School Reform, School Size, and Student Achievement

by Randall W. Eberts,
Ellen Kehoe Schwartz,
and Joe A. Stone

Randall W. Eberts is an assistant vice president and economist at the Federal Reserve Bank of Cleveland; Ellen Kehoe Schwartz is a research evaluator with the General Accounting Office; and Joe A. Stone is the W.E. Miner Professor of Economics at the University of Oregon. This work was supported in part by the National Institute of Education, when all three authors were at the University of Oregon.

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Introduction

The effectiveness of the U.S. educational system has been called into question in recent years. Various commissions and studies have declared our nation to be at risk of losing its comparative advantage in education, and consequently its intellectual and productive edge, to other nations. A recent evaluation of American industrial productivity by a commission sponsored by the Massachusetts Institute of Technology found a disturbing deterioration in student achievement levels (Dertouzos et al. [1989]). It cited recent studies that place American 10-year-olds eighth out of 15 countries in science achievement and even lower in mathematics skills. Since then, additional studies have appeared that support the declining status of elementary and secondary education in the United States (*Time,* September 11, 1989).

Much of the blame for our slippage among the ranks of developed countries has fallen on public schools. Opponents criticize public schools for a monopoly position that, in their view, insulates schools from being fully accountable to taxpayers, students, and parents, especially in larger school districts. It is argued that the lack of competition among schools promotes inefficient use of resources and a general decline in quality of the entire educational system. The alleged inability of our educational system to respond to "market" pressures for improved educational quality is particularly troubling as the nation continues to face mounting demands from greater global competition.

Recent proposals for reforming the educational system have called for increased parental and student choice, introducing elements of the private market system into public education. Increased freedom by parents and students to choose the school that best meets their educational needs would, in this view, not only provide a better match of supply with demand, but would also discipline teachers and administrators to be more responsive to the needs of students and thus provide a more efficient and effective educational program.

While there is much discussion about the pros and cons of market-based school reforms, few empirical tests of the effects of these reforms have been conducted. The primary reason for the lack of systematic assessments is simply that these programs have not been in place long enough for any meaningful evaluation. Until that happens, the best means of evaluation is to examine student outcomes associated with the different institutional arrangements that may stem from these reforms.

One institutional change that could result from these reforms is smaller schools. Chambers (1981) argues that student and parental choice would give school managers incentives to form smaller schools in order to provide students with more varied options within a given market area. Also, Chambers cites several studies showing that smaller schools are more cost efficient than larger schools, which would also be important as administrators compete for students with other schools. Whether school reform will actually result in smaller schools is unclear, although the possibility seems viable.

The purpose of this paper, then, is to examine the effect of school size on student achievement. The study is based on mathematics test scores of individual elementary students in 287 schools nationwide. While previous research suggests that student achievement may be influenced by school size (Coleman et al. [1966] and Summers and Wolfe [1977]), there is no consensus regarding the precise nature of this influence. This study will explore how school size affects student achievement in two steps. First, individual students are linked to school-related resources by estimating an educational production function with teacher and principal characteristics as inputs. Second, differences across various size classes of schools in the levels of inputs and in the effects of school-based inputs on student outcomes are examined in order to identify those characteristics that differ the most across school size.

This two-step approach allows an examination of both the direct and indirect effects of school size on student achievement. The direct effects are derived from greater effectiveness of school-based resources; indirect effects arise from changes in the amounts of school-based resources that are associated with differences in school size. Our results indicate that large elementary schools with more than 800 students are significantly less effective in producing positive student outcomes than schools with fewer than 200 students.

The paper is organized as follows. Section I provides a brief discussion of market-based reforms, emphasizing how they relate to school size. Section II outlines how school size may affect the behavior of key participants in the educational process: administrators, teachers, and students. Section III describes the methodology and data, and section IV contains the estimation results. The paper concludes with a summary of the results and a discussion of their implications for market-based school reforms.

I. Market-Based School Reform

Not surprisingly, economists have been supporting a market approach to providing education for some time. Nearly three decades ago, Milton Friedman (1962) advocated a financing scheme for education built on choice. He proposed that "...parents who choose to send their children to private schools would be paid a sum equal to the estimated costs of educating a child in a public school" (p. 93). Much earlier, Adam Smith advocated a system in which at least some of the financing of education would be made directly from the parent to the school, lest the teacher "... would soon learn to neglect his business" (as quoted in Levin [1989]).

The notion of choice in education has once again gained popularity with endorsements by public officials and scattered implementation at the state level. For example, Minnesota has adopted an open-enrollment plan in which students can use vouchers to attend schools outside their district. Ohio has recently legislated a somewhat similar plan that is scheduled to be phased in by 1993.

However, the wholesale application of the private-sector paradigm of market-driven incentives and unbridled choice in order to make the educational system more responsive and efficient has not been embraced with equal enthusiasm by everyone. Some critics claim that greater choice would increase inequality and reduce the ability of school systems, because of their monopoly position, to serve the handicapped and the underprivileged (Peterson [1989], p. 20). Others claim that the voucher and tax credit system would impoverish the public schools, weakening the very institutions that have most helped the needy (Cooper [1988]). Parental choice, opponents charge, would splinter existing schools into a rabble of smaller schools, reducing the educational opportunities that are available only to students in larger schools.

Nonetheless, choice is not altogether alien to the public school system. Several studies have found that residential choice within a metropolitan area is significantly affected by the quality of local schools, as measured by test scores and other quantifiable educational outcomes (Meadows [1976]). Furthermore, property values are positively correlated with quality schools. Thus, a structure is already in place in which local school boards and administrators have at least some incentive to provide services that parents want. Today, the typical individual living in a metropolitan area has an average of 23 independent school districts from which to choose without the need to change jobs. Furthermore, the average size of public schools has decreased slightly from a high of 680 pupils in 1970 to 650 pupils in recent years.

The efficacy of choice in inducing a more responsive and efficient provision of educational services rests with the ability of this incentive system to change the behavior of teachers and administrators, which in turn can affect student achievement. Unfortunately, except for the studies of residential choice mentioned above, there has been little experience within the present educational system to provide the basis for testing empirically the influence of choice on educational quality.

II. School Size and the Educational Process

Education takes place in the classroom. Therefore, for school size and thus for the consequences of school reform to influence student achievement, the effects must enter the classroom. The educational process is sufficiently complex that concentrating only on teachers, or on aspects of the interaction between teacher and student, is not sufficient to assess the overall effect of school size. Hence, we posit a simple model of the educational process that identifies four basic groups of determinants of student achievement: 1) student characteristics; 2) teacher characteristics; 3) instructional process; and 4) administrator characteristics. School size can affect student achievement by affecting these inputs.

Student Characteristics

A number of studies have suggested that school size affects certain student-specific characteristics such as student attendance, student satisfaction, and student participation in extracurricular activities (Huling [1980], Barker [1978], Gump [1978], and Lindsay [1982]). Lindsay's study, in particular, points to school size as a potential policy variable, since he found size to be independent of the effects of socioeconomic status, academic ability, and the urban or rural location of the school.

Teacher Characteristics

Previous studies underscore the importance of school size on various teacher characteristics. Dunathan (1980) stated that small schools have difficulty attracting and retaining qualified teachers and that this condition may be expected to worsen over time. Moreover, the continuity of the educational program in small schools may be disrupted by teacher turnover, which is often three to five times as high as that of average-sized schools. In support of smaller schools, Ayrault and Crosetto (1982) hypothesize that the degree of teacher participation in school-level decisions, such as those related to hiring or helping to orient a new teacher, is greater in small schools because "...teachers realize that even one new teacher will have a significant impact on the school" (p. 61).

Instructional Process

Prior research also indicates that school size may be related to student achievement through the way it affects the instructional process. Eberts (1984) found a significant inverse correlation between school size and the time teachers spend on instruction. One might also expect school size to be related to the mode of instruction in terms of class size and the degree to which the instructional program is individualized. A study by Erickson and Nault (1978) suggested that the benefits of small schools include a greater probability that teachers would become more familiar with the needs of individual students and an increased likelihood that parents would get involved in their child's educational program.

Administrative Leadership

In an atmosphere of concern about low student achievement in public schools, the relationship between administrative leadership and school effectiveness has received considerable attention. A number of studies have provided evidence that administrative leadership is indeed a promising area for research relating to school improvement. For example, Keeler and Andrews (1973) found that the leadership behavior of the principal, as perceived by his or her staff, was significantly related to the productivity of the school. More recently, a number of researchers have provided corroborating evidence in support of the hypothesis that school–principal involvement in instructional leadership is correlated with improved student outcomes (Eberts and Stone [1984], Edmonds [1979], Brookover et al. [1979], and Wellisch et al. [1978]).

For example, the findings of Wellisch et al. suggest that administrative leadership can lead to better schools and that leadership includes an interrelated and complex set of functions that require further exploration. For example, principals in schools where there had been student achievement gains were significantly more likely to "...review and discuss teaching performance regularly with their staff" (p. 217). Wellisch et al. also reported that principals and teachers in these more successful schools were significantly more likely to report a high degree of program coordination.

While the studies noted above support the notion that principal involvement in instructional leadership will lead to school improvement, others have found that principals who actively engage in such activities are indeed rare (Deal et al. [1975], Lortie [1969], and Corwin [1970]). Moreover, even researchers who accept the notion that instructional leadership is linked to school improvement have asserted that this leadership is not necessarily embodied in the principal per se, but rather that there are critical support functions that must be carried out. These support functions may be performed by a variety of school personnel other than the principal, including curriculum specialists, department heads, and teachers (Gersten and Carnine [1981]).

Finally, yet others caution that even when principals engage in the comprehensive set of tasks referred to as instructional leadership, the participation of teachers must also be considered as a critical variable (Wellisch et al. [1978]). Unfortunately, however, Wellisch et al. did not include a measure of the participation of teachers in their study. Therefore, we intend to explore the relationship of student achievement to both administrative leadership and to the degree to which teachers work well together and feel that the instructional program is well planned.

III. Methodology and Data

Our analysis is based on estimating an educational production function that relates gains in individual student test scores in mathematics to various measures of educational inputs. Mathematics is chosen over reading achievement because school-based resources, primarily teachers, have been shown by Madaus et al. (1979) to play a relatively greater role in mathematics achievement than in reading achievement.

Output is measured as the gain in achievement of individual students. Each student's post-test score, which is administered at the end of the school year, is regressed against the pretest score, along with the other variables described below. The method is similar to using the difference in the two test scores as the dependent variable, but without constraining the coefficient on the pretest score to be one. This approach reflects the concern that prior achievement in mathematics should be considered as a predictor of achievement in mathematics in a later time period, and therefore should be held constant in an attempt to discern what other types of input variables may be related to student achievement.

Various factors that may influence student achievement in mathematics are considered: student background characteristics (sex, race, childhood experience, parental involvement, economic status), teacher characteristics (years of teaching experience, terminal degree, courses taken in mathematics in the three years before the survey was administered, hours of in-service training in mathematics taken in the last three years), and principal characteristics (years of teaching experience, years of administrative experience, terminal degree, and hours per year spent in curriculum development in mathematics; hours per year spent in needs assessment, program planning, and program evaluation related to mathematics; and a composite measure of "instructional leadership" including the last two sets of variables).

We also consider variables related to time teachers spend on various types of tasks related to instruction, preparation, and administration. In addition, we include the number of administrators, teachers, and office personnel per student as a measure of the human resources available for assisting in the task of "producing" student achievement. Finally, since we believe principal and teacher attitudes about instructional management are important, we examine how these may be related to student achievement in mathematics. Teacher attitudes include the degree to which the principal is an effective leader overall, the principal is encouraging and supportive, the school program is well planned, the principal provides active leadership related to the mathematics program, the teachers work well together and are kept well informed, and conflicts are identified and resolved. The above set of attitudinal data, with the exception of the first two items, was also included in the educational production function with the principal as respondent.

Integrating the various determinants of student achievement with school size requires a data set that relates both to the basic learning process and to the institutional and governance structure of school systems. Fortunately, the "Sustaining Effects Study," conducted by the Systems Development Corporation (SDC) for the former Office of Education, contains many of the variables needed to examine the issues of student achievement, administrative leadership, and school size (Hemenway et al. [1978]). Our analysis utilizes

TABLE 1

Distribution of School Size

Description	Range	Mean School Size	Number of Schools
Small	0-199	129	58
Small/medium	200-399	308	86
Medium	400-599	492	94
Medium/large	600-799	691	30
Large	Over 800	1,044	19

SOURCE: Authors' analysis of Systems Development Corporation dataset.

a subsample of the original SDC data set, which includes information from 287 schools. As shown in table 1, this subsample was partitioned further into five subsamples on the basis of school size. The criteria used for partitioning the sample are described in the next section.

The representative sample of 14,000 fourth-grade students attending the 287 schools was then sorted according to the size of school they attended. Based on individual student test scores, separate education production functions were estimated for each size category.

One drawback of the data set is that it is not current. Unfortunately, no comparable data base exists for more recent years. Nonetheless, since we are examining different institutional structures, which presumably change rather slowly, and since we are able to control for a host of educational factors, we find the results of this study pertinent to the current discussion of school reform.

IV. Estimation Results

The analysis of differences in the educational process across schools of various sizes includes an examination of differences across school sizes in both the levels of school-based resources and the effectiveness of these resources in influencing student achievement in mathematics. Differences in the means are regarded as unconditional, in the sense that school size may or may not be the cause of these differences. Differences in the coefficients, on the other hand, are conditional on other factors included in the regression and thus can be considered a more direct result of school size.

Differences in Levels of Resources

The first part of this analysis focuses on the levels of resources available for use in schools of various sizes. The next section discusses size-related differences in the effectiveness of these resources. However, before looking at differences in levels or effectiveness, we first must determine the relevant set of factors to consider. Based on previous research (Eberts and Stone [1984]), we found the following school-related variables to be major determinants of student achievement in mathematics: teacher instruction time, teacher preparation time, teacher experience, principal involvement, principal experience in teaching, principal experience in administration, teacher and principal attitudes, and the teacher–student ratio.

The means of these variables and others are listed in table 2 by school size. Selection of the school-size categories was based on earlier research on economies of scale in school operations and on school size and student outcomes. Garms, Guthrie, and Pierce (1978), summarizing past findings on school size, suggested that elementary schools of between 300 and 800 students seem to be the most economical (p. 365). More recently, Levin (1983) has argued that it may be more efficient for school districts to maintain small schools, rather than to close them in response to declining enrollments, as small schools may produce greater student achievement. Therefore, we classified schools with more than 800 students as large and schools with less than 200 as small; medium schools are defined as having between 400 and 600 students. We purposefully omitted the categories of 200–400 and 600–800 to simplify the presentation of the findings. Where relevant to the interpretation of the findings, the results related to small/medium and medium/large schools will also be discussed.

Looking first at student characteristics, only economic status and pretest scores exhibit significant differences across school size. On average, students in both small and large schools are less economically advantaged than those in medium-sized schools. Since city type and geographical region have not been held constant (because of lack of relevant data), these factors seem to be responsible for the variation in economic status rather than school size per se.

Pretest scores are significantly higher in small schools and significantly lower in large schools when compared with the scores of students attending medium-sized schools. However, while we do account for a number of student, teacher, and principal characteristics, it is likely that at

TABLE 2

Means of Educational Inputs by School Size

Variables	Small (0-199 students)	Medium (400-599 students)	Large (More than 800 students)
Sex (Male = 1)—Student	0.510	0.501	0.498
Race (White = 1)—Student	0.875	0.764	0.504
Childhood experience—Student	0.935	1.057	1.023
Parental involvement—Student	1.841	1.882	1.850
Economic status—Student	215.923[a]	226.827	199.170[a]
Administrators per student	0.005	0.004	0.004
Teachers per student	0.058	0.056	0.052
Office staff per student	0.017	0.018	0.025
Teacher time in instruction	4.970	4.893	4.763
Teacher time in preparation	1.506	1.355	1.426
Teacher time in administrative duties	0.788	0.767	0.775
Total years teaching—Teacher	13.744[a]	11.600	10.614[a]
Highest degree—Teacher	2.458	2.450	2.559
College math courses—Teacher	0.440	0.634	0.720
Math in-service—Teacher	3.911[a]	7.697	7.693
Principals' leadership/Teachers' perception	2.958[a]	3.347	3.706[a]
Principals' encouragement/Teachers' perception	3.119	3.238	2.957[a]
Pretest score	29.458[a]	28.755	26.390[a]
Pretest score—squared	961.191[a]	924.071	774.590[a]
Highest degree—Principal	2.933	3.012	3.000
Total years teaching—Principal	10.961[a]	9.588	9.617
Total years administration—Principal	8.265[a]	9.189	8.002[a]
Math participation—Principal	8.023[a]	9.472	10.750[a]
Math involvement—Principal	8.632[a]	11.016	15.157[a]
Instructional leadership—Principal	49.648[a]	52.882	54.783[a]
Attitudes:			
Well planned—Principal	3.008	3.358	3.148
Well planned—Teacher	2.769	2.651	2.155[a]
Active leadership—Principal	2.914	3.208	3.234
Active leadership—Teacher	2.365	2.256	2.105
Work well together—Principal	3.568	3.549	3.253
Work well together—Teacher	3.259[a]	2.982	2.573
Well informed—Principal	3.229	3.382	3.350
Well informed—Teacher	2.483	2.317	2.077[a]
Conflicts identified—Principal	3.271	3.345	3.085
Conflicts identified—Teacher	2.819[a]	2.311	1.585
Post-test score	40.268[a]	38.950	35.775[a]

a. The difference between the mean for this subgroup and for the medium-sized-school subgroup is significant at the .05 level.
SOURCE: Authors' analysis of Systems Development Corporation dataset.

least part of this difference can be attributed to factors other than school size. One set of variables that we have not included, the degree to which classrooms are heterogeneously grouped according to ability, race, and socioeconomic status (SES), may have accounted for some of the difference in pretest scores. In smaller schools, it is less likely that students will be tracked by ability levels (which in turn may be correlated with SES and race).

There is some evidence, though the results are mixed, that achievement scores for students with lower ability may be positively affected by the presence of higher-ability peers in the classroom (Hedrick [1984], Murnane [1981]). Consequently, if these types of conditions are, in fact, more prevalent in smaller schools, it is likely that school size alone is not responsible for the difference in means for students' pretest scores in mathematics across school size.

Earlier we noted that previous studies have found school size to be correlated with such factors as student participation in extracurricular activities, attendance, and satisfaction. However, these studies focused on high school students rather than elementary students. Given that elementary students have little choice about attendance or, perhaps, participation in extracurricular activities, and that measures of student satisfaction are not included as part of this data set, similar analyses have not been undertaken here.

No significant differences in the number of administrators, teachers, or office personnel per student were found across school size. Similarly, no significant differences were found in the amount of time teachers reported devoting to instruction, preparation, or administration. With regard to teachers' years of experience, however, significant differences are apparent. Teachers in small schools have significantly more years of experience than do those in medium schools. This finding downplays Dunathan's (1980) concern about high teacher turnover in small schools. Instead, teachers in large schools tend to have fewer average years of experience. (Teachers in both small/medium and medium/large schools have, on average, 12.5 years of experience.) However, this does not seem to be a major problem for districts with large schools, as the relationship between teacher experience and student achievement is such that after three years of experience it is not clear that students are reaping additional benefits from the additional years of teacher experience for which the district must allocate scarce resources to "purchase" (Murnane [1981]).

While averages for teachers across all three types of schools are similar in terms of the highest degree obtained and number of math courses taken, school size does seem to be related to the amount of in-service work teachers have done in mathematics. Generally, those in larger schools spend more time in on-the-job training in mathematics instruction. Perhaps this stems from a relationship between the degree of discretionary funds available for such programs and school size. An equally plausible explanation is that, due to economies of scale, districts that have a high proportion of large schools feel it is cost-efficient to offer in-service training in mathematics, rather than have teachers take courses outside the district that might be unrelated to districtwide programs.

The degree to which teachers perceive the principal as an effective leader is significantly related to school size. Principals in small schools are perceived as less effective than their counterparts in medium schools, and even less effective than principals in large schools. One possible explanation is that in very small schools, elementary principals may also take on duties that would be done by teachers in larger schools. Perhaps role ambiguity or the breadth of the job makes it difficult for principals in small schools to be effective leaders. Gersten and Carnine (1981) report that in order to have instructionally effective schools, certain support functions must be carried out, though not necessarily by the principal. In larger schools, principals generally can delegate those instructional support tasks to other school personnel for areas in which they themselves are weakest, or perhaps for areas they like least. Therefore, in larger schools, where a principal has more discretion over which tasks he or she will perform, it seems plausible that the principal may be seen as a stronger leader.

Size does seem to be related to many principal characteristics. Principals in smaller schools generally did not attain degrees as high as those earned by principals in medium or large schools, although the difference is not statistically significant. Cross-tabulations not reported here show that approximately 10 percent of principals in small schools did not hold master's degrees, compared to less than 3 percent for principals employed in other schools, and that none of the principals in our sample of small schools hold doctorates. The latter finding is not surprising, as only 2 percent of the principals in our sample of 287 schools hold doctorates. Like teachers in small schools, principals in small schools have more years of teaching experience than do those in medium or large schools. However, principals in both small and large schools have less experience as administrators than do those in moderately sized schools.

Principals were asked to report the amount of time they spent during the school year participating in activities related to curriculum development in mathematics. The pattern of responses to this question revealed that progressively more time was spent in curriculum development as school size increased. Principals adhered to the same general pattern with respect to the number of hours during the year that they "devoted to needs assessment, program planning, and program evaluation" for math activities in their schools.

Both principals and teachers were also asked their opinions about their working relationships and instructional leadership. Each group was asked to rate the following statements between one and four, with a one denoting strong disagreement with the statement and a four signifying strong agreement.

1) The school's programs are well planned and clear.

2) The principal provides active leadership to reading and mathematics programs.

3) Teachers in this school work well together.

4) Administrators keep teachers well informed.

5) Conflicts among individuals are identified and faced, and are not allowed to fester.

Teachers in large schools seemed to be less satisfied than teachers in medium-sized or small schools by giving significantly lower scores to statements (1), (3), and (5). Teachers in large schools appeared to be particularly dissatisfied with the way conflicts were managed. In fact, this complaint seemed to be common across all categories (including small/medium and medium/large), with the possible exception of teachers in small schools. In contrast, closer ties among teachers seemed to be established in small schools, which not only improved conflict management, but also improved cooperation among teachers in general.

Differences in the Effectiveness of Resources

Differences in the levels of school-related resources are not the only reason that student achievement differs across school size. Differences in the school environment, related to size, may also influence the effectiveness of these resources, as measured by student test scores. Separate education production functions are estimated for the three school-size categories, and the estimated coefficients are displayed in table 3.

When comparing large schools to medium-sized schools, the largest positive changes in student achievement stemmed from the influence of the following variables: race, administrators per student, teachers per student, amount of time teachers spend in preparation, amount of time teachers spend in in-service programs in mathematics, and teachers' perception that the principal provides active leadership to the mathematics program. The strongest negative influences between medium-sized and large schools were found in office personnel per student, teachers' highest degree, and the degree to which teachers feel the principal is encouraging.

With respect to small and medium-sized schools, differences in the coefficients of the following variables were related to positive increases in student achievement: the ratio of teachers to students, office personnel per student, the degree to which teachers perceive that principals provide active leadership to the mathematics program, and the degree to which principals perceive that they keep the teachers well informed. The following variables appeared to have a weaker or more negative relationship with student achievement in mathematics for smaller schools compared with medium schools: the amount of time principals report spending in activities related to instructional leadership, and the degree to which principals perceive that teachers in the school work well together.

Overall Impact of School Size on Student Achievement

In order to estimate the overall impact of school size on student achievement, it is necessary to determine jointly how school size relates to levels of educational inputs (measured by differences in means across school size) and to the effectiveness of these inputs (measured by differences in coefficients across school size). The combined effect of these two sets of changes is displayed in table 4 (comparing small schools to medium schools) and table 5 (comparing large schools to medium schools). To account fully for differences in student achievement gains across school size, however, we must also consider a third component—the product of differences in means and differences in coefficients.

The combined effects of school size on student achievement are significant when medium-sized schools are compared to small schools. First, to estimate these differences, we multiply the differences in levels of resources available between small schools and medium schools (ΔX) times the coefficients for medium schools (which serve as the quasi-control group). From table 4, we see that the sum of these ($\beta \Delta X$) is 1.27. Note that this includes significant differences in means for the individual variables that were discussed earlier, as well as those that are relatively minor. Since the average gain in test scores over the year is approximately 10 percent, this tells us that the influence of the changes in

TABLE 3

Estimates of Educational Production Functions by School Size

Variables	Small (0-199 students)	Medium (400-599 students)	Large (More than 800 students)
Intercept	0.45	14.66	14.84
Sex (Male = 1)—Student	-2.01	-2.07	-1.88
Race (White = 1)—Student	1.72	1.54	1.34
Childhood experience—Student	0.09	-0.09	-0.10
Parental involvement—Student	0.05	0.03	0.12
Economic status—Student	0.03	0.02	0.015
Administrators per student	51.34	-105.19	-202.64
Teachers per student	90.37[a]	-8.37	24.23[a]
Office staff per student	113.27[a]	-36.59	-14.04[a]
Teacher time in instruction	0.06	0.47	0.45
Teacher time in preparation	0.79	-0.06	0.22
Teacher time in administrative duties	0.78	-0.01	-0.24
Total years teaching—Teacher	0.04	-0.01	0.022
Highest degree—Teacher	-1.73	-0.33	-0.78
College math courses—Teacher	0.74	-0.52	0.11[a]
Math in-service—Teacher	0.03	0.01	-0.018[a]
Principals' leadership/Teachers' perception	0.02	0.11	0.053
Principals' encouragement/Teachers' perception	-0.53	-0.20	-0.39
Pretest score	0.90	0.86	0.92
Pretest score—squared	-0.00	0.00	-0.00
Highest degree—Principal	2.08	-0.91	-2.03
Total years teaching—Principal	0.06	0.11	0.06
Total years administration—Principal	0.12	0.05	0.08
Math participation—Principal	-0.00	-0.06	-0.04
Math involvement—Principal	0.06	0.06	0.06
Instructional leadership—Principal	-0.26[a]	0.03	0.01
Attitudes:			
Well planned—Principal	0.49	-0.44	0.37
Well planned—Teacher	-0.51	-0.25	0.12[a]
Active leadership—Principal	-1.13	-0.89	0.20[a]
Active leadership—Teacher	1.57[a]	0.13	0.14
Work well together—Principal	-1.07[a]	0.85	0.35
Work well together—Teacher	0.31	-0.05	-0.03
Well informed—Principal	2.24[a]	-0.67	0.03
Well informed—Teacher	0.14	-0.24	-0.12
Conflicts identified—Principal	1.33	-0.13	0.11
Conflicts identified—Teacher	-0.11	0.32	-0.01[a]
R^2	0.59	0.58	0.50

a. The difference between the coefficient for this subgroup and for the medium-sized-school subgroup is significant at the .05 level.
SOURCE: Authors' analysis of Systems Development Corporation dataset.

the levels of resources available to promote student achievement accounts for 12.7 percent of the average gain in mathematics achievement. In other words, small schools seem to have a greater amount of resources that are shown to have a positive net influence on student achievement gains. However, this estimate may have an upward bias if we have not accounted for other variables, which might be correlated with school size, that are predictors of student

TABLE 4

Effects on Student Achievement of Differences Between Small Schools and Medium-Sized Schools

Variables	$\beta\Delta X$	$X\Delta\beta$	$\Delta\beta\Delta X$
Intercept	0.000	14.209	0.000
Sex (Male = 1)—Student	-0.019	0.033	0.001
Race (White = 1)—Student	0.170	0.157	0.020
Childhood experience—Student	0.011	0.166	-0.022
Parental involvement—Student	-0.001	0.035	-0.001
Economic status—Student	-0.197	1.473	-0.075
Administrators per student	-0.091	0.262	0.046
Teachers per student	-0.011	5.690	0.127
Office staff per student	0.051	2.527	-0.207
Teacher time in instruction	0.036	-2.028	-0.032
Teacher time in preparation	-0.009	1.277	0.128
Teacher time in administrative duties	0.000	0.626	0.016
Total years teaching—Teacher	-0.028	0.712	0.112
Highest degree—Teacher	-0.003	-3.448	-0.012
College math courses—Teacher	0.101	0.551	-0.244
Math in-service—Teacher	-0.021	0.109	-0.105
Principals' leadership/Teachers' perception	-0.041	-0.242	0.032
Principals' encouragement/Teachers' perception	0.023	-1.049	0.040
Pretest score	0.606	0.943	0.023
Pretest score—squared	0.005	-1.361	-0.052
Highest degree—Principal	0.072	8.777	-0.239
Total years teaching—Principal	0.157	-0.604	-0.076
Total years administration—Principal	-0.043	0.569	-0.064
Math participation—Principal	0.091	0.490	-0.088
Math involvement—Principal	-0.132	-0.002	0.000
Instructional leadership—Principal	-0.098	-14.387	0.937
Attitudes:			
Well planned—Principal	0.154	2.799	-0.326
Well planned—Teacher	-0.029	-0.746	-0.032
Active leadership—Principal	0.263	-0.706	0.071
Active leadership—Teacher	0.015	3.395	0.157
Work well together—Principal	0.016	-6.877	-0.036
Work well together—Teacher	-0.015	1.176	0.100
Well informed—Principal	0.103	9.406	-0.446
Well informed—Teacher	-0.039	0.936	0.063
Conflicts identified—Principal	0.010	4.805	-0.109
Conflicts identified—Teacher	0.161	-1.208	-0.218
Sum	1.270	0.048	-0.512

NOTE: β refers to the coefficients of the medium-sized-school production function in table 3. X refers to the medium-sized-school means from table 2. The changes are calculated by subtracting the medium-sized-school value from the corresponding small-school value.
SOURCE: Authors' analysis of Systems Development Corporation dataset.

achievement in mathematics.

Second, we examine the differential effect of resources on student achievement, holding constant this time for the levels of various resources available by using medium-sized schools as a quasi-control group. Therefore, we multiply the differences in coefficients between small and medium schools ($\Delta\beta$) by the means for the medium schools (X). The sum of the effects of these individual changes in coefficients ($X\Delta\beta$), as shown in table 4, is 0.048, which accounts for about 0.5 percent of the average gain in mathematics achievement from pretest to post-test scores.

TABLE 5

Effects on Student Achievement of Differences Between Large Schools and Medium-Sized Schools

Variables	$\beta\Delta X$	$X\Delta\beta$	$\Delta\beta\Delta X$
Intercept	0.000	0.166	0.000
Sex (Male = 1)—Student	0.007	0.096	-0.001
Race (White = 1)—Student	-0.400	-0.100	0.051
Childhood experience—Student	0.003	0.082	-0.003
Parental involvement—Student	-0.001	0.156	-0.003
Economic status—Student	-0.498	-0.601	0.083
Administrators per student	0.023	-0.368	0.021
Teachers per student	0.034	1.703	-0.133
Office staff per student	-0.239	0.558	0.147
Teacher time in instruction	-0.074	-0.096	0.003
Teacher time in preparation	-0.004	0.395	0.019
Teacher time in administrative duties	-0.000	-0.177	-0.002
Total years teaching—Teacher	0.013	0.381	-0.035
Highest degree—Teacher	-0.036	-1.149	-0.049
College math courses—Teacher	-0.045	0.448	0.053
Math in-service—Teacher	-0.000	-0.180	0.000
Principals' leadership/Teachers' perception	0.038	-0.194	-0.018
Principals' encouragement/Teachers' perception	0.056	-0.568	0.053
Pretest score	-2.041	1.513	-0.135
Pretest score—squared	-0.021	-0.595	0.114
Highest degree—Principal	0.011	-3.361	-0.013
Total years teaching—Principal	0.003	-0.525	-0.002
Total years administration—Principal	-0.056	0.280	-0.041
Math participation—Principal	-0.080	0.266	0.031
Math involvement—Principal	0.230	0.113	0.031
Instructional leadership—Principal	0.057	-2.528	-0.087
Attitudes:			
Well planned—Principal	1.716	0.220	-0.041
Well planned—Teacher	-0.038	0.787	-0.181
Active leadership—Principal	6.430	2.206	0.017
Active leadership—Teacher	0.525	0.001	-0.000
Work well together—Principal	-3.375	-1.637	0.148
Work well together—Teacher	0.073	0.058	-0.009
Well informed—Principal	6.605	2.346	-0.022
Well informed—Teacher	0.916	0.243	-0.028
Conflicts identified—Principal	-1.629	0.787	-0.066
Conflicts identified—Teacher	-1.415	-0.521	0.238
Sum	-3.195	0.207	0.196

NOTE: β refers to the coefficients of the medium-sized-school production function in table 3. X refers to the medium-sized-school means from table 2. The changes are calculated by subtracting the medium-sized-school value from the corresponding large-school value.
SOURCE: Authors' analysis of Systems Development Corporation dataset.

Finally, we must take into account any interactive effects that occur as a result of differences in the level of resources and differences in the effect of resources on achievement. The interaction component accounts for 5 percent of the gain in student achievement in mathematics over the time period. However, since the interactive effect is negative, this reduces the overall impact of size (between medium and small schools) on student achievement to about 8 percent of the typical gain in student achievement.

School size has a much larger impact on student achievement when medium schools are compared with large schools. As shown in table

5, the gain in test scores is 28 percent lower in large schools than in medium schools, when all three components are considered. This means that student achievement in larger schools is substantially lower on average than in moderately sized schools, even when certain student, teacher, principal, school-climate, and time-on-task variables are taken into account.

The largest of the three components is the difference in the level of resources between the two school sizes, with a third of this due to the student's race and economic status. However, if these were equal between school size, the difference in student achievement due to differences in levels of other variables would still be more than 20 percent of the average gain in test scores.

The number of teachers per student is only slightly lower in large schools than in medium schools, but it seems to have a relatively major negative impact due to the large differences in coefficients between these large and medium schools. Similarly, the difference in the mean for principals' highest degree between large and medium schools was minor, but the negative impact was significant, which is consistent with past research described earlier. Ironically, the time principals from large schools reported spending in needs assessment, program planning, and program evaluation related to mathematics was found to have a significant negative impact on students' achievement in mathematics. We hope this means that the correlation may be reversed. Where mathematics achievement tends to be low when compared to similar schools, principals may then begin to devote more time to needs assessment, program planning, and program evaluation in an attempt to improve the mathematics program.

V. Conclusion

Proponents of market-based school reform argue that offering parents and students a choice of schools will induce administrators and teachers to perform more effectively and efficiently. However, since only a few states have actually implemented such reforms, and the ones that have adopted these programs have done so only recently, there is little opportunity to test systematically whether these reforms have brought about the necessary behavioral responses of teachers and administrators. Until such time, one way to gain some insight into the consequences of reforms is to examine differences in student achievement resulting from existing differences in institutions. A possible consequence of school reform that we focus on in this study is the emergence of smaller schools. This paper estimates the effect of school size on student achievement.

Based on achievement gains in mathematics for fourth-grade students, our results show that students in large elementary schools exhibit smaller gains in student achievement than comparable students in smaller schools. For example, students in schools with 800 or more students had a 28 percent lower gain in achievement than otherwise comparable students in schools with between 400 and 600 students. This disparity resulted from differences across school size in both levels of educational inputs and in effectiveness of these inputs.

Our research identified a number of educational inputs that differed significantly according to school size. From a policy perspective, it is interesting that many of the variables that differed by school size were ones over which educational policymakers presumably have some control, such as teacher characteristics, principal characteristics, school climate, and the number of school personnel per student.

The results suggest that market-based school reform could enhance student performance if the resulting decentralization reduced school size. However, a reduction in school size is not the only potential effect of school reform. Providing students and parents with an opportunity to choose among schools may generate additional institutional changes, which could offset some of the gains from smaller schools. For example, open enrollment could skim the best students from each school, leaving teachers to deal with students who, along with their parents, have little interest in education. This study recognizes that education is a complex process and that there are no simple answers to reforming the institution. We offer some evidence that one result of school reform based on choice could be beneficial to students, if indeed such reforms result in smaller schools.

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