Allocative Inefficiency and School Competition

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Abstract A substantial literature indicates that the public school system in the United States is inefficient. Some have posited that this inefficiency arises from a lack of competition in the education market. On the other hand, the Tiebout hypothesis suggests that public schools may already face significant competition. In this paper, the authors examine the extent to which competition for students influences public school inefficiency in Texas. They use a Shephard input distance function to model educational production and use bootstrapping techniques to examine allocative inefficiencies. Switching regressions estimation suggests that school districts in noncompetitive metropolitan areas are more than twice as allocatively inefficient as school districts in competitive metropolitan areas.

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I. Introduction

A substantial literature indicates that the public school system in the United States is inefficient. Hanushek's 1986 survey of the literature on educational production functions overwhelmingly concludes that expenditures are uncorrelated with student achievement gains. Cost function studies and data envelopment analyses support similar conclusions (see, for example, Bessent et al. 1982, Färe, et al. 1989 or Callan and Santerre 1990).

Some have posited that this inefficiency arises from a lack of competition in the education market. Chubb and Moe (1990 and 1991) find evidence that administrative autonomy fosters school efficiency and argue that increased competition among schools would promote such autonomy. Other researchers attribute school inefficiency to the monopoly powers of the public school system (for examples, see Boaz 1991 or Gwartney 1991). Couch, Shughart and Williams (1993) and Hoxby (1994a) find evidence that student performance in public schools is lower when there is less competition from private schools.

On the other hand, public schools in the U.S. may already face significant competition in the sense of Tiebout (1956). A number of researchers have demonstrated that a greater variety of public schools in a metropolitan area leads, ceteris paribus, to increased homogeneity within local jurisdictions, (Hamilton et al. 1975, Eberts and Gronberg 1981, Gramlich and Rubinfeld 1982, Munley 1982 and Grubb 1982). Jud (1983) demonstrates that residents express their preferences for public schools by voting with their feet. Martinez-Vazquez and Seaman (1985) find that private schools are less prevalent in communities with a variety of public school choices. Hoxby (1994b) and Borland and Howsen (1993) find evidence that Herfindahl indices of competition for student enrollment can explain some of the variation in educational production.

To evaluate directly the connection between school efficiency and competition for students, we model the multiple output, multiple input school production technology using a Shephard (1953) input distance function. By bootstrapping the distance function, we can test for allocative inefficiencies in educational production. We find evidence that competition for students significantly reduces the allocative inefficiency of Texas school districts.

II. The Literature

Over the years, economists have used a variety of techniques to evaluate school performance. Most researchers have focused on estimating single-output, average production functions for schooling. Although a few recent studies have examined monetary returns to schooling (Betts 1995 and Card and Krueger 1992a, 1992b), the most common measures of educational outputs have been test scores (for examples, see Berger and Toma 1994, Eberts and Stone 1987, Wahlberg and Fowler 1987 and the literature surveyed in Hanushek 1986). Generally, researchers assume that schools produce these educational outputs using inputs related to school personnel, per-pupil expenditures, and family background.[1]

The production functions yield estimates of the marginal products of the inputs, and allow researchers to infer which inputs would have the greatest marginal impact on achievement.[2] Most researchers using this approach have found that inputs within school district control (such as expenditures or class sizes) have little or no marginal impact on test scores (Hanushek 1986). Card and Krueger (1992a, 1992b) find evidence that school inputs have a positive effect on the monetary returns to schooling, but their analysis is based on state-level data about school characteristics and may be subject to aggregation bias (see Hanushek, Rivkin and Taylor 1996). Using less aggregate data, Betts (1995) finds no evidence of marginal effects.

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[1]See Cohn and Geske (1990) for a thorough review of the output and input measures employed in these types of studies,

[2]See Levin (1974) and Hanushek (1979) for critical reviews of the production function approach.

Recently, some researchers have modified production function analysis to incorporate allocative and technical inefficiencies, and multiple measures of educational output. Most of the researchers using this generalized approach have relied on nonstochastic techniques like data envelopment analysis (e.g., Bessent and Bessent 1980; Bessent et al. 1982, 1984; Färe et al. 1989; and Grosskopf et al. 1994). However, a few researchers have used stochastic techniques. Deller and Rudnicki (1993) assume that school inefficiency has a half-normal distribution and use maximum likelihood techniques to estimate a single-output frontier production function. McCarty and Yaisawarng (1993) and Ray (1991) combine DEA and regression analysis in a partially stochastic two-step procedure that incorporates multiple outputs.[3] Grosskopf et al. (1997) use an indirect output distance function to examine the consequences of budgetary reforms when school districts are inefficient. Like the production-function analyses, these studies generally find evidence of substantial school inefficiency.

Analyses of educational cost functions yield similar results. Barrow (1991) estimated a cost function frontier for schools in England and found that actual costs were 4 percent to 16 percent above the minimum estimated cost for the schools in his sample. Callan and Santerre (1990) found evidence that school districts in Connecticut produce primary and secondary education using inefficiently large quantities of capital and transportation services. Jimenez (1986) concluded that schools in Bolivia and Paraguay used excessive amounts of capital and that many of the schools in Bolivia exhibited diseconomies of scale. Eberts and Stone (1986) found that rent extraction in the form of higher teacher salaries adds between 7 percent and 15 percent to educational costs in unionized school districts in the United States.

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[3]In the first step, they construct efficiency measures for schools by applying DEA to data on multiple educational outcomes and discretionary inputs (such as teachers and administrators). In the second step, they regress the efficiency measures on a set of non-discretionary inputs (such as student body characteristics).

III. The Distance Function

We use a Shephard (1953) input distance function to model school production and generate measures of allocative inefficiency. The input distance function is a convenient tool for analyzing potentially inefficient public enterprises for a number of reasons. Because the distance function is dual to the cost function, it lends itself to fully stochastic frontier estimation without sacrificing the ability to evaluate multiple outputs. However, the input distance function requires data on input quantities rather than input prices. Thus, the distance function is preferable in cross-section settings where prices do not vary, such as when making comparisons across schools within a single labor market. The distance function also has the advantage for our purposes of being "agnostic" with respect to the economic motivation of the decision maker, unlike the cost function which presumes cost minimizing behavior.[4]

Formally, the input distance function is a mapping from the set of all nonnegative input vectors $x = (x_1, x_2, \ldots, x_N)$ and nonnegative output vectors $y = (y_1, y_2, \ldots, y_M)$ into the real line, i.e.,

$$D(y,x) = \max \{\lambda : (x / (\lambda)) \text{ is an element in } L(y)\} \tag{1}$$

where

$$L(y) = \{(x) : x \text{ can produce } y\}. \tag{2}$$

The distance function satisfies fairly general regularity properties (see Färe and Grosskopf (1990) for details), including being homogeneous of degree one in inputs, concave in inputs, convex in outputs, and nondecreasing in inputs.

The distance function is perhaps most easily understood with the aid of a diagram. Consider

[4]While the cost function assumes cost minimizing behavior, inefficiency can be allowed for in the cost function using techniques outlined by Schmidt and Sickles (1984).

Figure 1. Observation K employs the input bundle (x_i, x_j) to produce output level y. The distance function seeks the largest proportional contraction of that input bundle which allows production of the original output level y (which may be a vector). In this example, the value of the distance function for observation K is OK/OK'. This illustrates the following characteristic of the distance function, namely

$$D(y,x) \geq 1 \quad <=> \quad x \in L(y). \tag{3}$$

Furthermore, $D(y, x) = 1$ if and only if the input bundle is an element of the isoquant of $L(y)$.[5]

As discussed in Blackorby and Russell (1989) the first derivatives of the input distance function with respect to input quantities yield (cost-deflated) shadow or support prices of those inputs.[6] We use these shadow prices to test for allocative efficiency. Let $w = (w_1, w_2, \ldots, w_N)$, where w is positive, be the vector of observed input prices. If a school district is allocatively efficient then the following holds:

$$D_i(y,x)/D_j(y,x) = w_i/w_j, \text{ for all } i,j = 1,2,...N. \tag{4}$$

D_i is the partial derivative of D(y,x) with respect to input i and is interpreted as the virtual or shadow price of the ith input. Alternatively, we can define a measure κ_{ij} as the degree to which the shadow price ratio agrees with the actual price ratio, where the formulation in (5) follows the nonminimal cost literature,[7]

[5]The reciprocal of the value of the input distance function is the Farrell (1957) input-saving measure of technical efficiency.

[6]This result follows from Shephard's (dual) lemma because the input distance function is dual to the cost function (see Färe and Grosskopf (1990)).

[7]In this literature, firms are assumed to minimize (unobservable) shadow costs given (unobservable) shadow prices. This is achieved by introducing additional parameters into the cost function that essentially allow input prices to "pivot". These parameters are used to construct the κ_{ij}

$$\kappa_{ij} = \frac{D_i(\cdot)/D_j(\cdot)}{w_i\ /w_j}. \tag{5}$$

See for example Toda (1976) or Atkinson and Halvorsen (1986).

If $\kappa_{ij} = 1$ for all i,j then the observation is said to be allocatively efficient. When $\kappa_{ij} \neq 1$ we can have the following non-optimal situations. If

$$\kappa_{ij} > 1, \tag{6}$$

factor i is underutilized relative to j at observed relative prices, and if

$$\kappa_{ij} < 1, \tag{7}$$

factor i is overutilized relative to j at observed relative prices. In figure 2, the school district is observed to employ input bundle $\overline{x}$. The observed relative price of the two inputs is given by the absolute value of the slope of the line ww. The relative shadow prices (ratio of marginal products) that supports the input vector $\overline{x}$ is given by the absolute value of the slope w*w*. In this case the ratio of shadow prices is less than the ratio of observed prices implying that input i is overutilized relative to input j. That is, $\kappa_{ij} < 1$. Based on observed relative prices, allocative efficiency occurs at x', where the isoquant is tangent to the line w'w' which is parallel to the line w. Another way of interpreting the value of $\kappa_{ij} < 1$ is that the marginal product per dollar paid the input j exceeds the marginal product per dollar paid for input i at the observed input mix and prices.

in equation 5. Unlike the distance function methodology, this technique cannot identify firm-specific relative shadow prices.

IV. The Data

The Texas public school system is particularly well suited to analyses of the relationship between school efficiency and competition for students. The large number of school districts in the state and the wealth of district-level data on school inputs and student performance support credible estimates of school district efficiency. Meanwhile, the school finance formula directly ties state aid to enrollment, creating strong incentives for school districts to compete for students.[8] Finally, data on enrollments in all public school districts and accredited private schools allow us to construct reasonable measures of the degree of competition for students.

Data for this analysis come from a variety of sources. The Texas Research League provides data for the 1988-89 school year on Texas' 1055 public school districts. The data include information on enrollment, the effective number of teachers, administrators, staff and teacher aides employed in each district (per pupil), the average salaries paid to each type of employee and other school characteristics. The Texas Education Agency (TEA) provides information by school district on average student achievement in reading, writing and mathematics in odd numbered grades, the number of students taking the test battery by grade level, student ethnicity and other student body characteristics. From these data, we construct measures of school outputs, student and family inputs and school inputs for each school district. We construct our competition measures from TEA data on total enrollments in all public and accredited private schools in Texas. Our demographic data come from the 1990 Census of Housing and Population.

Together, the combined sources provide complete information on 262 urban school districts with at least 50 students in both the 5th and 11th grades. We restrict our attention to school districts in

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[8] During the 1988-89 school year, Texas had a complicated school finance formula that combined a foundation grant per pupil with a guaranteed yield per pupil for enrichment (for details, see Texas Research League 1989 and Salmon et al. 1988). On average, state aid represented 46.9 percent of school district spending.

metropolitan areas because the Tiebout model is more appropriate to urban areas. We restrict our attention to school districts with at least 50 students in each of the relevant grades to avoid sampling problems that might be introduced by a small number of students.

Output Measures

The literature on measuring school effects has reached a broad consensus that the most appropriate measure of school output is the marginal effect of the school on educational outcomes (see, for example, Hanushek 1986, Hanushek and Taylor 1990, Aitkin and Longford 1986 or Boardman and Murnane 1979). We use student achievement on a battery of test scores as the relevant educational outcome and extract the marginal effect of schools by following the value-added residuals techniques described in Hanushek and Taylor and Aitkin and Longford.

Thus, we estimate school district output per pupil using Texas Educational Assessment of Minimum Skills (TEAMS) scores in mathematics, reading and writing, data on changes in cohort size, and demographic data on the racial and socioeconomic composition of the student body (Texas Education Agency 1987, 1989). At the primary (5th grade) and secondary (11th grade) levels, we estimate the per-pupil value added by the school district according to equation (8),

$$\begin{aligned} MATH89_{sg} &= \alpha_g + \sum_{j=1}^{2} \delta_{jg}\, ETHNICITY_{sj} + \delta_{3g} SES_s \\ &+ \delta_{4g} XCOHORT_{sg} + \sum_{j=5}^{7} \delta_{jg} TEAMS87_{sj(g-2)} + \epsilon_{sg} \end{aligned} \tag{8}$$

where $MATH89_{sg}$ is the average TEAMS mathematics score for school district s for grade level g in 1989, $TEAMS87_{sj(g-2)}$ is the average TEAMS score in subject j (reading, writing and mathematics) for the same cohort two years previously, $ETHNICITY_{sj}$ is the fraction of the student body of school district s that is BLACK or HISPANIC (respectively), SES_s is the fraction of the student body of school district s that is not receiving free or reduced-price lunches (the best available proxy for socio-economic status), $XCOHORT_{sg}$ is the ratio of the grade g cohort size in 1989 divided by the grade g-2 cohort size in 1987 (a control to prevent schools from improving their average score by shedding students), and the estimated residual, ϵ_{sg}, represents the average value added per pupil in school district s, plus an error term.[9] We focus on value added in mathematics because Bishop (1992) suggests that mathematics skills are disproportionately valued.

Estimating school outputs as equation residuals generates output measures that represent deviations from the state average. School districts that add less value than the state average have negative output measures. Since the distance function methodology is not designed for negative outputs, we transform the value-added residuals into tractable per-pupil output measures by adding the mean of the post-test scores to the corresponding value-added residuals. To further transform the per-pupil output measures into total output measures, we multiply by grade-level enrollment ($ENROLL_{sg}$). Therefore,

$$OUTPUT_{sg} = (\overline{MATH89_g} + \epsilon_{sg}) \cdot ENROLL_{sg} \tag{9}$$

is our proxy for the output of school district s. It represents the total achievement level we would expect school district s to produce if it had the same student-body characteristics as the sample average. Alternatively, one can think of $OUTPUT_{sg}$ as the level of total student achievement purged of the effect of home production and earlier achievement.[10] Since we are examining value added on achievement test scores in grades 5, and 11, there are two outputs for each school district.

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[9]Because the two value-added equations share common regressors ($ETHNICITY_{i,j}$ and SES_i) we estimate the output measures simultaneously using the standard SAS package for seemingly unrelated regression (SUR). The estimation results are presented in the appendix.

[10]We note that this general technique for measuring educational quality was also employed by Grosskopf et al. 1997 and Callan and Santerre (1990). However, Callan and Santerre did not have access to pretest information and therefore were unable to derive a value-added quality measure.

Input Measures

We focus on two variable inputs within school district control -- instructional and administrative personnel. We define the quantity of instructional inputs per pupil as the weighted average of the number of teachers and teacher aides per pupil.[11] The quantity of administrative inputs per pupil is the weighted average of the number of administrators and support personnel per pupil.[12] In both cases, we derive weights from the average wages paid for the personnel categories in each metropolitan area.[13] To generate measures of total instructional (INST) and administrative (NINST) inputs, we multiply these per-pupil measures of variable input by the sum of the enrollments in grades 5 and 11 ($ENROLL_s = ENROLL_{s5} + ENROLL_{s11}$).

Other important school inputs are beyond school district control, at least in the near term. We have identified two: non-labor school inputs and family inputs. Unfortunately, there are no direct measures for either of these inputs. Because the quantity of non-labor inputs should be highly correlated with expenditures on library books, furniture and equipment, and maintenance and operations, we use a principle components index of per-pupil expenditures in these three categories, multiplied by $ENROLL_s$, as our proxy for the quantity of non-labor inputs (CAPINPUT).[14] We use the predicted values from equation (9) multiplied by the corresponding grade-level

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[11] Ideally, we would like to adjust the quantity numbers for variations in teacher quality. However, Hanushek (1986) has demonstrated that observable teacher characteristics like salary, experience and educational background do not indicate classroom effectiveness. Lacking a reliable indicator of teacher quality, we treat teachers as homogeneous.

[12] Support personnel include supervisors, counselors, librarians, nurses, physicians and special service personnel.

[13] For example, if teacher aides are paid half the salary of teachers, on average, in the metropolitan area, then each teacher aide is counted as one half of a teacher.

[14] $CAPINPUT = ENROLL_s \cdot (0.055771 \cdot BOOKS + 0.004722 \cdot FURNITURE + 0.001517 \cdot M\&O)$ where BOOKS is per-pupil expenditures on books and films, FURNITURE is per-pupil expenditures for the purchase of furniture, data processing, vehicles and other equipment, and M&O is per-pupil expenditures on plant maintenance and operation.

enrollments ($ENROLL_{sg}$) to measure the contribution of home production at each grade level ($STUINPUT_{sg}$). In essence, $STUINPUT_{sg}$ is an index that depends on the ethnic and socio-economic composition of the school district, the percentage change in enrollment for each grade, and past achievement test scores. For each school district there are two measures of fixed student inputs corresponding to the primary and secondary grade levels.

Competition Measures

We construct two measures of the degree of competition for students. For both of our competition measures, we use data on enrollments in both public and accredited private schools (Texas Education Agency 1990, 1989). First, we construct Herfindahl indices (HIs) of student enrollment for each metropolitan statistical area (MSA).[15] The values of the Herfindahl indices range from less than 11 in the Dallas MSA to nearly 87 in the Victoria MSA. Second, we construct four-firm concentration ratios (CRs) for each MSA.[16] The concentration ratios range from less than 50 percent for the Dallas and Houston MSAs to 100 percent in the Bryan-College Station and Laredo MSAs.

Area Attributes

To control for demand and monitoring factors that the literature suggests may influence school district inefficiency, we also incorporate a number of metropolitan area characteristics. These variables are school district enrollment (ENROLL), the square of school district enrollment

[15]The Herfindahl index for a given market is the sum of the squared enrollment shares for all of the public and private school systems in that market. For ease of exposition, we multiply the values of the Herfindahl index by 100.

[16]The four-firm concentration ratio for a given market is the sum of enrollment shares for the four largest school districts (public or private) in that market.

(ENROLL**2), the per-pupil tax base of the school district (TAX BASE), the shares of the population that are less than 16 years of age (UNDER16), Catholic (CATHOLIC) and homeowners (OWNERS) and the shares of the population over 25 that attended at least some college (COLLEGE) or that graduated from high school but did not attend college (HIGH SCHOOL).

Table 1 presents descriptive statistics for the data used in this analysis.

V. Estimation

The translog cost function has a long history of use in estimating cost functions because of its flexibility and ability to nest various hypotheses within its structure. In this analysis we use a translog form for the distance function. Suppressing the observational subscript,

$$\begin{aligned}\ln D = \alpha &+ \sum_j \beta_j \ln x_j + \tfrac{1}{2}\sum_j\sum_k \beta_{jk} \ln x_j \ln x_k + \sum_j\sum_m \rho_{jm} \ln x_j \ln y_m \\ &+ \sum_j\sum_r \gamma_{jr} \ln x_j \ln z_r + \sum_r \delta_r \ln z_r + \tfrac{1}{2}\sum_r\sum_j \delta_{rj} \ln z_r \ln z_j \\ &+ \sum_r\sum_m \nu_{rm} \ln z_r \ln y_m + \sum_m \lambda_m \ln y_m + \tfrac{1}{2}\sum_m\sum_n \lambda_{mn} \ln y_m \ln y_n + \epsilon.\end{aligned} \tag{10a}$$

where ln D equals zero, x_j is the quantity for discretionary inputs (INST and NINST), z_n is the quantity for non-discretionary inputs ($STUINPUT_5$, $STUINPUT_{11}$, and CAPINPUT) and y_m are the output quantities ($OUTPUT_5$ and $OUTPUT_{11}$). We impose homogeneity in the discretionary inputs ($\sum\beta_j = 1$, $\sum\beta_{jk} = 0$, $\sum\rho_{jm} = 0$, $\sum\gamma_{jr} = 0$) as required by the definition of the input distance function (Färe and Grosskopf, 1990).

One advantage of the translog specification is that by Shepherd's lemma the first derivative of (10a) with respect to x_1 equals the expenditure share for input 1 ($S_1 = w_1 x_1/(w_1 x_1 + w_2 x_2)$). Because estimating the distance function and the share equation together in a system of simultaneous equations would improve the efficiency of the estimated parameters, we use the observed input quantities and the average prices for teachers and administrators ($P = w_2/w_1$) in each metropolitan area to define instructional expenditure shares (S_1) for each observation. We use the ratio of average prices to derive expenditure shares rather than the observed relative prices because the observed prices may include rents.[17]

Thus, we estimate the following system of equations:

$$\begin{aligned}
\ln D = \alpha &+ \sum_j \beta_j \ln x_j + \tfrac{1}{2}\sum_j\sum_k \beta_{jk} \ln x_j \ln x_k + \sum_j\sum_m \rho_{jm} \ln x_j \ln y_m \\
&+ \sum_j\sum_r \gamma_{jr} \ln x_j \ln z_r + \sum_r \delta_r \ln z_r + \tfrac{1}{2}\sum_r\sum_j \delta_{rj} \ln z_r \ln z_j \\
&+ \sum_r\sum_m v_{rm} \ln z_r \ln y_m + \sum_m \lambda_m \ln y_m + \tfrac{1}{2}\sum_m\sum_n \lambda_{mn} \ln y_m \ln y_n + \epsilon, \\
S_1 = \beta_1 &+ \beta_{11}\ln x_1 + \beta_{12}\ln x_2 + \sum_m \rho_{1m}\ln y_m + \sum_r \gamma_{1r}\ln z_r + \mu
\end{aligned} \tag{10b}$$

using restricted least squares to accommodate the nonvariance of the left hand side of the first equation (Hayes et al. 1995).[18]

Because expenditure shares by definition sum to one, the predicted values from the instructional share equation (together with the variable input quantities and the ratios of average prices $P = w_2/w_1$) provide sufficient information to generate a point estimate of κ for each school district (κ_s).[19] If $\kappa_s >$ 1 (< 1) then the wage-deflated marginal product of instructors is greater than (less than) the wage-deflated marginal product of administrative staff. We use the value of κ_s as our measure of allocative

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[17]Implicitly, this approach assumes that although wage levels may vary among school districts in a metropolitan area, teachers and administrators receive the same compensating differential (in percentage terms).

[18] In addition to the restrictions needed to satisfy the homogeneity conditions ($\sum\beta_j = 1$, $\sum\beta_{jk} = 0$, $\sum\rho_{jm} = 0$, $\sum\gamma_{jr} = 0$), we also impose symmetry (e.g. $\beta_{jk} = \beta_{kj}$).

[19] With some rearrangement, the definition of κ_{12} given in equation 5 becomes

$$\kappa_s = \left(\frac{\partial D/\partial x_1}{\partial D/\partial x_2}\right) / \frac{w_1}{w_2} = \left(\frac{\partial D/\partial x_1}{\partial D/\partial x_2}\right) \cdot P.$$

where x_1 in INSTR and x_2 is NINST. Because there are only two variable inputs under consideration, we have dropped the subscripts on κ indicating input type.

inefficiency: the farther κ_s is from 1, the greater is the difference between the market price and the observed price and the more allocatively inefficient is the school district.

To isolate the relationship between competition and inefficiency, we regress our measure of allocative inefficiency against a measure of competition (either the Herfindahl Index or the the four-firm concentration ratio) and the various school and metropolitan area attributes (ENROLL, ENROLL**2, TAX BASE, UNDER16, CATHOLIC, OWNERS, COLLEGE and HIGH SCHOOL). For the purposes of these regressions, allocative inefficiency is measured as the absolute value of (κ_s - 1).[20] After transformation, our measure of allocative inefficiency ($|\kappa_s -1|$) has been multiplied by 100 for ease of exposition. As $|\kappa_s -1|$*100 increases, allocative inefficiency increases.

To allow for non-linearities in the relationship between competition and inefficiency, we follow a "switching regimes" technique suggested by White (1976) and Alexander (1994). Thus, we create a dummy variable (denoted DSwitch) that takes on the value of one for market concentration measures that are greater than or equal to a critical value (z_0) and search sequentially for the z_0 that maximizes the log likelihood function conditional on z_0.[21]

This approach creates three challenges. First, the standards errors for (10b) will be incorrect

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[20] Recall that allocative efficiency implies that $\kappa_s = 1$.

[21] The log likelihood function is

$$Log\ L = -T\log(\sqrt{(2\pi)}) - \frac{T}{2} - \frac{T_1}{2}\log\left(\frac{\sum_{t=1}^{T_1} e^2_{it}}{T_1}\right) - \left(\frac{T-T_1}{2}\right)\log\left(\frac{\sum_{t=T_1+1}^{T} e^2_{it}}{T-T_1}\right)$$

because the regression includes generated regressors. Second, statistical significance can not be determined for our measures of allocative inefficiency (κ_s) because they represent transformations of the predicted values from (10b). Third, we cannot obtain unconditional standard errors for the coefficients in the switching regressions because the critical value (z_0) is determined endogenously by a sequential search.

A nested bootstrap allows us to address each of these challenges. Specifically, we create 250 data sets (of 262 observations each) based on random draws with replacement from the original data. We then replicate each stage of the analysis 250 times—one replication for each of the 250 data sets. Thus, equation (8) is re-estimated 250 times. In turn, the resulting $OUTPUT_{sg}$ and $STUINPUT_{sg}$ measures are used to re-estimate (10b). Appendix Tables 1 and 2 present information about the distribution of coefficient estimates from equations (8) and (10b).

Each estimate of (10b) yields a distribution of κ_s . Thus, we can use the switching regressions technique discussed above to estimate the relationship in each of our 250 replicated data sets between our estimates of inefficiency (κ_s) and our measures of competition. Using the replicated data sets in this way allows us to generate distributions not only of the coefficient estimates from the switching regressions, but also of the endogenous critical values (z_0).

VI. Results

Table 2 presents our results for four different models of school district efficiency. Model I excludes any measure of market concentration. Model II adds an intercept dummy (DSwitch) to the estimation of Model I. DSwitch equals one whenever market concentration equals or exceeds z_0 (and zero otherwise). Model III replaces DSwitch with an interaction term (DSwitch X market concentration). The interaction term takes on the value of the market concentration variable whenever market concentration equals or exceeds the critical value z_0 (and zero otherwise). If $z_0 = 0$, there is no switch, and Model III is a simple linear model including a market concentration variable. Model IV adds a non-switching market concentration variable to Model III. Table 2a presents our results using the Herfindahl index as the measure of market concentration; table 2b presents the results for the four-firm concentration ratio.

As tables 2a and 2b illustrate, we find systematic evidence that school district inefficiency reflects competitive pressures. Across the various specifications, the positive coefficient on the measure of market concentration indicates that allocative inefficiency rises with market concentration. Furthermore, our evidence suggests that the relationship is non-linear—the likelihood function is maximized with a switching point at a Herfindahl index of 27.61 (or equivalently at a four-firm concentration ratio of 83.65). By this criterion, nearly half of the metropolitan areas in Texas (containing 20 percent of the urban school districts and enrollments in our sample) are highly concentrated markets.

Model IV also indicates that allocative inefficiency increases with market concentration whenever the Herfindahl index is above the critical level; below the critical level there is no relationship between allocative inefficiency and market concentration. Thus, we find evidence that increased competition could enhance the efficiency of school districts in concentrated markets, but would have little systematic effect on school districts in competitive markets.

The switching regressions also suggest that school districts in highly concentrated markets are substantially more allocatively inefficient than school districts in competitive markets. Table 3 compares the predicted efficiency scores for school districts in highly concentrated markets with the predicted efficiency scores for school districts in competitive metropolitan areas. Evaluating the models at the means of the other regressors, we find that markets with Herfindahl indices (concentration ratios) at or above the critical value have predicted inefficiency scores at least 50 percent higher than markets with Herfindahl indices (concentration ratios) below the critical value.

On average, school districts in concentrated markets are more than twice as allocatively inefficient as school districts in competitive metropolitan areas (using either measure of competition).

Interestingly, the analysis does not support the notion that school district size influences allocative inefficiency. Enrollment and enrollment squared are individually insignificant in all of the models. Furthermore, evaluated at the mean of enrollment, the partial derivative of the models with respect to enrollment (∂Enroll) is insignificantly different from zero.

VII. Conclusions

Policies that foster competition among school districts have been proposed as a partial solution to the problem of school inefficiency. However, school districts already face competition for enrollments from private schools and other area public schools. If inefficiency in the school system could be reduced by increasing the degree of competition among schools, then we would expect to find evidence that school districts that currently face a lot of competition are more efficient than school districts that currently face less competition.

Using an input distance function to model the relationship among the multiple inputs and multiple outputs of Texas school districts, we find substantial evidence that increased competition for enrollments could enhance the efficiency of school districts in concentrated markets. On average, school districts in highly concentrated markets are more than twice as allocatively inefficient as school districts in competitive markets. However, only 20 percent of the urban school districts in our sample are located in highly concentrated markets. Thus, while our analysis offers support for the notion that increased school competition—fostered either by vouchers or charter schools—would improve school efficiency in some metropolitan areas, our analysis also suggests that increased competition is not a panacea.

Table 1
Descriptive Statistics

	Mean	Std.Dev.	Minimum	Maximum
$ENROLL_5$	676.16	1209.57	51.00	13121.00
$MATH89_5$	825.75	34.38	713.00	915.00
$TEAMS87_{math,5}$	835.27	36.39	707.00	944.00
$TEAMS87_{reading,5}$	801.92	40.74	618.00	914.00
$TEAMS87_{writing,5}$	758.89	36.99	613.00	865.00
$XCOHORT_5$	99.48	8.56	79.80	128.07
$ENROLL_{11}$	545.18	900.80	50.00	8521.00
$MATH89_{11}$	774.96	27.58	692.00	851.00
$TEAMS87_{math,11}$	788.42	30.45	702.00	893.00
$TEAMS87_{reading,11}$	789.22	27.36	711.00	869.00
$TEAMS87_{writing,11}$	745.38	35.24	668.00	861.00
$XCOHORT_{11}$	81.12	10.14	50.00	112.70
BLACK	10.59	14.04	0.00	89.40
HISPANIC	24.88	29.57	0.10	98.80
SES	69.06	23.75	2.41	100.00
NINST	11.30	19.50	0.85	211.89
INST	73.11	122.97	6.70	1291.76
P	1.61	0.05	1.47	1.73
CAPINPUT	1885.55	3348.02	72.49	31062.68
HERFINDAHL	20.81	14.24	10.91	86.63
CONCENTRATION RATIO	65.76	15.54	47.34	100.00
TAXBASE (millions per pupil)	0.18	0.12	0.02	1.07
ENROLL (thousands)	9.77	17.82	.80	190.29
UNDER16	27.01	2.52	20.48	34.62
CATHOLIC	21.31	21.57	1.10	81.00
OWNER	59.93	6.14	41.87	70.80
COLL_SHR	47.97	7.97	27.00	61.65
HIGH_SHR	25.30	3.67	16.46	34.24

Table 2a
Allocative Inefficiency and the Herfindahl Index

	Model I	Model II	Model III	Model IV
Intercept	5.92 (-5.44, 18.71)	-0.50 (-12.76, 13.65)	-0.25 (-11.69, 12.78)	3.52 (-10.33, 16.25)
DSwitch	.	2.15 (1.29, 2.89)	.	.
DSwitch X HI	.	.	0.04 (0.02, 0.06)	0.08 (0.03, 0.13)
Herfindahl Index	.	.	.	-0.05 (-0.11, 0.01)
Tax Base	-3.34 (-4.90, -1.99)	-2.21 (-3.36, -0.68)	-2.39 (-3.66, -0.95)	-2.30 (-3.56, -0.75)
Owner	0.11 (0.02, 0.23)	0.12 (0.04, 0.21)	0.11 (0.04, 0.22)	0.11 (0.01, 0.22)
Under 16	-0.05 (-0.33, 0.17)	0.01 (-0.30, 0.25)	0.04 (-0.29, 0.29)	-0.04 (-0.38, 0.40)
College	-0.04 (-0.13, 0.06)	0.01 (-0.10, 0.11)	0.001 (-0.09, 0.10)	-0.005 (-0.11, 0.09)
High School	-0.24 (-0.39, -0.09)	-0.19 (-0.34, -0.09)	-0.20 (-0.34, -0.10)	-0.21 (-0.35, -0.10)
Catholic	-0.02 (-0.05, 0.02)	-0.01 (-0.05, 0.02)	-0.02 (-0.05, 0.02)	-0.01 (-0.06, 0.03)
Enroll	-0.01 (-0.04, 0.01)	-0.02 (-0.05, 0.002)	-0.02 (-0.05, 0.003)	-0.02 (-0.05, 0.001)
Enroll**2	3E-5 (-1E-4, 5E-4)	8E-5 (-6E-5, 5E-4)	9E-5 (-5E-5, 7E-4)	9E-5 (-5E-5, 7E-4)
∂Enroll	3E-4 (-0.001, 0.004)	8E-4 (-7E-4, 5E-3)	9E-4 (-5E-4, 6E-3)	9E-4 (-5E-4, 6E-3)
Log L	-531.2 (-560.8, -506.5)	-491.3 (-514.9, 461.6)	-493.4 (-516.7, -464.0)	-491.0 (-514.2, -462.0)
z_0	.	27.61 (13.03, 27.61)	27.61 (13.03, 27.61)	27.61 (12.77, 27.61)

note: median coefficient values. The 5th and 95th percentile values are in parentheses.

Table 2b
Allocative Inefficiency and the Concentration Ratio

	Model I	Model II	Model III	Model IV
Intercept	5.92 (-5.44, 18.71)	-0.25 (-12.64, 13.84)	0.19 (-11.89, 14.63)	2.09 (-10.61, 18.69)
DSwitch	.	2.13 (1.16, 2.86)	.	.
DSwitch X CR	.	.	0.02 (0.01, 0.03)	0.02 (-0.05, 0.04)
Concentration Ratio	.	.	.	0.01 (-0.04, 0.16)
Tax Base	-3.34 (-4.90, -1.99)	-2.21 (-3.41, -0.68)	-2.29 (-3.74, -0.82)	-2.26 (-3.63, 0.72)
Owner	0.11 (0.02, 0.23)	0.12 (0.02, 0.21)	0.11 (0.01, 0.21)	0.10 (-0.02, 0.23)
Under 16	-0.05 (-0.33, 0.17)	0.01 (-0.31, 0.25)	0.02 (-0.31, 0.32)	-0.02 (-0.42, 0.28)
College	-0.04 (-0.13, 0.06)	0.01 (-0.10, 0.11)	0.01 (-0.10, 0.11)	-0.01 (-0.16, 0.09)
High School	-0.24 (-0.39, -0.09)	-0.20 (-0.33, -0.09)	-0.20 (-0.34, -0.09)	-0.23 (-0.37, -0.09)
Catholic	-0.02 (-0.05, 0.02)	-0.01 (-0.05, 0.02)	-0.02 (-0.06, 0.02)	-0.02 (-0.07, 0.02)
Enroll	-0.01 (-0.04, 0.01)	-0.02 (-0.05, 0.003)	-0.02 (-0.05, 0.003)	-0.02 (-0.05, 0.002)
Enroll**2	3E-5 (-1E-4, 5E-4)	8E-5 (-7E-5, 5E-4)	8E-5 (-7E-5, 5E-4)	9E-5 (-6E-5, 7E-4)
∂Enroll	3E-4 (-0.001, 0.004)	8E-4 (-7E-4, 5E-3)	8E-4 (-7E-4, 5E-3)	9E-4 (-6E-4, 6E-3)
Log L	-531.2 (-560.8, -506.5)	-491.2 (-514.9, -461.6)	-492.0 (-516.7, -462.3)	-487.9 (-515.5, -459.6)
z_0	.	83.65 (49.69, 83.65)	83.65 (49.69, 83.65)	74.73 (49.69, 83.77)

note: Median coefficient values. The 5th and 95th percentile values are in parentheses.

Table 3
Relative Inefficiency of School Districts in
Highly Concentrated Markets

$$\frac{|\hat{\kappa}_s - 1|_{z=z_0}}{|\hat{\kappa}_s - 1|_{z<z_0}}$$

	Model II	Model III	Model IV
Herfindahl index			
	2.33 (1.64, 2.55)	1.53 (1.20, 1.85)	2.63 (1.31, 4.36)
Concentration ratio			
	2.31 (1.64, 2.55)	1.98 (1.50, 2.51)	1.70 (0.23, 3.72)

note: Median predicted ratios.
The 5th and 95th percentile values are in parentheses.

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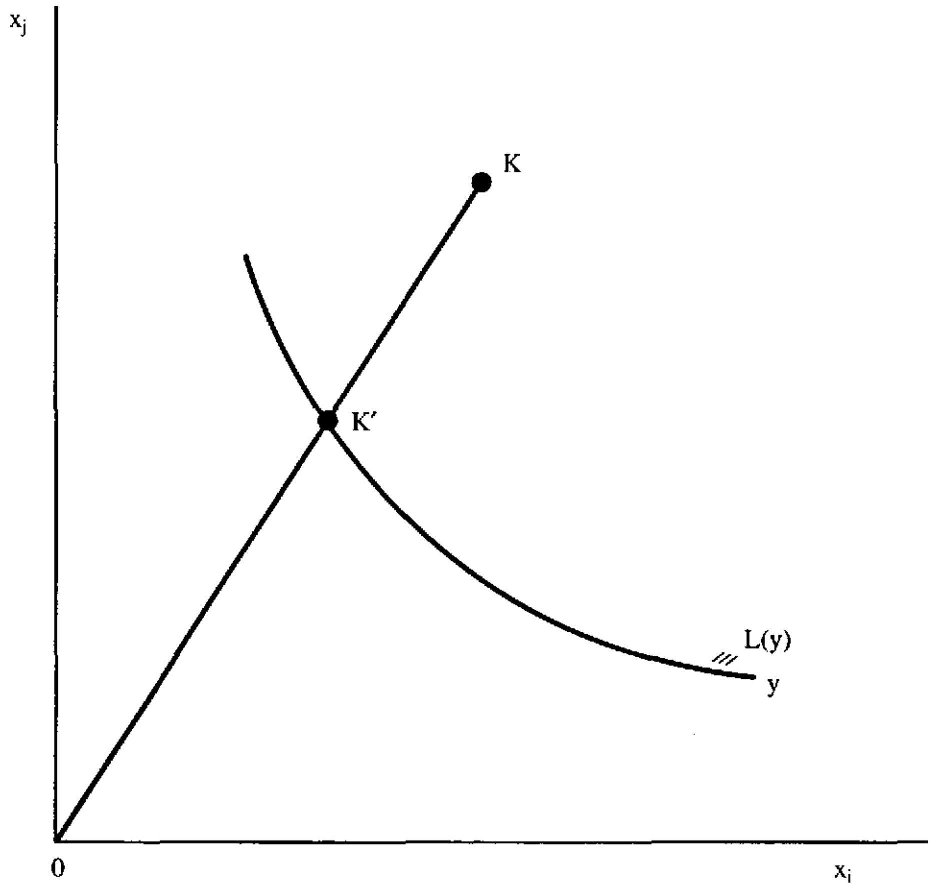
Appendix Table 1
Predicted Outcomes in Mathematics by Grade

	5th Grade			11th Grade		
	5th percentile	median	95th percentile	5th percentile	median	95th percentile
Intercept	381.42	507.99	638.77	192.66	250.89	312.97
$TEAMS87_{math,j}$	0.02	0.18	0.35	0.30	0.39	0.48
$TEAMS87_{reading,j}$	-0.20	0.03	0.24	0.09	0.20	0.33
$TEAMS87_{writing,j}$	0.04	0.24	0.41	0.04	0.10	0.16
BLACK	-0.46	-0.23	0.06	-0.43	-0.29	-0.13
HISPANIC	-0.29	-0.08	0.19	-0.17	-0.03	0.10
$XCOHORT_j$	-0.83	-0.49	-0.19	-0.61	-0.41	-0.19
SES	0.04	0.32	0.66	0.07	0.25	0.43

Appendix Table 2
Estimates of the Translog Input Distance Function

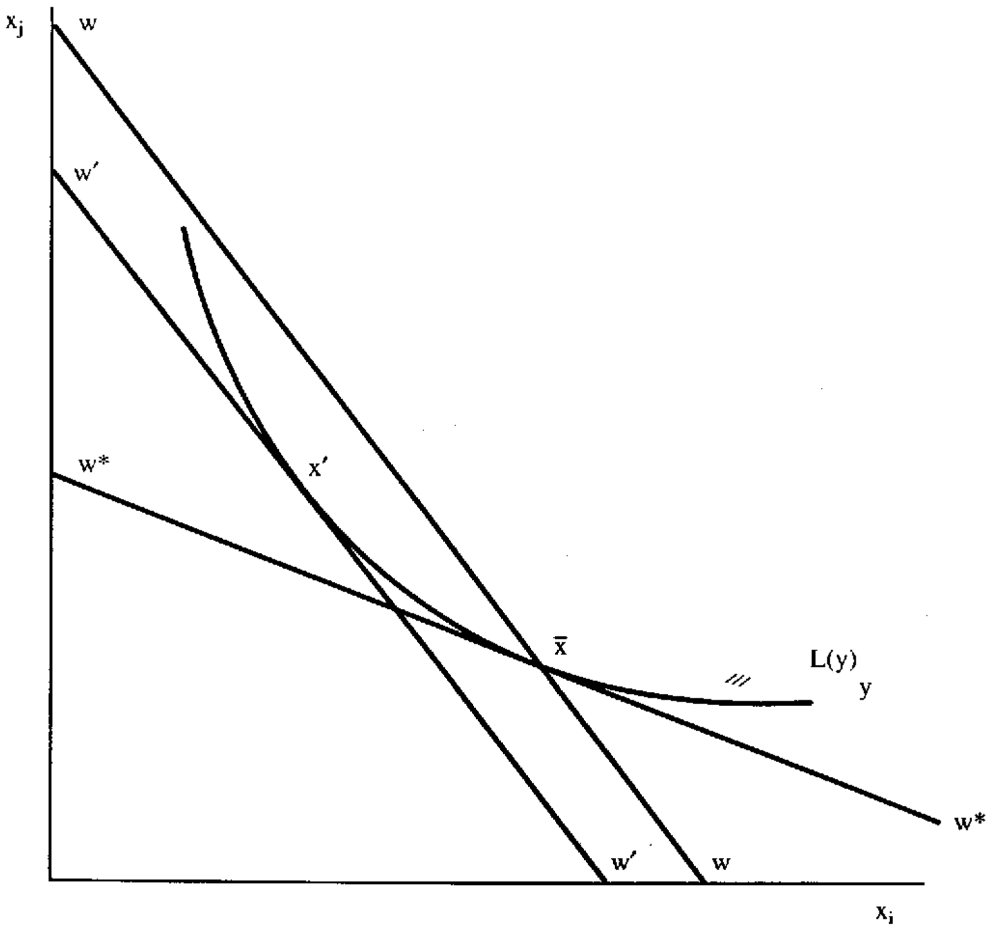
	5th percentile	median	95th percentile
INTERCEPT	-1.695	1.897	5.004
ℓX1	0.495	0.503	0.514
ℓX2	0.486	0.497	0.507
ℓY1	-3.434	2.907	9.067
ℓY2	-4.475	1.480	8.213
ℓR1	-8.847	-2.855	2.556
ℓR2	-8.243	-0.473	5.121
ℓR3	-2.171	-1.309	-0.549
ℓX1ℓX1/2	0.151	0.155	0.158
ℓX1ℓX2	-0.158	-0.155	-0.151
ℓX2ℓX2/2	0.151	0.155	0.158
ℓX1ℓY1	-0.004	0.008	0.020
ℓX1ℓY2	-0.020	-0.008	0.004
ℓX1ℓR1	-0.027	-0.014	-0.001
ℓX1ℓR2	0.002	0.016	0.029
ℓX1ℓR3	-0.003	-0.001	0.001
ℓX2ℓY1	-0.020	-0.008	0.004
ℓX2ℓY2	-0.004	0.008	0.020
ℓX2ℓR1	0.001	0.014	0.027
ℓX2ℓR2	-0.029	-0.016	-0.002
ℓX2ℓR3	-0.0001	0.001	0.003
ℓY1ℓY1	-13.067	-5.215	3.248
ℓY1ℓY2	-6.409	2.897	14.667
ℓY1ℓR1	-6.855	10.409	25.756
ℓY1ℓR2	-15.383	-3.780	6.451
ℓY1ℓR3	-0.711	0.431	1.498
ℓY2ℓY2	-5.390	-1.079	3.303
ℓY2ℓR1	-12.536	-0.992	8.852
ℓY2ℓR2	-9.580	-0.500	8.043
ℓY2ℓR3	-0.802	0.083	1.116
ℓR1ℓR1	-12.721	-5.053	3.770
ℓR1ℓR2	-10.051	1.108	13.204
ℓR1ℓR3	-1.576	-0.533	0.514
ℓR2ℓR2	-2.751	1.153	6.201
ℓR2ℓR3	-0.922	0.144	1.050
ℓR3ℓR3	-0.118	-0.056	0.001

Figure 1



Input Distance Function: $D(y^K,x^K) = 0K/0K'$

Figure 2



Overutilization of x_i at $\bar{x}$

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