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School Inputs and Educational Outcomes in North Carolina: Comparison of Static and Dynamic Analyses

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ABSTRACT

The relationship between student achievement and school inputs has long been a subject of academic research. The general conclusion of past research is that school inputs, such as the number of teachers relative to pupils, has little impact on student academic outcomes. This paper provides a fresh look at this issue. Seventeen alternative measures of student performance in North Carolina school districts are related to a wide array of school policy inputs and socioeconomic characteristics of students and their families. Both static and dynamic analyses are performed. The key findings are (1) the school policy inputs significantly related to student achievement vary by the measure of student achievement used, (2) the joint contribution of school policy inputs to student achievement is relatively small, and (3) the results differ between the static and dynamic analyses; in particular, changes in the number of teachers relative to the number of pupils in the district have a much stronger association with student achievement in the dynamic analysis.

Key Words: *public education, student achievement.*

For several years there has been widespread concern about improving performance in the public schools. The concern is based on a national decline in average Scholastic Aptitude Test (SAT) scores, especially math scores, since the early 1960s, although some recovery was made in the 1980s (U.S. Department of Education, 1993). Less controversial measures of school performance, such as the National Assessment of Educational Progress, show the same trends.[1]

In Southern states the concern about educational performance is enhanced because leaders see education as a development tool which can improve the relative social and economic standing of the rural regions. Although progress has been made, most Southern states still lag behind the nation in per-capita income, average wages, and other socioeconomic measures. Leaders see educational improvement as the road to economic and social advancement.

As the literature review will reveal, a large body of research examining what policymakers can do to improve educational outcomes exists. One of the themes of this research is that school inputs, and particularly the teacher/pupil ratio, have little impact on educational

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[1] The National Assessment of Educational Progress (NAEP) tests are preferred measures of student performance because they are based on a representative sample of students at different ages (Congressional Budget Office, 1993).

outcomes. Yet many of these studies suffer from an extended "omitted variables" problem. It is very difficult to control for all the factors, especially innate student characteristics, that affect school performance.

One way to handle the omitted variables problem in school performance studies is to conduct a dynamic analysis rather than a static analysis. The most common study estimates the relationships between student outcomes and school inputs using a cross section of data from many schools or districts at a point in time. We call this a *static analysis* (other researchers call it a *"level" analysis*). In a static analysis it is crucial to include as many control variables as possible so that parameter estimates are unbiased.

A dynamic analysis utilizes input and outcome data from schools and districts over time. Changes in outcome measures are related to changes in inputs (some researchers call this a *"value-added" analysis*). In this case, omitting variables such as the innate characteristics of students is not as worrisome for two reasons. First, the effects of their "levels" on these characteristics will be captured by the initial level of student achievement. Second, in a dynamic analysis it is the changes in innate characteristics that are omitted. As long as the innate student characteristics and the geographic definition of the school districts change little, then the omission of innate characteristics will have little impact on the analysis.

The contribution of this paper to the literature on school inputs and educational outcomes is the comparison of results derived from a static analysis and dynamic analysis. In particular, do the results for key input factors, such as the number of teachers relative to pupils, change when moving from a static analysis to a dynamic analysis? Can the failure to use a dynamic analysis in most studies explain the lack of significance of key school input variables?

There are other important features of the paper. First, the study uses data at the school district level, where most control and decision-making about school inputs reside. Second, the study uses 17 measures of educational outcomes. Third, the study includes an extensive collection of both human and capital school inputs. Last, the study explicitly considers the issue of how much collective impact school inputs have on educational outcomes.

The paper is structured into five sections. The next section reviews the literature examining linkages between school inputs and educational performance of students. The third section presents the static and dynamic models of the educational production function. The data used to implement the models and the empirical results are discussed in Section Four. Conclusions, implications, and recommendations are offered in the last section.

Previous Work

The examination of the relationship between student performance and school inputs began with the Coleman report in 1966. Since then, scores of articles and research reports have been published on the topic. Studies have been conducted in almost every conceivable way. Cross section and time series analyses have been performed. The unit of analysis has included individual students, individual schools, and school districts.

Hanushek (1986) provides an excellent review of 147 of these studies. The most telling conclusion of his review is the inconsistency of findings regarding school policy variables. Variables such as the teacher/pupil ratio, teacher education, and expenditures per pupil were largely found to have no impact on student performance. For example, in the 112 studies which included the teacher/pupil ratio, Hanushek reports that only nine found a statistically significant positive linkage to student performance. Similarly, in the 65 studies which included expenditures per pupil, only 13 found a positive and statistically significant tie to student output.

In contrast, Hanushek found a strong tie between socioeconomic characteristics of students' backgrounds and student achievement in the studies. In particular, students whose parents have more income or more education tend to perform better in school.

Since Hanushek's review, additional studies have examined the effect of administrative control on student achievement. Downes and Horowitz (1995) examined whether moving resource control from the district level to the building level had any impact on student performance in Chicago schools. They found these changes had little impact on student achievement after accounting for student and neighborhood characteristics.

Anderson, Shughart, and Tollison (1991) focused on potential negative impacts of school bureaucracies on student performance. They speculated that increases in the number of school bureaucrats, or administrators, and in their spending may reduce student output by creating more rules, paperwork, and workshops for teachers to add to their busy schedules. Such work substitutes for classroom time and preparation by teachers and thereby reduces successful achievement by students. The authors found support for their theory by finding that increases in non-teaching staff and spending were associated with lower student achievement.

Ballou and Podgursky (1997) found no positive relationship between teacher pay and student performance. They attribute this finding to the structure of public schools, which generally provides across-the-board pay raises rather than raises tied directly to performance.

Finally, Ferguson and Ladd (1995) have added to the debate about the influence of the teacher/pupil ratio on student performance. In their study of Alabama schools they found smaller class sizes were consistently related to improved student test scores. However, they did not control for the effects of non-instructional spending.

The variation in findings for the education production function and the inconsistent findings for school policy variables indicate it is risky to apply findings from other studies to a region or state of interest. In addition, no work has been done comparing results for the same data set for a static analysis and a dynamic analysis.

Models

We use a standard production function model to analyze the determination of student achievement. The model relates a measure of student achievement, A, to a series of school policy inputs, X, and a set of socioeconomic characteristics of the student and student's family, Z:

$$(1) \quad A = f(X, Z).$$

Typically, student achievement, A, is measured by standardized test scores. The school policy inputs are usually measured on a per-pupil basis, such as teachers per pupil, administrators per pupil, and spending per pupil. The socioeconomic characteristics are often the income and education of students' parents and any special characteristics of students.

Focusing on the school policy inputs, equation (1) can be rewritten as:

$$(2) \quad A = f(x_1/p, x_2/p, \ldots, x_n/p, z_1/p, z_2/p, \ldots, z_n/p)$$

where $x_1, x_2, \ldots, x_n$ are individual school policy inputs such as total number of teachers, total number of administrators, and total spending, p is total number of pupils, and $z_1, z_2, \ldots, z_n$ are individual socioeconomic characteristics.

Taking the log of the dependent variable and of the input ratios and expressing equation (2) in log-linear form yields:

$$(3) \quad \ln(A) = a_1(\ln x_1) + a_2(\ln x_2) + \cdots a_n(\ln x_n) - (a_1 + a_2 + \cdots a_n)\ln p + b_1(\ln z_1) + b_2(\ln z_2) + \cdots b_n(\ln z_n) - (b_1 + b_2 + \cdots b_n)\ln p, \quad \text{or}$$

$$(4) \quad \ln(A) = a_1(\ln x_1) + a_2(\ln x_2) + \cdots a_n(\ln x_n) + b_1(\ln z_1) + b_2(\ln z_2) + \cdots b_n(\ln z_n) - (a_1 + a_2 + \cdots a_n + b_1 + b_2 + \cdots b_n)\ln p.$$

Note in equation (4)'s formulation that the impact of the number of pupils (p) is estimated separately from the impacts of the school policy inputs and socioeconomic characteristics.

However, our results are still comparable to those where school policy inputs, such as the number of teachers, are measured on a per-pupil basis (i.e., the teacher/pupil ratio). For example, in equation (4), assume the school policy input x_1 is the number of teachers. Then, the coefficient a_1 measures the effect of a change in the (log of the) number of teachers on student achievement, holding all other inputs and the number of pupils constant. That is, a_1 measures the effect of changing the teacher/pupil ratio by changing the number of teachers and leaving the number of pupils unchanged.

Since there are three years of data for each school district, we have the ability to conduct a dynamic analysis. The dynamic analysis examines the relationship between changes in student achievement measures and changes in inputs. Many researchers consider dynamic analysis to be superior to static analysis because the inability to measure innate student characteristics is not as much of a problem when examining changes in output measures.

In deriving the dynamic estimating equation, consider first the equations for the determination of achievement in the same school district in two time periods, t and t + 1:

$$(5)\quad A_t = a_t X_t/p_t + b_t Z_t/p_t,$$

$$(6)\quad A_{t+1} = a_{t+1} X_{t+1}/p_{t+1} + b_{t+1} Z_{t+1}/p_{t+1},$$

where, for simplicity, X now stands for all school policy inputs and Z stands for all socioeconomic inputs. If we assume the production functions are the same in both time periods, that is, $a_t = a_{t+1} = a$ and $b_t = b_{t+1} = b$, then the difference in achievement scores between the two time periods is:

$$(7)\quad A_{t+1} - A_t = a(X_{t+1}/p_{t+1} - X_t/p_t) + b(Z_{t+1}/p_{t+1} - Z_t/p_t).$$

Taking the log of scores and input ratios and then expressing the difference in the achievement scores gives:

$$(8)\quad \ln A_{t+1} - \ln A_t = c(\ln X_{t+1} - \ln X_t) + d(\ln Z_{t+1} - \ln Z_t) - c(\ln p_{t+1}) + c(\ln p_t) - d(\ln p_{t+1}) + d(\ln p_t).$$

Rearranging terms yields:

$$(9)\quad \ln A_{t+1} = \ln A_t + c(\ln X_{t+1} - \ln X_t) + d(\ln Z_{t+1} - \ln Z_t) - (c + d)(\ln p_{t+1} - \ln p_t).$$

Equation (4) is the form of the production function estimated in the static model and equation (9) is the model for the dynamic analysis.

Last, an important issue for policy makers is how much collective influence school policy inputs have in explaining variation in student achievement. We use two procedures to answer this question. As a maximum, or upper bound, of the collective contribution, we regress the student achievement measure on only the school policy inputs and take the R^2 from this regression as the upper bound. This is the maximum joint contribution of school policy inputs because it gives credit to school policy inputs for effects that, in fact, might be due to socioeconomic inputs that are merely correlated with the school inputs.

We calculate the minimum, or lower bound, of the joint contribution of the school policy inputs in the following way. First, we regress the school achievement measure on only the socioeconomic inputs. We then take the residuals from this regression and regress them on the school policy inputs. The sum of squares due to regression from this residuals regression divided by the sum of squares total from the upper bound procedure is the lower bound R^2. This is the minimum joint contribution of school policy inputs because, this time, all of the impact from joint correlation between the school policy inputs and socioeconomic inputs is attributed to the latter inputs.

Data and Empirical Results

The study is performed using school districts in North Carolina as the unit of analysis. There

Table 1. Measures of Student Achievement, North Carolina School Districts

CAT3RED	California Achievement Test, grade 3 reading score
CAT3MAT	California Achievement Test, grade 3 math score
CAT6RED	California Achievement Test, grade 6 reading score
CAT6MAT	California Achievement Test, grade 6 math score
CAT8RED	California Achievement Test, grade 8 reading score
CAT8MAT	California Achievement Test, grade 8 math score
NC6WRIT	North Carolina grade 6 writing test score
NC8WRIT	North Carolina grade 8 writing test score
NC3SCI	North Carolina grade 3 science test score
NC6SCI	North Carolina grade 6 science test score
NC8SCI	North Carolina grade 8 science test score
NCALGE1	Algebra 1 test score
NCSCHOL	Number of high school graduates completing N.C. scholars program courses
UNCADM	Number of graduates completing required UNC admission courses
UNITS5	Number of students grades 9–12 earning 5 of the 22 units required for graduation
VERB	Scholastic Aptitude Test verbal score
MATH	Scholastic Aptitude Test math score

Source: North Carolina Department of Public Institution, *North Carolina Report Card,* Raleigh, North Carolina, 1991, 1992, 1993.

are 129 districts in the state.[2] Data were collected for each of these districts for three academic years—1989–1990, 1990–1991, and 1991–1992. Student achievement, non-financial school policy inputs, and socioeconomic inputs were taken from annual editions of the *North Carolina Report Card* published by the North Carolina Department of Public Instruction. Financial policy inputs were taken from annual editions of the *Statistical Profile,* also published by the North Carolina Department of Public Instruction.

[2] All the districts are public school districts, and two-thirds are single-county districts. Private and home schooling are relatively minor, ranging from a low of 0.2 percent to a high of 12 percent of students in the districts, with the state average being 5.7% (North Carolina Department of Public Instruction).

A feature of our study is the use of multiple measures of student achievement. Seventeen alternative measures, listed in Table 1, are used. Most are scores on standardized tests. A wide range of school policy inputs, including the number of teachers, administrators, aides and other staff, and spending on salaries, equipment, and supplies, is used in the study. These are listed and identified in Table 2. Unfortunately, one factor we are lacking is teach-

Table 2. School Policy Inputs, North Carolina School Districts

TEACHER	Number of teachers
GRAD	Number of teachers with a graduate college degree
ADMIN	Number of administrators (superintendents, assistant superintendents, principals, assistant principals)
AIDES	Number of teacher assistants
SPECIAL	Number of specialists (guidance counselors, librarians, audio-visual specialists)
OTSTAFF	Number of other staff (technicians, clerical staff, cafeteria workers, janitorial staff)
REALCOMP	Spending on employee salaries and benefits (1992 $)
REALEQUIP	Spending on instructional equipment (1992 $)
REALSUPP	Spending on supplies (1992 $)
REALSER	Spending on purchased services (1992 $)
REALOTH	Spending on other goods and services (1992 $)

Source: North Carolina Department of Public Instruction, *Statistical Profile,* Raleigh, North Carolina, 1991, 1992, 1993.

Table 3. Socioeconomic Inputs

PUPILS	Number of pupils
NONWHITE	Number of non-white pupils
GIFTED	Number of pupils classified as gifted
HANDICAP	Number of pupils classified as handicapped
FREELUN	Number of pupils receiving free or reduced lunch
DROPOUT	Number of dropouts in grades 9–12
ABSENT	Number of pupils absent more than 14 days during the year
EDU8	Number of parents with less than 8th grade education
EDU8TO12	Number of parents with an 8th but less than 12th grade education
EDUHS	Number of parents with a 12 grade education but no college education
EDUCOL	Number of parents with some college education
NUMTEST	Number of students taking SAT test (for VERB and MATH equations only)

Source: North Carolina Department of Public Instruction, *North Carolina Report Card,* Raleigh, North Carolina, 1991, 1992, 1993.

er experience.[3] All financial amounts are expressed in 1992 dollars.

Socioeconomic characteristics of the school districts' students and their parents are given and identified in Table 3.[4] Income of parents was not available, but the number of pupils receiving a free or reduced school lunch should be a proxy for this characteristic.

Last, since the data are pooled over three years, dummy variables are included to control for year effects. In the static analysis, YEAR9091 means the observation is from academic year 1990–91 and YEAR9192 means the observation is from academic year 1991–92. The intercept category is academic year 1989–90. In the dynamic analysis, the dummy variable DYR9192 indicates the observation is measured by the change from academic year 1990–91 to academic year 1991–92. The intercept category includes the year effect when the observation is measured from academic year 1989–90 to academic year 1990–91.

Means, standard errors of means, and ranges for all variables in levels (that is, non-log form) are given in Table 4. Since there are three years of data for each school district, there are 387 (129 × 3) observations.

In the static model, each of the 17 student achievement measures was regressed on the set of school policy inputs and the socioeconomic characteristics. Since the equations were estimated in log-linear form, the parameter estimates are elasticities.

The results are given in Table 5 and are summarized in Table 9. Looking first at the socioeconomic characteristics, the race, income proxy (FREELUN) and education variables are statistically significant in most of the equations. NONWHITE is negative and statistically significant in 12 of the 17 equations with most elasticities in the −0.02 to −0.06 range.[5] FREELUN is negative and statistically significant in 16 of the 17 equations and has elasticities in the −0.04 to −0.20 range. Of the education variables, the high school education variable (EDU8T012) and the highest education category (EDUCOL) are the most consistent throughout the equations. EDU8T012 is negative and statistically significant in 11 of the 17 equations with elasticities between −0.02 and −0.20. EDUCOL is positive and statistically significant in 13 of the 17 equations with most elasticities ranging from 0.10 to 0.40. Everything else being equal, children from parents who did not complete high school perform poorer than children from parents with some college education.

Of the remaining socioeconomic characteristics, GIFTED, ABSENT, and PUPILS have the most consistent results. GIFTED is positive

[3] Hanushek found a positive effect of teacher experience on student performance in one-third of the studies he examined, while Ferguson and Ladd found no impact of teacher experience.

[4] The number of pupils (PUPILS) is classified as a socioeconomic input and not a school policy input because school districts are more likely to be presented with the number of students they serve than they are to select and determine the number of pupils in the district.

[5] Ferguson and Ladd found a similar result.

Table 4. Descriptive Statistics

Variable	Mean	Standard Error of Mean	Minimum	Maximum
Achievement Measures				
CAT3RED	50.63	8.21	26.00	74.00
CAT3MAT	67.50	8.57	44.00	89.00
CAT6RED	49.09	8.54	25.00	73.00
CAT6MAT	61.03	9.74	28.00	88.00
CAT8RED	51.89	8.75	27.00	80.00
CAT8MAT	57.21	9.14	34.00	86.00
NC6WRIT	51.62	13.97	15.00	91.00
NC8WRIT	58.58	11.76	23.00	89.00
NC3SCI	57.73	8.82	34.00	86.00
NC6SCI	51.92	8.92	26.00	73.00
NC8SCI	54.24	8.62	29.00	90.00
NCALGE1	51.43	11.68	13.00	88.00
NCSCHOL	104.46	145.80	0.00	1,131.00
UNCADM	242.98	359.39	15.20	2,972.00
UNITS5	2,005.55	2,412.29	195.00	18,447.00
VERB	391.22	26.05	313.00	503.00
MATH	432.79	29.41	348.00	555.00
School Policy Inputs				
TEACHER	495.19	601.81	47.00	4,235.00
GRAD	154.52	207.83	11.23	1,711.00
ADMIN	39.45	46.30	5.00	402.00
AIDES	145.22	183.05	12.00	1,461.00
SPECIAL	58.45	80.85	3.00	691.00
OTSTAFF	221.88	284.01	27.00	2,178.00
REALCOMP	$30,381,991	$40,221,474	$2,998,000	$304,361,055
REALEQUIP	$473,062	$743,769	$18,255	$898,000
REALSUPP	$2,747,770	$3,055,876	$297,071	$19,874,477
REALSER	$1,971,905	$3,359,679	$173,640	$32,800,000
REALOTH	$273,732	$308,472	$1,046	$2,849,898
Socioeconomic Inputs				
PUPILS	8,307.28	10,506.69	719.00	76,291.00
NONWHITE	2,792.32	4,471.11	11.00	33,339.00
GIFTED	563.98	955.65	7.00	8,293.00
HANDICAP	960.41	1,135.82	70.00	8,239.00
FREELUN	2,832.93	3,275.57	137.00	23,574.00
DROPOUT	88.40	135.69	2.00	1,487.00
ABSENT	656.49	799.79	13.00	6,485.00
EDU8	211.70	255.89	0.00	1,864.00
EDU8TO12	1,142.96	1,114.73	60.00	7,605.00
EDUHS	3,323.18	3,526.70	309.00	23,116.00
EDUCOL	3,626.35	6,091.35	187.00	44,848.00

N = 387.

and statistically significant in nine of the 17 equations, and it is negative and statistically significant in only two equations. ABSENT is negative and statistically significant in six of the 17 equations.[6] PUPILS is positive and sta-

[6] It could be argued that ABSENT is an endogenous variable. We use it as an exogenous variable to

Table 5. Regression Results for Student Achievement Measures, Static Model

Dep. Var.	CAT3RED	CAT3MAT	CAT6RED	CAT6MAT	CAT8RED
R^2	0.520***	0.339***	0.675***	0.423***	0.675***
Intercept	3.868***	4.069***	4.465***	3.670***	4.319***
YEAR9091	−0.012	−0.022	0.006	0.026	0.032**
YEAR9192	−0.013	0.011	0.035*	0.082***	0.051***
School Policy Inputs					
TEACHER	0.116	0.059	−0.008	0.074	0.055
GRAD	0.039	0.054**	0.009	0.009	0.035
ADMIN	0.073**	0.073**	0.084**	0.094**	0.116***
AIDES	0.049	0.096**	0.049	0.078	0.029
SPECIAL	0.046	0.018	0.075**	0.032	0.087***
OTSTAFF	0.043	−0.005	0.021	−0.024	0.031
REALCOMP	−0.221	−0.208	−0.069	−0.156	−0.225*
REALEQUIP	0.011	0.021*	0.019	0.042***	0.031***
REALSUPP	0.048	0.011	0.054	−0.024	0.109**
REALSER	−0.041	−0.031	−0.065**	−0.088***	−0.079***
REALOTH	0.009	0.016	0.010	0.007	−0.010
Socioeconomic Inputs					
PUPILS (1000s)	0.000	0.001**	0.000	0.000	0.000
NONWHITE	−0.043***	−0.032***	−0.058***	−0.043***	−0.036***
GIFTED	0.005	0.008	0.041**	0.037*	0.065***
HANDICAP	−0.074*	−0.049	0.003	0.002	−0.066*
FREELUN	−0.109***	−0.054**	−0.163***	−0.086***	−0.166***
DROPOUT	−0.015	−0.030*	0.026	0.016	0.012
ABSENT	−0.011	0.005	−0.046**	−0.078***	−0.024
EDU8	−0.021	−0.017	0.008	−0.007	−0.026*
EDU8TO12	−0.135***	−0.070***	−0.176***	−0.089***	−0.079***
EDUHS	0.088**	0.073**	0.093***	0.081*	−0.020
EDUCOL	0.133***	0.061	0.101***	0.124***	0.162***
NUMTEST	N.A.	N.A.	N.A.	N.A.	N.A.

*** Significant at the .01 level.
** Significant at the .05 level.
* Significant at the .10 level.
N.A. = not applicable.

tistically significant in four of the equations.[7] Since in equation 4 the parameter estimate for PUPILS is multiplied by a negative, this result means the underlying parameter estimate for PUPILS $[\ln(a_1 + a_2 + \cdots a_n + b_1 + b_2 + \cdots b_n)]$ is negative. Therefore, in four of the equations, increasing PUPILS and holding all other inputs constant reduces educational outcomes. This makes sense, as more pupils means educational inputs are stretched thinner.

Among the school input variables, REALSER, ADMIN, GRAD, SPECIAL, and REALEQUIP have the most consistent impacts on the various measures of student achievement. REALSER is negative and statistically significant in 12 of the 17 equations. GRAD, SPECIAL and REALEQUIP are positive and statistically significant in seven, six and five, respectively, of the 17 equations. ADMIN is positive and statistically significant in nine of the 17 equations, and negative in three equa-

represent student motivation. A high number of absences can mean a large number of unmotivated students who lack the desire to perform on standardized tests.

[7] Following equation (5), the parameter estimates on PUPILS were restricted to equal the sum of the other parameter estimates.

Table 5. (Continued)

Dep. Var.	CAT8MAT	NC6WRIT	NC8WRIT	NC3SCI	NC6SCI	NC8SCI
R^2	0.490***	0.354***	0.223***	0.394***	0.622***	0.587***
Intercept	3.152***	4.234***	3.490***	3.988***	4.171***	4.261***
YEAR9091	0.000	−0.102***	−0.112***	−0.019	0.030*	0.023
YEAR9192	0.022	0.268***	−0.020	0.091***	0.062***	0.099***
School Policy Inputs						
TEACHER	−0.036	−0.041	−0.413*	−0.109	−0.097	−0.263**
GRAD	0.027	0.078	0.050	0.095***	0.009	0.047*
ADMIN	0.091***	0.342***	0.256***	0.027	0.079**	0.034
AIDES	0.073	−0.035	−0.043	0.147***	0.070	0.072
SPECIAL	0.020	0.207***	0.113**	−0.004	0.032	0.021
OTSTAFF	0.004	0.127	0.136**	−0.005	0.004	0.066*
REALCOMP	−0.124	−0.190	−0.206	−0.026	−0.058	−0.081
REALEQUIP	0.029**	0.037	−0.006	−0.010	0.021	0.022*
REALSUPP	−0.001	−0.075	−0.030	0.022	0.036	0.109**
REALSER	−0.120***	−0.152***	−0.096*	−0.067**	−0.602**	−0.042
REALOTH	−0.013	0.034	0.005	0.009	0.011	−0.010
Socioeconomic Inputs						
PUPILS (1000s)	0.000	−0.003***	0.000	0.000	−0.001	0.000
NONWHITE	−0.028***	0.015	0.004	−0.046***	−0.056***	−0.047***
GIFTED	0.040**	0.153***	0.070**	0.006	0.019	0.030*
HANDICAP	0.013	−0.073	0.082	−0.021	0.027	0.013
FREELUN	−0.062***	−0.142***	−0.099***	−0.023	−0.142***	−0.092***
DROPOUT	−0.033*	−0.089**	0.029	0.016	0.052***	−0.014
ABSENT	−0.080***	−0.052	−0.071**	−0.026	−0.083***	−0.039**
EDU8	−0.032**	0.004	−0.014	−0.023	−0.015	−0.015
EDU8TO12	0.004	−0.015**	−0.023	−0.103***	−0.125***	−0.038
EDUHS	−0.020	0.097	0.073	0.066	0.108***	0.009
EDUCOL	0.246***	0.092	0.193***	0.075***	0.171***	0.217***
NUMTEST	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

*** Significant at the .01 level.
** Significant at the .05 level.
* Significant at the .10 level.
N.A. = not applicable.

tions. Thus, the findings of the static analysis do not support the work of Anderson, Shughart, and Tollison (1991), who expect spending on school administrators to be negatively related to student performance.

The number of teachers (TEACHER) is statistically significant in only five equations, with one positive and four negative signs. Again, because the coefficient on the number of teachers is estimated holding the number of pupils constant, these results are comparable to testing the impact of the teacher/pupil ratio by altering the number of teachers. Thus, the findings are similar to the results of many other studies which show no major impact of the number of teachers (or the teacher/pupil ratio) on student achievement.[8]

It is interesting to contrast the lack of significant impacts for TEACHER to the better findings for SPECIAL and GRAD in the static model. The static results suggest that school districts will have a greater likelihood of im-

[8] A reviewer suggested that one explanation for the weak findings for number of teachers could be inadequate variations in the teacher/pupil ratio: The teacher/pupil ratio varied from a low of 0.056 to a high of 0.065.

Table 5. (Continued)

Dep. Var.	NCALGE1	NCSCHOL	UNCADM	UNITS5	VERB	MATH
R^2	0.367***	0.784***	0.843***	0.850***	0.630***	0.561***
Intercept	3.315***	−1.949	2.079	3.108**	6.688***	6.767***
YEAR9091	0.032	0.118*	−0.002	0.070	0.003	0.012*
YEAR9192	−0.038	0.237***	0.067	0.089	0.015**	0.033***
School Policy Inputs						
TEACHER	0.073	0.550	0.374	1.111***	−0.123**	−0.095*
GRAD	−0.041	0.417***	0.207**	0.172**	0.017*	0.014
ADMIN	0.019	−1.264***	−1.393***	−1.386***	0.007	0.016
AIDES	0.045	−0.211	−0.068	−0.155	0.052***	0.065***
SPECIAL	0.178***	−0.186	−0.072	−0.082	0.015	0.023*
OTSTAFF	−0.013	−0.044	−0.140	−0.043	−0.039**	−0.024
REALCOMP	0.054	0.037	0.652	0.152	0.163***	0.126**
REALEQUIP	0.020	0.014	−0.017	−0.007	−0.001	0.000
REALSUPP	0.006	−0.152	0.018	−0.008	0.014	0.008
REALSER	−0.180***	−0.333***	−0.203**	−0.149*	−0.011	−0.013
REALOTH	−0.043*	0.163***	0.082**	0.057	0.001	0.002
Socioeconomic Inputs						
PUPILS	0.000	0.050***	0.052***	0.050***	0.000	0.000
NONWHITE	−0.030**	0.061**	0.063**	0.048**	−0.020***	−0.012***
GIFTED	0.095***	−0.183***	−0.034	−0.107**	0.012*	0.011
HANDICAP	−0.012	0.127	−0.108	−0.207*	−0.016	−0.010
FREELUN	−0.121***	−0.206**	−0.214***	−0.184***	−0.040***	−0.053***
DROPOUT	−0.074**	0.185***	0.133**	0.184***	0.005	0.009
ABSENT	−0.024	0.119	0.213***	0.171***	0.016**	0.007
EDU8	0.020	−0.007	0.020	0.036	0.007	0.010*
EDU8TO12	−0.118**	0.093	0.042	0.018	−0.049***	−0.064***
EDUHS	0.030	0.057	0.033	0.264**	−0.031**	−0.020
EDUCOL	0.118*	0.764***	0.411***	0.113	0.025*	0.004
NUMTEST	N.A.	N.A.	N.A.	N.A.	−0.005	−0.003

*** Significant at the .01 level.
** Significant at the .05 level.
* Significant at the .10 level.
N.A. = not applicable.

proving student performance if specialists are increased or if existing teachers are encouraged to attain graduate degrees rather than if the number of teachers is simply increased.

It is also interesting to note the lack of consistent results for REALCOMP (teacher pay and benefits). REALCOMP is statistically significant in only three equations, and in one of these the sign is negative.[9] The static results don't support the notion of raising teacher pay as a way of improving student performance.

In the two SAT equations (VERB and MATH) it is important to control for the number of test takers because, unlike the other tests, the SAT is an elective test. It is expected that the greater the number of test takers, the lower the average score. In the VERB and MATH equations the signs on NUMTEST are negative but not statistically significant.

There are some notable differences in the results across achievement measure and grade level. The highest $\bar{R}^2$'s are for the sixth and eighth grade CAT reading scores, sixth grade

[9] As was noted, we do not have teacher experience as an explanatory variable. If teacher experience and teacher compensation are positively correlated, then the omission of experience will bias upward the coefficients on REALCOMP.

Table 6. Joint Contribution of School Policy Inputs to Variation in Student Achievement Measures, Static Analysis

Achievement Measure	Lower Bound	Upper Bound
CAT3RED	1.62%	11.11%
CAT3MAT	3.48	10.47
CAT6RED	1.40	14.86
CAT6MAT	2.15	9.03
CAT8RED	2.29	19.41
CAT8MAT	2.10	16.80
NC6WRIT	5.25	6.46
NC8WRIT	4.31	7.70
NC3SCI	3.04	14.63
NC6SCI	1.23	10.84
NC8SCI	2.04	17.46
NCALGE1	4.37	14.46
NCSCHOL	9.53	86.08
UNCADM	9.41	94.28
UNIT35	11.03	98.32
VERB	2.97	28.42
MATH	2.84	25.15

science scores, and for NCSCHOL, UNCADM, UNITS5, and VERB, each with $\bar{R}^{2\prime}$ above 0.600. In contrast, among the lowest $\bar{R}^2$'s are the equations for North Carolina sixth and eighth grade writing test scores. These results make sense if writing tests tend to be more subjective.

Recent attention has focused on improving early grades' educational outcomes. The most consistent school input performers among the three third grade scores (CAT3RED, CAT3MATH, NC3SCI) are GRAD, ADMIN and AIDES, with each being statistically significant in two of the three equations.

How much collective influence do the school policy inputs have on student achievement? The results of implementing our lower- and upper-bound calculations are given in Table 6. The numbers are sobering for the impact schools can have on student achievement. In the lower-bound calculations, the joint contribution of school policy inputs ranges from 1 percent to 11 percent. In the upper-bound calculations, with three exceptions, the contribution of school policy inputs ranges from 6 percent to 28 percent. The three exceptions are NCSCHOL (86 percent), UNCADM (94 percent) and UNITS5 (98 percent). Thus, with these three exceptions, the most that variation in school inputs can collectively "explain" is 28 percent of the variation in student achievement.

Next, the results of the dynamic model are presented and discussed. Since we have three years of data for 129 districts, there are 258 two-year comparisons. The regression results are given in Table 7 and are summarized and compared to the static results in Table 9.

Clearly the most important determinant of this year's test score is last year's test score. The lagged value of the test score is positive and significant in each of the 17 equations, and in the majority of equations the coefficient is between 0.7 and unity.

Among the socioeconomic inputs, the most consistent results are for ΔPUPILS, and ΔEDUCOL. The coefficient on ΔPUPILS is positive and statistically significant in seven of the 17 equations and not significantly negative in any equation. In equation 9 the parameter estimate on ΔPUPILS is multiplied by a negative.[10] Therefore, our results suggest that, holding other inputs constant, increases in the rate of increase of students in a school district will lead to lower average student achievement measures next year for seven of the 17 output measures. Notice that three of the seven significant ΔPUPILS coefficients occur for third grade test scores.

The coefficient on ΔGIFTED is negative and statistically significant in four of the 17 equations. This is contrary to expectations, but one possible explanation follows. If faster increases in the number of students classified as gifted in a school district is due not to more gifted students moving into the district, but is a result of more existing students being classified as gifted, then such students may perform more poorly on standardized tests as a result of the time they are "pulled away" from regular classroom instruction.

[10] Again, the parameter estimates on ΔPUPILS were restricted to equal the sum of the parameter estimates on school policy inputs and socioeconomic inputs, but not including the parameter estimate on the lagged score.

Table 7. Regression Results for Student Achievement Measures, Dynamic Model

Dep. Var.	CAT3RED	CAT3MAT	CAT6RED	CAT6MAT	CAT8RED
R^2	0.664***	0.553***	0.750***	0.643***	0.758***
Intercept	0.881***	1.106***	0.459***	0.849***	0.601***
LAGSCORE	0.768***	0.730***	0.886***	0.979***	0.851***
ΔYR9192	0.019	0.046**	0.000	0.016	−0.009
School Policy Inputs					
ΔTEACHER	0.204	0.162	0.380**	0.390**	0.210
ΔGRAD	−0.021	0.015	−0.098	−0.127	−0.169**
ΔADMIN	−0.014	0.005	0.087	0.052	0.101*
ΔAIDES	−0.142	0.054	−0.012	0.011	−0.189**
ΔSPECIAL	0.068**	0.024	0.109***	0.007	0.032
ΔOTSTAFF	0.051	0.019	−0.036	−0.038	−0.003
ΔREALCOMP	0.413	0.150	−0.604***	−0.482*	−0.035
ΔREALEQUIP	−0.005	0.002	0.003	−0.008	0.013
ΔREALSUPP	0.123**	0.067	0.046	0.037	0.064
ΔREALSER	−0.118**	−0.048	0.018	−0.038	−0.040
ΔREALOTH	−0.001	−0.005	−0.011	−0.005	−0.026**
Socioeconomic Inputs					
ΔPUPILS	0.623**	0.356*	−0.314	−0.107	0.238
ΔNONWHITE	−0.192	0.036	0.159	0.164	0.117
ΔGIFTED	0.008	−0.013	−0.049	−0.097**	−0.003
ΔHANDICAP	0.003	−0.017	0.040	0.072	−0.027
ΔFREELUN	−0.044	0.006	−0.323**	−0.007	0.054
ΔDROPOUT	−0.016	−0.037**	0.006	0.011	0.014
ΔABSENT	0.003	0.009	−0.032*	−0.033	−0.021
ΔEDU8	0.009	0.016	0.017	0.012	0.006
ΔEDU8TO12	−0.006	0.050	−0.043	−0.074*	0.031
ΔEDUHS	0.039	0.069*	0.060	0.001	0.003
ΔEDUCOL	0.163**	0.096	0.148**	0.043	0.106*
ΔNUMTEST	N.A.	N.A.	N.A.	N.A.	N.A.

*** Significant at the .01 level.
** Significant at the .05 level.
* Significant at the .10 level.
N.A. = not applicable.

The coefficient on ΔEDUCOL is positive and significant in six of the 17 equations. All of the significant coefficients occur for elementary school scores. The coefficient on ΔNONWHITE is statistically significant in only two of the 17 equations, with one coefficient being positive and one being negative.

Among the school input variables, the most noteworthy result is for ΔTEACHER. The coefficient on ΔTEACHER is positive and statistically significant in six of the 17 equations and significantly negative in none. This is dramatically different from the results in the static analysis, where the coefficient on TEACHER was positive and statistically significant in only one equation. The dynamic results suggest that districts which increase the number of teachers at a faster rate than other districts will see a greater increase in test scores for six of the 17 performance measures.

Among the other school inputs, the most consistent results are for ΔGRAD, ΔADMIN, and ΔSPECIAL. The variable ΔGRAD is statistically significant in six of the equations, with five of the coefficients being negative. This is almost the reverse of the findings in the static model. In contrast, the results for ΔADMIN and ΔSPECIAL are similar, al-

Table 7. (Continued)

Dep. Var.	CAT8MAT	NC6WRIT	NC8WRIT	NC3SCI	NC6SCI	NC8SCI
$\bar{R}^2$	0.663***	0.454***	0.429***	0.554***	0.708***	0.667***
Intercept	0.956***	2.022***	1.141***	1.515***	0.829***	1.116***
LAGSCORE	0.760***	0.456***	0.689***	0.617***	0.795***	0.724***
ΔYR9192	0.007	0.263***	0.142***	0.134***	−0.008	0.054***
School Policy Inputs						
ΔTEACHER	0.075	0.651	0.013	0.139	0.410**	0.431**
ΔGRAD	−0.107	0.174	0.270*	−0.018	−0.171**	−0.238***
ΔADMIN	0.124**	0.026	0.085	0.010	0.112*	0.136**
ΔAIDES	−0.123	−0.002	0.147	−0.093	−0.068	−0.070
ΔSPECIAL	0.039	−0.071	0.007	0.033	0.060*	0.032
ΔOTSTAFF	−0.030	0.015	0.019	0.001	−0.011	−0.053
ΔREALCOMP	0.153	−1.121*	−0.230	0.409	−0.376	−0.183
ΔREALEQUIP	0.007	0.033	−0.021	−0.008	−0.012	0.008
ΔREALSUPP	0.059	−0.266*	0.120	0.087	0.091	0.062
ΔREALSER	−0.078	0.089	−0.059	−0.147**	−0.701	−0.099*
ΔREALOTH	−0.004	0.037	−0.018	0.007	0.000	−0.011
Socioeconomic Inputs						
ΔPUPILS	0.370	−0.293	0.432	0.687***	0.310	0.391*
ΔNONWHITE	0.092	−0.112	−0.190	0.129	0.298***	0.079
ΔGIFTED	−0.021	−0.235***	−0.061	−0.001	−0.046	−0.058
ΔHANDICAP	0.006	0.258*	0.122	−0.010	−0.001	0.048
ΔFREELUN	0.332**	0.421	0.280	−0.064	−0.088	0.173
ΔDROPOUT	−0.011	0.032	0.025	0.005	0.027	0.015
ΔABSENT	−0.012	0.037	−0.019	0.001	−0.037*	−0.016
ΔEDU8	−0.002	0.012	−0.001	0.015	0.009	0.013
ΔEDU8TO12	−0.043	−0.085	0.032	0.026	−0.022	0.008
ΔEDUHS	−0.054	−0.050	−0.117	0.028	0.047	0.004
ΔEDUCOL	−0.030	−0.137	0.029	0.140**	0.160**	0.109*
ΔNUMTEST	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

*** Significant at the .01 level.
** Significant at the .05 level.
* Significant at the .10 level.
N.A. = not applicable.

though not as strong, as in the static analysis. Both have positive and statistically significant parameter estimates in four equations, and statistically negative estimates in none.

The same procedures that were used in the static analysis to estimate the total contribution of school policy inputs were also applied to the dynamic analysis.[11] Upper- and lower-bound estimates for the total contribution of change in school policy inputs to this year's achievement scores, given last year's scores, are given in Table 8. The results again suggest the relative small contribution of school policy inputs, with most total upper-bound contributions being under 10 percent.

[11] In these calculations, the lagged achievement score was included with the socioeconomic inputs.

Conclusions and Implications

This paper has examined the relationships between various measures of student performance and school policy inputs and socioeconomic inputs in North Carolina school districts. The relationships were examined in two ways. First, a static analysis was performed in which the data for three years were

Table 7. (Continued)

Dep. Var.	NCALGE1	NCSCHOL	UNCADM	UNITS5	VERB	MATH
$\bar{R}^2$	0.659***	0.903***	0.958***	0.981***	0.733***	0.767***
Intercept	0.748***	0.257***	0.064	0.087	0.981***	0.901***
LAGSCORE	0.809***	0.954***	0.977***	0.994***	0.834***	0.851***
ΔYR9192	−0.082**	0.078	0.158***	−0.021	0.010	0.007
School Policy Inputs						
ΔTEACHER	−0.011	1.547***	0.175	0.513**	0.004	0.034
ΔGRAD	−0.057	−0.751***	−0.354**	0.163	0.001	−0.012
ΔADMIN	0.072	−0.005	−0.060	−0.011	−0.018	−0.009
ΔAIDES	−0.303**	0.016	−0.122	0.015	0.031	−0.013
ΔSPECIAL	0.108*	0.115	−0.019	−0.053	0.016	0.006
ΔOTSTAFF	0.029	−0.177	0.092	−0.046	−0.035**	−0.037***
ΔREALCOMP	1.172***	0.063	0.753	−0.642*	0.244**	0.205**
ΔREALEQUIP	0.012	−0.051	−0.025	0.017	−0.005	−0.002
ΔREALSUPP	−0.137	−0.074	0.186	0.134*	−0.038*	−0.001
ΔREALSER	−0.083	−0.140	−0.178	0.082	0.006	−0.015
ΔREALOTH	0.028	−0.015	−0.002	0.034**	−0.005	−0.002
Socioeconomic Inputs						
ΔPUPILS	1.138***	−0.041	−0.151	−0.164	0.159*	0.198**
ΔNONWHITE	−0.046	−0.161	−0.019	0.066	−0.031	−0.075**
ΔGIFTED	0.023	−0.213*	0.027	−0.151***	−0.007	0.010
ΔHANDICAP	0.100	0.201	0.277**	0.080	0.020	−0.002
ΔFREELUN	0.203	−0.297	−0.774***	−0.388**	0.045	0.142***
ΔDROPOUT	−0.036	0.116**	0.042	0.135***	−0.005	0.005
ΔABSENT	0.025	−0.026	−0.027	−0.003	0.004	0.012*
ΔEDU8	0.032	−0.005	0.003	−0.014	0.005	0.009**
ΔEDU8TO12	−0.037	−0.145	0.018	0.000	−0.032**	−0.024*
ΔEDUHS	0.085	−0.128	−0.035	−0.021	−0.007	−0.004
ΔEDUCOL	−0.063	0.089	0.154	−0.075	0.002	0.022
ΔNUMTEST	N.A.	N.A.	N.A.	N.A.	−0.0229*	−0.051***

*** Significant at the .01 level.
** Significant at the .05 level.
* Significant at the .10 level.
N.A. = not applicable.

pooled and the "level" of student performance was related to the "levels" of school policy inputs and socioeconomic inputs. Second, a dynamic analysis was conducted in which this year's student performance was related to last year's performance and the changes in school policy inputs and socioeconomic inputs.

The results of the two analyses provide a number of conclusions and implications. First, the results varied by the measure of student performance used. For example, in the dynamic analysis, increases in the rate of increase of teachers were associated with increases in sixth grade reading and math test scores but not with changes in third grade reading and math test scores. This means it is potentially misleading for analysts and policymakers to base general conclusions about how school inputs affect student performance from results derived from one student achievement measure.

Second, substantial differences were found for specific variables in the static and dynamic analyses. The most notable differences were for school policy inputs. For example, in the static analysis, little impact on student performance measures was found for the number of

Table 8. Joint Contribution of School Policy Inputs to Variation in Student Achievement Measures, Dynamic Analysis

Achievement Measure	Lower Bound	Upper Bound
CAT3RED	2.26%	8.20%
CAT3MAT	0.90	3.90
CAT6RED	1.73	5.62
CAT6MAT	0.95	5.64
CAT8RED	2.12	5.32
CAT8MAT	1.71	7.33
NC6WRIT	2.63	20.76
NC8WRIT	1.99	4.55
NC3SCI	1.76	5.59
NC6SCI	1.87	7.65
NC8SCI	2.97	6.93
NCALGE1	1.94	16.97
NCSCHOL	0.50	5.57
UNCADM	0.22	4.94
UNIT35	0.15	5.12
VERB	2.06	3.96
MATH	0.96	5.86

Table 9. Summary of Regression Results for Student Achievement Measures, Static and Dynamic Models

	Statistically Significant Positive Coefficient		Statistically Significant Negative Coefficient	
School Policy Inputs	Static Model	Dynamic Model	Static Model	Dynamic Model
TEACHER	1	6	4	0
GRAD	7	1	0	5
ADMIN	9	4	3	0
AIDES	4	0	0	2
SPECIAL	6	4	0	0
OTSTAFF	2	0	1	2
REALCOMP	2	3	1	4
REALEQUIP	5	0	0	0
REALSUPP	2	2	0	2
REALSER	0	0	12	3
REALOTH	2	1	1	1
Socioeconomic Inputs				
PUPILS	4	7	1	0
NONWHITE	3	1	12	1
GIFTED	9	0	2	4
HANDICAP	0	2	3	0
FREELUN	0	2	16	3
DROPOUT	4	2	4	1
ABSENT	3	1	6	2
EDU8	1	1	2	0
EDU8TO12	0	0	11	3
EDUHS	6	1	1	0
EDUCOL	13	6	0	0

teachers, whereas significant positive impacts were found for the number of teachers with a graduate degree, the number of administrators, the number of specialists, and spending on equipment.

In the dynamic analysis, the findings were different. No impacts were found for changes in equipment spending, and faster increases in the number of teachers with a graduate degree had a negative impact on student performance in five of the 17 equations. In contrast, in six of the equations, faster increases in the number of teachers were positively associated with student performance. More rapid increases in the number of administrators and specialists continued to have positive impacts on student achievement, but in fewer equations. Therefore, to the extent that the dynamic analysis is superior because of the way it handles unmeasurable innate student abilities, researchers and policymakers may be worried about results from static analyses.

A third conclusion of the study concerns the relative contribution of school policy inputs and socioeconomic characteristics to student achievement (Table 8). Measures of the total contribution of all school inputs together revealed that, at a maximum, they could generally account for 20 percent of the variation in student achievement measures in the static analysis and 10 percent in the dynamic analysis. These findings suggest student performance is heavily dominated by socioeconomic inputs and unobservable innate abilities of students. They also raise a question about how scarce public resources can best be allocated to improve student performance. Would school outcomes be more improved if marginal public resources are added to school inputs or if these resources are used to improve the socioeconomic status of students? The results reported in this study suggest the second choice.

There are three major implications of this study for public school decision-makers. First, the study has demonstrated the usefulness of dynamic analysis in measuring student progress and the relationships between inputs and student achievement. Again, to the extent that dynamic analysis controls for unobservable innate student abilities better than static analysis, dynamic analysis is the preferred method for both measuring student performance and measuring the relationship between performance and school inputs.

School policymakers are increasingly being held accountable for student achievement and for effective allocation of resources. For example, in North Carolina, school principals in many districts have some discretion over how resources are allocated; that is, principals can spend marginal dollars on additional teachers or additional teaching materials. However, school principals can also be removed if their students don't perform to certain levels. In this environment it becomes very important to properly measure student achievement and relationships between achievement and inputs. Fortunately, North Carolina is applying a dynamic method, measuring the change in student achievement scores and relating those changes to changes in inputs.

A second policy implication concerns what the study reveals about which school inputs are most effective in improving student performance. Using the dynamic model as the better approach, the answer is the number of teachers. In six of the 17 student achievement equations, faster rates of increase in the number of teachers, with the number of pupils held constant, were associated with improved student performance. In no dynamic equations were greater increases in the number of teachers associated with poorer student performance.

A third policy implication is that school officials, politicians, and parents need to be realistic and modest in their expectations for what schools can deliver. The study found that school policy inputs, collectively, have a relatively small impact on student achievement. At best, school inputs can have marginal effects on student performance.

Several extensions are recommended for this topic in future research. Most states collect data similar to those used in this study, so the study could be replicated in other states. It would be helpful if more detailed information on school policy inputs could be gathered and used, such as spending on computers and technology and on specific teaching materials. Also, it would be interesting to repeat the analysis at the building level rather than the district level.

Last, this study has focused on the technical efficiency of the production function, that is, what inputs have the most impact on student achievement? The next step would be to also consider economic efficiency, that is, calculating the costs of changing alternative inputs necessary to change student achievement by a given amount.

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