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School District Expenditures and Student Achievement

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SCHOOL DISTRICT EXPENDITURES AND STUDENT ACHIEVEMENT

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ABSTRACT

Many studies argue that adding more money to schools has little effect on student achievement. However, there is a growing belief that the allocation of the funds in school districts matters. To test the importance of allocating extra funds to specific spending categories, I use a fractional logit model to estimate the proportions of students who pass the English and Mathematics MCAS exams in Massachusetts school districts. I first use a one-year lag of total in-district expenditures per-pupil as the variable of interest, then I break down the total into lagged teacher and non-teacher expenditures per-pupil. The results of my estimations show no evidence of an effect of total in-district expenditures per-pupil on the passing rate for the English and Mathematics MCAS exams. However, there is a positive and significant effect of teacher expenditures per-pupil on the passing rate of the 10^{th} grade Mathematics MCAS exam. I also use a multinomial fractional logit model to compare three outcomes (passing, needing improvement, and failing) rather than just two and find similar results. By understanding how each expenditure category affects student test scores, school district administrators can increase the benefits from their budgetary allocations.

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1. INTRODUCTION

From 1974 to 2014, the total expenditures per-pupil on primary and secondary public education in the United States grew from $6,356 to $12,509 in real dollars, a 97% increase in the budget in 40 years (National Center for Education Statistics). However, the addition of funds in the education sector has not produced much gain in student achievement, specifically student test scores. From 2003 to 2015, the average standardized score of U.S. 15-year-olds on the Program for International Student Assessment (PISA) reading literacy scale and the mathematics literacy scale sunk by 3.2 and 2.9 point respectively (National Center for Education Statistics). The lack of a clear effectiveness of money spent on public schooling on student outcomes may be why the United States has been cutting back on education funding in recent years (OECD, 2017). But just considering how total funds affect test scores is too broad. Determining how the money is spent on specific resources in a school district provides a deeper understanding of the way school finance influences student outcomes like test scores.

A district's total funds for its public education are spent on teachers' salaries, maintenance of the schools, transportation services, textbooks, etc. Certain categories of expenditure may affect student achievement more than others. When only considering the aggregate of all expenditure categories, the effects of these significant categories of expenditure will not shine through, leading to the belief that money does not matter. Or, in findings where total expenditures are significant, the result could be driven by only a few significant expenditure categories. In either case, adding extra funds to school districts does not ensure that this money makes a significant impact on student outcomes. According to Hanushek, "local districts do not use funds effectively, which complicates just throwing money at the schools"

(Hanushek, 1997). Studying how each expenditure category affects test scores may lead to insights on maximizing student achievement subject to the district funding budget constraint. My research focuses on estimating the effect of expenditures per-pupil on the proportions of students who pass, need improvement, or fail the 10^{th} grade Massachusetts Comprehensive Assessment System (MCAS) exams for English and for Mathematics in a school district.

There are four test outcomes students can earn on the 10^{th} grade MCAS exams: advanced, proficient, needs improvement, and fail. Each of these outcomes results in different consequences according to the Massachusetts Department of Education. Both advanced and proficient scores are considered passing and satisfy the state's competency determination requirement for graduating high school. The difference between these two outcomes is that an advanced score makes a student eligible for state-funded college scholarships. Therefore, in my research, I combine advanced and proficient into a passing category. If a student received a needs improvement score on a 10^{th} grade MCAS exam, they must fulfill the requirements of an Educational Proficiency Plan. These plans include the school district reviewing a student's strengths and weaknesses in the specific subject area, the student completing extra courses in the subject area, the school administering a retake of the MCAS test and the student showing progress toward proficiency in the grade 10 standards of that subject. Once these requirements are met, the student is deemed competent and allowed to graduate high school. A student who fails an MCAS exam is unable to graduate high school. The student must fulfill the requirements of the Educational Proficiency Plan but cannot be deemed competent in the grade 10 curriculum standards until his/her score is in the needs improvement zone. The difference between needs improvement and fail is the value of improvement for the goal of earning a high school diploma.

If a student with a needs improvement score gets a slightly better score on next year's exam but still receives needs improvement, he/she passes the state's competency determination requirement for graduating. A student who fails the MCAS test and earns a few points higher the next year while staying in the failing range is unable to graduate. With different consequences attached to each MCAS score outcome, it's important to consider each category when looking at the effect of school district expenditures on test scores.

The first model I use is a fractional logit model. I estimate the effect of school district expenditures on the log odds of the proportion passing versus not passing the MCAS exams in a district. The second model I use is a multinomial fractional logit model to break down the score options further into the proportions of students in a district passing, needing improvement, and failing the MCAS exams. In the fractional multinomial logit model, I estimate the effect of school district expenditures on the log odds of a district's students passing relative to needing improvement on the MCAS exams and the log odds of a district's students failing relative to needing improvement on the MCAS exams. I use variations of these two models to estimate the effect of expenditures on MCAS test outcomes. I first use a one-year lag of total in-district expenditures per-pupil as the variable of interest, then I break down the total into lagged teacher and non-teacher expenditures per-pupil. I use teacher expenditures because teachers have a direct impact on student learning. Also, there is evidence of a relationship between teacher wages and teacher quality (Loeb and Page, 2000). I lag the expenditure variables because the budget is determined for the next school year before the MCAS test is taken. For example, the budget for the 2015-2016 school year is determined at the end of the 2014-2015 school year. Therefore, the scores on the 2016 MCAS exam are matched with school budget expenditures determined in 2015 that were allocated in the 2015-2016 school year. The model also includes control variables like teacher retention rate and the number of students in the district. These are variables that are correlated with student test scores that would bias the estimates if not included.

The biggest problem with my research is the omitted variable bias. There are unobserved variables, such as teacher experience and parental involvement, in the error term of my models that are correlated with student test scores and possibly school district expenditures as well. The omitted variable bias creates biased coefficient estimates. To remedy this problem, I add district fixed effects to the model to pick up any district-specific effects that are correlated with the school expenditures. Although the omitted variable bias might remain with this approach, the coefficients are less biased when using the district fixed effects.

From my research, I find that allocating extra funds towards teachers' salaries increases the proportion of students in the district who pass the Mathematics MCAS exam the following year. My research also reveals that the students most likely affected by additional funds in the budget are those who need improvement. These middle-ground students are easier to push into the passing score range, but also are more likely to fall into the failing score range. I find that adding funds to teacher expenditures will push needs improvement students up to a passing score on the 10th grade Mathematic MCAS exam. I also find that additional funds towards non-teacher expenditures will cause scores of students who need improvement to decrease to a failing score on the 10th grade Mathematics exam. However, before pouring too much money towards teachers, one must consider the disaggregated categories of non-teacher expenditures. Future research could delve further into this.

2. LITERATURE REVIEW

The education production function is the basis of my research. A production function describes the maximum level of output possible from combinations of inputs. In an education setting, examples of output are students' test scores or high school drop-out rates. Examples of inputs are class size and number of hours in the school day. The input variables can be separated into two types: school input variables and student input variables (Lamdin, 1996). School input variables, like student-teacher ratio and expenditure per-pupil, are easier to change than student input variables, like socioeconomic status and innate student ability. School input variables are subject to direct changes from educational policies. Policymakers focus on school inputs for this reason, but research provides mixed results on the relationship between these inputs and education outputs. Out of estimates from 377 separate production-functions, 71% exhibited no correlation between teacher experience and student performance (Hanushek, 2010). Education production functions do not have a clear list of inputs consistently used because of this uncertainty of the relationship between the inputs and output.

One problem that occurs with the estimation of the education production function is omitted variable bias. It's difficult to include all necessary input variables that affect student achievement because they might not be available with the given data or they may not be measurable. Goldhaber and Brewer ameliorated omitted variable bias in their study by using value-added production functions to control for previous knowledge or ability (Goldhaber and Brewer, 1997). Stanca estimated the effect of lecture attendance on test scores in an introductory microeconomics course using fixed and random effects in the education production function (Stanca, 2006). While these approaches eliminate some bias in the coefficients, there may still be omitted variable bias in the estimations.

The topic of the effectiveness of school spending has been widely covered in the past and is still debated today. Debate on the topic began in 1966 with the release of the report “Equality of Educational Opportunity,” in which Coleman presented evidence that school funding does not have a significant effect on student’s test scores (Coleman, 1966). Twenty years later, Hanushek compiled data from the educational production function from 38 different articles and books and 187 equations to gain insights on whether money matters in schools. He found only 20% of the estimates showed a positive and statistically significant relationship between per-pupil expenditure and student outcome (Hanushek, 1986). In response to Hanushek’s article, researchers reanalyzed Hanushek’s sample using a stronger statistical method and found evidence of a positive effect of school resources on student achievement (Hedges, Lane, and Greenwald, 1994).

Clashing evidence has fueled research regarding the importance of money in public education. While some researchers show the amount of money in a school budget does not affect student achievement (Hanushek, 1986; Okpala, Okpala, and Smith, 2001), other researchers provide evidence that expenditures plays a significant role in student test scores and other long-run outcomes (Lafortune, Rothstein, and Schanzenbach, 2018; Jackson, Johnson, and Persico, 2016; Ram, 2004; Payne and Biddle, 1999). With varying methodologies and models producing mixed results, no consensus has been reached on the effect of school funding on student achievement.

Researchers have gone beyond aggregated expenditure data to consider specific categories of school resource expenditures. The categories researchers have focused on include teacher salaries, administrative services and books and technology. There exists mixed evidence on the effect of fund allocation on student achievement. Some studies find positive effects of increasing expenditures in certain categories, specifically categories directly tracked to the classrooms like instructional support materials (Archibald, 2006; Elliot, 1998). Cobb-Clark and Nikhil's study on the allocation of school resources in Australia found evidence that spending on experienced teachers is linked to writing achievement at the elementary school level (Cobb-Clark and Nikhil, 2016). Increased spending on learning and teaching support materials is strongly associated with lower Grade 1 and Grade 7 repetition rates in two provinces in South Africa (Boateng, 2014). Okpala, Okpala, and Smith, however, use a sample of schools from a low-income county in North Carolina find that expenditures on instructional supplies were not significant in explaining mathematics test scores (Okpala, Okpala, and Smith, 2001).

Increases in teacher salaries might result in increased teacher quality, which may influence student achievement. Some research has been done into the effect of teacher wages on student test scores. Currall et al. studied the relationship between pay satisfaction and organizational outcomes using survey results from 6,394 public school teachers. They found that pay satisfaction was positively correlated to school district-level academic performance (Currall et al., 2005). Loeb and Page provide evidence that raising teachers' wages by 10% would reduce high school dropout rates by between 3% and 6% (Loeb and Page, 2000). Many studies also show a connection between high quality teaching and improved test scores, higher future wages, and greater education attainment (Aaronson, Barrow, and Sander, 2007; Chetty et al., 2011; Archibald, 2006; Darling-Hammond, 2000). Teachers' salaries and teacher quality could have a positive impact on student achievement.

Although this topic has been covered by many researchers in the past, no clear consensus on the effect of school funds and resources on student test scores means there is still more to learn. My research differs from past studies in a few ways. First off, I use data from 2012 to 2017, which is more recent than other studies. Second, I focus on a wider geographical region than most studies. I include districts from the whole state of Massachusetts, rather than just from a certain region. Lastly, I model three outcomes on the MCAS exam instead of just passing and not passing. This allows me to consider improvements– from failing to needing improvement and needing improvement to passing– that would not be detected in a two-outcome model.

Public-School Finance in Massachusetts

Education funding in Massachusetts relies on local revenue, state revenue, and federal revenue. Compared to other states, Massachusetts more heavily relies on local sources, like property taxes, to fund its public education. In fact, in 2010, the state ranked seventh most dependent on local dollars and fourth least dependent on federal dollars to fund education (Gustafson, 2012). Because Massachusetts is a relatively wealthy state and federal funding targets low-income districts, education is funded mainly by local and state revenue.

The Chapter 70 program establishes the amount of state aid a district receives in Massachusetts. The formula considers how much the local government can raise through property taxes to fund education in its district and how much the state would need to contribute to ensure that a district has sufficient resources to provide education to all its students. The program strives to equalize expenditures per-pupil by transferring more aid to low-income districts and less aid to wealthy districts.

According to the Massachusetts Department of Elementary and Secondary Education, Chapter 70 aid is determined by the following simplified steps. The first is a calculation of the minimum spending requirements of a school district known as the foundation budget. The second step is calculating the required local contribution or how much local tax revenue a district can raise and allocate to education spending. Chapter 70 fills the gap between the local contribution of the district and its foundation budget. Districts may contribute more than the required local contribution, which creates inequality in total funding across the state. Wealthy districts have the capital to allocate more funds towards education, while some poor districts are unable to meet the required local contribution set by the state. Even with the gap in total school expenditures between districts, Massachusetts spends more in terms of per-pupil expenditures than the national average. In 2010, the cost-adjusted per-pupil expenditure in Massachusetts was $13,454 while the national average that year was $10,847, roughly a $3,000 difference (Gustafson, 2012). Once the total expenditure per-pupil budget is finalized for each district, the administration of the district decides how to allocate the funds to categories of expenditures like teacher salaries.

3. DATA DESCRIPTION

In this study, I use data from the Massachusetts Department of Elementary and Secondary Education. The website provides information on all districts and schools within the state. I collected data on districts that provide levels of education from kindergarten through high school. From this specification, I include 225 school districts in my dataset. For each district, I collected the proportion of students who passed, needed improvement, and failed on both the 10^{th} grade English MCAS exam and the 10^{th} grade Mathematics MCAS exam. The proportion of 10^{th} grade students in a district who pass an exam is the sum of the proportions of students whose score is either advanced or proficient on an exam. I compiled the assessment result data for the years 2013 through 2017.

Table 3.1: Descriptive Statistics of MCAS Test Results

Variables	Mean (standard deviation)	Minimum	Maximum
*Proportion who **pass** the **English MCAS** exam*	0.9262 (.0618)	0.62	1
*Proportion who **need improvement** on the **English MCAS** exam*	0.0505 (.0445)	0	0.26
*Proportion who **fail** the **English MCAS** exam*	0.0232 (.0221)	0	0.18
*Proportion who **pass** the **Mathematics MCAS** exam*	0.8190 (.1160)	0.35	1
*Proportion who **need improvement** on the **Mathematics MCAS** exam*	0.1197 (.0704)	0	0.35
*Proportion who **fail** the **Mathematics MCAS** exam*	0.0613 (.0549)	0	0.38

The descriptive statistics of the MCAS test results in Table 3.1 show the differences between districts. The average proportion of 10th grade students who pass the English MCAS exam is about 10 percentage points higher than the average proportion who pass the Mathematics MCAS exam. Also, the minimum pass rate on the English exam is double the minimum pass rate on the Mathematics exam. The proportions of results on the Mathematics MCAS exam have more variation than on the English MCAS exam. Because results are more spread out on the Math MCAS exam, the expenditure variables may have a larger effect on these outcomes than on the outcomes of the English MCAS exam.

I obtain the school finance data in years 2012 to 2017 from the Massachusetts Department of Elementary and Secondary Education website as well. School finance data is only available at the district level. The dataset includes the total in-district expenditures and ten categories of in-district expenditures: administration, instructional leadership, teachers, other teaching services, professional development, instructional materials/equipment/technology, guidance/counseling/testing, pupil services, operations and maintenance, and benefits and fixed charges. Table A.1 in the appendix describes the types of expenditures fit into each of the ten categories. All expenditures used in my dataset are given as per full-time enrolled pupil, rather than a total amount spent on each category for the year. In my model, I use total in-district expenditures per-pupil and the breakdown of total in-district expenditures into teacher expenditures per-pupil and non-teacher expenditures per-pupil. The teacher expenditures per-pupil category includes spending on classroom teachers and specialist teachers like art or gym. Although the total in-district expenditure data included in my dataset is for 2012 to 2017, the breakdown of expenditures is only recorded for 2013 to 2017.

Table 3.2: Descriptive Statistics of Expenditures and District Control Variables

Variable	Mean (standard deviation)	Minimum	Maximum
Total In-district Expenditures Per-Pupil	\$14,020.03 (2531.29)	\$9,351.93	\$29,621.61
Teacher Expenditures Per-Pupil	\$5,532.56 (892.97)	\$3,747.96	\$10,902.67
Median Household Income	\$81,770.92 (27,162.01)	\$31,628	\$201,200
Urban	0.244 (0.430)	0	1
Suburban	0.659 (0.474)	0	1
Rural	0.097 (.296)	0	1
Proportion of White Students	0.784 (0.189)	.045	.991
Proportion of African-American Students	0.042 (0.067)	.001	.57
Proportion of Hispanic Students	0.095 (0.138)	0	.922
Proportion of Asian Students	0.047 (0.0600)	0	.379
Proportion of Other Students	0.032 (0.0180)	.001	.122
Student-Teacher Ratio	13.46 (1.596)	8.4	21
Teacher Retention Rate	0.881 (0.056)	.36	.984
% Students Chronically Absent	0.108 (.052)	.016	.318
Number of Students	3,771.4 (4,791.36)	414.1	56,858.8

Table 3.2 provides descriptive statistics of expenditure as well as the district control variables. There is a wide range of total in-district expenditures per pupil, from a minimum of just under \$10,000 per-pupil to a maximum of just under \$30,000 per-pupil. However, 97% of the observation fall between \$10,000 per-pupil and \$20,000 per-pupil. Although the Chapter 70

program is in place to ensure equity, there is still a big gap between the lowest per-pupil expenditure and the highest. The amount of per-pupil expenditures spent on teachers also varies quite a bit, from a minimum of $3,747 per-pupil to a maximum of $10,900 per-pupil. The average teacher expenditure per-pupil accounts for almost 40% of the average total expenditures per-pupil. The large amount of per-pupil expenditure spent solely on teacher salaries indicates the value that school districts place on teachers.

I use control variables in my model to account for any differences between districts that change over time and would not be picked up by the district fixed effects. I collected data for the median household income, location, total number of pupils, racial composition of the students, student-teacher ratio, teacher retention rate, and percent of students chronically absent (absent for over 10% of school days) for each school district. Data on median household income for each year in each district came from the U.S. Census Bureau 2012-2016 American Community Survey 5-Year Estimates. Because the median household income will be released in September, I obtain data between 2012 and 2016. To avoid losing observations, I use a 1-year lag for median household income in the model. It's appropriate to use a 1-year lag for median income because it takes time for changes in income to trickle down and affect a student's education. The change is not immediate. For regional school districts, I use a weighted average of the median household income calculated using the median household income of each town in the district and weighting based on the total population of the town. In most of the regional school districts, the towns within the district had similar median household incomes. From Table 3.2, the median household incomes of districts in my dataset range from $31,628 to $201,200, a difference of around $170,000.

The location of the district is categorized as either urban, suburban, or rural. I use a classification system released by the Metropolitan Area Planning Council (MAPC), a government regional planning agency in Massachusetts, to decide which location category each district would fit into. MAPC identified five basic community types across the state: Inner Core, Regional Urban Centers, Maturing Suburbs, Developing Suburbs, and Rural Towns. I aggregated Inner Core and Regional Urban Centers to create my urban location category. I aggregated Maturing Suburbs and Developing Suburbs to create my suburban location category. The Rural Towns community type makes up my rural location category. In my dataset, 24.4% of the districts are urban, 65.9% are urban, and 9.7% are rural. Because the location type of the district is constant through the years for each district, the location variable is not included for the estimations with district fixed effects to avoid perfect multicollinearity.

The other control variables are provided by the Massachusetts Department of Elementary and Secondary Education for each district. I include the total number of pupils in the district, the racial composition of students in the school district, student-teacher ratio, teacher retention rate, and percent of students considered chronically absent. Student-teacher ratio is used as an indicator of class size. Although they are not equal because not all teachers counted in the student-teacher ratio are directly teaching students, one expects that a higher student-teacher ratio is related to larger class sizes. Multiple studies have found that smaller class sizes improve students' test scores (Schanzenbach, 2010; Chetty et al., 2011; Jepsen and Rivkin, 2009). There is evidence that teacher retention rate has a significant effect on achievement as well. Ronfeldt, Loeb, and Wyckoff show that high teacher turnover results in lower test scores in both English and Math and the effect is especially strong in schools with high proportions of low-performing students (Ronfeldt, Loeb, and Wyckoff, 2012). Lastly, I include the percent of students considered chronically absent. These students have been absent from school 10% of the whole school year. Since the mandatory length of a school year is 180 days and there are approximately 21 school days in a month, this is the equivalent of missing approximately a month of school. Adding this variable in the model will control for the chronically absent students who receive poor test scores because they were not in school and did not learn anything. High levels of chronic absenteeism could also affect the learning environment for regularly-attending students and slow the pace of learning to try to catch-up the frequently absent students.

4. MODEL

Fractional Logit Model

I use a fractional logit model to estimate the effect of expenditures on the proportion of 10^{th} grade students in the district who pass the English MCAS exam and Mathematics MCAS exam. The baseline is the proportion of 10^{th} grade students in the district who do not pass the exam. The "not passing" rate is the consolidation of the needs improvement and failing rates.

$$PROP_{pass} = \frac{e^{\alpha_{pass}+\beta_{pass}X+\delta_{pass}C+\rho_{pass}D+\varepsilon_{pass}}}{1+e^{\alpha_{pass}+\beta_{pass}X+\delta_{pass}C+\rho_{pass}D+\varepsilon_{pass}}}$$

$$\frac{PROP_{pass}}{1-PROP_{pass}} = e^{\alpha_{pass}+\beta_{pass}X+\delta_{pass}C+\rho_{pass}D+\varepsilon_{pass}}$$

$$\mathbf{ln}\left[\frac{\boldsymbol{PROP_{pass}}}{\mathbf{1}-\boldsymbol{PROP_{pass}}}\right] = \boldsymbol{\alpha_{pass}} + \boldsymbol{\beta_{pass}X} + \boldsymbol{\delta_{pass}C} + \boldsymbol{\rho_{pass}D} + \boldsymbol{\varepsilon_{pass}}$$

In the equations above, $\mathbf{PROP_{pass}}$ is the proportion of 10^{th} grade students in a district who pass the English or Mathematics MCAS exam, **X** is the vector of one-year lagged categories of expenditures (total in-district expenditures, teacher expenditures, non-teacher expenditures), **C** is the vector of control variables, and **D** is a vector of district dummy variables for the district fixed effects. The control variables are median household income, location dummies, total number of students, racial composition of the students, student-teacher ratio, teacher retention rate, and percent of student chronically absent. The coefficient of interest is $\boldsymbol{\beta_{pass}}$: the coefficients for the expenditure variables. If any of these coefficients is significant, it means that allocating extra money to that expenditure category is significant in changing the log-odds of proportion of 10th grade students who pass versus the proportion of 10th grade students who do not pass the English or Mathematics MCAS exam.

Multinomial Fractional Logit Model

I use a multinomial fractional logit model to estimate the effect of expenditures on the log-odds of passing and failing on the English and Mathematics MCAS exams, using needing improvement as the baseline category. The three proportions I use are 1.) $\mathbf{PROP_{pass}}$, or the proportion of students who pass the 10th grade English (Mathematics) MCAS exam 2.) $\mathbf{PROP_{ni}}$, or the proportion of students who need improvement on the 10th grade English (Mathematics) MCAS exam and 3.) $\mathbf{PROP_{fail}}$, or the proportion of students who fail the 10th grade English (Mathematics) MCAS exam. By modeling with a multinomial logit, I allow for multiple outcomes on the MCAS exams, instead of passing and not passing. Rather than additional expenditures bumping up the passing rate by lowering the non-passing rate, additional expenditures could be shifting up the proportion of students with needs improvement score by decreasing the number of students with a failing score. Although these students with a needs improvement score would not be passing, the extra money still produces better scores on the exam. The fractional logit model using proportion of student who pass the English or Mathematics MCAS exam does not account for this improvement within the non-passing score category. Questions regarding movement in the proportions of students needing improvement and failing these exams when additional funds are distributed to a district can be answered using the multinomial fractional logit model. The details on the formation of a model that can be estimated are below. The equations I estimate are (4.1) and (4.2).

$$PROP_{pass} = \frac{e^{\alpha_1+\beta_1 X+\delta_1 C+\rho_1 D+\varepsilon_{pass}}}{e^{\alpha_1+\beta_1 X+\delta_1 C+\rho_1 D+\varepsilon_1} + e^{\alpha_2+\beta_2 X+\delta_2 C+\rho_2 D+\varepsilon_2} + 1}$$

$$PROP_{ni} = \frac{1}{e^{\alpha_1+\beta_1 X+\delta_1 C+\rho_1 D+\varepsilon_1} + e^{\alpha_2+\beta_2 X+\delta_2 C+\rho_2 D+\varepsilon_2} + 1}$$

$$PROP_{fail} = \frac{e^{\alpha_2+\beta_2 X+\delta_1 C+\rho_1 D+\varepsilon_2}}{e^{\alpha_1+\beta_1 X+\delta_1 C+\rho_1 D+\varepsilon_1} + e^{\alpha_2+\beta_2 X+\delta_2 C+\rho_2 D+\varepsilon_2} + 1}$$

$$\frac{PROP_{pass}}{PROP_{ni}} = e^{\alpha_1+\beta_1 X+\delta_1 C+\rho_1 D+\varepsilon_1}$$

$$\boldsymbol{ln\left[\frac{PROP_{pass}}{PROP_{ni}}\right] = \alpha_1 + \beta_1 X + \delta_1 C + \rho_1 D + \varepsilon_1} \qquad (\mathbf{4.1})$$

$$\frac{PROP_{fail}}{PROP_{ni}} = e^{\alpha_2+\beta_2 X+\delta_2 C+\rho_2 D+\varepsilon_2}$$

$$\boldsymbol{ln\left[\frac{PROP_{fail}}{PROP_{ni}}\right] = \alpha_2 + \beta_2 X + \delta_2 C + \rho_2 D + \varepsilon_2} \qquad (\mathbf{4.2})$$

As in the previous model, **X** is the vector of 1-year lagged expenditure categories (total in-district expenditures, teacher expenditures, non-teacher expenditures), **C** is the vector of control variables, and **D** is a vector of district dummy variables. The coefficients of interest are $\boldsymbol{\beta_1}$ and $\boldsymbol{\beta_2}$ the coefficients for the expenditure variables. $\boldsymbol{\beta_1}$ represents how a monetary change in expenditures affects the log odds of a district's students passing the exam versus needing improvement on the exam. $\boldsymbol{\beta_2}$ represents how a monetary change in expenditures affects the log odds of a district's students failing the exam versus needing improvement on the exam.

5. RESULTS AND DISCUSSION

Fractional Logit Model

The first model I estimate is the fractional logit model with the one-year lagged total in-district expenditures per-pupil as the variable of interest. I use the *fracreg logit* command in Stata to fit a logit distribution for the proportion of students in a district who pass the MCAS exams because my dependent variable contains values between 0 and 1. The results of the analysis are in Table 5.1 for both the proportion of 10^{th} grade students in the district who pass the English MCAS exam and the proportion of 10^{th} grade students in the district who pass the Mathematics MCAS exam as response variables.

From the preferred estimation with district fixed effects, there is no evidence that the one-year lag of total in-district expenditures per-pupil has a significant effect on the log odds of the proportion of 10^{th} grade students in a district that pass the English MCAS exam or the Mathematics MCAS exam. The p-values for the lagged total in-district expenditure coefficients are well above any relevant alpha level for both model estimations. Compared to the model estimations performed without the district effects, the coefficients on expenditures became insignificant, lower, and even switched signs when district dummies were included. The drastic change when adding the district fixed effects shows that omitted variable bias created unreliable coefficients. The unobserved variables captured with the district dummy variables have a greater effect on the log odds of a district's students passing relative to not passing the MCAS exams than the lagged total in-district expenditures in the district.

Table 5.1: Fractional Logit Model with Total In-District Expenditures as the Variable of Interest

	Dependent: pass_eng				**Dependent: pass_math**			
	Coeff. (Std. Err.)	P>|z|	Coeff. (Std. Err.)	P>|z|	Coeff. (Std. Err.)	P>|z|	Coeff. (Std. Err.)	P>|z|
Lagged total in-district expenditure (in thousands of dollars per-pupil)	**.0161* (.0096)**	0.095	.0042 (.0190)	0.823	**.0310*** (.0085)**	0.000	-.0120 (.0148)	0.415
Lagged income (in thousands of dollars)	**.0149*** (.0011)**	0.000	-.0034 (.0025)	0.172	**.0137*** (.0009)**	0.000	.0021 (.002)	0.289
Urban	**-.0806* (.0425)**	0.058	-	-	-.0538 (.0356)	0.131	-	-
Rural	**.238*** (.0665)**	0.000	-	-	**.1470*** (.0489)**	0.003	-	-
Proportion of African American Students	**-1.087*** (.2034)**	0.000	1.045 (1.954)	0.593	**-1.05*** (.2027)**	0.000	-.3707 (1.761)	0.833
Proportion of Hispanic Student	**-1.134*** (.1173)**	0.000	-.4803 (.7890)	0.543	**-1.106*** (.1243)**	0.000	-.6578 (1.015)	0.517
Proportion of Asian Students	.1518 (.2463)	0.538	1.840 (1.679)	0.273	**1.465*** (.299)**	0.000	0.6967 (1.296)	0.591
Proportion of Other Race Students	**-2.006** (.9445)**	0.034	-.2106 (2.349)	0.929	**-1.324* (.7790)**	0.089	-2.880 (2.169)	0.184
Student-Teacher Ratio	**-.0318** (.0133)**	0.017	.0195 (.0182)	0.284	-.0166 (.0112)	0.138	.0113 (.0151)	0.453
Teacher Retention	**.6579*** (.2324)**	0.006	.1151 (.2378)	0.628	**1.142*** (.2348)**	0.000	**.5803** (.2363)**	0.014
Chronic Absence	**-2.926*** (.481)**	0.000	.2356 (.7547)	0.755	**-3.297*** (.425)**	0.000	-.7270 (.5589)	0.193
Number of Students (in thousands)	**.0042** (.0020)**	0.041	**-.1065** (.050)**	0.033	**.0081*** (.0021)**	0.000	-.053 (.0403)	0.189
Constant	**1.647*** (.3513)**	0.000	**2.531*** (.5171)**	0.000	-.2097 (.3255)	0.519	**1.109*** (.4876)**	0.023
District fixed effects?	NO		YES		NO		YES	
Number of observations	1,125		1,125		1,125		1,125	

Wald chi2	2839.53		52305.52		3146.43		36941.5	
Prob > chi2	0.00000		0.00000		0.00000		0.00000	
Pseudo R^2	0.0655		0.0808		0.0711		0.0854	

*=significant at α=0.10; **=significant at α=0.05; ***=significant at α=0.01

Although there is no significance of the one-year lag of total in-district expenditures per-pupil on the passing rates on the English and Math MCAS exams, there could be one or more significant expenditure category that is hidden by the insignificance of other expenditure categories when the expenditures are aggregated into a total. For this reason, I estimate the fractional logit model with one-year lagged teacher expenditures per-pupil and one-year lagged non-teacher expenditures per-pupil as the variables of interest. The results of this analysis are found in Table 5.2 for both the proportion of 10th grade students in the district who pass the English MCAS exam and the proportion of 10th grade students in the district who pass the Mathematics MCAS exam as response variables.

The results of the model including district fixed effects with one-year lagged total in-district expenditures split into teacher expenditures and non-teacher expenditures shows that one-year lagged teacher expenditures shows a significant and positive effect only on the proportion of 10th grade students who pass the Mathematics MCAS exam. The effect of the one-year lagged teacher expenditures is insignificant on the proportion of 10th grades students who pass the English MCAS exam. Also, the one-year lagged non-teacher expenditures is significant (and negative) in the estimation for the Mathematics MCAS exam but not for the estimation with the English MCAS exam. This suggest expenditures affect learning and the ability to pass the exams in these two subjects differently.

Table 5.2: Fractional Logit Model with Teacher and Non-Teacher Expenditures as the Variables of Interest

	Dependent: pass_eng				**Dependent: pass_math**			
	Coeff. (Std. Err.)	P>|z|	Coeff. (Std. Err.)	P>|z|	Coeff. (Std. Err.)	P>|z|	Coeff. (Std. Err.)	P>|z|
Lagged teacher expenditures (in thousands per-pupil)	**.1046*** (.0402)**	0.009	.0507 (.058)	0.382	**.0891*** (.0282)**	0.002	**.1469*** (.0539)**	0.006
Lagged non-teacher expenditures (in thousands per-pupil)	-.0119 (.015)	0.428	.0179 (.0314)	0.569	.0175 (.0127)	0.169	**-.0564** (.0273)**	0.039
Urban	**.0141*** (.0013)**	0.000	-	-	**.0132*** (.0010)**	0.000	-	-
Rural	**-. 0882* (.0476)**	0.064	-	-	-.0610 (.0402)	0.129	-	-
Lagged income (in thousands of dollars)	**.2371*** (.0730)**	0.001	.0012 (.0040)	0.755	**.1465*** (.0537)**	0.006	.0041 (.0032)	0.193
Proportion of African-American Students	**-1.19*** (.2187)**	0.000	-1.049 (2.983)	0.725	**-1.654*** (.225)**	0.000	-2.218 (2.577)	0.389
Proportion of Hispanic Students	**-1.14*** (.1328)**	0.000	.4785 (.8744)	0.584	**-1.089*** (.1366)**	0.000	.9001 (1.40)	0.521
Proportion of Asian Students	-.0065 (.2724)	0.981	2.238 (2.323)	0.335	**1.438*** (.3357)**	0.000	-2.292 (1.806)	0.204
Proportion of Other Race Students	**-2.279** (1.017)**	0.025	-.9643 (2.653)	0.716	-.8808 (.8555)	0.303	-4.135 (2.766)	0.135
Student-Teacher Ratio	-.0182 (.0164)	0.268	.0252 (.0230)	0.272	-.0074 (.0132)	0.576	.0153 (.0181)	0.396
Teacher Retention	**.4869** (.2382)**	0.041	.1677 (.2320)	0.470	**1.034*** (.2419)**	0.000	**.5395** (.2238)**	0.016
Chronic Absence	**-2.94*** (.5306)**	0.000	-.4313 (.8592)	0.616	**-3.415*** (.4538)**	0.000	**-.9145* (.5547)**	0.099
Number of Students (in thousands)	**.0059** (.00234)**	0.012	-.0972 (.0692)	0.160	**.0103*** (.0023)**	0.000	-.0151 (.0538)	0.779
Constant	**1.439*** (.4030)**	0.000	**1.808*** (.6573)**	0.006	-.433 (.3571)	0.225	.5228 (.5453)	0.338
District fixed effects?	NO		YES		NO		YES	
Number of observations	900		900		900		900	

Wald chi2	2238.64		52665.01		2627.11		74491.21	
Prob>chi2	0.00000		0.00000		0.00000		0.00000	
Pseudo R^2	0.0675		0.0830		0.0736		0.0885	

*=significant at α=0.10; **=significant at α=0.05; ***=significant at α=0.01

An extra $1,000 per-pupil in the school budget allocated fully to teacher expenditures increases the log odds of passing the Mathematics MCAS exam by 0.1469 the following year, holding all other variables constant. An extra $1,000 per-pupil in the school budget allocated fully to non-teacher expenditures decreases the log odds of passing the Mathematics MCAS exam by 0.0564 the following year, holding all other variables constant. Not adding any of the extra funds to teachers' salaries is expected to decrease the proportion of the students in the district who pass the 10th grade Mathematics MCAS exam.

Comparing the estimations with and without the district fixed effects, one can clearly see significant differences. For one, the coefficient on the lagged teacher expenditures per-pupil is significant in the English MCAS exam estimation without district fixed effects and insignificant in the estimation with them. The magnitude of the coefficient is also twice as large in the estimation without district fixed effects than with them. From this information, the coefficient on the lagged teacher expenditures per-pupil in the estimation without district fixed effects faced upward bias due to the unobserved variables in the error term that are captured by adding district dummy variables. Looking at the differences in the estimations using the Mathematics MCAS exam, the coefficient on the lagged teacher expenditures per-pupil faced downward bias from the unobserved variables in the error term. Adding the district fixed effects almost doubled the size of the coefficient. As for the lagged non-teacher expenditure per-pupil variable, the coefficient goes from being positive and insignificant with no district dummy variables to negative and significant with district dummy variables. These changes from including district fixed effects show the dangers of unobserved but important variables in the error term. Some of the omitted variable bias is alleviated by adding district fixed effects.

Why is the effect of teacher and non-teacher expenditures per-pupil significant on the log odds of the passing rate on the Mathematics MCAS exam and not on the log odds of the passing rate on the English MCAS exam? One reason could be that teacher expenditure does not correlate as well with the proportion of students who pass the 10^{th} grade English MCAS exam as other variables. A student's home life and parental involvement could have more correlation than school expenditures. For instance, exposure to books and conversations with advanced vocabulary help students improve their English skills and can occur naturally outside of school. Math requires practice that may not be as natural outside of school. In this case, the school administrators may be more willing to spend extra money on a good math. Also, when a school does not put extra funds towards teachers' salaries, the math teachers could feel less willing to teach productively. Learning math could be more affected by the teacher and the teacher's characteristics than learning English. These are possible reasons why the effect of teacher expenditures could be more correlated with the proportion who pass the Mathematics MCAS exam than the English MCAS exam. More research could look into why school resources affect scores in English and mathematics differently.

Another question posed from my analysis is why spending more on teachers would improve student test scores. One possible connection between the two is improved teacher quality. The higher pay may reflect an increase in the productivity of teachers or an increase in the quality of the teachers. Because I include the student-teacher ratio and number of students in the district, the number of teachers in the district must also be fixed when considering the effects of changes in teacher expenditures per-pupil. Therefore, in the case of better teacher quality, either the current teachers in the district may increase their quality or the district may replace low-quality teachers with high-quality teachers when teacher salaries increase. Another theory is the higher spending on teachers could be due to overtime work by teachers that is paid for by the school district. Examples of overtime work could include spending extra time planning lessons or tutoring after school hours. It may also be true that teachers affected by the pay jump become more satisfied with their salaries. The increased pay satisfaction could lead to improved school district-level academic performance (Currall et al., 2005). These examples increase a teacher's salary, improve the teacher's quality, and help students learn more. The ideas posed are theories, but future research could provide evidence that support or oppose these theories.

The models showed although increasing total in-district expenditures per-pupil may not be significant in raising test scores, the allocation of extra funds matters, especially for math test scores. The significance of teacher expenditures per-pupil and non-teacher expenditures per-pupil for the passing rate on the 10^{th} grade Mathematics MCAS exam is hidden when the effect of expenditures is examined as a total. When extra funds are distributed efficiently, the passing rate for the MCAS exams should be the highest possible holding other variables, like the teacher retention rate or median household income, constant. Future studies could break down the total expenditure variable even more to find how additional funds in each expenditure category affects test scores in the district.

Robustness Check for Fractional Logit Model

In the fractional logit model, the categories of test outcomes are passing or not passing, with the not passing category a combination of needing improvement and failing the MCAS exams. As a robustness check, I instead combined needing improvement with passing to create new test outcome categories. The fractional logit model in this case estimates the effect of school district expenditures on the log odds of proportions of 10^{th} grade students in a district not failing relative to failing the English and Mathematics MCAS exams. The purpose of the robustness check is to see if the placement of the needs improvement category changes the significance and/or the magnitude of the coefficients. If redefining the test outcomes significantly changes the estimates from the original classification of the fractional logit model, there is reason to follow-up by using the multinomial fractional model to consider three categories of test scores rather than just two.

The results from the robustness check are found in Table 5.3 and 5.4. The most noticeable difference between the fractional logit with a base of failing rather than not passing is that the coefficient on lagged total in-district expenditure per-pupil is significant and negative in the English MCAS exam estimation. That is, adding an extra $1,000 per-pupil to a school district's budget decreases the log odds of the proportion of students in the district not failing relative to failing by 0.07 in the following year, holding all else equal. Adding money to the budget increases the failing rate on the 10^{th} grade English MCAS exam. One possible explanation for this is that the money added to the district is used to help the students who are on the border of passing the test but does not help those on the border of failing. Therefore, the additional funds do not prevent the border students into falling into the failing zone. However,

Table 5.3: Robustness Check of Fractional Logit Model with Total In-District Expenditures as the Variable of Interest

	Dependent: notfail_eng		**Dependent: notfail_math**	
	Coefficient (Std. Err.)	P>|z|	Coefficient (Std. Err.)	P>|z|
Lagged total in-district expenditure (in thousands of dollars per-pupil)	**-.0700**** **(.0305)**	0.022	-.0244 (.0206)	0.237
Lagged income (in thousands of dollars)	-.0071 (.0044)	0.104	.0016 (.0024)	0.506
Proportion of African American Students	-.2443 (3.300)	0.941	.3047 (2.816)	0.914
Proportion of Hispanic Student	**-2.383*** **(1.421)**	0.094	**-2.166**** **(1.042)**	0.038
Proportion of Asian Students	4.041 (2.492)	0.105	**3.548*** **(1.873)**	0.058
Proportion of Other Race Students	-.5570 (4.082)	0.891	-2.438 (2.576)	0.344
Student-Teacher Ratio	.0047 (.0345)	0.890	.0312 (.0213)	0.144
Teacher Retention	-.3704 (.3720)	0.319	.0071 (.3569)	0.984
Chronic Absence	-.1682 (1.235)	0.892	-1.044 (.8757)	0.233
Number of Students (in thousands)	**-.1964***** **(.0738)**	0.008	**-.1379**** **(.0577)**	0.017
Constant	**5.992***** **(.9331)**	0.000	**2.924***** **(.7011)**	0.000
District fixed effects?	YES		YES	
Number of observations	1,125		1,125	
Wald chi2(234)	9835.21		12679.04	
Prob > chi2	0.00000		0.00000	
Pseudo R^2	0.0572		0.0804	

*=significant at α=0.10; **=significant at α=0.05; ***=significant at α=0.01

from the previous estimation in Table 5.1, the coefficient on lagged total in-district expenditure is insignificant in the English MCAS exam estimation. Continuing with my theory, this means that the additional funds that may be devoted to pushing needs improvement students into the passing area is not making a significant difference. Data on how funds affect each individual student would provide more insight into this finding.

Another interesting difference comes from the estimation when total in-district expenditure is broken into teacher and non-teacher expenditures in Table 5.4. In the estimation with the Mathematics MCAS exam, the coefficient on the lagged teacher expenditure per-pupil variable is no longer significant. It is also half the magnitude of the coefficient in the estimation from Table 5.2. One reason could be that adding extra funds to teachers' salaries raises students who need improvement up to a passing score but does not have a big impact on raising failing students up to higher scores. The coefficient on the lagged non-teacher expenditures per-pupil in the Mathematics MCAS estimation is significant just like the estimation in Table 5.2. Holding all else equal, an additional $1,000 per-pupil devoted solely to non-teacher expenditures will lower the log odds of the proportion of students in a district who do not fail relative to the proportion who fail by 0.095 in the next year. This means when extra money is not put into teachers' salaries, the proportion of students who fail the Mathematics MCAS exam increases. This is the same finding as when the two test categories being compared were passing and not passing, however, the magnitude of the coefficient is larger in the robustness check.

Table 5.4: Robustness Check for Fractional Logit Model with Teacher and Non-Teacher Expenditures as the Variables of Interest

	Dependent: notfail_eng		**Dependent: notfail_math**	
	Coefficient (Std. Err.)	P>|z|	Coefficient (Std. Err.)	P>|z|
Lagged teacher expenditures (in thousands per-pupil)	-.0493 (.0946)	0.602	.0864 (.0534)	0.105
Lagged non-teacher expenditures (in thousands per-pupil)	-.0208 (.0544)	0.702	**-.095*** (.0345)**	0.006
Lagged income (in thousands of dollars)	-.0009 (.0066)	0.882	**.0087** (.0037)**	0.018
Proportion of African-American Students	-4.707 (4.101)	0.251	-.6231 (3.347)	0.852
Proportion of Hispanic Students	-1.889 (1.538)	0.220	**-2.613** (1.085)**	0.016
Proportion of Asian Students	1.247 (3.371)	0.711	.0535 (2.257)	0.981
Proportion of Other Race Students	.5387 (4.397)	0.902	-5.498* (3.106)	0.077
Student-Teacher Ratio	.0264 (.0394)	0.502	.0273 (.0249)	0.272
Teacher Retention	-.4581 (.3787)	0.226	.2675 (.3366)	0.427
Chronic Absence	.0503 (1.415)	0.972	-.6392 (1.009)	0.527
Number of Students (in thousands)	**-.1769** (.0997)**	0.076	-.1363** (.0664)	0.040
Constant	**4.753*** (1.081)**	0.000	2.356*** (.7564)	0.002
District fixed effects?	YES		YES	
Number of observations	900		900	
Wald chi2(235)	41747.11		17705.65	
Prob>chi2	0.00000		0.00000	
Pseudo R^2	0.0609		0.0830	

*=significant at α=0.10; **=significant at α=0.05; ***=significant at α=0.01

From this test, I find the placement of the needs improvement category matters when determining if school district expenditures affect test outcomes on the English and Mathematics MCAS exam. This shows that separating the test outcomes into three categories rather than two categories can provide more insight on the connection between expenditures and student achievement.

Multinomial Fractional Logit Model

After finding estimates for the fractional logit model, I estimated the multinomial fractional logit model. This model allows for multiple outcomes on the MCAS exam, rather than passing and not passing or not failing and failing. The outcomes I consider are the proportion of students who pass, need improvement, or fail the 10^{th} grade English and Mathematics MCAS exams. I use Maarten L. Buis's Stata command *fmlogit* to fit the fractional multinomial logit model, a multivariate generalization of the fractional logit model (Buis, 2017). Tables 5.5 and 5.6 show estimates from the multinomial fractional logit model using the one-year lagged teacher and non-teacher expenditures per-pupil as the explanatory variables. The base category in these estimations is the proportion of 10^{th} grade students who need improvement on the English MCAS exam and the proportion of 10^{th} grade students who need improvement on the Mathematics MCAS.

In Table 5.5, the coefficient on the one-year lag of teacher expenditures per-pupil is insignificant in the estimation of the log odds of a district's students passing versus needing improvement on the 10^{th} grade English test. The same coefficient is also insignificant in the estimation of the log odds of a district's students failing relative to needing improvement on

Table 5.5: Multinomial Fractional Logit Model to Estimate the Effect of Teacher and Non-Teacher Expenditures on Proportions of Student Performance on the English MCAS Exam

	pass_eng		**fail_eng**	
	Coefficient (Std. Err.)	**P>|z|**	**Coefficient (Std. Err.)**	**P>|z|**
Lagged teacher expenditure (in thousands per-pupil)	.0991 (.0646)	0.125	.1416 (.1042)	0.174
Lagged non-teacher expenditure (in thousands per-pupil)	.0345 (.0346)	0.319	.0541 (.0601)	0.368
Lagged income (in thousands)	.0025 (.0049)	0.604	.0034 (.0081)	0.669
Proportion of African American Students	.8551 (3.364)	0.799	5.531 (4.545)	0.224
Proportion of Hispanic Students	1.522 (1.069)	0.155	3.213* (1.882)	0.088
Proportion of Asian Students	3.163 (3.170)	0.318	1.865 (4.645)	0.688
Proportion of Other Race Students	-1.405 (3.331)	0.673	-1.819 (5.550)	0.743
Student-Teacher Ratio	.0232 (.0251)	0.354	-.0051 (.0430)	0.905
Teacher Retention	**.4579* (.2763)**	0.098	.8807** (.4490)	0.050
Chronic Absence	-.6542 (1.014)	0.519	-.660 (1.675)	0.694
Number of Students (in thousands)	-.0555 (.0653)	0.396	.1298 (.0872)	0.137
Constant	**1.360* (.7621)**	0.074	**-3.249*** (1.252)**	0.009
District fixed effects?	YES			
Number of observations	900			
Wald chi2(470)	708546.78			
Prob>chi2	0.00000			

Base outcome: proportion of 10th grade students in a district who need improvement on the English MCAS exam; *=significant at α=0.10; **=significant at α=0.05; ***=significant at α=0.01

the English test. These results are consistent with the findings in Table 5.2 and Table 5.4. Spending extra money on teacher salaries does not have a significant impact on improving (or worsening) test scores on the 10^{th} grade English MCAS exam.

Table 5.6 shows the one-year lag of teacher expenditures per-pupil is significant in raising the proportion of passing students by decreasing the number of needs improvement students on the 10^{th} grade Mathematics exam. A $1,000 increase in teacher expenditures per-pupil in the previous year results in a positive, statistically significant change of 0.1552 in the log odds of proportion passing versus proportion needing improvement on the Mathematics MCAS exam. The extra funds towards teachers also has no significant effect on the log odds of proportion failing versus proportion needing improvement on the Mathematics MCAS exam. This finding shows that the positive and significant coefficient on the lagged teacher expenditure per-pupil variable in Table 5.2 for the Mathematics MCAS exam estimation is driven by the needs improvement students being pushed up to passing scores. The lack of significance of the coefficient in the log odds of a district's students failing versus needing improvement estimation is consistent with the finding in Table 5.4.

The coefficients on the lagged non-teacher expenditures per-pupil in Table 5.6 are also consistent with previous results. Starting with the log odds of failing relative to needing improvement on the Math exam, the coefficient is positive and significant. An additional $1,000 distributed solely to non-teacher expenditures will increase the log odds of a district's students failing versus needing improvement by 0.0725 in the next year, all else constant. The needs improvement students who are on the border of failing might drop into the failing zone when additional funds are not allocated toward teachers' salaries. However, there is

Table 5.6: Multinomial Fractional Logit Model to Estimate the Effect of Teacher and Non-Teacher Expenditures on Proportions of Student Performance on the Mathematics MCAS Exam

	pass_math		**fail_math**	
	Coefficient (Std. Err.)	**P>|z|**	**Coefficient (Std. Err.)**	**P>|z|**
Lagged teacher expenditure (in thousands per-pupil)	**.1552** (.0659)**	0.018	.0348 (.0722)	0.630
Lagged non-teacher expenditure (in thousands per-pupil)	-.0337 (.0307)	0.273	**.0725* (.038)**	0.056
Lagged income (in thousands)	.0019 (.0039)	0.613	-.0070 (.004)	0.134
Proportion of African American Students	-2.58 (3.589)	0.472	-1.296 (4.953)	0.793
Proportion of Hispanic Students	2.626 (1.735)	0.130	**4.449618*** (1.541903)**	0.004
Proportion of Asian Students	-3.309 (2.241)	0.140	-2.780 (2.885)	0.335
Proportion of Other Race Students	-3.030 (3.425)	0.376	3.289 (4.014)	0.412
Student-Teacher Ratio	.0077 (.0203)	0.706	-.0204 (.0274)	0.457
Teacher Retention	**.6089*** (.2204)**	0.006	.2177 (.3304)	0.510
Chronic Absence	-.9874 (.6177)	0.110	-.1628 (1.128)	0.885
Number of Students (in thousands)	.0547 (.0697)	0.433	**.177** (.0893)**	0.048
Constant	.7423 (.6224)	0.233	-1.258 (.8652)	0.146
District fixed effects?	YES			
Number of observations	900			
Wald chi2(470)	268733.85			
Prob>chi2	0.00000			

Base outcome: proportion of 10^{th} grade students in a district who need improvement on the Math MCAS exam; *=significant at α=0.10; **=significant at α=0.05; ***=significant at α=0.01

no significant effect of additional funds towards non-teacher expenditures on the log odds of a district's students passing versus needing improvement on the Mathematics MCAS exam.

The multinomial fractional models show consistency with the previous estimations in Table 5.2 and 5.4 as well as add some support to my theory that the needs improvement students who are on the border of either passing or failing the MCAS exam are the most affected by school district expenditures. Individual student data is needed to test this hypothesis. When considering how to allocate extra funds between teacher and non-teacher expenditures, the estimation using the Mathematics MCAS exam suggests that putting that money towards teachers will improve test scores. However, this is an extremely simplistic approach. Throwing money at teachers without considering the functions of all other expenditure categories separately is not a recommended policy. Categories like custodians, bus drivers, building maintenance, and textbooks are necessary and should not be ignored. The ideal option is to break down all expenditure categories to find how each contributes to test scores. Aggregating expenditure categories hides the statistical significance of specific categories and can be misleading. While throwing money at teachers is an ill-advised policy decision, it should be recognized that increasing teacher salaries does have an affect on students' test scores. Looking into why this occurs will lead to a better understanding of the function of a teachers' salary in student achievement and better policy regarding teachers' salaries.

6. CONCLUSION

From my research, I found the amount of money allocated to teachers matters for improving student achievement. Although lagged total in-district expenditures per-pupil was insignificant in my estimations of the fractional logit model, the category of lagged teacher expenditures per-pupil was significant for the passing rate on the Mathematics MCAS exam. This shows that looking at the aggregate of all categories of education expenditures does not show enough information about the effects of money. The results of my estimations show no evidence of an effect of total in-district expenditure per-pupil on the passing rate for the English and Mathematics MCAS exams. However, there is a positive and significant effect of teacher expenditures per-pupil on the passing rate of the 10th grade Mathematics MCAS exam. Teachers' salaries may be important because they reflect boosted productivity and create incentive for high quality teachers to stay in the profession. But just looking at teacher versus non-teacher expenditures is too simplistic. A suggestion to school district officials and future researchers would be to discover how each expenditure category affects student achievement to better allocate extra money in their budget.

A limitation of my research is the aggregated district data. It would be ideal to gather data at the individual level to see the effects of increasing expenditures on individual student test scores by tracking an individual over time. I could gain a better understanding of how students on the border of failing or passing these MCAS exams, specifically the Mathematics exam, are affected by additional money to specific expenditure categories. Also, individual data would allow me to find the demographics of students who most benefit from increases in specific expenditure categories. Another limitation is only including a lag for one year in my model. Ideally, I would account for the fact that students are influenced by the school expenditures made from kindergarten through high school. One lag only allows for the effect of expenditures made the previous year. Another potential problem with my model is the omitted variable bias. I am unable to account for all relevant variables that affect student achievement. For example, parental involvement in education, independent of household income, affects both student test scores and expenditures and is not included in my models. Parents more involved in their child's education will be more willing to practice skills at home. This results in better test scores. More involved parents also advocate for a larger school budget and more local contribution to school expenditures. By adding district fixed effects to my model, I alleviated some of the problems caused by omitted variable bias. However, there is still a possibility that my coefficients are biased and unreliable. Other researchers have solved this issue using regression discontinuity design or a value-added model.

Future research would involve addressing these limitations. I could use a regression discontinuity design focused around districts where the school budget decided at the local level barely passed or barely failed. Also, another addition to the research could be looking at other measures of school achievement. For example, Jackson, Johnson, and Persico found that a 10% increase in per-pupil spending every year for all twelve years of schooling leads to 7.25% higher wages (Jackson, Johnson, and Persico, 2016). The long-term effects of increasing significant categories of expenditures should yield interesting results. Also, with more time, I would like to breakdown the total expenditures per-pupil into more groups. Specifically, I'd like to see how money spent in classrooms (teacher salaries, books, computers, etc.) affects the proportion of students who pass these exams.

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APPENDIX

Table A.1: Categories of Expenditures

Categories of Expenditures	Types of Expenditures in Each Category
Administration	school committee, superintendent, assistant superintendents, business and finance, human resources, legal services, information systems
Instructional Leadership	curriculum directors, department heads, school leadership, curriculum leaders, administration technology, instructional coordinators
Teachers	classroom teachers, specialist teachers (art, gym, etc.)
Other Teaching Services	medical/therapeutic services, substitute teachers, paraprofessionals, librarians, media center directors
Professional Development	professional development leaders, professional days, substitutes for professional development, professional development costs
Instructional Materials/Equipment/Technology	textbooks, instructional software or media, instructional equipment, general classroom supplies, classroom technology, library technologies, library materials (books)
Guidance, Counseling, Testing	guidance/adjustment counselors, testing and assessment, psychological services
Pupil Services	attendance and parent liaisons, medical and health services, transportation services, food services, athletics, other student activities, school security
Operations and Maintenance	custodial services, heating of buildings, utility services, maintenance of grounds, maintenance of buildings, building security systems, maintenance of equipment, extraordinary maintenance, networking/telecommunications, technology maintenance
Benefits and Fixed Charges	employer retirement contributions, employee separation costs, insurance for active employees, insurance for retired employees, other non-employee insurance, rental lease of equipment, rental lease of buildings, short term interest RANSs, other fixed charges, school crossing guards

Table A.2: Descriptive Statistics of Expenditures

Type of expenditure ($ per-pupil)	**Mean (standard deviation)**	**Minimum**	**Maximum**
Administration	$528.22 (193.81)	$201.85	$3,332.07
Instructional Leadership	$930.50 (265.42)	$397.58	$2,321.85
Teachers	$5,532.56 (892.97)	$3747.96	$10,902.67
Other Teaching Services	$1,129.70 (330.08)	$386.88	$2,407.69
Professional Development	$171.71 (124.07)	$10.65	$1,054.99
Instructional Materials /Equipment/Technology	$362.36 (196.75)	$32.46	$1,703.16
Guidance, Counseling, Testing	$4567.60 (144.83)	$113.88	$1,305.36
Pupil Services	$1,357.99 (364.05)	$301.90	$2,930.01
Operations and Maintenance	$1,120.86 (273.47)	$485.71	$2,569.87
Benefits and Fixed Charges	$2,435.17 (726.50)	$899.02	$6,315.50
Total In-district Expenditures	$14,020.03 (2531.29)	$9,351.93	$29,621.61