The Effects of School Violence and Crime on Academic Achievement[1]

By Brandon R. Carroll
Davidson College

This paper tests the effect of criminal and violent acts in North Carolina public middle schools on the academic performance levels of 8th graders, controlling for a variety of relevant factors. Results confirm that these incidents lower academic achievement, as measured by the percentage of students at or above grade level on N.C. 8th Grade Math and Reading End-of-Grade tests; the first incidents are more disruptive to achievement than later incidents; and the relationship is small in magnitude but statistically significant. Specifically, the average marginal influence of one more incident of crime or violence is a 0.138 decrease in Math scores and a 0.143 decrease in Verbal scores; these findings were also strongly inelastic. The paper directs future research to determine if these effects compound over time and to create education policy around them so as to produce a more efficient public sector.

[1] I wish to thank my research supervisor David Martin, PhD at Davidson College for research and editorial support, and reviewer Bobby Kenner, also of Davidson College, for his help in clarifying several points. Responsibility for interpretation of the data remains solely with me.

I. Introduction

Politicians and the general public frequently assert that public schools are failing in their mission to educate America's children. Two aspects of this debate have concerned both declining achievement levels and the safety of the school environment. Surprisingly, little research has been done to investigate the relationship of one to the other. As recently as the late 1990s, school uniforms were being pushed as a policy to reduce distractions in the classroom, and a series of school shootings had turned the nation's attention to violence in public schools.

This paper tests the effect of criminal and violent acts in North Carolina public middle schools on the academic performance levels of 8^{th} graders, controlling for a variety of relevant factors. Results confirm that these incidents lower academic achievement, as measured by the percentage of students at or above grade level on the sum of N.C. 8^{th} Grade Math and Reading End-of-Grade tests; the first incidents are more disruptive to achievement than later incidents; and the relationship is statistically significant. The paper directs future research and to create education policy around these findings so as to produce a more efficient public sector.

The paper isolates the effects on verbal and mathematics scores, correcting for possible statistical correlations caused by suspected omitted variable bias using Seemingly Unrelated Regression. I test the hypothesis that increased incidence of crime and violence in schools either is associated with a more disruptive learning environment. Consequently, as the number of these events rises, academic achievement should decline.

The primary focus of this paper is to quantify the effect of severe disruptions in the school environment on student achievement, thus filling a gap in the literature. The goal is to create a better "production function" for education and to provide a model of evaluation of whole schools by showing that school crime and violence, among other control variables, belongs in this function. Public policy-makers and educators can then use that improved function to achieve more socially efficient outcomes.

II. Literature Review

Measuring academic achievement is a difficult challenge. Some social scientists prefer to measure outcomes such as access to college, employment, income, etc. later in life. While outcome-oriented measures are useful, they are longitudinal, time-series studies and do not allow for immediate corrective action. Others look to standardized tests in order to gauge information useful in the short term to educational outcomes, as will be done here.

The selection of standardized tests as measures of academic performance is not without controversy. For decades, critics have complained that an education cannot be quantified or that those results aggregated in meaningful ways. Improvements have been made to address these concerns. Yet as Hanushek (1986) writes, "Nevertheless, performance on tests is being used to evaluate educational programs, and even to allocate funds, and there are some pragmatic arguments for the use of test scores as output measures."[2] He also concludes that test scores are determinants in future educational progress and that educators place value on them, however incomplete a picture they might present. Beyond these reasons, I selected standardized test data because the dataset for crime and violence is a cross-section, and so a cross-section measure of academic achievement is also necessary.

Certainly North Carolina, under an education accountability program known as the ABCs instituted in the mid-1990s, fits the profile of educators and politicians using test scores as incentives. In 1995, the General Assembly ordered the State Board of

[2] Hanushek, Eric A. "The Economics of Schooling: Production and Efficiency in Public Schools." *Journal of Economic Literature* 24 (1986), pp. 1141-77.

Education to design and implement an accountability testing structure. Following a pilot program, the foundation of the ABCs was applied to the rest of the state the next year. Tests were initially limited to certain subjects in certain years in grades K-8. The State Board of Education established incentives such as $1,000 bonuses for teachers whose students achieved performance targets, and they set up punishments for schools that consistently underperformed and failed to show improvement. The precise nature, timing, and subjects of the tests and incentives have been continuously tweaked. In 2002-03, the ABCs were set to also meet federal No Child Left Behind standards.[3] In addition, advocates of the Tiebout theory claim that voting and migration activity provide evidence that test scores are used by parents and education officials to gauge schools relative to one another and make location decisions.[4]

Discipline is also a factor in creating the learning environment at a school. A survey of behaviors in high schools revealed that a study by Rutter et al. reports that school-level performance is correlated with delinquency, attendance, and misbehavior in school, but did not report the magnitude of the association.[5] School-level policies like "welfare" or "discipline" based approaches and the use of corporal punishment did affect the rates of misbehavior. The studies do not suggest causality: increased performance may reduce incidents of misbehavior, or vice versa, or unknown third factors may explain both.

Private schools have not been shown in the literature to affect consistently public school academic achievement. Sanders (1999) studied the consumption of private school

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[3] "Evolution of the ABCs." <http://www.ncpublicschools.org/docs/accountability/reporting/abc/2004-05/abcevolution.pdf>

[4] O'Sullivan, Arthur., ed. 2000. Urban Economics. 4th edition. McGraw-Hill Higher Education. Tiebout theory expects that economic actors, such as individuals or family units, will located in the geographic area or jurisdiction that provides them with the highest level of utility provided by a bundle of services, tax rates, or characteristics of that area or jurisdiction. In this case, for those with the means to move household location, the performance of local public schools or the availability of private schools will be a factor in that location decision, and standardized test data are used to inform that decision.

[5] Gaddy, Gary D. "High School Order and Academic Achievement," *American Journal of Education*, Vol. 96, No. 4 (Aug., 1988). pp. 496-518

education (including Catholic schools but controlling for their unique characteristics) on public and private school educational outcomes in Illinois.[6] Contrary to expectations, no evidence supported the hypothesis that competition from private schools would increase public school outcomes or for the alternate hypothesis that private schools would lead to a "brain drain" of top students from public schools. Because of the potential that these two effects have offset each other in that study, I include the variables for Charter and Private schools in the model specification.

O'Sullivan (2000) puts forth a basic education production function in his textbook on Urban Economics. In this model, educational performance for the individual student is the result of five primary considerations: class size, school financial resources, the curriculum, peer effects, and parents' background.[7] On the subject of financial considerations, there is a word of caution: in Hanushek's (1986) review of education studies, mixed evidence suggested the effect of financial resources may be somewhat weaker than what would otherwise be expected. In particular, only 13 of 65 studies found that expenditures per pupil had a statistically significant, positive impact on student performance (3 were statistically significant in the unexpected direction).[8]

Parents' education levels influence academic achievement, in part because "a family with a lot of schooling tends to value schooling."[9] Some aspects of intelligence are also hereditary, so to the extent that an earlier generation had the opportunity to realize that intellectual potential, this will be reflected in their own educational attainment. In an analysis of 15 studies, Haveman and Wolfe (1995) determine that "human capital" of the

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[6] Sander, William. "Private Schools and Public School Achievement," Journal of Human Resources. Vol. 34, No. 4. Fall 1999. pp. 697-709.

[7] O'Sullivan, Arthur., ed. 2000. Urban Economics. 4th edition. McGraw-Hill Higher Education.

[8] Hanushek, Eric A. "The Economics of Schooling: Production and Efficiency in Public Schools." *Journal of Economic Literature* 24 (1986), pp. 1141-77.

[9] Levitt, Steven D., and Dubner, Stephen J. *Freakonomics: A Rogue Economist Explores the Hidden Side of Everything*. HarperCollins Books, New York, NY. 2005.

parents, i.e., educational attainment, is significant and quantitatively important.[10] The trend holds true even as the definition of human capital changes from study to study.

Similarly, I expect income to positively influence academic achievement. Higher socioeconomic status leads to higher academic performance in early grades, when it is more an indicator of success than a cause of it.[11] Later, financial affluence may provide the means for students to remain engaged with their interests in the educational process, or provide educational opportunities that would be otherwise unavailable.

Empirical literature suggests that smaller class sizes may have little discernable impact on test scores.[12] Hanushek (1986) also finds that of all the relationships tested in a survey of studies, the relationship between teacher experience and student performance had the strongest results and in the expected direction. Nevertheless, reducing class size is frequently advocated by policy-makers as a means to improve public education, suggesting class sizes are worth including.

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[10] Haveman, Robert, and Wolfe, Barbara. "The Determinants of Children's Attainments: A Review of Methods and Findings." *Journal of Economic Literature*, Vol. 23, No. 4 (Dec. 1995). pp. 1829-1878.

[11] Fryer, Ronald G., Jr., and Levitt, Steven D. "Understanding the Black-White Test Score Gap in the First Two Years of School," *The Review of Economics and Statistics* 86, no. 2. 2004. pp. 447-464.

[12] Hanushek, Eric A. "The Economics of Schooling: Production and Efficiency in Public Schools." *Journal of Economic Literature* 24 (1986), pp. 1141-77.

III. Theory and Model Development

Table 3.1. Variables, Model Names, and Definitions

Tier	Variable & Model Name	Definition
n/a	*Academic Achievement* *TACH / MACH / VACH*	Achievement, the percentage of students at-or-above grade level, as measured by End-of-Grade test scores administered in the spring of year 2004. (*T* stands for the sum, *M* for Math, and *V* for Verbal test scores.)
I	*Severe Discipline, Crime, Violence* *DIS*	Number of serious crime incidents reported by schools to the North Carolina Department of Public Instruction, in year 2003-04
II	*Past Academic Achievement* *PTACH / PMACH / PVACH*	Past Achievement, the test scores for the preceding grade in the preceding year (7th grade in 2002-03).
II	*Charter-Private* *CHPR*	Number of private or charter schools in a county in 2003-04.
II	*Elementary* *EL*	Control for presence of grades K-4: 1 = "yes," 0 = "no"
II	*High School* *HS*	Control for presence of grades 10-12: 1 = "yes," 0 = "no"
III	*Parents' Education (PED)* *PercBA*	Percentage of population with at least a Bachelor's degree in school's zip code, in year 2000
III	*Income* *INC*	Median incomes in school's zip code, in year 2000
III	*Enrollment* *ENR*	School Enrollment, a 7-month attendance average, in year 2003-04
III	*Teacher Experience* *EXPCOM (EXP)*	Average years of teacher experience in year 2003-04 (extrapolated).
III	*Suburban* *SUB*	Control for school location by zip code: 1 = suburban, 0 = rural
III	*Urban* *URB*	Control for school location by zip code: 1 = urban, 0 = rural
III	*Class Size* *CSZ*	Average Class Size, defined as Students/Teachers, in year 2003-04

The purpose of this section is to develop a model that will examine year-on-year increase in student academic achievement, measured at the school level. Table 3.1 lists the variables included in this model. These have been grouped into three tiers: the discipline variable and its interaction effects, control variables of interest, and other control variables. This section will focus primarily on the first, and to some extent, second tiers.

The dependent variable is student achievement in math or verbal standardized tests, as represented by the percentage of students reported as scoring at or above grade level on North Carolina's End-of-Grade (EOG) standardized tests. First, the value used as the dependent variable will be the sum of the two scores. Then, Math and Verbal will be estimated in separate regressions. Data will come from the 2003-04 academic year for eighth graders.[13] I selected eighth graders for a variety of factors. First, the eighth grade is a period of adolescence, which many students find a troubling time. Thus, it is likely the first time that school crime and violence rises to significant enough proportions to possibly affect academic achievement. Further, North Carolina state law requires attendance of all children until the age of 16, and typical eighth graders will be within a range of 12-15 years of age. Thus, poor academic performers in the eighth grade, unless they have been held back repeatedly, are required by law to still attend school, so self-selection bias is avoided.

At this time I would like to note that data for several variables could not be obtained. Ideally, quantitative information would be available on school financial resources and academic curricula alternatives, to highlight those influences that the model largely fails to capture. Other information, such as home school and private/charter school enrollment, better definitions of "urban," or better measures of class size would help to refine the relationships in the data. When interpreting the results, the possibility of omitted variable bias cannot be ignored.

` *Tier I Variables*

Incidents of violence are the most extreme level of classroom disruptions. By law, schools must report these incidents and report them to North Carolina's Department of Public Instruction annually.[14] I expect crime and violence to have an adverse effect on academic performance, for the following reasons. These incidents create distractions within an education environment, reducing the effectiveness of classroom teaching time. These serious incidents also probably reflect numerous less serious incidents that occur on a more frequent basis that also can divert a pupil's attention from the teacher or

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[13] "Education First: NC Report Cards." North Carolina Department of Public Instruction. <www.ncreportcards.org>

[14] "2003-04 Annual Report on School Crime and Violence."State Board of Education and Department of Public Instruction, North Carolina. <http://www.charlotte.com/multimedia/charlotte/KRT_packages/archive/misc/2003-04.pdf>

lesson. Finally, these serious acts may inhibit the educational process by causing individual students and parents to be more concerned about the safety of the school environment than the material being taught there, distracting from the goal of high educational performance.

There is some evidence in the literature to support these assertions. Bosworth (1994) used individual-level survey data to examine the effect of truancy and attitudes towards education on measures of educational attainment, and he concluded that they adversely affect test scores.[15] He noted that higher levels of attainment are linked with the desire of students to be in school; it is insufficient for students to simply be present and do well. It is entirely reasonable that crime and violence issues are symptomatic of poor student attitudes towards education; the students who commit these acts would probably not choose to be in school otherwise, and therefore they would have lower test scores as a result of their inclinations towards truancy.

One or a few of these incidents will likely be sensational in a school community but not result in an overall culture of crime or concerns about safety. Rather, they would be viewed as aberrations. As these sorts of incidents continue, however, the academic environment would be expected to deteriorate significantly. Therefore, the relationship between school discipline problems and academic achievement is expected to accelerate.

The discipline variable should have several interaction effects with other variables. First, higher enrollment is generally associated with higher numbers of disciplinary problems; thus higher enrollment increases the rate at which academic performance is affected by those acts, resulting in lower achievement. Mathematically, this relationship is:

$$\partial^2 ACH_i \Big/ \partial DIS_i \partial ENR_i > 0 \qquad (1)$$

[15] Bosworth, Derek. "Truancy and Pupil Performance." *Education Economics* vol. 2, no. 3 (1994).

Second, children in rural settings may be more desensitized to violence and crime and those in suburban or urban settings. Thus incidents may affect their academic performance more than children attending school in the other settings. Mathematically, these interaction terms are:

$$\partial^2 ACH_i \big/ \partial URB_i \partial DIS_i > 0 \tag{2}$$

$$\partial^2 ACH_i \big/ \partial SUB_i \partial DIS_i > 0 \tag{3}$$

Tier II Variables

Past academic performance will be a primary benchmark to control for variations in achievement by student populations. In addition, including this variable helps to measure year-on-year changes in students attaining grade level skills, based in part on factors that occurred during the past year. Data on school crime and violence will be used from the 2003-04 school year, as will the academic performance data for the dependent variable. Past Academic Achievement, both verbal and math, will be measured by the 2002-03 seventh grade EOG test scores. With the exception of the failure to promote students, over-promoting students, migration, injury or death, or other changes to the composition of the student population at a particular middle school, the same students who took tests in 2002-03 will be taking the tests in 2003-04. I expect past achievement to have a positive marginal influence on current academic achievement, but theory does not suggest whether that marginal influence will be linear, increasing, or decreasing.

A variable representing the sum of the number of registered private and charter schools per county was included as a proxy in order to at least partially capture the substitute schools effects.[16] I predict that a higher demand for alternatives to public schools (private and charter schools) will be associated with lower test scores, perhaps

[16] "Private School Review." <http://www.privateschoolreview.com/state_private_schools/stateid/NC>

because of higher violence. Parents concerned with school violence often enroll their children in substitutes for public schools if they have the means to do so. The ability to withdraw children from public schools depends on the number of substitutes available and the cost of those substitutes. Charter schools, private schools (including religious schools), and home-schooling are the most ubiquitous alternatives. Charter schools and home-schools are free, though the latter are associated with the immeasurable cost of income foregone.

Fourth, the availability of substitute schools will affect academic performance directly, in part through the phenomenon of "brain drain." High achievers may be eligible for scholarships at private schools. Students whose parents believe that they are capable of high attainment may also place their children in alternatives to public schools, extending beyond just private schools to public charter schools and home-schools. These parents are often more involved in their child's education, and so these children would be expected to have better academic performance to some degree anyway. With the removal of these children from public schools, the quality of the peers remaining in public school declines on the margin and the remaining students perform more poorly.

Some schools serving eight graders included Elementary school grades (K-4) or High School grades (10-12). I included dummy variables to control for the different academic setting, especially pertaining to discipline, that these age groups might introduce. The marginal influence of elementary grades cannot be predicted, because the presence of younger students may cause older students to receive either more, less, or the same amount of attention than if they were in a school with just peer age groups. The marginal influence of high school grades cannot be predicted for the same reasons.

Tier III Variables: Controls

Previous research and theory predict that the Tier III variables belong in the model, but the discussion below is cursory so as not to distract the reader from the focus on discipline (see Literature Review, above). Home and peer effects play a substantial role in academic performance. Most studies to date are able to examine these influences directly, because they use individual-level data. This paper takes a more macro approach. Thus census data overlapping a school's service area creates an aggregate "home environment" that can proxy for individual-level effects. By assumption, all students at a school come from this background, so in aggregate this method removes peer effects caused by differences in home environments.

The two most important home environment variables to control for are family income and parents' education level. The variable Income represents the median incomes in a school's zip code. The variable Parents' Education represents the percentage of adults with bachelor's degrees or higher in those same zip codes. The location variables Urban and Suburban (mentioned above as interaction terms) control for whether the school is in a rural, suburban, or urban setting.

School Enrollment affects academic performance in different ways depending on the magnitude of that enrollment. Initially over a range, as enrollment climbs, schools may take advantage of economies of scale to specialize their curricula. They may offer more electives, advanced placement or academically gifted courses, for instance. Yet at some point the benefits of increased enrollment should begin to peter out as diseconomies of scale are introduced.

The quality of teachers can affect academic performance; presumably, teachers with more years of experience are more effective teachers than younger teachers. I also expect teacher experience and enrollment to have an interaction effect, with a positive cross-derivative as increased teachers' experience may reduce the rate at which larger enrollments adversely affects performance. The assumption that smaller Class Sizes improve education rests on the notion that students are able to respond better academically when they receive more individualized attention. Diminishing marginal returns from this benefit should set in as class size decreases.

The two "home environment" variables also interact with one another to affect academic performance. Parental income is a reflection of work ethic and education, among other factors. If students with higher parental education levels are innately better learners, then those with higher income will also be expected to have a marginally higher work ethic and achieve better academic results.

Estimated Model

To model the variable of primary interest, Discipline, I have selected a quadratic form.

$$A_t = \beta_0 + \beta_1 DIS_i + \beta_2 DIS_i^{\,2} + ... + \varepsilon_i \qquad (4)$$

I assume that the turning point of the quadratic occurs outside the range of data for Discipline.

The regression model, presented below, was specified so as to incorporate non-linear effects for many of the variables. These effects are detailed in Appendix A, and the resulting coefficient expectations are located in Table 3.2.

$$\begin{aligned} ACH_i = {} & \hat{a}_0 + \hat{a}_1 DIS_i + \hat{a}_2 DIS_i^2 + \hat{a}_3 PACH_i + \hat{a}_4 Ch\,\mathrm{Pr}_i + \hat{a}_5 EL_i + \hat{a}_6 HS_i + \\ & \hat{a}_7 PED_i + \hat{a}_8 PED_i^{\,2} + \hat{a}_9 INC_i + \hat{a}_{10} INC_i^{\,2} + \hat{a}_{11} ENR_i + \hat{a}_{12} ENR_i^{\,2} + \\ & \hat{a}_{13} EXPCOM_i + \hat{a}_{14} URB_i + \hat{a}_{15} SUB_i + \hat{a}_{16} \ln CSZ_i + \hat{a}_{17} EXP_i ENR_i + \\ & \hat{a}_{18} INC_i PED_i + \hat{a}_{19} DIS_i ENR_i + \hat{a}_{20} URB_i DIS + \hat{a}_{21} SUB_i DIS_i + \mathring{a}_i \end{aligned} \qquad (5)$$

Three regression analyses will be presented, using total achievement (the sum of math and verbal scores), math achievement, and verbal achievement as the dependent variables in the respective models. The total achievement model will be estimated by OLS regression and corrected for heteroskedasticity with White's heteroskedasticity corrected standard errors. The second two models will be conducted with Seemingly Unrelated Regression (SUR) to control for uncontrolled-for correlation between the error terms of the two models. The SUR estimation will also include weighted least squares to correct for heteroskedasticity.

Table 3.2 Theoretical Expectations of Model

Coefficient (Estimated Model)	Expectations
_1	Uncertain
_2	Must be negative
_3	Uncertain
_4	Must be negative
_5	no prediction
_6	no prediction
_7	Uncertain
_8	Must be positive
_9	Uncertain
_10	Must be positive
_11	Uncertain
_12	Must be negative
_13	Uncertain
_14	Uncertain
_15	Uncertain
_16	Must be positive
_17	Uncertain
_18	Uncertain
_19	Uncertain
_20	Uncertain
_21	Uncertain

IV. Data Analysis

Table 4.1. Summary Statistics

Variable	Sample Size	Mean	Std. Deviation	Minimum	25th Percentile	Median	75th Percentile	Maximum
TACH	487	172.5403696	14.3680863	92.2	164.9	175.1	183.5	190
MACH	487	84.6696099	8.6305003	40	80.3	86.5	91.3	95
VACH	487	87.8707598	6.4373564	52.2	84.5	89.2	92.7	95
DIS	487	8.3835619	7.9981234	0	2.2321429	6.4794816	12.3287671	43.2357043
PTACH	487	165.9455852	16.4512341	91.5	157.2	168.3	178.1	190
PMACH	487	82.3412731	9.2468658	44.6	77.7	84.4	89.1	95
PVACH	487	83.6043121	7.8838404	46.9	79.4	84.6	89.8	95
CHPR	487	13.8562628	18.5246992	0	2	7	14	73
EL	487	0.1478439	0.3553102	0	0	0	0	1
HS	487	0.0184805	0.1348195	0	0	0	0	1
percBA	487	8.6140525	5.8374045	1.6994819	4.9672186	6.4772438	9.9683088	30.4999008
INC	487	22209.82	5241.87	7452.0	19380	21289	23730	60528
ENR	487	651.9589322	272.9812290	93	464	644	813	1701
EXPCOM	487	11.8609035	2.0830752	5.965	10.51	11.94	13.22	17.625
L2	487	0.1416838	.3490841	0	0	0	0	1
L1	487	0.3613963	0.4808990	0	0	0	1	1
CSZ	487	14.1024383	2.0758136	6.09375	12.8888889	14.2758621	15.5757576	21.6388889

All data in this model are cross-sectional and from the 2003-04 school year, with the exception of the lagged achievement data (discussed below) and census data, where I used the most recent data of sufficient detail. Of the original 551 observations, 487 schools have data on all of the variables.

The dependent variable is writing scores, math scores, or the sum of the two for 8^{th} graders in North Carolina public schools during the 2003-2004 school year (while the state collects data for charter schools, they were excluded from this analysis). There are 487 observations used in the regression. Each school reports the percentage of its students performing at or above grade level, although federal privacy regulations prevent reporting exact scores below 5 percent or above 95 percent. The sum of Total Achievements is restricted in value to between 10 and 190. Several schools reported the upper limits.

The independent variable of primary interest is discipline (*DIS*), or the incidence of criminal and violent incidents that disrupt the learning environment. North Carolina state law requires the Department of Public Instruction to file public reports on incidents of crime and violent acts in 17 categories that occur in schools annually. Discipline represents the number of these acts per 1000 students for each school during the 2003-04 school year. These acts are: possession of a weapon, possession of a controlled substance, possession of alcoholic beverage, assault on school personnel, assault resulting in serious injury, sexual assault, assault involving use of a weapon, sexual offense, possession of a firearm, robbery without a dangerous weapon, robbery with a dangerous weapon, taking indecent liberties with a minor, rape, death by other than natural causes, kidnapping, bomb threats, and the burning of a school building. The number of acts at each school is divided by the seven-month average of daily attendance and multiplied by 1000 to obtain the values used in the regression.

As noted earlier, each school's zip code was used to match to census records about that zip code. Income represents the median income of that zip code in 1999, the most recent zip-code-level data available.

I measure parents' education by the percentage of residents with a bachelor's degree or higher in each zip code, obtained by summing men and women who have achieved this level of education (25-years and older), dividing by the population of the zip code, and multiplying by 100. These education levels vary greatly, from less than two percent of the population having a college education to over 30 percent.

Census data were also used to determine how to code for a school's location. If the urban populations were larger than the rural populations, then the larger of the subcategories took on the value of "1" (Urban is urbanized areas and suburban is urban clusters). If the rural population was larger than the combined urban populations, both dummy variables took a value of "0." In the coding process, I noticed that small towns such as county seats often took on the value for "suburban," as well as the fringe areas of larger cities, so it may be helpful to the reader to conceive of the variable and its reported parameters in the context of smallish incorporated communities. Census data define roughly 37 percent of zip codes as urban areas and 14 percent as suburban ones.

Individual school "report cards" lists the percentage of teachers with 0-3, 4-10, and more than 10 years of experience, which allowed me to create a weighted average of experience.

All data, except the private school county data, come from North Carolina state or federal agency sources. I judge that these are "fair dealers" of the information. The possibility that the data themselves are corrupt cannot be ruled out, given the incentive structure that local officials may have to achieve low crime rates and high test scores, sometimes by unethical means. Unfortunately, this problem—to the extent it may exist—is beyond the scope of this paper to correct.

Specifically, the data come from the website database "www.ncreportcards.org," in collaboration with the Department of Public Instruction. Criminal data come from the "2003-2004 Annual Report on School Crime and Violence," published by the State Board of Education, and I obtained it from the website of *The Charlotte Observer*. I constructed tables from census data at the website "factfinder.census.gov."

There is strong evidence that my model suffers from multicollinearity (Table 4.2), inflating standard errors of the estimates and reducing the significance level of the t-tests. Because of the partially quadratic specification, discipline, income, parents' education, and enrollment all show Variance Inflation Factors (VIFs) well into the teens and twenties, as the results from the regression results clearly show. Variables associated with interaction effects also have multicollinearity issues. Statistically significant results in the face of this multicollinearity can be interpreted to be particularly robust.

Table 4.2. Variance Inflation Factors of the Models

Variable	Total Achievement	Math Achievement	Verbal Achievement
DIS	**15.79**	**15.83**	**15.75**
DisSQ	**7.30**	**7.55**	**7.53**
PVACH	1.39	1.34	1.42
ChPr	2.73	2.57	2.59
EL	1.41	1.40	1.42
HS	1.05	1.07	1.07
percBA	**42.12**	**43.10**	**43.25**
percBAsq	**56.42**	**55.54**	**55.62**
Income	**23.13**	**23.32**	**23.26**
IncomeSQ	**78.09**	**78.46**	**77.96**
ENR	**71.95**	**71.37**	**71.35**
ENRsq	**18.57**	**18.62**	**18.63**
EXPCOM	**7.24**	**6.99**	**7.01**
Suburban	2.46	2.49	2.49
Urban	4.36	4.18	4.19
lnCLsize	1.79	1.92	1.94
EXPENR	**40.62**	**39.38**	**39.34**
INCPBA	**242.64**	**246.53**	**245.43**
disENR	**12.31**	**11.78**	**11.75**
urbanDIS	4.70	4.63	4.64
SuburbDIS	2.46	2.500	2.49

Variance Inflation Factors in bold indicate the presence of extreme multicollinearity (VIF>5).

V. General Empirical Results

The Total Achievement Model (Model 1) was the first model estimated, through Ordinary Least Squares Regression with White's heteroskedasticity corrected standard errors using SAS. Having obtained statistically significant and economically meaningful results (see Table 5.2), I decided to investigate the relationship between the independent variables in the original model and the math and verbal test scores independently. The right-hand side of these two equations differed only the past achievement variable, which was confined to the past achievement in the respective subject. Because Models 2 and 3 were otherwise identical, I worried that an uncontrolled for, systematic bias between the two regressions might exist that would give misleading results if run and interpreted separately. For example, schools' policy decisions might not affect math and verbal achievement independently and/or omitted variables might affect both variables. This suspicion was confirmed by a statistically significant correlation between the two models.

Models 2 and 3 were thus estimated with a technique known as Seemingly Unrelated Regression (SUR), which controls for this effect. Following the run of an initial SUR regression, Breusch-Pagan-Godfrey (BPG) tests were performed to determine the appropriate way to correct for heteroskedasticity (See Table 5.1). Ultimately, these regressions were weighted by the inverse of the predicted values of the original regression in a Weighted Seemingly Unrelated Regression. The results of the corrected regressions are presented in Table 5.2.

Table 5.1. Breusch-Pagan-Godfrey Test Results.

Model	Regression	Adjusted R^2	F-Test statistic
Both	$Residual^2$=Predicted	0.1837	110.58
	$Residual^2$=$Predicted^2$	0.1236	69.66
	$Residual^2$=Predicted + $Predicted^2$	**0.8013**	982.89
Math	**$Residual^2$=Predicted**	**0.0642**	34.34
	$Residual^2$=$Predicted^2$	0.0638	34.11
	$Residual^2$=Predicted + $Predicted^2$	0.0623	17.14
Verbal	**$Residual^2$=Predicted**	**0.0579**	30.86
	$Residual^2$=$Predicted^2$	0.0571	30.41
	$Residual^2$=Predicted + $Predicted^2$	0.0568	15.64

Table 5.2. Results of OLS and SUR Regressions.

Comparison						
	Model 1: Math+Verbal (OLS)		Model 2: Math (SUR)		Model 3: Verbal (SUR)	
Variable	Parameter Estimate†	Heteroskedasticity Corrected SE T-statistic	Parameter Estimate (SE)	P-value	Parameter Estimate (SE)	P-value
Intercept	57.25393	---	23.48734	0.0002	44.57074	<.0001
DIS	-0.4003*	-18.39823242	-0.21813**	0.0436	-0.32279***	0.0002
DISSQ	0.00663*	826.437576	0.003423	0.1711	0.003609*	0.0662
PMACH	0.70471*	1161.693124	0.681434***	0.0001	0.617865***	<.0001
ChPr	-0.06795*	-106.3484467	-0.04351**	0.0194	-0.03865***	0.0086
EL	-1.87494*	-2.017939588	-0.78132	0.2882	-2.01368***	0.0006
HS	-1.90055	-0.33768343	1.614636	0.3425	-0.54315	0.6846
percBA	0.52019*	9.412475212	0.406739	0.1042	0.472545**	0.0166
percBAsq	0.0216*	187.143096	0.000310	0.9750	0.017585**	0.0242
Income	-0.00021692*	-5948.977508	-0.00005	0.8254	-0.00033**	0.0416
IncomeSQ	1.67182E-08*	524900345.9	6.096E-9	0.3521	1.639E-8***	0.0015
ENR	-0.00072929*	-9.270148518	-0.00406	0.5467	-0.00759	0.1523
ENRsq	0.00000138*	220968.1479	4.949E-7	0.8316	1.797E-6	0.3269
EXPCOM	0.18505	1.23997282	0.052859	0.8470	-0.22258	0.3026
Suburban	-0.82337	-0.496645621	-1.01371	0.3082	0.177666	0.8202
Urban	0.18129	0.153209972	-0.35624	0.7015	0.781921	0.2853
lnCLsize	-0.55539	-0.107483336	1.573329	0.4070	-0.80326	0.5916
EXPENR	-0.00008503*	-342.9248233	0.000276	0.4868	0.000395	0.2055
INCPBA	-0.00004293*	-160291.7736	-0.00001	0.3815	-0.00004***	0.0025
disENR	0.00012128*	5824.704817	0.000091	0.4506	0.000243**	0.0103
urbanDIS	-0.06381*	-7.994198675	-0.10209	0.1378	-0.08811	0.1040
SuburbDIS	0.0242*	1.493411651	-0.00084	0.9928	-0.05330	0.4667

*Significant at the 10 percent level. ***Significant at the 1 percent level. **Significant at the 5 percent level.

†Because the White Test was used, results are only tested for significance at the 10 percent level.

Immediately, one notices that Model 1 has more statistically significant variables than the Models 2 and 3. Most variables that are significant in Model 3 are also significant in Model 1. This is not the case for Model 2, where only the linear Discipline variable, the past achievement variable, and the Charter and Private schools variable are significant. This suggests that the relationships affecting the verbal scores are strong enough to be reflected in the total achievement model.

Because of the non-linear specifications for some variables, subset F-tests needed to test if the average marginal influences of the variables are significantly different from zero. The results of these tests follow in Tables 5.3 and 5.4.

Table 5.3. F-Tests of Marginal Influence: Math

Variable	H_0	H_A	F-Statistic	P-Value	Result
Discipline	$\beta_1 + 2*\beta_2*DIS_i + \beta_{19}*ENR_i + \beta_{20}*URB_i + \beta_{21}*SUB_i = 0$	Otherwise	11.67	0.0007	Reject Null
Parents' Education	$\beta_7 + 2*\beta_8*PercBA_i + \beta_{18}*INC_i = 0$	Otherwise	1.25	0.2640	Fail to Reject
Income	$\beta_9 + 2*\beta_{10}*INC_i + \beta_{18}*PercBA_i = 0$	Otherwise	1.71	0.1919	Fail to Reject
Enrollment	$\beta_{11} + 2*\beta_{12}*ENR_i + \beta_{17}*EXP_i = 0$	Otherwise	0.21	0.6457	Fail to Reject
Experience	$\beta_{13} + \beta_{17}*ENR_i = 0$	Otherwise	4.20	0.0408	Reject Null

Table 5.4. F-Tests of Marginal Influence: Verbal

Variable	H_0	H_A	F-Statistic	P-Value	Result
Discipline	$\beta_1 + 2*\beta_2*DIS_i + \beta_{19}*ENR_i + \beta_{20}*URB_i + \beta_{21}*SUB_i = 0$	Otherwise	20.50	0.0001	Reject Null
Parents' Education	$\beta_7 + 2*\beta_8*PercBA_i + \beta_{18}*INC_i = 0$	Otherwise	1.08	0.2982	Fail to Reject
Income	$\beta_9 + 2*\beta_{10}*INC_i + \beta_{18}*PercBA_i = 0$	Otherwise	1.25	0.2637	Fail to Reject
Enrollment	$\beta_{11} + 2*\beta_{12}*ENR_i + \beta_{17}*EXP_i = 0$	Otherwise	1.96	0.1618	Fail to Reject
Experience	$\beta_{13} + \beta_{17}*ENR = 0$	Otherwise	0.15	0.7008	Fail to Reject

In both cases, the joint influence of Discipline in the model is statistically significant at the 1 percent level. Interestingly, the marginal influence of Teacher's Experience on students' mathematics performance is not zero at the 5 percent level, although the individual coefficients are insignificant.

VI. Interpretation of Empirical Results

Table 6.1. Comparison of Theory with Results: Math

Coefficient (Estimated Model)	Restriction	Parameter Estimate (Math)	Consistent with Theory?
_1 --DIS	Uncertain	-0.21813**	--
_2 – DIS^2	Must be negative	0.003423	O.K.—see analysis
_3—PACH	Uncertain	0.681434***	--
_4—ChPr	Must be negative	-0.04351**	Yes
_5—EL	no prediction	-0.78132	--
_6—HS	no prediction	1.614636	--
_7—PercBA	Uncertain	0.406739	--
_8—$PercBA^2$	Must be positive	0.000310	Yes
_9—INC	Uncertain	-0.00005	--
_10—INC^2	Must be positive	6.096E-9	Yes
_11—ENR	Uncertain	-0.00406	--
_12—ENR^2	Must be negative	4.949E-7	No
_13—EXPCOM	Uncertain	0.052859	--
_14—URB	Uncertain	-1.01371	--
_15—SUB	Uncertain	-0.35624	--
_16—lnCSZ	Must be positive	1.573329	Yes
_17—EXP*ENR	Uncertain	0.000276	--
_18—INC*PercBA	Uncertain	-0.00001	--
_19—DIS*ENR	Uncertain	0.000091	--
_20—URB*DIS	Uncertain	-0.10209	--
_21—SUB*DIS	Uncertain	-0.00084	--

Table 6.2. Comparison of Theory & Results: Verbal

Coefficient (Estimated Model)	Restriction	Parameter Estimate (Verbal)	Consistent with Theory?
_1 --DIS	Uncertain	-0.32279***	--
_2 – DIS^2	Must be negative	0.003609*	O.K.—see analysis
_3—PACH	Uncertain	0.617865***	--
_4—ChPr	Must be negative	-0.03865***	Yes
_5—EL	no prediction	-2.01368***	--
_6—HS	no prediction	-0.54315	--
_7—PercBA	Uncertain	0.472545**	--
_8—$PercBA^2$	Must be positive	0.017585**	Yes
_9—INC	Uncertain	-0.00033**	--
_10—INC^2	Must be positive	1.639E-8***	Yes
_11—ENR	Uncertain	-0.00759	--
_12—ENR^2	Must be negative	1.797E-6	No
_13—EXPCOM	Uncertain	-0.22258	--
_14—URB	Uncertain	0.177666	--
_15—SUB	Uncertain	0.781921	--
_16—lnCSZ	Must be positive	-0.80326	No
_17—EXP*ENR	Uncertain	0.000395	--
_18—INC*PercBA	Uncertain	-0.00004***	--
_19—DIS*ENR	Uncertain	0.000243**	--
_20—URB*DIS	Uncertain	-0.08811	--
_21—SUB*DIS	Uncertain	-0.05330	--

Three effects stand out from the empirical results: the consistently significant effect of Discipline on academic performance, the surprisingly strong significance of charter and private school presence on suppressing academic achievement, and the largely different sets of variables that appear to influence gains in math versus reading.

The mean marginal influence of Discipline on Math achievement is -0.1160875 and -0.1373606 on Verbal. Both are negative first-order conditions, as predicted by theory. The marginal influences are negative for over 95 percent of the observations for Math and over 90 percent in Verbal (see Table 6.3).

The quadratic coefficient for Discipline in all models has a puzzling, statistically significant positive sign. The results indicate that as incidents of violence and crime in schools increase, at some point test scores would be expected to increase at an increasing rate. Upon further examination, this upturn happens only the upper tail of the data. Perhaps as discipline problems become the norm, school officials learn to deal with those issues more effectively.

The elasticity of Math and Verbal scores can be obtained by multiplying the marginal influence of Discipline by Discipline incidents over test scores for each observation. Mathematically, this is represented as (for Math):

$$\varepsilon = \frac{\partial MACH_i}{\partial DIS_i} \cdot \frac{DIS_i}{MACH_i} = \text{Marginal Influence} \cdot \frac{DIS_i}{MACH_i} \qquad (6)$$

Table 6.3 presents statistical information on the marginal influence of Discipline and the elasticity of academic achievement to changes in Discipline incidents.

Table 6.3. Marginal Influences and Elasticities with Respect to Discipline.

Marginal Influence				
	Mean	25th Percentile	Median	75th Percentile
Math	-0.1384218	-0.1904660	-0.1445975	-0.1004657
Verbal	-0.1432458	-0.2030698	-0.1552313	-0.0851365
Elasticity				
	Mean	25th Percentile	Median	75th Percentile
Math	-0.0090402	-0.0134502	-0.0081363	-0.0029832
Verbal	-0.0079816	-0.0135717	-0.0068940	-0.0015151

The resulting Marginal Influences are very small. To put these numbers in perspective, a school that saw an increase in incidents of crime from five to six (20 percent rise) would see, on average, a decline of roughly 0.2 percent of students at or above grade level in math (20 percent times the mean elasticity). A school that started from a lower number of incidents would see a larger decline in test scores.

The presence of charter and private schools also seemed to have a remarkably strong statistical influence, in the anticipated (negative) direction, suggesting that theory on the availability of substitutes for public schools was on the mark. However, the magnitude of these effects is small: -0.04351 in Math and -0.03865 in verbal. On average and all else constant, nearly 25 charter or public schools need to exist in a county to cause a reduction of one-percent of students performing at or above grade level. This would suggest that public school students in large counties like Mecklenburg or Wake or near larger cities might be starting from a structural handicap (brighter or richer students opting out of the public school system).

The most surprising finding (because theory did not predict an outcome) might be the negative influence of younger grades on eight grade Verbal achievement. The presence of some or all of grades K-4 at a school with eighth graders reduced the percentage of students at or above grade level by more than two points. There are two probable explanations. The first is that districts that lump many grades together do so because they are poor or very rural. In these instances, a lack of financial resources to operate two separate schools may also mean a lack of resources to invest in education. The alternative suggests that teachers and administrators are preoccupied with the challenges of educating younger children, and older students with different learning and development needs receive the short end of that stick.

Excluding the variables already mentioned, the difference between the results of the Math model and the Verbal model are striking. Specifically, they would seem to indicate that mathematical aptitude is much more strongly driven by personal characteristics and teacher experience (suggesting better teaching methods), while reading and verbal aptitudes are dependent in large part on not only the classroom environment but also on general societal environment. The statistical significance of elementary grades' presence, parents' education, and median income around a school—as well as the decreased magnitude of the coefficient on past verbal achievement as opposed to past math achievement—seems to provide evidence that Verbal learning occurs through a path substantially different than and independent from Math.

VII. Summary and Conclusion

The results of the estimated model strongly endorse the notion that acts of violence and crime do adversely affect academic achievement, though the magnitude of the effect is small. Many control variables endorsed by academic literature proved to be significant as well, although not all matched with expectations.

This paper shows that it is the first incidents of crime or violence in public schools that have the greatest disruption. Further research needs to confirm and to expand on this finding. To explain the finding, I hypothesize that students and teachers simply become desensitized to crime and violence as incidents increase—the first discovery of a weapon on a "safe" campus may be shocking and thus disruptive, but after repeated incidents, they come to be expected. Students and educators would divert less attention to the later instance from their studies than the earlier ones. Another possible explanation supposes that at the first incidents of crime and violence, parents would attempt to transfer their child or enroll them in substitute schools; in the latter case, many times only students of higher achievement or higher parental income (associated with higher achievement) would be eligible.

The Discipline variable (and others, like the presence of Charter and Private Schools) seemed to have effects of small magnitude. If reducing crime and violence in public schools is costly, these elasticities suggest that the academic benefit may not be worth the cost to prevent them. The cross-sectional nature of this analysis prevents one from reaching this conclusion, because these effects are likely to exist year in and year out. It is possible that there may be compounding effects over time that cause the effects of the variables to be more significant. The model estimated that only 60 to 70 percent of grade-level ability could be based on the previous year's performance. A one percent of grade level drop, year after year, could potentially increase the costs to students (and society) of not addressing this problem.

This paper raises more questions than it answers, making further research necessary. First, these findings need to be confirmed in other analyses. If data can be found to move towards the "ideal" model proposed in Section II, new empirical results should be estimated. In any case, new analyses should use a similar methodology and model, but confirm the robustness of these findings by taking data from other states and from other years, both in North Carolina and the other states. Further, controlling for drop-out rates and the characteristics of the drop-out population, this model should be tested on high school populations. These results from the high school-age control variable seem to indicate that middle school and high school students may respond to crime and violence in the same capacity; that assumption, along with the others, need to be tested to determine the potential specificity of results to this data set as well as their wider applicability.

Future studies should also attempt to take a longitudinal view, both of standardized tests and of outcome-oriented measures of success, where data can be located. Outcome-oriented measures could include college attendance and graduation rates, or earning power at a set age. Different cohorts could be tracked in order to determine if the detriment of disruptions cause year-specific setbacks, or if they can be cumulative in hindering the educational development of students throughout an academic career.

The different factors in the production of successful Math versus Verbal achievement levels also warrants further research. Do students really learn math and reading differently? Can schools overcome negative external influences, once identified? Can schools reallocate resources or plan curricula that take advantage of any new knowledge gained in this area?

Finally, the surprising effect of school enrollment and that of mixing elementary and middle school grades in that enrollment should also be explored in further research. What level, for what grades, is the optimum size? These data strongly indicate that the optimum is larger than a mean and median of approximately 650 students. For reasons that are still unclear—perhaps because of a focus on younger students' performance, rather than providing support for adolescent cohorts—elementary school grades seem to lower academic achievement of eighth graders.

Using the estimates presented in this paper, and hopefully confirmation and insights from the research suggested above, better public policy can be made. Research should examine the costs associated with various security and safety measures within schools as well as the effectiveness of those measures in reducing school crime and violence. These costs should be compared to the benefits, over time, of increased academic achievement through reduced incidents of crime and violence. With that information, policymakers could determine if limited financial resources could be best spent in such a non-traditional way to achieve the highest student achievement gains. Given the high expenditures on public primary education in this country and the importance of a well-educated workforce to a strong economy, controlling disruptions to the learning environment could potentially provide strong efficiency gains to both the public and private sectors.

Works Cited

Bosworth, Derek. "Truancy and Pupil Performance." *Education Economics* vol. 2, no. 3 (1994).

Fetler, Mark. "School Dropout Rates, Academic Performance, Size, and Poverty: Correlates of Educational Reform." *Educational Evaluation and Policy Analysis*, Vol. 11, No. 2 (Summer 1989). pp. 109-116.

Fryer, Ronald G., Jr., and Levitt, Steven D. "Understanding the Black-White Test Score Gap in the First Two Years of School," *The Review of Economics and Statistics* 86, no. 2. 2004. pp. 447-464.

Gaddy, Gary D. "High School Order and Academic Achievement," *American Journal of Education*, Vol. 96, No. 4 (Aug., 1988). pp. 496-518

Hanushek, Eric A. "The Economics of Schooling: Production and Efficiency in Public Schools." *Journal of Economic Literature* 24 (1986), pp. 1141-77.

Haveman, Robert, and Wolfe, Barbara. "The Determinants of Children's Attainments: A Review of Methods and Findings." *Journal of Economic Literature*, Vol. 23, No. 4 (Dec. 1995). pp. 1829-1878.

Levitt, Steven D., and Dubner, Stephen J. *Freakonomics: A Rogue Economist Explores the Hidden Side of Everything*. HarperCollins Books, New York, NY. 2005.

Myers, David E.; Milne, Anne M.; Baker, Keith; and Ginsburg, Alan. "Student Discipline and High School Performance." *Sociology of Education,* Vol. 60, No. 1 (Jan., 1987), 18-33.

O'Sullivan, Arthur., ed. 2000. Urban Economics. 4th edition. McGraw-Hill Higher Education.

Sander, William. "Private Schools and Public School Achievement," Journal of Human Resources. Vol. 34, No. 4. Fall 1999. pp. 697-709.

“2003-04 Annual Report on School Crime and Violence.” State Board of Education and Department of Public Instruction, North Carolina. <http://www.charlotte.com/multimedia/charlotte/KRT_packages/archive/misc/2003-04.pdf>

“Education First: NC Report Cards.” North Carolina Department of Public Instruction. <www.ncreportcards.org>

“Evolution of the ABCs.” <http://www.ncpublicschools.org/docs/accountability/reporting/abc/2004-05/abcevolution.pdf>

“Private School Review.” <http://www.privateschoolreview.com/state_private_schools/stateid/NC>

Appendix A. Expected Marginal Influences of Estimated Model

Variable	Theory: $\partial TACH / \partial VAR$	Model: $\partial TACH / \partial VAR$	Theory: $\partial^2 TACH / \partial VAR^2$	Model: $\partial^2 TACH / \partial VAR^2$
DIS	$\partial TACH / \partial DIS < 0$	$\partial TACH / \partial DIS =$ $\beta_1 + 2 \cdot \beta_2 DIS_i + \beta_{19} ENR_i +$ $\beta_{20} L2_i + \beta_{21} L1_i$	$\partial^2 TACH / \partial DIS^2 < 0$	$\partial^2 TACH / \partial DIS^2 = 2 \cdot \alpha_2$ Requires α_2 to be negative.
PTACH	$\partial TACH / \partial PTACH > 0$	$\partial TACH / \partial PTACH = \beta_3$ α_3 must be positive	$\partial^2 TACH / \partial PTACH^2 = 0$ Assumed linear, so second derivative equals 0.	$\partial^2 TACH / \partial PTACH^2 = 0$ Assumed linear.
CHPR	$\partial TACH / \partial CHPR < 0$	$\partial TACH / \partial CHPR = \alpha_4$ α_4 must be negative	$\partial^2 TACH / \partial CHPR^2 = 0$ Assumed linear, so second derivative equals 0	$\partial^2 TACH / \partial CHPR^2 = 0$ Assumed linear.
EL	$\partial TACH / \partial EL = + or -$	$\partial TACH / \partial EL = \beta_5$	$\partial^2 TACH / \partial EL^2 = 0$ Assumed linear, so second derivative equals 0	$\partial^2 TACH / \partial EL^2 = 0$ Assumed linear.
HS	$\partial TACH / \partial HS =$ 0 or -	$\partial TACH / \partial HS = \beta_6$	$\partial^2 TACH / \partial HS^2 = 0$ Assumed linear, so second derivative equals 0	$\partial^2 TACH / \partial HS^2 = 0$ Assumed linear.
PED	$\partial TACH / \partial PED > 0$	$\partial TACH / \partial PED =$ $\beta_7 + 2 \cdot \beta_8 PED_i + \beta_{18} INC_i$	$\partial^2 TACH / \partial PED^2 > 0$	$\partial^2 TACH / \partial PED^2 = 2 \cdot \alpha_8$ α_8 must be positive.
INC	$\partial TACH / \partial INC > 0$	$\partial TACH / \partial INC =$ $\beta_9 + 2 \cdot \beta_{10} INC_i + \beta_{18} PED_i$	$\partial^2 TACH / \partial INC^2 > 0$	$\partial^2 TACH / \partial INC^2 = 2 \cdot \alpha_{10}$ α_{10} must be positive.
ENR	$\partial TACH / \partial ENR$ $> 0 \rightarrow = 0 \rightarrow < 0$	$\partial TACH / \partial ENR =$ $\beta_{11} + 2 \cdot \beta_{12} ENR_i +$ $\beta_{17} EXP_i + \beta_{19} DIS_i$	$\partial^2 TACH / \partial ENR^2 < 0$	$\partial^2 TACH / \partial ENR^2 = \alpha_{12}$ α_{12} must be negative
EXP	$\partial TACH / \partial EXP > 0$	$\partial TACH / \partial EXP = \beta_{13} + \beta_{17} ENR_i$	$\partial^2 TACH / \partial EXP^2 \geq 0$	$\partial^2 TACH / \partial EXP^2 = 0$ Does not allow for possibility that second derivative is > 0
URB	$\partial TACH / \partial URB > 0$	$\partial TACH / \partial URB =$ $\beta_{14} + \beta_{21} DIS_i$	$\partial^2 TACH / \partial URB^2 = 0$ Assumed to be linear, so second derivative equals 0.	$\partial^2 TACH / \partial URB^2 = 0$ Assumed linear.
SUB	$\partial TACH / \partial SUB > 0$	$\partial TACH / \partial L2 = \beta_{15} + \beta_{20} DIS_i$	$\partial^2 TACH / \partial SUB^2 = 0$ Assumed to be linear, so second derivative equals 0.	$\partial^2 TACH / \partial SUB^2 = 0$ Assumed linear.
CSZ	$\partial TACH / \partial CSZ > 0$	$\partial TACH / \partial CSZ = \beta_{16} / CSZ_i$ β_{16} must be positive.	$\partial^2 A_t / \partial CSZ^2 < 0$	$\partial^2 A_t / \partial CSZ^2 = -\beta_{16} / CSZ^2$ β_{16} must be positive.

Appendix B. Average Marginal Influences of OLS Regression (Total Achievement)

Variable	Theory: $\partial TACH / \partial VAR$	Results:
DIS	$\partial TACH / \partial DIS < 0$	$\partial TACH / \partial DIS$ = -0.40030 + 2*0.00663*DIS_i + 0.00012128*ENR_i + 0.02420*$Suburban_i$ - 0.06381*$Urban_i$ = -0.40030 + 2*0.00663*10.656 + 0.00012128*655.172 + 0.02420*0.136 - 0.06381*0.366 = -0.19960544 Average marginal influence conforms to theory.
DIS	$\partial^2 TACH / \partial DIS^2 < 0$	$\partial^2 TACH / \partial DIS^2$ = 2*0.00663 = 0.01326 Does not conform to theory.
PTACH	$\partial TACH / \partial PTACH > 0$	$\partial TACH / \partial PTACH$ = 0.70471 Conforms to theory.
CHPR	$\partial TACH / \partial CHPR < 0$	$\partial TACH / \partial CHPR$ = -0.06795 Conforms to theory.
EL	$\partial TACH / \partial EL = + \text{ or } -$	$\partial TACH / \partial EL$ = -1.87494 Conforms to theory.
HS	$\partial TACH / \partial HS = 0 \text{ or } -$	$\partial TACH / \partial HS$ = -1.90055 Conforms to theory; not statistically signficant
PED (percBA)	$\partial TACH / \partial PED > 0$	$\partial TACH / \partial PED$ = =0.52019+2*0.02160*PED_i-0.00004293*INC_i =0.52019+2*0.02160*8.662-0.00004293*22177.65 = - 0.057698115 Average marginal influence does not conform to theory.
PED (percBA)	$\partial^2 TACH / \partial PED^2 > 0$	$\partial^2 TACH / \partial PED^2$ = 2*0.02160=0.04320 Conforms to theory.
INC	$\partial TACH / \partial INC > 0$	$\partial TACH / \partial INC$ =-0.00021692+2*1.671816*10^-8*INC_i-0.00004293*PED_i =-0.00021692+2*1.671816*10^-8*22177.65-0.00004293*8.662 =0.000152759 Conforms to theory.
INC	$\partial^2 TACH / \partial INC^2 > 0$	$\partial^2 TACH / \partial INC^2$ = 2*1.671816*10^-8 =3.34363E-08 Conforms to theory.
ENR	$\partial TACH / \partial ENR$ $> 0 \rightarrow = 0 \rightarrow < 0$	$\partial TACH / \partial ENR$ = -0.00072929+2*0.00000138*ENR_i-0.00008503*EXP_i+0.00012128*DIS_i =-0.00072929+2*0.00000138*655.172-0.00008503*11.810+0.00012128*10.656

		=0.00136714 Possibly conforms to theory.
ENR	$\partial^2 TACH / \partial ENR^2 < 0$	$\partial^2 TACH / \partial ENR^2 =$ 2*0.00000138 = 0.00000276 Does not conform with theory.
EXP	$\partial TACH / \partial EXP > 0$	$\partial TACH / \partial EXP =$ 0.18505-0.00008503*ENR_i =0.18505-0.00008503*655.172 =0.129340725 Conforms to theory; not statistically significant
URB	$\partial TACH / \partial URB < 0$	$\partial TACH / \partial URB$ =0.18129-0.06381*DIS_i =0.18129-0.06381*10.656 = - 0.49866936 Conforms to theory; not statistically significant.
SUB	$\partial TACH / \partial SUB > 0$	$\partial TACH / \partial SUB$ = -0.82337 + 0.02420*DIS_i = -0.82337 + 0.02420*10.656 = - 0.5654948 Does not conform to theory; not statistically significant.
CSZ	$\partial TACH / \partial CSZ > 0$	$\partial TACH / \partial CSZ =$ - 0.55539 / CSZ = -0.55539/13.894 =-0.03997337 Does not conform to theory; not statistically significant.
CSZ	$\partial^2 TACH / \partial CSZ^2 < 0$	$\partial^2 TACH / \partial CSZ^2 =$ -(-0.55539)/CSZ_i^2 = 0.55539 / (13.894^2) = 0.002877024 Does not conform to theory; not statistically significant.