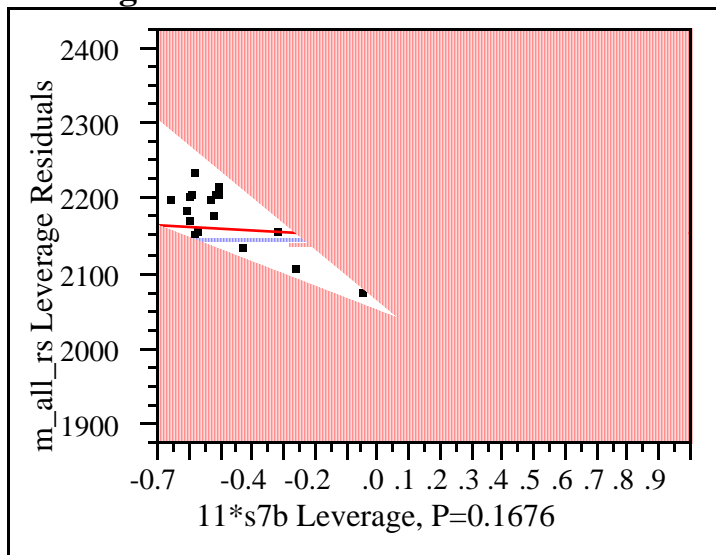
11*s7a

Leverage Plot



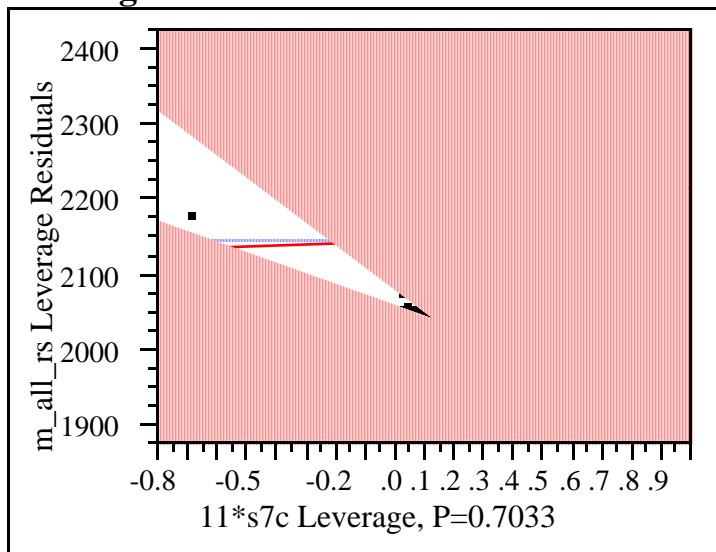
11*s7b

Leverage Plot



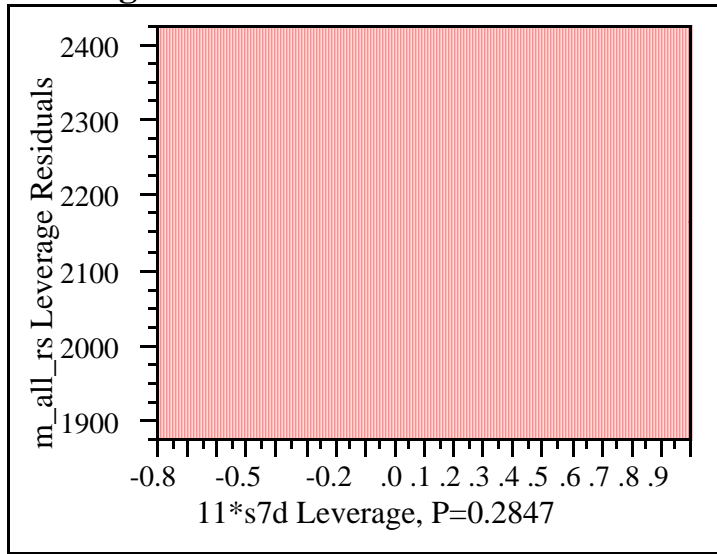
11*s7c

Leverage Plot



11*s7d

Leverage Plot



Appendix H : Model 4 – Complex Interaction Model Analysis

2005 Parameter Interpretation

- The autonomous average mathematics scale score for 9th grade urban schools was 2189. The S variable (Suburban schools) was statistically significant ($t = 6.65, p < .0001$). In other words, 9th grade Suburban TAKS math scale scores were 36 points higher than Urban scores ($\beta_1 + \beta_5$).
- The variable q2a (Students required to provide their own calculator) was statistically significant ($t = 3.13, p < .0018$). That is, if 9th grade urban students supplied their own calculator, math scale scores were 28 points higher, holding all else constant.
- The variable q2c (School provides teacher with a classroom set of calculators) was statistically significant ($t = -2.75, p < .0060$). That is, if the teacher reported that their school provided a set of classroom calculators, then 9th grade urban student TAKS math scale scores were lower by 25 points, holding all else constant.
- The variable q6a (Homework) was statistically significant ($t = 4.90, p < .0001$). That is, reported use of a graphing calculator with Homework assignments had an increase of 21 points in the TAKS math scale scores, holding all else constant.
- The variable 10*r7a (Rural 10th grade students use graphing calculators for operations) was also statistically significant ($t = -2.26, p < .0242$). That is, if graphing calculators were used to teach operations in rural schools, 10th grade TAKS math scale scores were on average 66 points lower, holding all else constant.
- The variable 10*s2c (Suburban School provides 10th grade teachers with a classroom set of calculators) was statistically significant ($t = 2.57, p < .0102$). That is, if the 10 grade suburban teachers were provided with a set of classroom calculators, then 10th grade suburban TAKS math scale scores were 60 points higher, holding all else constant.
- The variable 10*s7d (Suburban 10th grade students use graphing calculators for conceptual understanding) was statistically significant ($t = -2.77, p < .0056$). If 10 grade suburban teachers reported using graphing calculators to teach conceptual understanding, then the 10th grade TAKS math scale scores were 42 points lower on average, holding all else constant.
- The variable 11*r7a (Rural 11th grade students use graphing calculators for operations) was statistically significant ($t = -3.92, p < .0001$). In other words, if teachers reported using graphing calculators to teach operations in 11th grade rural math classes, then the 11th grade rural TAKS math scale scores were 111 points lower on average, holding all else constant.
- The variable 11*r7c (Rural 11th grade students use graphing calculators for problem solving) was statistically significant ($t = 2.19, p < .0288$). That is, if 11th rural teachers reported using graphing calculators for problem solving in math classes, then Rural 11th grade TAKS math scale scores increased by 76 points, holding all else constant.
- The variable 11*s2c (Suburban 11th grade teachers with a classroom set of calculators) was statistically significant ($t = 2.93, p < .0034$). That is, if the teacher reported that their school provided a set of classroom calculators, then 11th grade suburban student TAKS math scale scores were higher by 40 points, holding all else constant.
- The variable 11*s7b (suburban 11th grade students use graphing calculators for drill and practice) was statistically significant ($t = -1.95, p < .0509$). In other words, if graphing calculators are used to for drill and practice in suburban 11th grade math classes, then

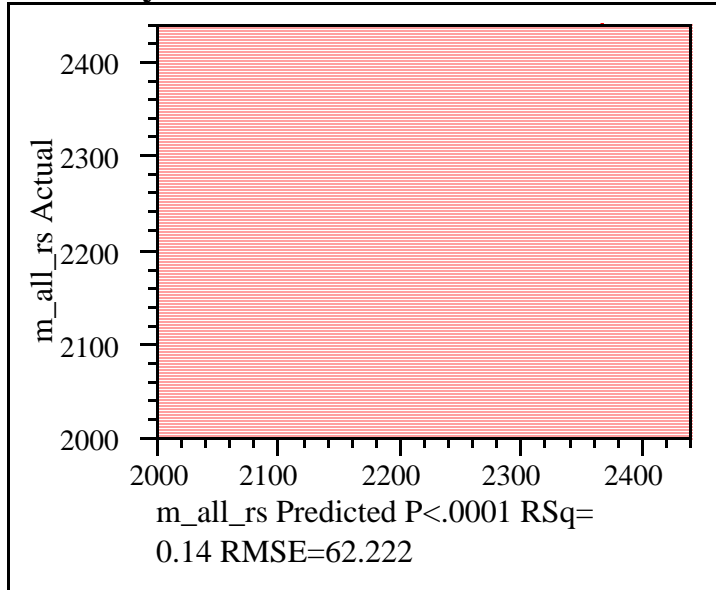
their TAKS math scale scores were 25 points lower on average, holding all else constant.

Appendix I: Model 4 -Regression Analysis and Plots: Complex Interaction

Response m_all_rs

Whole Model

Actual by Predicted Plot



Summary of Fit

RSquare	0.144921
RSquare Adj	0.125676
Root Mean Square Error	62.22152
Mean of Response	2195.275
Observations (or Sum Wgts)	2000

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	44	1282780.0	29154.1	7.5304
Error	1955	7568816.8	3871.5	Prob > F
C. Total	1999	8851596.7		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	565	2223189.7	3934.85	1.0232
Pure Error	1390	5345627.0	3845.77	Prob > F
Total Error	1955	7568816.8		0.3689
				Max RSq
				0.3961

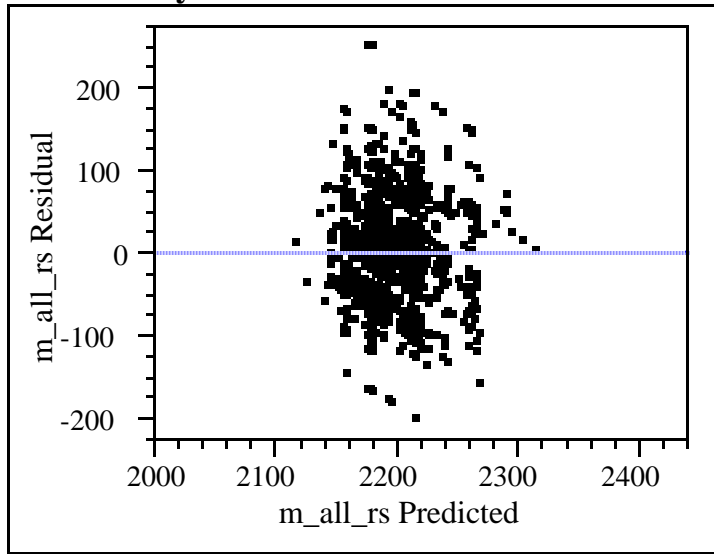
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	2189.1272	16.41422	133.37	0.0000
10th	-1.656556	5.887724	-0.28	0.7785

Term	Estimate	Std Error	t Ratio	Prob> t
11th	0.6017716	5.830517	0.10	0.9178
R	10.106281	6.293443	1.61	0.1085
S	36.22885	5.451635	6.65	<.0001
question.2a	27.881034	8.896679	3.13	0.0018
question.2c	-25.41183	9.232396	-2.75	0.0060
question.4.num	-0.037337	0.461632	-0.08	0.9355
question.6a	21.389227	4.362145	4.90	<.0001
question.7a	12.607366	11.53463	1.09	0.2745
question.7b	0.8755138	7.078557	0.12	0.9016
question.7c	-18.52358	12.85002	-1.44	0.1496
question.7d	-1.04608	7.853929	-0.13	0.8941
10*r2a	2.9840042	33.10547	0.09	0.9282
10*r2c	13.292754	16.91508	0.79	0.4320
10*r4	2.1356552	1.384011	1.54	0.1230
10*r6a	16.761102	14.10849	1.19	0.2350
10*r7a	-66.39963	29.44299	-2.26	0.0242
10*r7b	9.7988802	17.47605	0.56	0.5751
10*r7c	27.47185	30.71178	0.89	0.3712
10*r7d	-6.922185	20.22778	-0.34	0.7322
10*s2a	14.320696	17.73613	0.81	0.4195
10*s2c	59.62926	23.20304	2.57	0.0102
10*s4	-0.624924	1.07788	-0.58	0.5621
10*s6a	13.87473	11.5912	1.20	0.2314
10*s7a	9.4302369	20.82326	0.45	0.6507
10*s7b	-7.977122	14.15985	-0.56	0.5733
10*s7c	-26.06913	28.23742	-0.92	0.3560
10*s7d	-41.64429	15.03054	-2.77	0.0056
11*r2a	-18.62723	25.83677	-0.72	0.4710
11*r2c	-11.5587	18.65481	-0.62	0.5356
11*r4	1.5824822	1.207743	1.31	0.1903
11*r6a	-7.212387	14.27188	-0.51	0.6134
11*r7a	-111.3216	28.41296	-3.92	<.0001
11*r7b	21.927825	19.32725	1.13	0.2567
11*r7c	75.826174	34.65471	2.19	0.0288
11*r7d	14.858492	22.81668	0.65	0.5150
11*s2a	23.914234	15.79844	1.51	0.1303
11*s2c	40.495713	19.6385	2.06	0.0393
11*s4	-0.4388	1.032325	-0.43	0.6708
11*s6a	-10.40621	13.54292	-0.77	0.4423
11*s7a	-7.074707	21.77807	-0.32	0.7453
11*s7b	-28.26282	14.46457	-1.95	0.0509
11*s7c	24.59003	29.77694	0.83	0.4090
11*s7d	-19.63099	22.41222	-0.88	0.3812

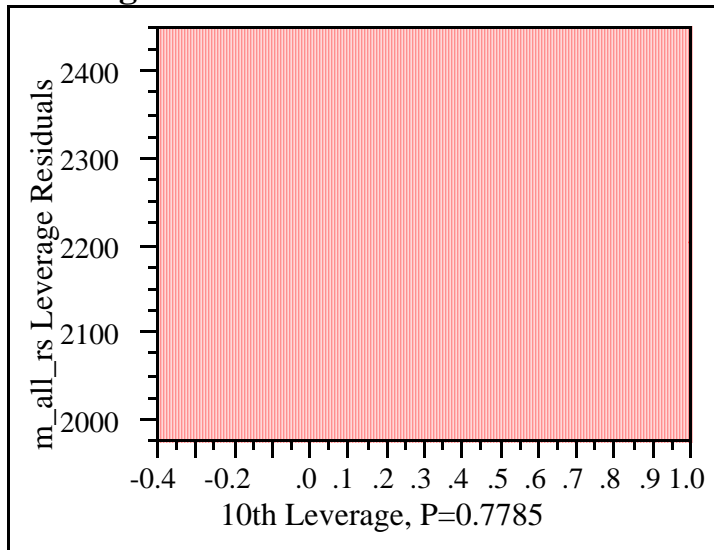
Effect Tests

Residual by Predicted Plot

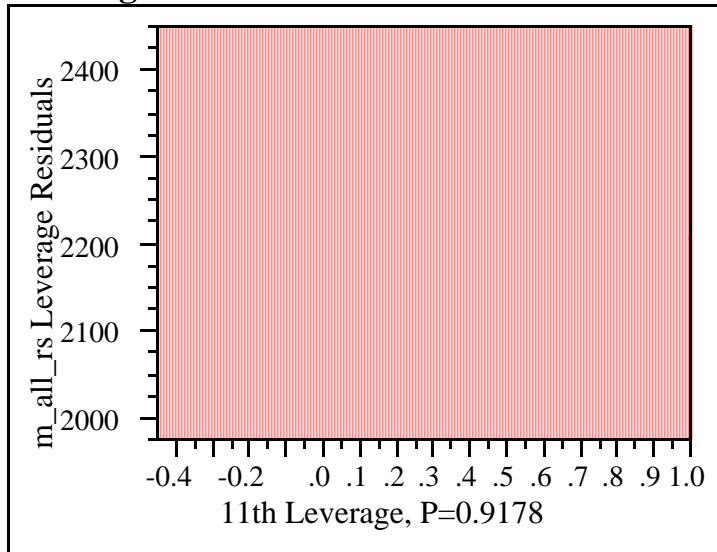


10th

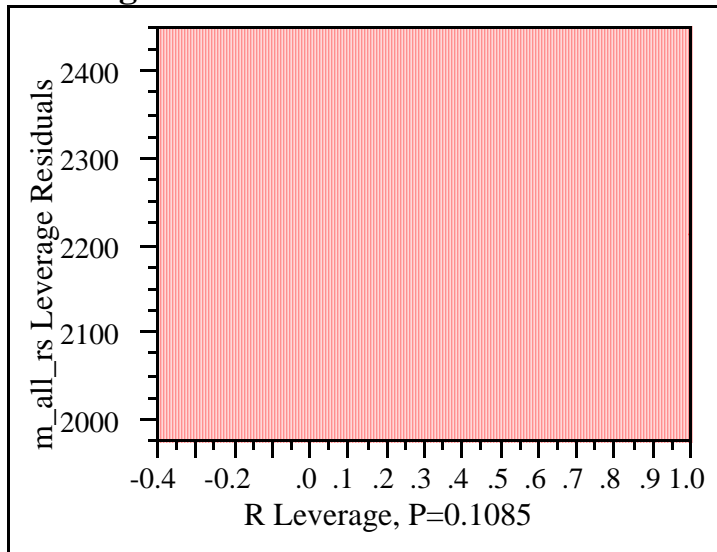
Leverage Plot



11th Leverage Plot

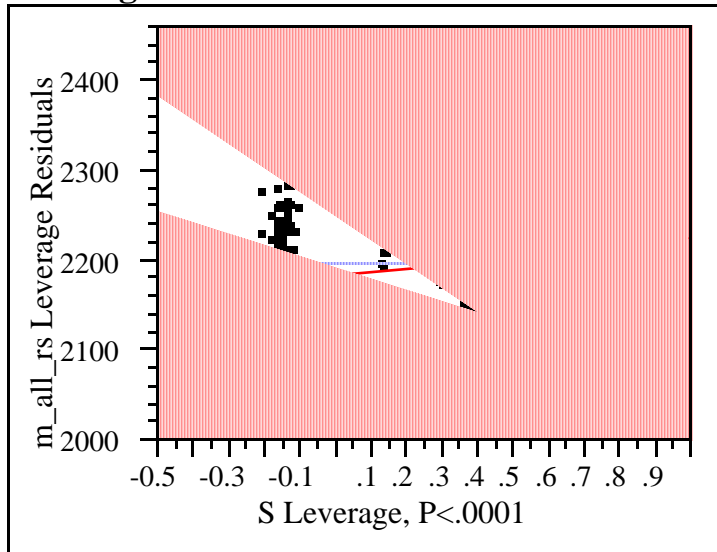


R Leverage Plot



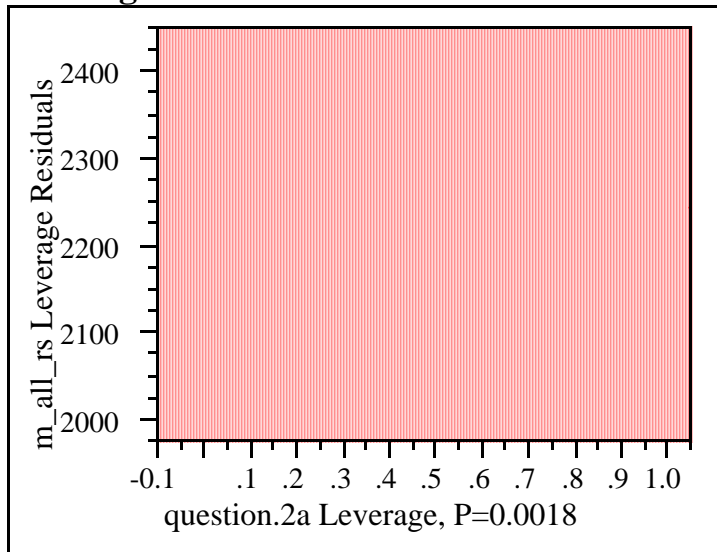
S

Leverage Plot

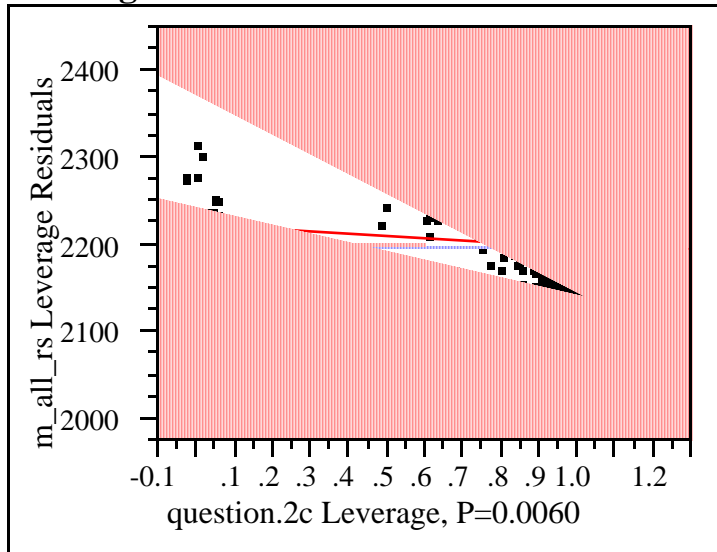


question.2a

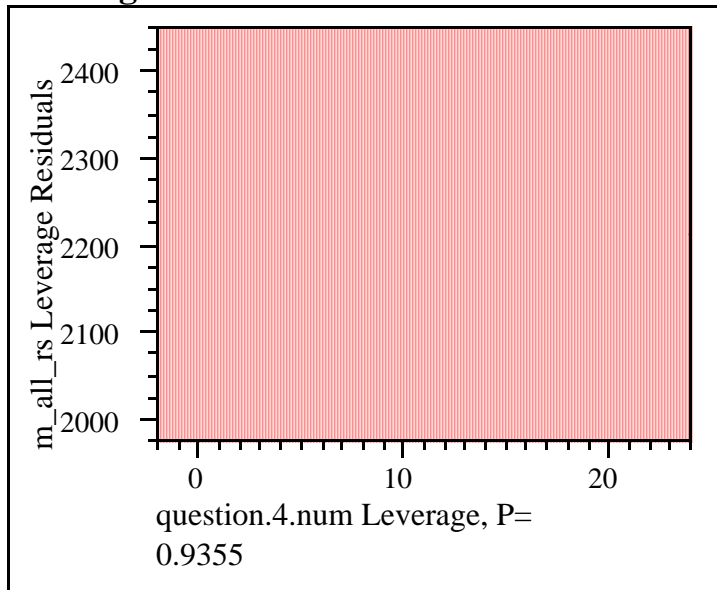
Leverage Plot



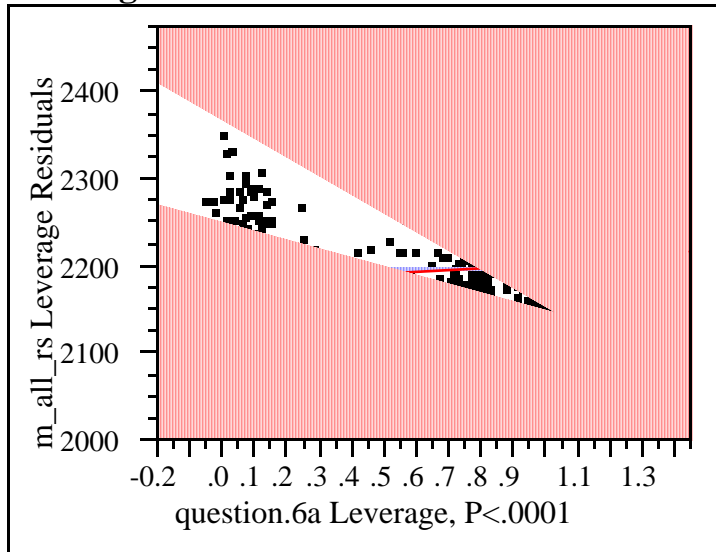
question.2c
Leverage Plot



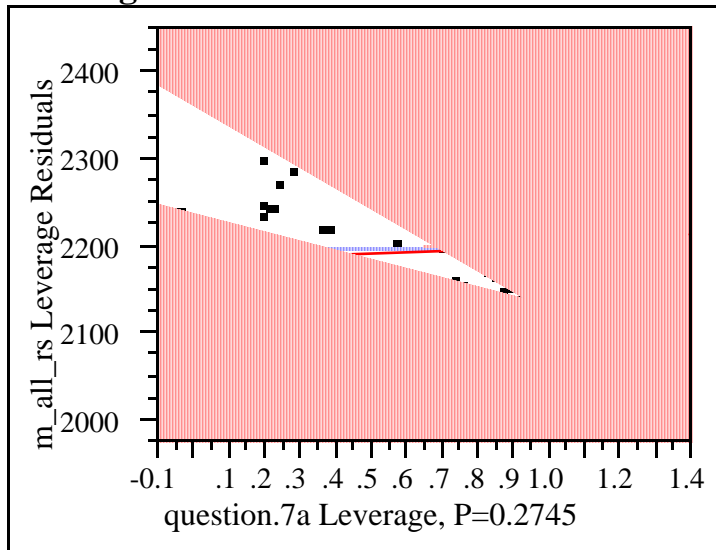
question.4.num
Leverage Plot



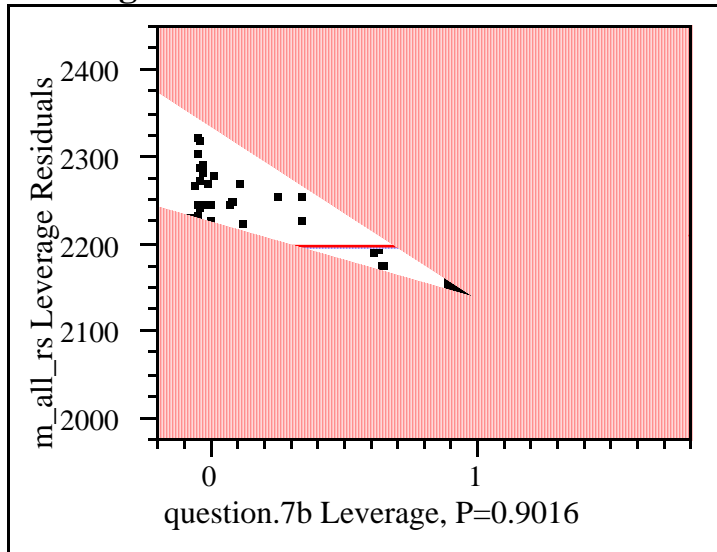
question.6a
Leverage Plot



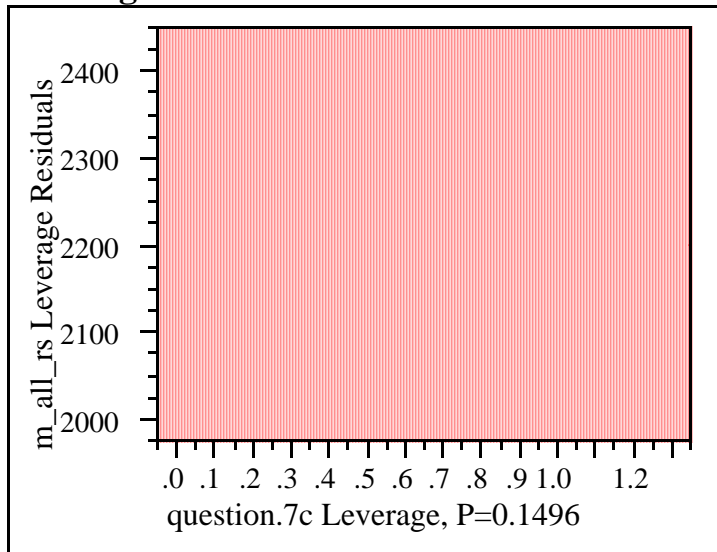
question.7a
Leverage Plot



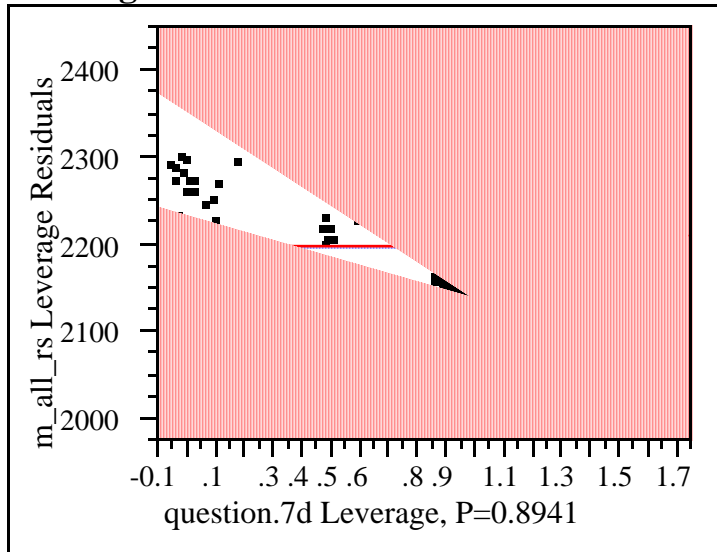
question.7b
Leverage Plot



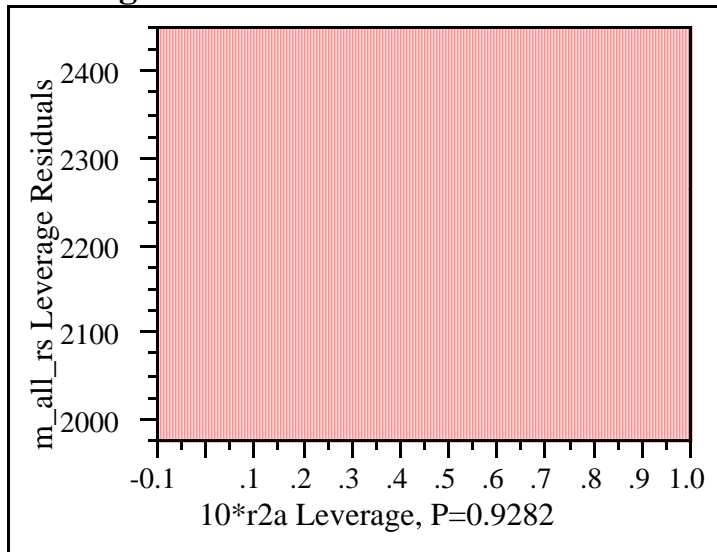
question.7c
Leverage Plot



question.7d
Leverage Plot

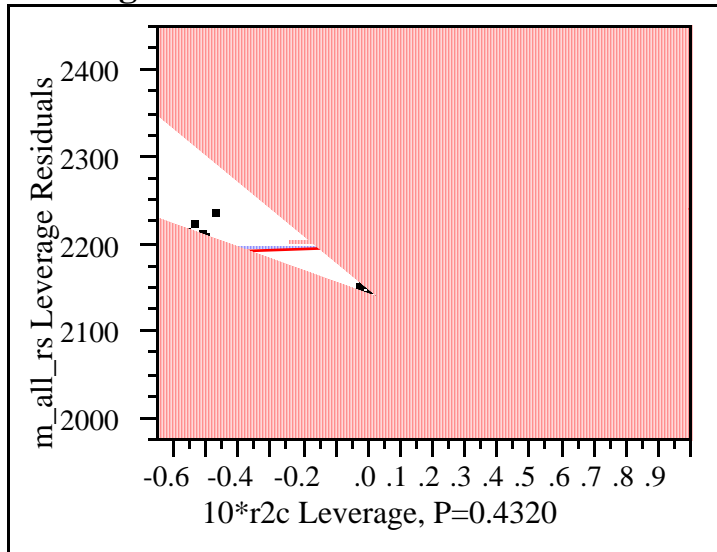


10*r2a
Leverage Plot



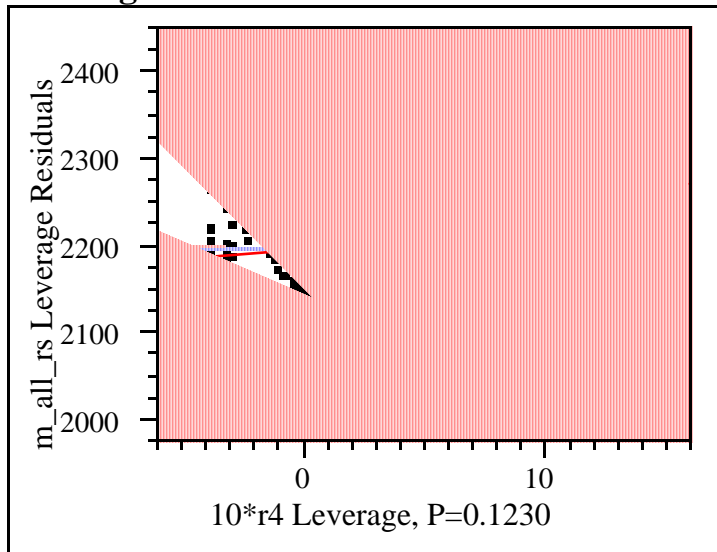
10*r2c

Leverage Plot



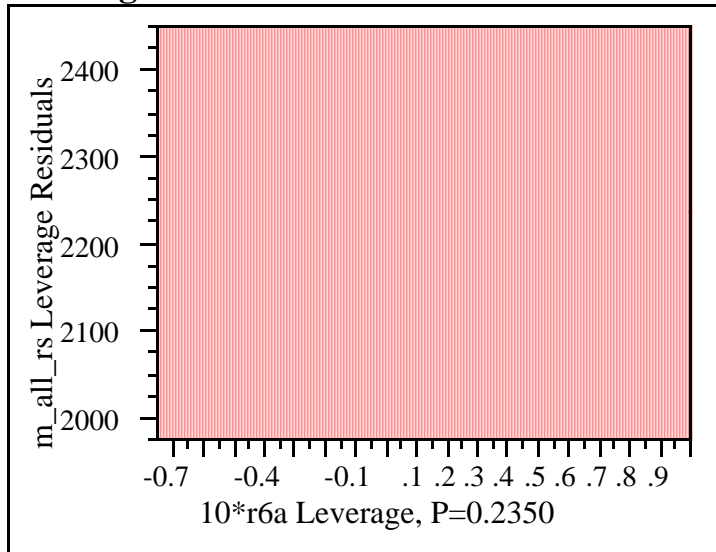
10*r4

Leverage Plot



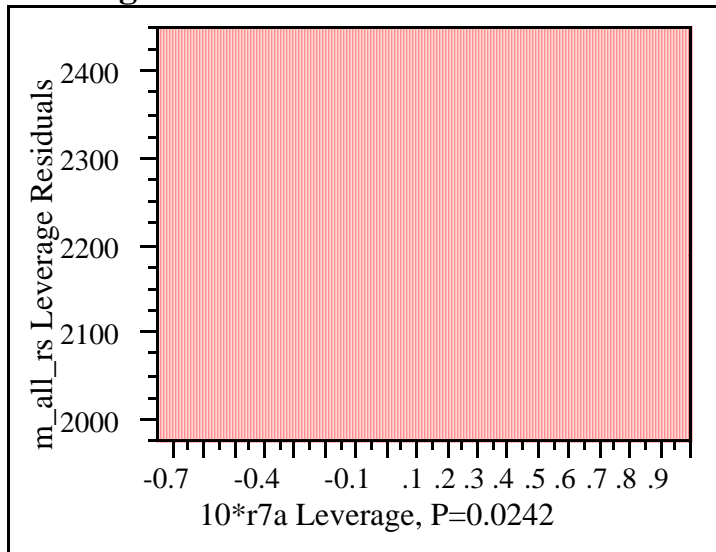
10*r6a

Leverage Plot



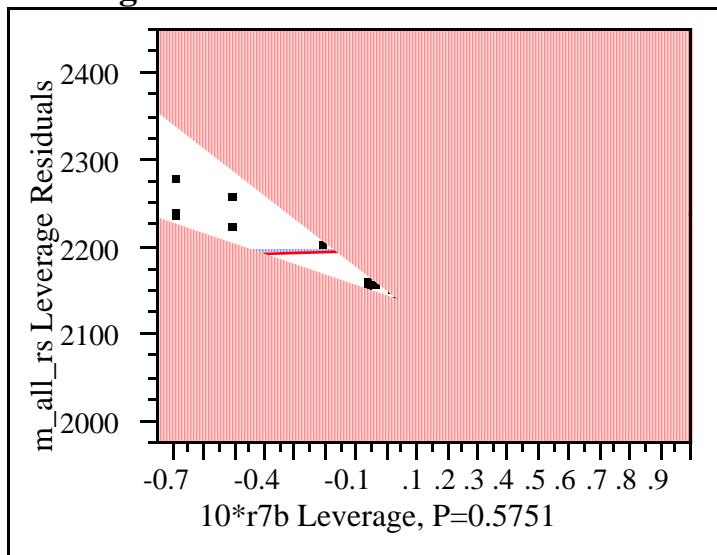
10*r7a

Leverage Plot



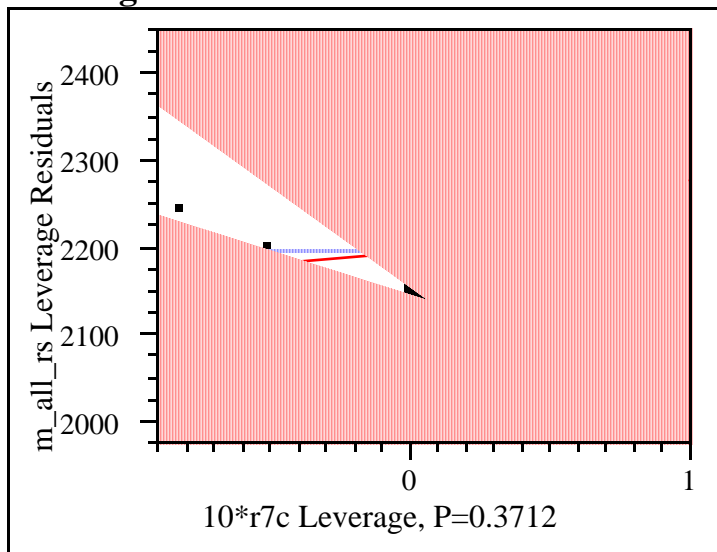
10*r7b

Leverage Plot



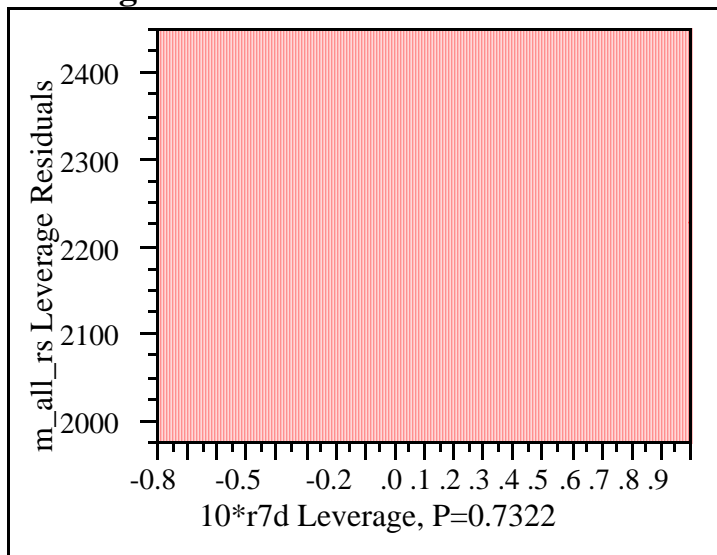
10*r7c

Leverage Plot



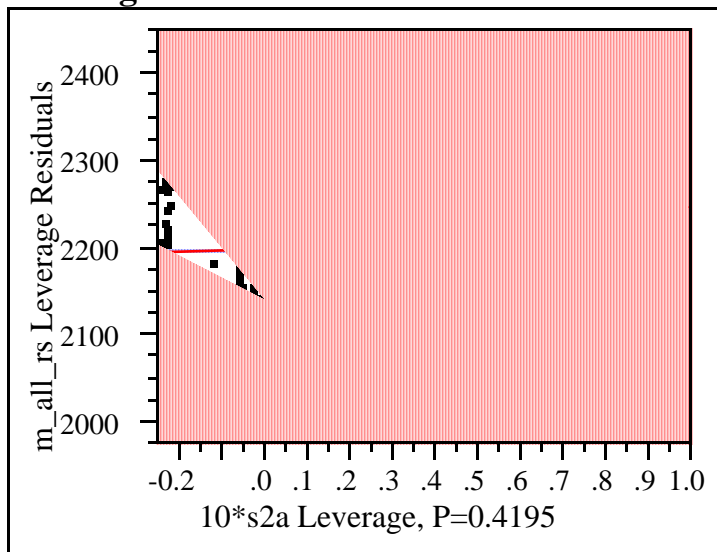
10*r7d

Leverage Plot



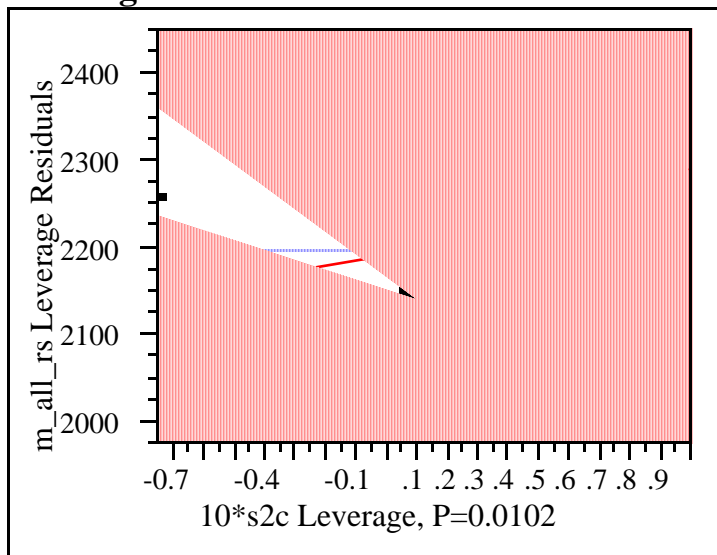
10*s2a

Leverage Plot



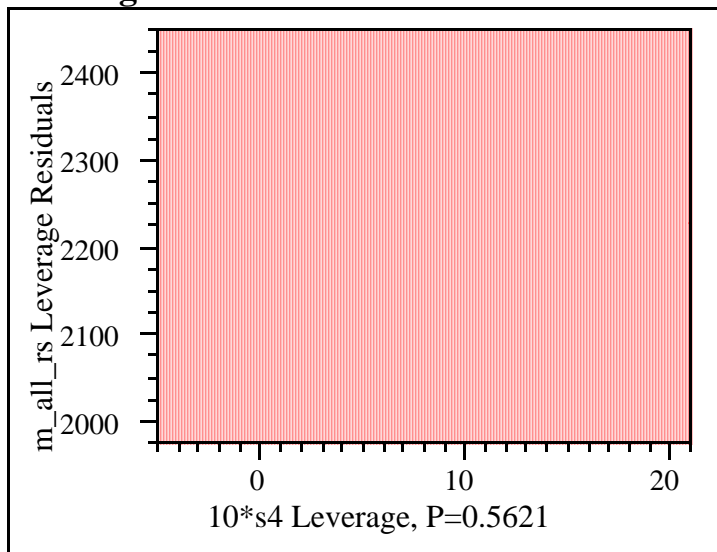
10*s2c

Leverage Plot



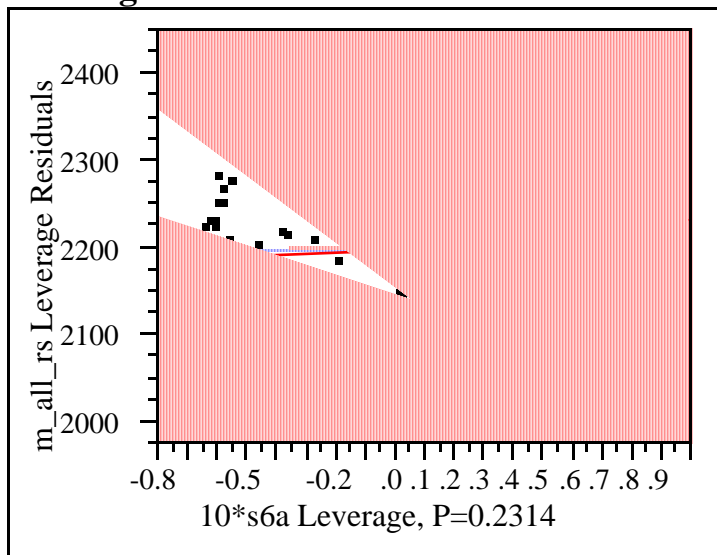
10*s4

Leverage Plot



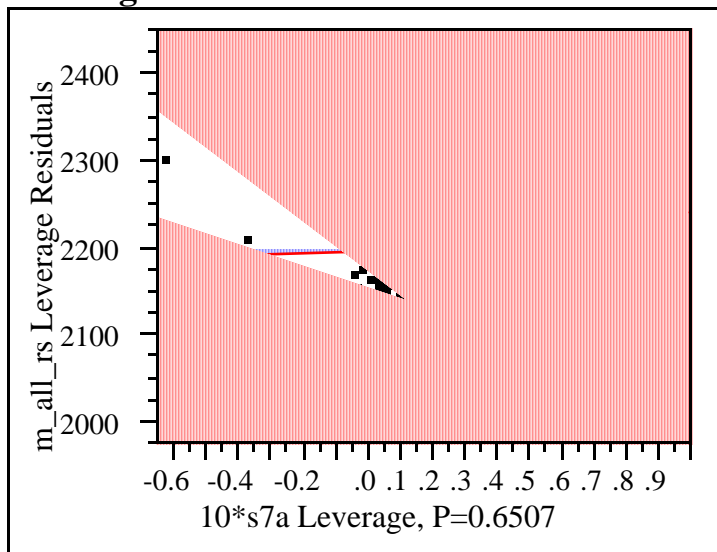
10*s6a

Leverage Plot



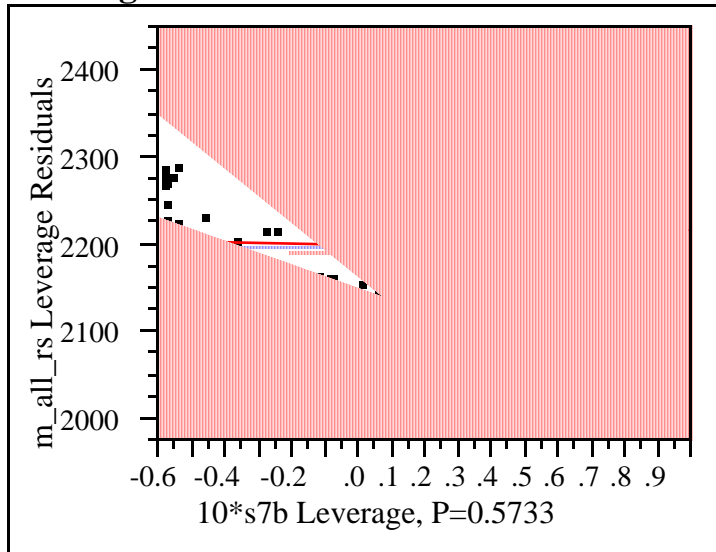
10*s7a

Leverage Plot



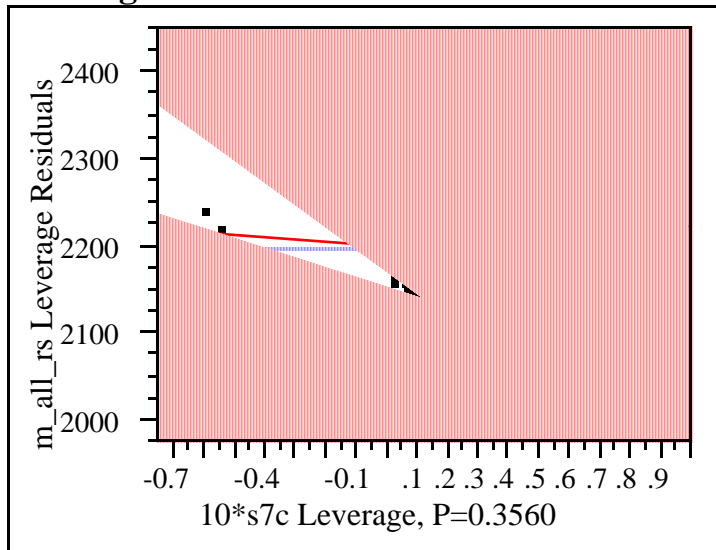
10*s7b

Leverage Plot



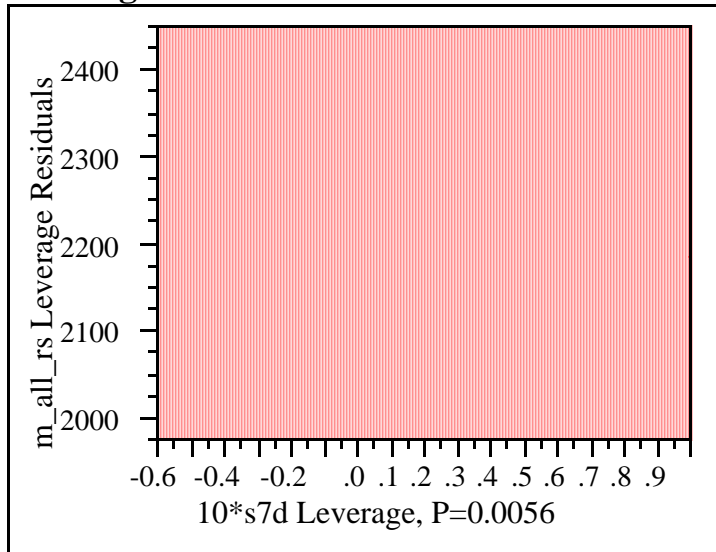
10*s7c

Leverage Plot



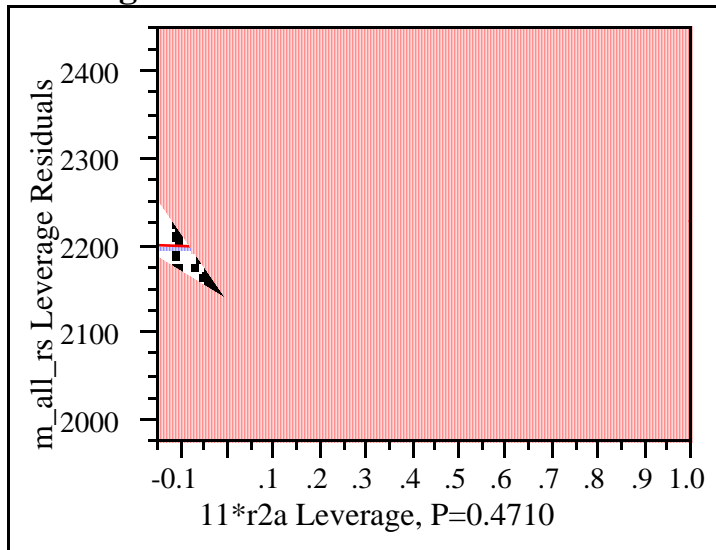
10*s7d

Leverage Plot



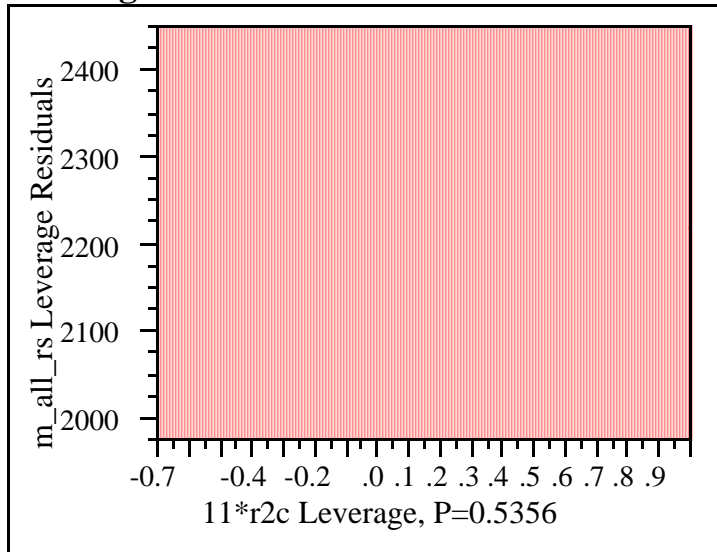
11*r2a

Leverage Plot



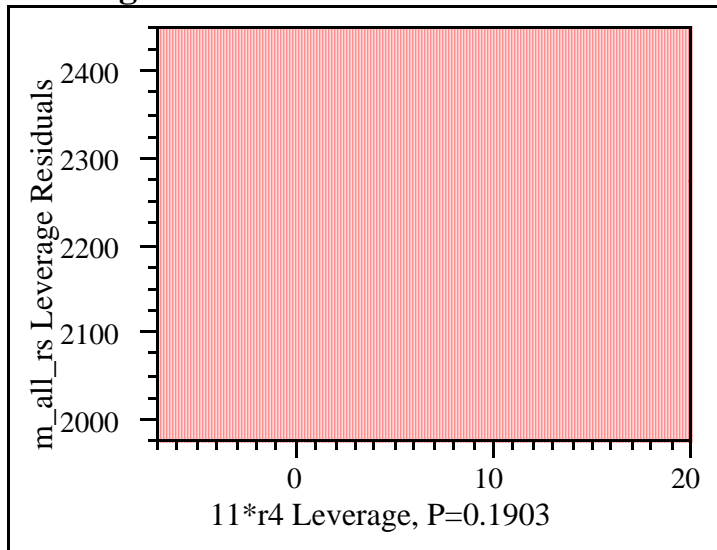
11*r2c

Leverage Plot



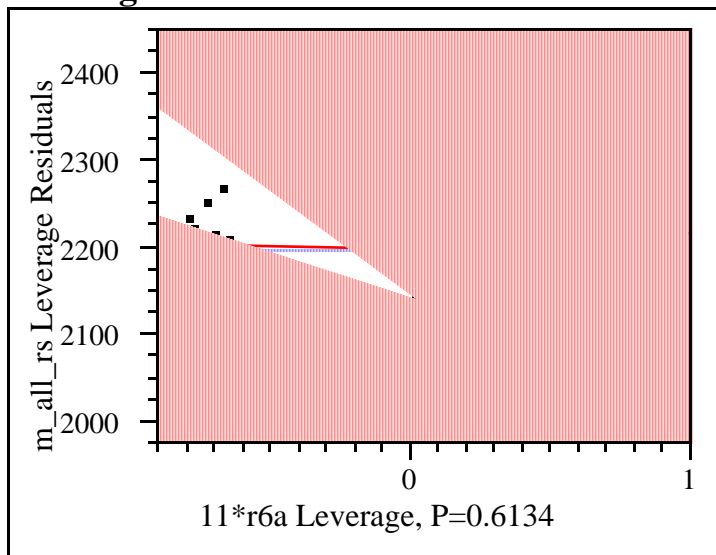
11*r4

Leverage Plot



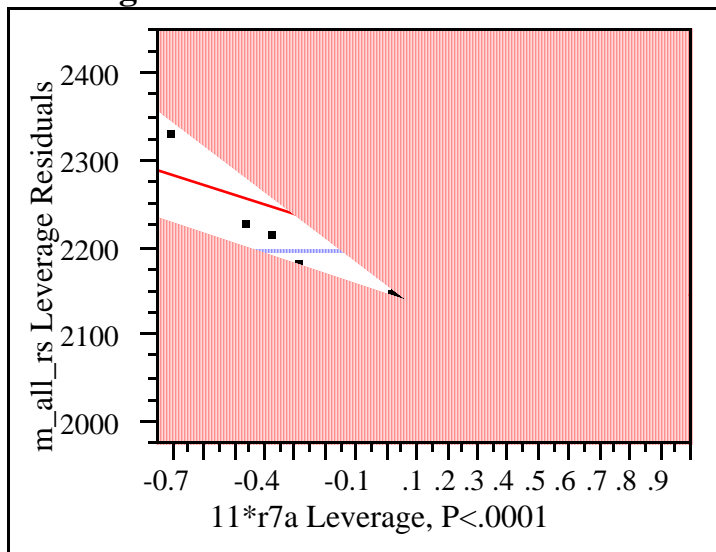
11*r6a

Leverage Plot



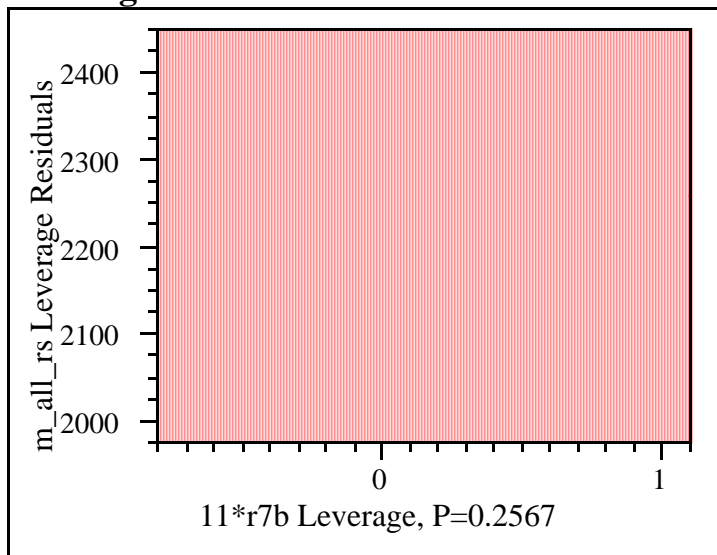
11*r7a

Leverage Plot



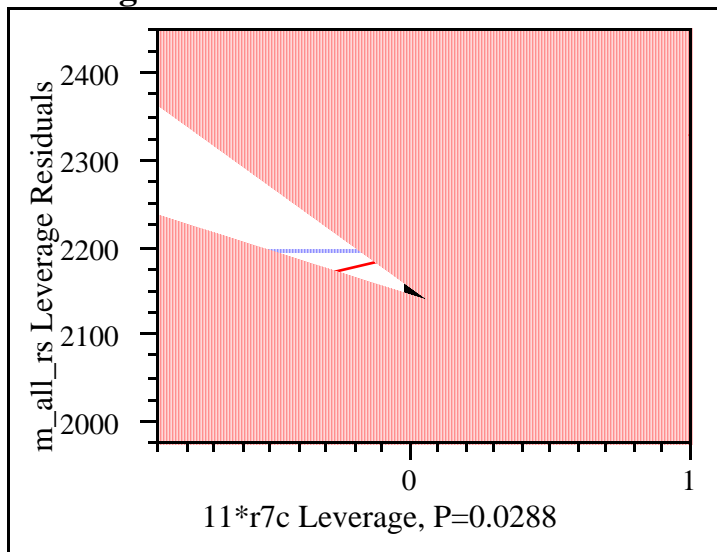
11*r7b

Leverage Plot



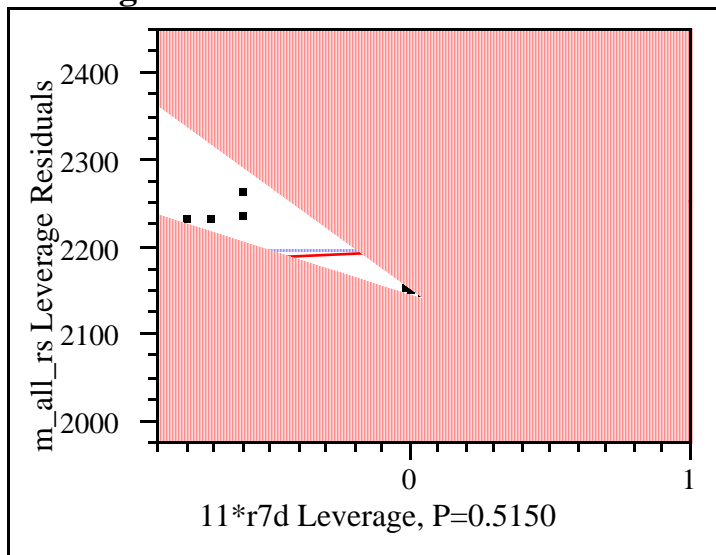
11*r7c

Leverage Plot



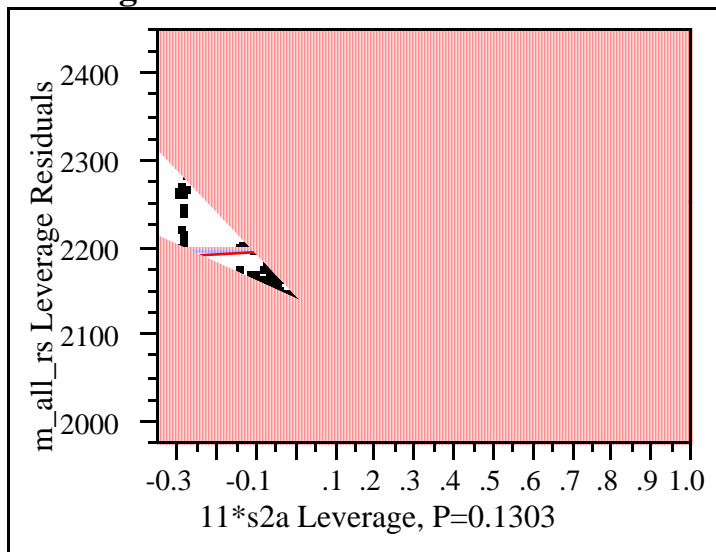
11*r7d

Leverage Plot



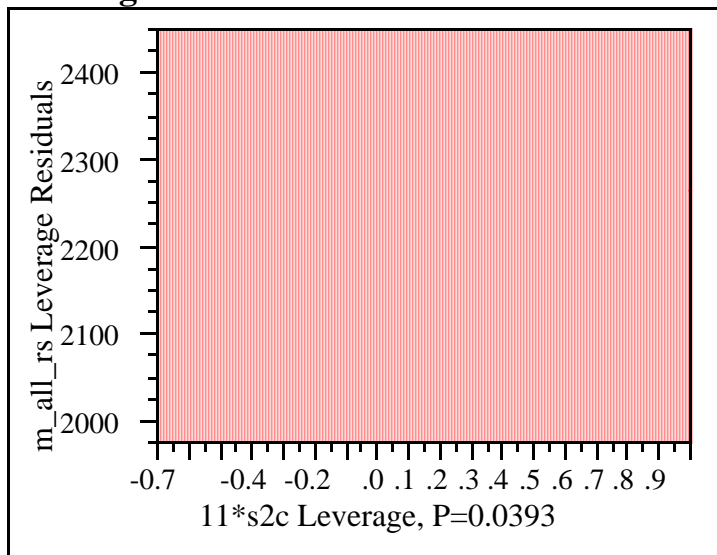
11*s2a

Leverage Plot



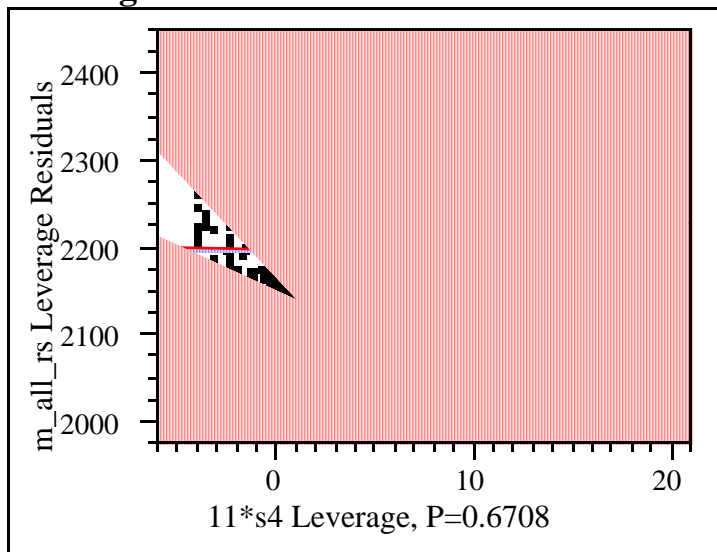
11*s2c

Leverage Plot



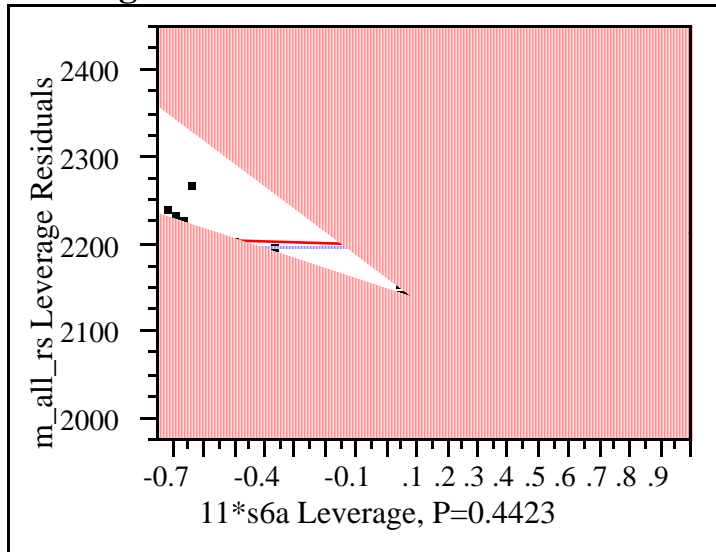
11*s4

Leverage Plot



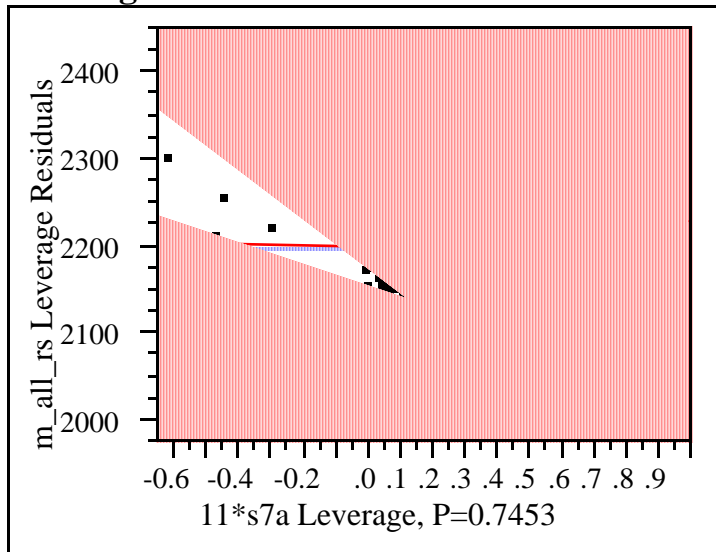
11*s6a

Leverage Plot



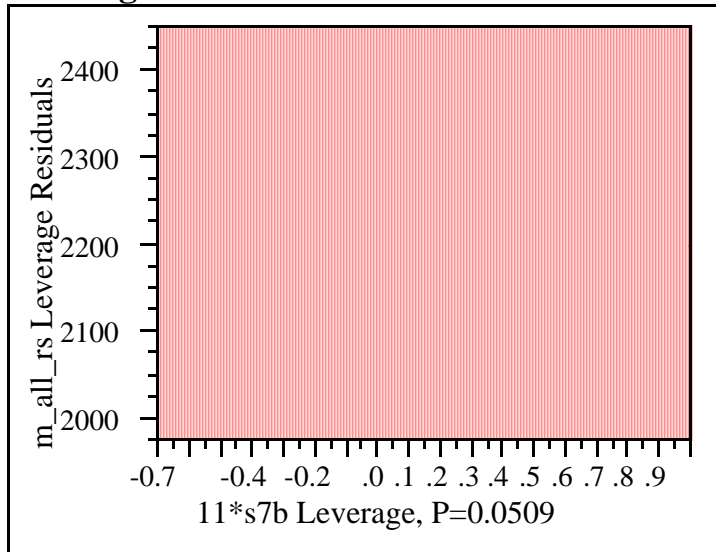
11*s7a

Leverage Plot



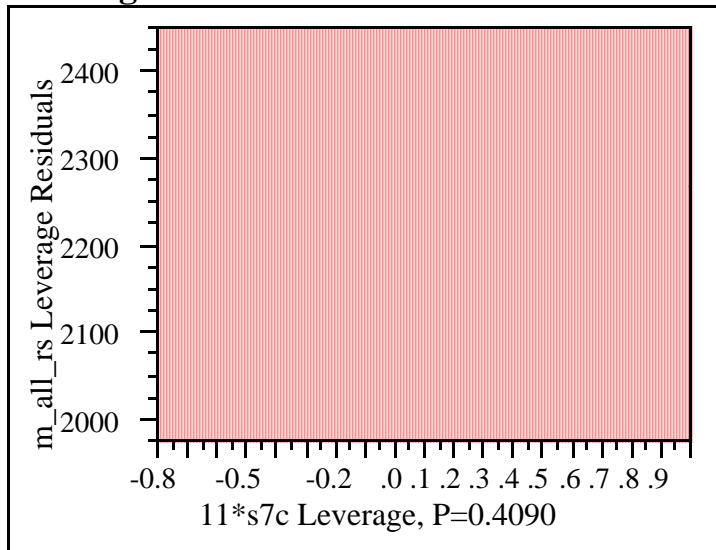
11*s7b

Leverage Plot



11*s7c

Leverage Plot



11*s7d

Leverage Plot

