Scale economies in public education

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Abstract. An empirical analysis is made of the relationship between cost per student and school size, school district size, and variables measuring the quality of output and environmental factors affecting the demand for public education. Based on data from the 40 school districts in Utah, it is shown that operating cost per student is inversely related to school size and school district size when each is considered separately. When both are included in the regression equation, however, only school size is significant. Consolidation of schools, not districts, may be the key to achieving lower per unit costs. Capacity to finance school operations, quality of output, and education levels of the adult population have positive effects on unit costs.

1. Introduction

This study analyzes the relationship between operating cost and school district size, average school size, and growth using data for school districts in Utah from 1982 to 1993. Estimates are made of economies of scale in school and district size. The magnitude of resources devoted to public education in the United States means that efficient operation of school districts and individual schools is essential. Inefficiency may be tolerated in a public program where budgets are small, but a small improvement in school efficiency could save significant resources, given the size of education expenditures. The issue of returns to scale is important because there may be substantial savings achieved by consolidating schools and/or school districts. Utah provides an unusually good laboratory because of the diversity in both size and growth among the state's 40 school districts.

The study is timely because of recent population growth in many areas in this state. After experiencing sluggish economic growth and net outmigration during most of the 1980-1990 period, Utah has recorded strong growth in the past five years. Along with rapid growth in employment, income, and population has come increased concern about the effect of growth on the environment and the public sector, especially education. The need to expand school facilities and staff has been accommodated to some degree by growing tax revenue, but a fiscally conservative political climate in the state has tempered the allocation of even larger resources to education. Like most states, Utah makes an effort to reduce disparities in local capacity to fund

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public education through redistribution of various kinds of income and wealth among school districts.[1]

The analysis focuses on the relationship of expenditure per student on operations and capital (including construction) and the size and growth of the school district and size of schools. We find that:

- Both operating and capital expenditures per student decline with increases in district size, average school size, and the rate of growth, although the effect of school size dominates; and
- Change in per student expenditures over a five year period is related negatively to growth in the number of students.

2. Background

By definition, economies of scale reduce long-run average costs as the rate of output increases. In studies of public education, output typically is measured by the number of students served by a given set of programs and services.[2] Most of the research has found that there are significant economies of scale in school operations.

One of the exceptions is the early study by Hirsch (1959) who applies multiple regression techniques to district level data from 27 St. Louis area public schools to estimate an average cost function. The statistical results show no significant economies of scale.

Riew (1966), in a study of 109 accredited high schools of Wisconsin in 1960-1961, relates data on operating expenditures (including cost of administration, teachers' salaries, other instruction and operating costs, and maintenance) to explanatory variables such as school size, teacher qualifications, class size, breadth of the school program, and the degree of specialization in instruction. Using multiple regression analysis, he finds that economies of scale exist for high schools up to a level of 1,675 students. He later (1986) extended this work to a study of school costs under conditions of declining enrollment for individual secondary and elementary schools. He finds significant scale economies in school operations with much larger economies for secondary than for elementary schools. The efficient operation of secondary schools (with their specialized instructional staff, more professional support personnel, and more varied programs) requires a larger pool of students to achieve lower per student costs.

In a study of economies of scale in Iowa high schools, Cohn (1968), estimates the following per student cost (C) function:

$$C = \alpha + \beta Q_i + \gamma Q_i^2 + \sum_{j=1}^{p} d_j Z_{ij} \qquad (1)$$

where:

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[1] Utah earmarks all revenue from the state's income tax for public education. These revenues are allocated to each district in inverse relation to a measure of real property wealth per student.

[2] See Tholkes and Sederberg (1990) for a general discussion of economies of scale as they apply to public education and for a more comprehensive literature review.

Q_i =   The number of students; and

Z_j =   Other variables influencing operating costs including quality measures (e.g., teacher-student ratio, number of college credit hours for the average teacher, and average teacher salary).

There are significant economies of scale for Iowa high schools up to a school size of 1,500 students.

Butler and Monk (1985) estimate the following Cobb-Douglas production function using 1978-1979 data for public schools in New York State:

$$Q = A \, N_i^{k\alpha} \, T^{k(1-\alpha)} \tag{2}$$

where:

Q =   An output measure (number of students processed);

T =   Teaching input;

N_i =   Other inputs; and

A, a, k =   Shift, share, and scale parameters.

Assuming schools operate efficiently, total cost is a function of total output (Q) and the prices of nonteaching and teaching inputs. The translog form of the cost function is estimated for both small and large school districts, and the cost structures of large and small schools are found to be qualitatively different. Further, cost differentials among schools and districts of different sizes are separated between scale effects and other effects. Schools with 2,500 or fewer students show greater economies of scale than do larger schools, and larger school districts are less efficient than smaller ones.

Kumar (1983) tests for economies of scale in various categories of educational costs at the individual school level in Ontario, Canada. Using a cost function quadratic in size and linear in quality of education and other exogenous variables, he finds that variables other than size affect school cost curves parametrically and that the average variable cost curve is parabolic rather than U-shaped, at least for the school sizes in his study.

In a similar study, Bee and Dolton (1985), investigate the relationship among size, other characteristics of the school, and the average cost of output. Using data from 309 independent secondary schools in the United Kingdom, they find that an increase in school size is related negatively to average cost and that the effect of student performance or quality (e.g., average number of passing grades per student, average number of A grades per student, and percentage of students entering college) is independent of size. Further, whatever standard of quality is chosen, it can be achieved at a lower cost in large schools.

Callan and Santerre (1990) use Connecticut data to estimate the relationship between educational cost per student and three fundamental inputs—instruction, administration, and support staff services. They assume that each school district minimizes the short-run variable cost of producing a particular mix of school outputs given a fixed stock of capital, the public transportation system, and the amount of home-produced education. To produce a particular mix of primary and secondary education at least cost, the school district chooses levels of educational inputs, i.e., instruction staff, support staff, and administrative service. A significant degree of

substitutability is found among these inputs, as are significant economies of scale for both primary and secondary schools.

Tholkes (1991) estimates the extent of cost savings from consolidating small school districts. He finds that:

- Most of the scale economies are associated with an increased staffing ratio and a reduction in the number of facilities that had to be operated;
- The potential for capturing economies of scale is reduced greatly if new facilities have to be constructed;
- Increased transportation costs associated with consolidation are a minor part of total expenditures, although cost to students in increased travel time could increase significantly;
- To the extent that new or expanded course offerings are made, the cost of this quality improvement will offset part of the savings from consolidation; and
- For the four districts in Minnesota studied, the net scale effect reduces total expenditures per student about 4.6 percent.

In summary, most studies find economies of scale as the size of school increases. The economies associated with district size are less clear. Butler and Monk report that larger districts tend to be less efficient, and Tholkes' work suggests that the savings from district consolidation may be associated with reducing the number of facilities (i.e., increasing average school size) which may be achieved without consolidation of districts.

3. The data set and preliminary analysis

A comprehensive data set for each of three school years (i.e., 1982-1983, 1987-1988, and 1992-1993) for the 40 school districts in Utah is developed from reports prepared by the Utah State Office of Education (1983, 1988, 1993, and 1994) and the Utah Education Association (1983, 1988, and 1993). These districts vary in size from 191 to more than 80,000 students. Seven districts have fewer than 1,000 students, and three have more than 40,000 students. Between 1982-1983 and 1987-1988 ten districts experienced absolute declines in the number of students. For the subsequent five year period eight districts showed declines, while ten grew in excess of 10 percent. The range in district size and growth experience should allow for a strong test of the relationship between expenditure per student and both size and growth.

The study area is unique in many ways. While thought of as predominantly rural, Utah is one of the most urbanized states with almost 80 percent of the population living in two adjacent standard metropolitan areas (i.e., Ogden-Salt Lake City and Provo-Orem). For the average school district 59 percent of revenue comes from state sources, primarily from the Uniform School Fund for which the entire Utah personal income tax is earmarked. This fund is distributed to local districts based on the difference between local real estate tax potential per student and a specified level of funding per student. This financing mechanism amounts to a redistribution of resources from districts with above average real property wealth per student to below average districts. Most of the remaining 41 percent of revenue is provided by local property tax collections. Class size is large compared to national averages, teachers'

salaries are below average, expenditure per student is low,[3] and educational outcomes are average to slightly above average.

The initial analysis focuses on per student operating and capital expenditures and the relation of each to size and growth of school districts. Table 1 shows per unit operating and capital expenditures and average school size classified by district size and growth rate for each of the three academic years. Average cost (or spending) per student generally falls as size increases and also tends to decline as the growth rate increases. Per student cost averages about 40 percent lower in the largest districts than in the smallest districts. Also, per unit cost in the rapid growth districts is 30 percent to 40 percent below that in districts experiencing decline in student numbers. One interpretation is that average cost will be lowest in a large, growing district due to economies of scale. The net effect of each component (i.e., size and growth) cannot be determined by these averages, however, nor can we account for the effects of quality. An alternative explanation is that the average small and/or declining size school district offers a higher quality academic program, but there is no *a priori* reason to expect this to be true nor is that explanation consistent with other evidence.

The argument that rapid growth will require higher per unit expenditures for construction also is not supported. Capital expenditure per student in each of the three years studied shows the same pattern of steady and significant decline in cost as size increases. The data relating capital expenditures and growth are not as definitive, but offer little support for that hypothesis.[4] It is possible that the negative relationship between expenditures and district size is accounted for by differences in school size. Larger districts have larger schools, and that factor may be explanation for these gross relationships.

Plots of these three key relationships are shown in Figures 1 through 3. The relationship between expenditure per student and size of district (Figure 1) is negative; the larger districts tend to have low expenditures, whereas there is considerable variability among the smaller districts. Some have per student costs comparable to those in the larger districts, while others have substantially higher costs. Figure 2 shows definite economies associated with larger average school size, and Figure 3 shows that the larger school districts tend to have larger schools.

These data suggest that there may be significant economies of scale associated with school district size and/or school size. Further, the lowest operating costs are in the rapidly growing districts; also, the rate of increase in operating costs tends to be lower for large districts and for growing districts. There are many explanations for these relationships. In addition to the school size effect, the largest districts also may

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[3]In recent years Utah has ranked at or near the bottom among the 50 states in terms of expenditure per student..

[4] Capital expenditures tend to be lumpy, and a comparison of spending in each of three years that are five years apart may be only indicative. A better measure would be cumulative spending over some multiyear period, but such data were not collected.

Table 1. Average operating and capital expenditure per student and average school size Utah school districts: 1982-1983, 1987-1988, and 1992-1993

	No. of districts	Average operating expenditure per student				Average capital expenditure per student				Average school size			
		'82-'83	'87-'88	'92-'93	% change '82-'93	'82-'83	'87-'88	'92-'93	% change '82-'93	'82-'83	'87-'88	'92-'93	% change '82-'93
District of size (students)													
< 1,000	8	$3,170	$3,389	$5,639	43.8	$1,051	$1,208	$1,104	4.7	149	161	138	-7.38
1,001-2,000	7	2,129	2,743	3,814	44.2	733	924	718	-2.0	314	322	373	18.78
2,001-5,000	9	2,164	2,741	3,890	44.3	835	588	762	-9.5	341	384	541	58.65
5,001-10,000	7	1,991	2,476	3,394	41.3	261	432	526	50.3	482	544	573	18.88
10,001-25,000	5	1,999	2,409	3,281	39.1	309	290	543	43.2	619	791	678	9.53
> 25,000	4	1,858	2,191	3,129	40.6	221	327	512	56.9	726	861	874	20.38
Median		$2,060	$2,536	$3,594		$282.8	$406.6	$585		438	511	529	19.80
District with growth rate													
< 0%	6	$2,909	$3,624	$5,198	44.0	$947	$592	$1,245	23.9				
0-10%	8	2,485	3,104	4,277	41.9	368	607	595	38.2				
10-20%	12	2,094	2,467	3,474	39.7	482	456	548	12.0				
> 20%	14	2,044	2,505	3,377	39.5	690	746	622	-10.9				

Source: Utah State office of Education (1983, 1988, 1993)

Figure 1. Total number of students in school district and expenditure per student, 1992-1993
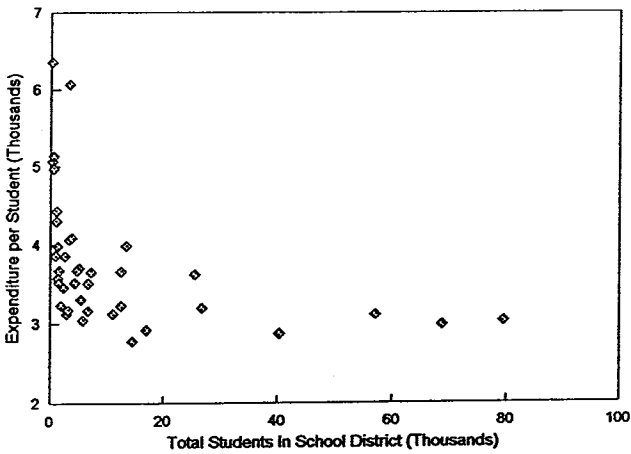

Figure 2. Average students per school and expenditure per student, 1992-1993
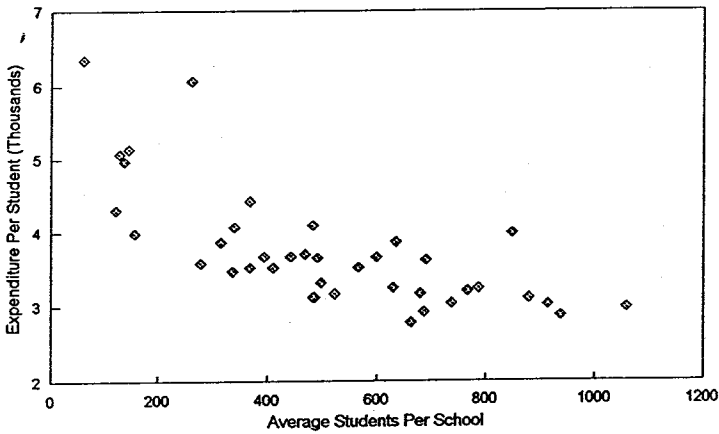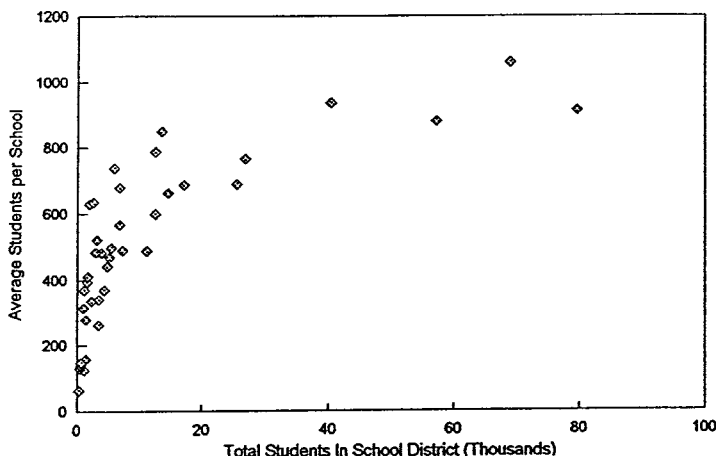
Figure 3. Average students per school and total students in school district, 1992-1993

be the fastest growing (thus, confounding the effects of the two variables on per unit costs). The higher costs in smaller districts possibly reflect higher quality.[5]

4. The regression model, specification issues, and estimates

Much of the empirical work in this area involves estimating a reduced form expenditure function and then using it as a cost function. Cost function estimation technically requires that output can be measured, which is difficult in many public sector contexts, although perhaps less so in education.[6]

Following Downes and Pogue (1994), we assume the school district produces a vector of outputs Y using inputs X that have prices p. The cost (C) function also depends on a set of community environmental variables that influence cost (E), that is:

$$C = pX = f(Y, p, E). \tag{3}$$

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[5] It may be that having lower cost schools is a causal factor in explaining growth. Perhaps persons are attracted to areas that offer lower cost-per-unit education.

[6] In public education enrollment could be considered an output measure with various other variables, such as standardized test scores, used as quality adjustments.

If output cannot be measured, cost can be derived from a reduced form expenditure function. Output is a function of demand (D), input prices, and the environment variables, i.e.

$$Y = g(D, p, E). \tag{4}$$

Now, substituting equation (4) into (3) yields

$$C = f[g(D, p, E), p, E] \tag{5}$$

or

$$C = h(D, p, E). \tag{6}$$

In the following both the cost function (i.e., direct) and the expenditure function (indirect) are estimated.

The variables included in the analysis include the following:

Dependent variable
> Operating expenditure per student

Independent variables
> Output
>> Number of graduates per student
>> Dropout rate
> Scale
>> Number of students in the district
>> Average school size
> Demand
>> Per capita income
>> Property tax revenue per student
> Environment/quality
>> Proportion of population with college degree
>> Proportion of population with high school diploma
>> Student-teacher ratio
>> Proportion of students needing special education
> Input prices
>> 20 year salary for teachers[7]
>> Average salary of classified personnel[8]

Using the data for the three school years as a panel, the cost function is estimated both directly and indirectly using both the random and fixed effects models. The natural logarithms of all variables are used except for those variables measured as

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[7] Total salary projected for a teacher over a 20 year period based on the district's salary schedule for the year specified.

[8] Includes custodians, bus drivers, kitchen staff, etc.

a percentage. Based on the Hausman statistic, the hypothesis that the district-specific effects are random is rejected at the 1.0 percent probability level. Therefore, the analysis will focus on the estimates of alternative functional forms estimated under the fixed effects model as shown in Table 2.

The statistical results are reasonably good; all of the coefficients that are statistically significant at or below the 0.05 probability level[9] have the correct signs, and the equations explain 93 percent to 96 percent of the variation in unit costs. The variables that are important in explaining unit costs are per capita income (demand), 20 year teacher salary (input price), district and school size (scale), and student teacher ratio (quality).

Model 1 includes both scale variables, whereas models 2 and 3 include only one—district size in model 2 and school size in model 3. The coefficient on average school size is always highly significant and about -0.15 in average magnitude. This implies that there is a 0.15 percent decline in cost per 1.0 percent increase in enrollment. In contrast, the coefficient on district size is consistently negative but is significant only in model 2 where the school size variable is omitted. The implication is that economies of scale are associated with school size and not with the size of the district.

One of the findings of Butler and Monk (1985) is that small school districts can capture most economies of scale with only marginal changes in size. The key appears to be changing school size. If consolidation of districts cannot achieve an increase in average school size, per student cost should not decline significantly. In contrast, a small district may be able to achieve significant cost reduction by consolidating schools into larger units, although Tholkes (1991) shows that this may mean significantly greater time spent traveling to school by the average student. In such cases, some costs have been shifted from the school district to the students.[10]

The coefficients on the two demand variables in the expenditure function (i.e., per capita income and property tax revenue per student) have the correct (i.e., positive) signs, but only the coefficient on per capita income is statistically significant. The coefficients on the two input price variables also have the correct sign, but only the 20 year teacher salary coefficient is significant. Of the four variables measuring environment and quality, only the coefficient on the student-teacher ratio is significantly different from zero. The coefficient is negative because quality (and cost) is inversely associated with class size.

The effect of growth on per unit cost is measured by adding an additional variable (percentage change in total students during the previous five years) to model 1 for both the direct and indirect estimations.[11] The coefficient on this variable is small and not significant in any of the equations.

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[9] In almost all of these cases the coefficients are significant at the 0.01 level.

[10] The increased time spent in school buses traveling longer average distances often is an argument used by opponents of both district and school consolidation in Utah. When winter weather conditions increase the danger of highway travel, the arguments become even more intense.

[11] Only the data for 1987-1988 and 1992-1993 are included in this panel because we did not have the district growth rate for the five years prior to 1982-1983.

Table 2. Estimate of the cost function parameters
Dependent variable: Ln (operating expenditure per student)

Description of the variables	Direct estimation (fixed)			Indirect estimation (fixed)		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Ln (graduates per student × 100)	-0.08268 (-1.590)	0.0104 (0.198)		0.03601 (0.591)	0.00590 (0.086)	0.03712 (0.618)
Ln (dropout rate)	0.00004 (0.921)	0.0000 (0.072)				
Ln (per capita income)			0.00005 (0.991)	0.06232 (3.240)*	0.05421 (2.510)*	0.06121 (3.447)*
Ln (tax revenue per student)						
Ln (20 year teacher salary)	0.77764 (3.169)*	0.65613 (2.449)*	0.69901 (2.880)*	0.66103 (2.857)*	0.55389 (2.134)*	0.67016 (3.013)*
Ln (average salary of classified employees)	0.08759 (0.607)	0.17717 (1.130)	0.04035 (0.286)	0.01745 (0.130)	0.13899 (0.935)	0.02308 (0.179)
Ln (total students in the school district)	-0.01335 (-0.818)	-0.05416 (-3.860)*		-0.00251 (-0.157)	-0.04140 (-2.910)*	
Ln (average student per school)	-0.15508 (-3.998)*		-0.15157 (-5.499)*	-0.14287 (-4.501)*		-0.13981 (-5.607)*
Ln (student-teacher ratio)	-0.46615 (-4.153)*	-0.66982 (-6.802)*	-0.55437 (-5.932)*	-0.47109 (-5.330)*	-0.64462 (-7.189)*	-0.46877 (-5.417)*
Proportion of population with four year degree	0.00302 (1.483)*	0.00228 (1.019)	0.00204 (1.021)	-0.00007 (-0.040)	0.00039 (0.182)	-0.00001 (-0.007)
Proportion of population with a H.S. diploma	-0.00361 (-2.173)*	-0.00332 (-1.817)	-0.00268 (-1.664)	-0.00169 (-1.062)	-0.00216 (-1.207)	-0.00176 (-1.160)
Proportion of students needing special care	-0.00047 (-0.129)	-0.00143 (-0.352)	-0.00320 (-0.928)	0.00106 (0.308)	0.00160 (0.412)	0.00112 (0.331)
R-squared	0.9508	0.9395	0.9481	0.9581	0.9560	0.9581
F-statistic	27.61	22.99	28.06	32.69	25.92	33.84
Hausman test statistic	45.40	13.18	46.18	36.44	3034	38.44

t-statistics in parentheses
* Significant at or below the 5 percent level
Hausman statistic is based on fixed versus random effect results from the corresponding models

Table 3. Predicted expenditure per student for alternative school and district size

Average school size (Students)	Estimated cost per student 1992-1993 District size (students)				
	2,000	10,000	30,000	50,000	80,000
200	$4,209	$4,120	$4,060	$4,032	$4,007
400	3,780	3,700	3,646	3,621	3,598
600	3,550	3,474	3,424	3,400	3,379
800	3,395	3,323	3,275	3,252	3,232
1,000	3,279	3,210	3,163	3,142	3,122
1,200	3,188	3,120	3,075	3,054	3,035
1,400	3,113	3,046	3,002	2,982	2,963

Model 1 of the fixed effects equation is used to predict the per student cost for various combinations of district and school size (Table 3). Using the mean values of all other explanatory variables, school size is varied in increments of 200 from 200 to 1,400 students while district size is varied from 2,000 to 80,000. The effect of changing district size is predictably modest; holding school size constant at 600, per unit cost for a district with 30,000 students ($3,424) is only $50 (i.e., 1.4 percent) less than in a district with 10,000 students. Thus, the aggregate effect of combining three districts each having 10,000 students would be a saving of $1.5 million.

The effect of increasing average school size is substantially greater. For example, a district with 10,000 students and an average school size of 600 would have a predicted cost per student of $3,474. Another district of the same size with an average school size of 800 would have a predicted cost of $3,323 per student or 4.3 percent less than the first district. The aggregate saving for the district with the larger schools is $1.51 million.

5. Summary

This analysis of Utah school districts indicates that the most important determinants of education cost per student in Utah are scale (as measured by average school size), per capita income in the district, the student-teacher ratio, and the 20 year teacher salary. District size, while appearing to be an important factor, is insignificant when average school size is taken into account. Further, growth effects are consistently negative, although not always statistically significant.

There are significant economies of scale, but most of the effect is captured by the scale of the individual school unit. Thus, consolidation of school districts in an attempt to reduce per unit costs may not be successful unless average school size can be increased at the same time. Further, there often is political resistance to such consolidation; if average school size is the driving force behind cost reduction, it may be possible to consolidate schools within a district and capture most of the scale economies.

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