Education Reform, Redistribution, and Student Achievement: Evidence From the Kentucky Education Reform Act

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Abstract

The Kentucky Education Reform Act (KERA), implemented in 1990, is one of the most ambitious and influential education reform policies ever attempted by any state. KERA's main components include a new funding system to correct large financial disparities between school districts, curriculum revision and standardization, and increased school and district accountability. In this paper I explore KERA's effects on school spending and student achievement. I find that KERA did successfully equalize per-pupil expenditures across rich and poor districts and that this equalization has been sustained throughout the decade since KERA's passage. KERA's effects on student achievement have been more modest. Black students in Kentucky have experienced modest test score gains since KERA's implementation, but the scores of white students have remained unchanged relative to their peers in surrounding states. I also find no evidence that KERA narrowed the gap in test scores between rich and poor districts. Instrumental variables estimates suggest the increased spending induced by KERA did not improve test scores.

1. Introduction

Improving public education is a primary concern of local, state, and federal policymakers, but there is considerable uncertainty over which education reform strategies work and, of particular interest to both economists and policymakers, the effects of increases in school spending on student achievement. The Kentucky Education Reform Act (KERA), an influential education reform plan that dramatically increased spending on public education, can provide important evidence on the effectiveness of the increasingly common "comprehensive" approach to education reform that it inspired, as well as on the efficacy of finance reform-induced increases in school spending.

KERA was passed into law in 1990 in response to a State Supreme Court ruling that Kentucky's entire system of public education was inequitable, inadequate, and therefore unconstitutional. Under the Court's mandate, KERA defined a new, comprehensive approach to education reform, encompassing a complete overhaul of the school finance system as well as broad governance, accountability, and curriculum reforms. Since its passage, KERA has had a profound influence on education reform policies throughout the country, inspiring similar attempts at comprehensive education reform in several other states.[1] But despite the magnitude and influence of Kentucky's education reform effort, there is only limited evidence of KERA's impact on Kentucky students. Now that more than a decade has passed since KERA was first put in place, we can begin to evaluate the reform's effectiveness in

[1] Courts in New Hampshire, Alabama, North Carolina, South Carolina, Massachusetts, and Ohio have directly cited the Kentucky court decision in their own school finances decisions.

establishing an adequate and equitable system of public education and to see what lessons can be learned from the nation's first attempt at comprehensive education reform.

In this paper, I address several questions about KERA: First, did the reform effectively equalize spending per pupil across the school districts, and has this equalization been sustained throughout the decade since KERA's implementation? Second, what effect did the reform have on student achievement, as measured by standardized test scores? In particular, I examine whether the reform raised test scores of Kentucky students relative to those of students in nearby states and also whether KERA narrowed the gap in test scores between students from rich and poor districts, as was one of its intentions. Finally, and more generally, what is the effect of school finance reform-induced spending on student achievement? I use the sharp change in the school finance formula under KERA as an instrumental variable for school spending to shed light on this question.

To examine KERA's effect on funding and expenditure disparities between rich and poor districts, I analyze district-level school finance data from the National Center for Education Statistics' annual F-33 Survey of Local Government Finances. I find that KERA resulted in a substantial increase in per-pupil state funding to low income districts, producing a substantial increase in spending per pupil in these districts. Ten years after KERA was first implemented, the poorest districts were, in fact, spending more per pupil on average than the wealthiest districts. The increased spending in the poorest districts funded moderate reductions in class sizes as well as dramatic increases in teacher salaries relative to the wealthier districts.

Measuring KERA's effect on student achievement is complicated by the difficulty of finding a reliable gauge of student performance. Many previous studies of KERA's effects on achievement have examined test scores from the state's assessment system. Focusing solely on results from the state assessment is problematic for several reasons, however. One concern is that improvements in scores on the state assessment may not be driven solely by actual gains in student achievement. Instead, score improvements may reflect growing familiarity with the test on the part of teachers and students when a new test is introduced. Alternatively, score improvements may reflect "teaching to the test" — devoting class time to test preparation while de-emphasizing material not covered by the exam. This is a particular concern when a state institutes a "high-stakes" accountability system, such as Kentucky's, that rewards and sanctions schools based on students' test performance.[2] A final concern regarding state assessment scores as a gauge of student achievement is that a high-stakes testing environment such as that put in place by KERA creates incentives for teachers to cheat on the exams by providing students with extra assistance, time, or even changing student responses on the tests.[3]

[2] Koretz and Barron (1998) find that Kentucky students performed better on exam questions that had appeared on previous years' tests, indicating that teachers may have spent considerable time teaching students the material they thought likely to be covered on the exam.

[3] Jacob and Levitt (2001) find evidence of teacher cheating from the Chicago public schools that suggests this is a valid concern that must be considered when relying on high-stakes standardized tests to evaluate student performance. According to Foster (1998), concerns about instances of teacher cheating have been raised in Kentucky and dealt with on an ad hoc basis.

To avoid the pitfalls associated with analyzing test scores from the state's assessment, I instead examine ACT and NAEP scores.[4] Unlike the state assessment, the ACT and NAEP are not used to evaluate teachers or schools under KERA's high-stakes accountability policy and may therefore more accurately reflect student achievement. Both exams are taken by students outside Kentucky, which allows me to implement a difference-in-differences estimation strategy, using test scores of students from nearby states to control for potentially confounding time trends in scores. An additional strength of the ACT data is that they are available at the individual level and contain a wide array of background information on the students, which allows me to control for characteristics such as race and family income that are likely to be correlated with test performance. NAEP data are available only for various subgroups (race, parental income category) at the state level. A limitation of the ACT data is that the exam is taken by a nonrandom subset of students — typically those who are applying to college. I present estimators that attempt to account for this potential sample selection bias.

I find that KERA has had mixed effects on student achievement. The ACT scores of black students in Kentucky relative to those in the control state of Tennessee have improved modestly over the decade since KERA's implementation, but ACT scores of white students have not improved significantly. Increases in NAEP scores are also small and not statistically distinguishable from zero. Even though KERA greatly increased school spending in the

[4] The ACT, formerly the American College Testing Program, is an exam required for admission to many colleges in Kentucky and other (predominantly Midwestern and Southern) states. NAEP is an acronym for National Assessment of Educational Progress, an assessment administered to a representative sample of students nationally and in participating states by the National Center for Education Statistics.

poorer districts, it seems not to have reduced the achievement gap between rich and poor districts.

Finally, I combine my reduced-form estimates of KERA's effects on school spending and student achievement and use the sharp change in the school finance formula under KERA as an instrument for school spending in order to estimate the effects of school spending on student achievement. The instrumental variables estimates suggest that the increased spending induced by KERA had no discernable effect on students' test scores. These estimates should be interpreted with caution, however, as the instrument's validity requires assumptions that may be violated if non-finance-reform components of KERA had a differential effect on school districts that was correlated with the districts' wealth.

The remainder of this paper is structured as follows. In section two, I present background information on KERA's passage and details of the reform itself. In section three I examine KERA's effects on school finance equalization, and in section four I examine KERA's effects on student achievement. In section five I present instrumental variables estimates of the effects of school spending on student achievement. In section six I conclude.

2. Background and Overview of KERA

For many years prior to KERA's implementation, Kentucky consistently ranked at or near the bottom of the nation in terms of school spending per pupil, student achievement, high school graduation rates, adult literacy, and a host of other indicators of human capital. There were also wide disparities within the state. Kentucky is economically diverse, comprising two relatively wealthy large cities and many extremely poor small towns and rural areas. Prior to

KERA, the school finance system in Kentucky, as in other states, relied heavily on local property tax revenues, and so economic disparities between the school districts were reflected in large inequalities in spending per pupil between the districts as well as wide disparities in student achievement between the districts.

In 1985, 66 Kentucky school districts with low property tax bases brought a lawsuit against the state, calling for equalized resources between rich and poor districts. Such a case was not unprecedented; at least 16 states had faced similar lawsuits over the previous two decades, and courts in seven of these states had found the school finance system unconstitutional.[5] The Kentucky Supreme Court's decision in *Rose v. Council for Better Education,* however, was groundbreaking in its scope. Previous state supreme courts had simply declared their state's school finance system unconstitutional; in the *Rose* decision the Court declared Kentucky's *entire* system of public education unconstitutional, stating that it was "underfunded and inadequate; … fraught with inequalities and inequities; … and … not uniform across the districts in educational opportunities." (*Rose v. Council for Better Education, Inc.*, 790 S.W.2d 186, Ky. 1989). The Court required the legislature to design a new educational system within the year.

The ruling precipitated the passage of KERA, a sweeping overhaul of Kentucky's public education system. The reform encompassed broad finance, curriculum, and governance reforms. This broad scope was the most radical aspect of KERA. Several other states had previously implemented finance reforms, and others had implemented various

[5] See Minorini and Sugarman (1999) for an overview of school finance litigation since the 1970s.

curriculum reforms, particularly in the area of standards and assessment. To that date, however, no state had attempted to integrate so many widely varied reforms into a package as comprehensive as KERA, which has come to be viewed as the nation's first experiment with comprehensive education reform. Below I describe KERA's finance, curriculum, and governance reforms in greater detail.

A. Background and Overview of KERA: Finance Reform

One of KERA's central components was finance reform, which was underway as of the 1990–91 school year and fully phased in by the 1995–96 school year. KERA established the Support Education Excellence in Kentucky (SEEK) fund, which was intended to equalize per-pupil expenditures across the districts and to provide significant increases in financial support for schools. The legislation established a base level of guaranteed funding per pupil ($2,305 in 1990–91), to be adjusted each year. The base amount was then adjusted in each district for the percentage of students "at risk" (qualifying for the federal school lunch program), the percentage of students with disabilities (weighted according to the severity of the disability), and cost of transportation in the district. The local governments were required to contribute revenues equal to 0.3 percent of their assessed property value per pupil.[6] The state would pay each district the difference between the base guarantee and the required local contribution.

[6] KERA also allocated $10 million over two years to improving the consistency of assessment methods across districts. By 1994, all real property was to be assessed at 100 percent of its fair cash value (Kentucky General Assembly, 1990 (Kentucky *Revised Statutes*, 160.470)).

Beyond its required minimum contribution, a district could increase its total spending per pupil up to 49.5 percent above the base guarantee. To provide incentives for poorer districts to contribute local revenues beyond the required minimum, the state would equalize local tax effort in districts according to the following formula: For amounts per pupil up to 15 percent above the base guarantee, any local tax increase beyond the required minimum would be met with state funds in an amount that would generate total revenues equal to that produced by an equivalent tax increase in a district with assessed property value equal to 150% of the statewide average.[7] The state provided no equalizing funds for revenues between 115% and 149.5% of the base guarantee.

While SEEK's underlying structure was similar to that of the MFP and PE plans previously in place, SEEK dramatically increased the state funding available for equalization, the level of foundation spending per pupil, and the tax equalization rates. It further reduced inequalities by requiring consistent property valuations across the districts and by allocating funds on a per-pupil rather than a per-classroom basis.

B. Background and Overview of KERA: Curriculum Reform

One of the overarching elements of KERA's curriculum reform was a shift to a "standards-based" curriculum, under which the state defined broad performance standards that students at each grade level were expected to meet or exceed. The goals of the new curriculum guidelines were to place increased emphasis on communication and problem-

[7] No equalizing funds were provided to districts with assessed property value per pupil greater than or equal to 150 percent of the statewide average.

solving skills and to teach students to organize and interpret information rather than simply memorize and recall it. The new curricula were expected to be phased into all schools by the 1995–96 school year.

To evaluate schools' success in meeting the new curriculum standards and to provide incentives for schools to improve, KERA also included new "high-stakes" assessment and accountability policies. The state developed a new assessment system, the Kentucky Instructional Results Information System (KIRIS), which consisted of both open-response and multiple-choice questions as well as writing portfolios. Under the accountability policy, the state computed an accountability index for each school by weighting test performance (excluding multiple-choice items) 85 percent and nonacademic indicators (attendance, dropout, and retention rates) 15 percent. Schools that met their individual biennial improvement goals received cash rewards (up to $2,311 per teacher in 1996). Schools that fell short of their improvement goals were required to develop plans for improvement, and severely underperforming schools received financial assistance plus consulting from a specially trained "distinguished educator."[8] The first two-year accountability cycle ended in 1994.

Of KERA's additional curriculum reforms, the most controversial was the establishment of "primary programs," under which all children in grades kindergarten through 3 were to be grouped into multi-age, multi-grade classrooms. These programs were intended to allow students to progress at their own pace, without the threat of failure in their first four

[8] Distinguished educators (now known as "highly skilled educators") were public school teachers who underwent special training and could then be selected for one-year sabbatical leaves, during which they would be assigned to consult in low performing schools.

years of school. The primary programs were expected to be phased in by the 1992–93 school year, although the implementation deadline was extended to 1993–94 in the 1992 legislative session.

Other curriculum reforms included the establishment of pre-school programs for all four-year-old at-risk (low-income) children, to be available by 1990–91; extended school services programs to provide tutoring outside of regular school hours; family resource and youth service centers to provide greater access to social and medical services; and an increase in funding for professional development programs and technology instruction.

C. Background and Overview of KERA: Governance Reform

Among its governance reforms, KERA gave the Department of Education authority to take over failing schools and districts (in the past, the Department had only had the authority to take over failing districts) and to enforce strong anti-nepotism regulations. It also devolved many responsibilities previously held by the state and district boards of education directly to the school level. Newly mandated school councils were given the responsibility to decide on policies relating to curriculum and instruction in an effort to allow schools to tailor their programs to the needs of their specific populations. All schools were expected to have their school councils operational by July 1996.

D. Background and Overview of KERA: Reform Efforts in Tennessee

In much of the analysis that follows, I pursue a difference-in-differences estimation strategy, relying primarily on students from Tennessee as a comparison group. It is important

to understand any education reform initiatives that may have affected the academic achievement of Tennessee students over the relevant period, since the difference-in-differences estimator relies on the assumption that students in the two states would have experienced similar trends in test scores in the absence of KERA. Tennessee shares a long border with Kentucky and is an ideal comparison state in the sense that the two states are relatively demographically similar, have very similar school system structures, and both had low levels of school spending and student achievement prior to KERA.

Like almost all states, Tennessee implemented some education reforms during the 1990s, although later in the decade and not on as large a scale as KERA. In particular, in 1992, Tennessee passed an education reform bill intended to reduce funding disparities between rich and poor districts. As I demonstrate below in my analysis of school finances, however, Tennessee's school finance equalizations were, in practice, relatively ineffective in reducing disparities in spending across rich and poor districts. Tennessee's 1992 education reform plan also included new accountability and assessment policies and an initiative to promote technology investments in classrooms (Dee, 2001).

3. KERA's Effect on District Revenues and Expenditures

One of KERA's main goals was to reduce school spending disparities across rich and poor districts by distributing state funds to the districts more progressively. A redistribution of state funds to poorer districts does not necessarily lead to an equalization of school *spending* across rich and poor districts, however, as districts could potentially offset increases in state funding by decreasing local spending. KERA's minimum local contribution

requirement and tax rate equalization component, described above, were intended to prevent such an offset. In this section I examine KERA's effectiveness in distributing state funds more progressively across the districts and the extent to which this redistribution of state funding translated into equalization of per-pupil spending across rich and poor districts.

Several cross-state studies have found that court-ordered school finance reforms generally result in a corresponding equalization of per-pupil spending across the districts. Murray, Evans, and Schwab (1998) find that states with court-ordered school finance reforms between 1972 and 1992 achieved considerable decreases in spending inequality across districts. Card and Payne (2002) find that court-ordered school finance reforms in the 1980s narrowed the gap in per-pupil expenditures between high- and low-income districts. Previous studies focusing specifically on KERA that analyzed school finance data from early in the decade, such as Adams and White (1997) and McNaught (2001), find that KERA did substantially reduce spending inequalities between rich and poor districts in the years immediately following KERA's implementation. Over time, however, districts may be able to adjust local revenues so as to offset some of KERA's equalizing effects.[9] Using more recent school finance data, I build upon these previous analyses and examine whether KERA's equalization of school spending has in fact been sustained throughout the decade.

[9] In a related literature, Gordon (2001) finds that districts receiving increases in funding from the federal Title I program initially increase expenditures dollar-for-dollar, but after about three years have almost entirely offset these funding increases.

A. KERA's Effect on District Revenues and Expenditures: Data and Methodology

To examine KERA's effects on spending disparities between school districts, I analyze district-level data from the National Center of Education Statistics' annual F-33 Survey of Local Government Finances. The F-33 data contain annual statistics on school districts' revenues by source and district expenditures. I merge these data with information on number of teachers, students, and schools in the district from the Common Core of Data and demographic characteristics of the district, including median household income and racial composition, from the 1990 and 2000 Censuses. I present data from both Kentucky and Tennessee, since I use students from Tennessee as a control group in my analysis of KERA's effects on ACT scores in section four.[10]

I exclude from the analysis districts that merged between 1990 and 2000 (2 in Kentucky and 4 in Tennessee) and districts with missing data (1 in Tennessee). (For the remainder of this paper, I refer to school years by the calendar year of the spring semester.) I drop one district that is an extreme outlier in median income (Anchorage Independent District in Kentucky, a district with 400 students and a median income of $120,000) and one district that is an extreme outlier in current expenditures per pupil (Owsley County in Kentucky, whose 1990 expenditure data in the F-33 survey seem to be in error and do not accord with expenditure data published by the state). Dropping these two outliers makes no substantive difference in the analysis, however, as these two districts are very small.

[10] School finance analyses of the five additional states used as a control group in my analysis of NAEP scores are in an appendix available on request.

Table 1 presents an overview of the district-level data for Kentucky and Tennessee. My sample includes 173 regular operating districts in Kentucky and 133 in Tennessee. As shown in the table, the school district structures in the two states are strikingly similar. The majority of districts (over two-thirds) in both states are organized at the county level. The remaining districts are classified as "independent" districts in Kentucky (and are termed "special" or "city" districts in Tennessee) and are typically organized at the city or town level. The vast majority of districts in both states are unified districts, meaning they span both elementary and secondary grades. Only four districts in Kentucky and 13 districts in Tennessee (14 in 1990) are organized at the elementary level, and neither state has any districts that solely serve secondary students. The majority of districts in both states are classified as rural, although in 2000, Tennessee has a somewhat higher percentage of urban districts, and a slightly lower percentage of rural districts, than Kentucky.[11] School districts in Kentucky tend to be smaller than those in Tennessee, and schools tend to be smaller as well. Tennessee also has a considerably higher percentage of black students than Kentucky and a slightly lower child poverty rate.

I first present a variety of statistics on the dispersion of state funding per pupil and per-pupil expenditures across the districts. In Kentucky, as in many other states, however,

[11] In 1990 the opposite is true. While some of these changes may be due to actual changes in the composition of the population served by the districts, some are most likely due to improvements in the National Center for Education Statistics' methodology in classifying district location between 1990 and 2000. For consistency, in the analysis that follows I classify districts according to their 2000 urban/suburban/rural classification, although this makes little substantive difference in the results. "Urban" districts are those that primarily serve the central city of a Metropolitan Statistical Area; "suburban" districts serve an MSA but not primarily its central city; and "rural" districts are those that do not serve an MSA.

inequalities in spending in and of themselves may be of less immediate concern to legislators than the strong link between district wealth and school expenditures and systematic disparities in spending between rich and poor districts. To examine how KERA affected these disparities, I adopt the specification used by Card and Payne (2002), characterizing the effectiveness of school finance equalizations according to the correlation between state funding per pupil, or district expenditures per pupil, and district wealth. Specifically, I begin with the following model:

$$Y_{dt} = \beta_0 + \beta_1(MEDINC_d) + \beta_2 \boldsymbol{X}_{dt} + \varepsilon_{idt} \qquad (3.1)$$

In this model, Y_{dt} represents the school finance outcome variable of interest, either state funding per pupil or current expenditures per pupil for district *d* in year *t*. $MEDINC_d$ is a measure of the district's wealth, in this case 1989 median household income.[12] $\boldsymbol{X}_{dt}$ is a vector of district-level covariates that affect district revenues or expenditures, including log of district enrollment and dummy variables for whether the district is elementary or unified and whether it is organized at the county level. In this model, the coefficient β_1 characterizes the

[12] I use median household income instead of assessed property value as a measure of a district's wealth in part because median income data are more easily obtained, and in part because property value assessment methods across the Kentucky districts were extremely inconsistent and often severely understated true property values prior to KERA's passage, ranging from 33 1/3 % of the fair cash value to as low as 12 1/2 % of that value, according to *Rose v. Council*. I use 1989 values of median household income throughout the analysis for two reasons. First, 1989 median income is likely to be exogenous to the education reforms in Kentucky, whereas it is plausible that KERA had an impact on districts' wealth after it was implemented. Second, and more prohibitively, district-level tabulations of 1999 median income from the 2000 Census are not yet available. An examination of *county-level* median household income from the 1990 and 2000 Censuses reveals the correlation between the two years to be quite high, however, at .96, suggesting that district-level median income is also likely to be highly correlated between 1989 and 1999.

income gradient in state funding per pupil (or district expenditures per pupil). In the model with state funding per pupil as the dependent variable, β_1 will generally be somewhat negative, as most school finance formulas are at least moderately progressive and provide at least somewhat more generous revenues to poorer districts; a more progressive school finance formula will have a more negative β_1 coefficient. Similarly, in the model with district expenditures per pupil as the dependent variable, β_1 will generally be positive, as wealthier districts typically spend more per pupil than poorer districts, and a more equalizing school finance system will be characterized by a smaller β_1 coefficient.

The *change* in the progressivity of the state finance formula following KERA's implementation can be represented by the following model:

$$Y_{dt} = \gamma_0 + \gamma_1(MEDINC_d) + \gamma_2(POST_{dt}) + \gamma_3(MEDINC_d \times POST_{dt}) + \gamma_4 \boldsymbol{X}_{dt} + \upsilon_{dt} \quad (3.2)$$

In this model $POST_{dt}$ is an indicator variable equal to one in 2000 (post-KERA) and zero in 1990 (pre-KERA). γ_1 represents the income gradient in state funding (or district expenditures) in the base year (1990). The coefficient on the interaction term *MEDINC* x *POST*, γ_3, then represents the change in the income gradient in state funding or district expenditures between 1990 and 2000.

B. KERA's Effect on District Revenues and Expenditures: Results

Table 2 provides an overview of school finance in Kentucky and Tennessee, as well as evidence on KERA's effects on the dispersion of school expenditures. The top panel of the

table presents summary statistics on district revenues per pupil by source in 1990 and 2000 in Kentucky and Tennessee. In 1990, state revenue accounted for 67 percent of per pupil school revenues in Kentucky, and 48 percent in Tennessee. Between 1990 and 2000, there was a very large increase in local revenues per pupil in Kentucky, most likely reflecting the strict minimum local contribution requirements KERA created for districts.

The bottom panel of Table 2 presents statistics on per-pupil expenditures in Kentucky and Tennessee. For consistency with the previous literature, throughout this analysis I study current expenditures, a fairly targeted measure of spending on the day-to-day operations of schools and districts, including instruction, support services, and food services. Real current expenditures per pupil grew by 29 percent in Kentucky and 27 percent in Tennessee between 1990 and 2000. Inequality in current expenditures per pupil decreased in both states over this period, as measured by a 29 percent decrease in the Gini coefficient for per pupil expenditures in Kentucky and a lesser decrease of 21 percent in the Gini coefficient for Tennessee. The standard deviation in per pupil expenditures decreased by 13 percent in Kentucky and only 2 percent in Tennessee. There were increases in per-pupil expenditures at all levels of the distribution in both Kentucky and Tennessee, with the smallest percentage increases at the top of the distribution. The ratio of spending at the 10^{th} percentile relative to spending at the median actually declined slightly in Kentucky, indicating a widening in the per-pupil expenditure gap between these districts. The ratio of expenditures at the 25^{th} percentile to the median increased slightly, and the ratio of both the 75^{th} and 90^{th} percentiles to the median declined, all indicating a narrowing of the dispersion of expenditures among these districts.

As discussed above, the dispersion of school expenditures alone does not fully reflect the relationship between state funding, district expenditures and district wealth, which was a primary concern of the legislators who crafted KERA. Figure 1 presents a graphical version of model 3.1 (excluding covariates), plotting each district's revenue per pupil from the state against its median income in 1989. The diameters of the circles are proportional to district enrollment. A regression line, weighted by district enrollment, is fitted through the points. Panel 1A shows the relative lack of redistribution in the Kentucky school finance formula in 1990 — despite the state's previous attempts at finance equalization, funding from the state to the districts was allocated relatively equally across the districts, irrespective of median income and the districts' differential abilities to raise local revenues. By 2000, in contrast, state funding to the districts in Kentucky had changed dramatically, with wealthier districts receiving about the same amount as they had in 1990, but poorer districts receiving considerably more. The figure on the far right shows the change in state revenues between 1990 and 2000. Panel 1B illustrates state funding to the districts in Tennessee — while the state achieved some redistribution across the districts between 1990 and 2000, the magnitude of the change was not nearly as dramatic as that in Kentucky.

I next examine whether KERA's redistribution of state funding translated into equalization of per-pupil expenditures across rich and poor districts. Figure 2 plots current expenditures per pupil against median household income in 1989. Panel 2A shows a substantial equalization of current expenditures per pupil between 1990 and 2000 in Kentucky. Whereas in 1990 poorer districts were spending considerably less per pupil than richer districts, by 2000 the lowest income districts were spending approximately equal

amounts to the highest income districts. As shown in Panel 2B for comparison, there was considerably less equalization of spending per pupil in Tennessee across rich and poor districts.[13]

A snapshot of these two years may not provide the full picture of changes in revenues and expenditures throughout the decade. Figure 3 suggests that just comparing 2000 to 1990 may mask important changes that occurred over the course of the decade. The figure plots current expenditures per pupil against 1989 median income for each of the Kentucky districts in 1990, 1992, and 1995–2000 (F-33 data for 1991, 1993, and 1994 are excluded since they are available only for a sample of Kentucky districts in those years). The first seven panels show that by 1995, the year before the new finance formula was to be fully phased in, poorer districts were actually spending more per pupil than wealthier districts. As the decade progressed, expenditures in wealthier districts increased, while those in the poorer districts remained relatively unchanged. By the end of the decade, expenditures per pupil were relatively equal across low- and high-income districts. The final panel of Figure 3 summarizes the previous seven panels by plotting the slope of the regression line from the previous seven panels by year. A positive slope indicates wealthier districts are spending more than poorer districts, whereas a negative slope indicates the converse. This panel again shows that spending per pupil went from being higher in wealthier districts before KERA to higher in poorer districts by mid-decade, and had roughly equalized by the end of the decade.

[13] These figures look similar even when federal revenues are subtracted out of district expenditures, indicating that changes in revenues from federal sources such as Title I grants are probably not responsible for the equalization of district expenditures in Kentucky relative to Tennessee.

Table 3 presents more formally the changes illustrated in Figures 1 and 2. The top panel examines changes in the progressivity of state funding per pupil. The first three columns present the results from the regression specified in model 3.2 for Kentucky, Tennessee, and the difference between the two, excluding covariates; the next three columns add controls for log of district enrollment, district grade level (elementary or unified), and district governance level (county versus independent/city/special). All models are computed by weighted least squares, using district enrollment as weights.[14]

The coefficient on median household income in the top panel represents the income gradient in state funding per pupil in the base year, 1990. This coefficient is negative but small in models with and without covariates for both Kentucky and Tennessee, indicating a moderately progressive distribution of state funds in both states. The coefficient of –4.23 on median household income in the model with covariates for Kentucky, for instance, reveals that, on average, a district at the 10th percentile of the distribution of median income in Kentucky (around $20,000) was receiving about $85 more in state funding per pupil than a district at the 90th percentile (around $40,000) in 1990.

In contrast, the coefficient on the median income-post-reform interaction in Kentucky is large and negative in models with and without covariates, indicating a substantial reduction in the income gradient in state funding across Kentucky districts between 1990 and 2000. The coefficient of –54.78 on the median income-post-reform interaction in model 2, summed with the coefficient on median income, indicates that a district at the 10th percentile of the median

[14] Results are substantively similar when computed without weights. The differences between the Kentucky and Tennessee coefficients on the interaction of median income and post-reform are smaller in magnitude in the state funding models and virtually identical in the school spending models.

income distribution in 2000 received about $1,180 more in state funding per pupil on average than an observationally similar district at the 90th percentile — or almost 14 times the differential of 1990. Tennessee also experienced a reduction in the income gradient in state funding per pupil over the decade, but this reduction was of significantly smaller magnitude than that in Kentucky.[15]

The bottom panel of table 3 presents analogous results for current expenditures per pupil. The coefficient on median income is positive for Kentucky and Tennessee in the model with no covariates. When covariates are added, this coefficient actually becomes negative, although insignificant at conventional levels, for Kentucky, with a value of –4.38. This indicates that poorer districts in Kentucky were actually already spending slightly more per pupil on average than the richer districts in 1990, holding the specified district-level characteristics constant. On average, a district at the 10th percentile of the median income distribution was spending about $85 more per pupil than a district at the 90th percentile in 1990, all else equal. The income gradient in per-pupil expenditures in Kentucky became even more negative by 2000, as represented by the coefficient on the median income-post-reform interaction.[16] By 2000, a district at the 10th percentile of the median income distribution was spending on average about $765 more per pupil than a district at the 90th percentile. This

[15] As noted above, the sample excludes one Kentucky district that is an outlier in median income and a second Kentucky district that is an outlier in per-pupil expenditures. When these districts are included, results are substantively similar; for instance, the coefficient on the interaction of median income and post-reform in the model with covariates increases from –54.78 to –52.06 (standard error=3.12).

[16] Again, results are not sensitive to the exclusion of two outlier districts in Kentucky. When these districts are included, the coefficient on the interaction of median income and post-reform in the model with covariates increases from –33.89 to –27.08 (standard error=8.32).

suggests that KERA not only managed to eliminate the gap in expenditures between rich and poor districts, but it actually raised per-pupil spending levels in the most economically disadvantaged districts above those in the richest districts. Changes in the income gradient in per-pupil expenditures in Tennessee over this period were, in contrast, small and not significantly different from zero.

An important question is how the districts allocated the increased expenditures induced by KERA. Table 4 examines changes in the income gradient in pupil-teacher ratios and average teacher salaries, two possible channels through which the increased spending under KERA could have been directed. In both Kentucky and Tennessee, the income gradient in pupil-teacher ratios increased over the decade, indicating that pupil-teacher ratios declined in the poorest districts relative to the wealthiest. Differences in the change in the income gradient in pupil-teacher ratios between Kentucky and Tennessee are small and not statistically significant. In contrast, the income gradient in average teacher salaries decreased dramatically in Kentucky, even while it increased in Tennessee. The estimates indicate that in 1990 average teacher salary in the Kentucky district at the 90^{th} percentile of the median income distribution was $1,460 greater that that in the district at the 10^{th} percentile. In contrast, by 2000 the average teacher salary in the district at the 10^{th} percentile of the median income distribution *exceeded* that in the district at the 90^{th} percentile by about $2,000. In

Tennessee, average teacher salaries in the wealthiest districts increased relative to those in the poorest districts over this period.[17]

Overall, it appears that KERA's school finance formula, by combining a more progressive distribution of state funds with stringent minimum local tax effort requirements and a tax rate equalization scheme targeted at the poorest districts, not only succeeded in reducing spending inequalities across rich and poor districts, it in fact went one step further. By the end of the decade the poorest districts were, on average, spending more per pupil than the wealthiest districts in the state. Much of the increased expenditures in the poorest districts was directed towards raising teacher salaries. Whether the dramatic increase in relative expenditures in the poorest districts, along with KERA's other curriculum and governance reforms, translated into improved student achievement and a narrowing of the achievement gap between rich and poor districts remains to be seen, however. In the next section, I examine KERA's effects on student achievement and the gap in achievement between rich and poor districts.

4. KERA's Effect on Student Achievement

Previous studies of KERA's effects on student achievement have stirred considerable controversy. Initial analyses of student performance on the KIRIS assessment found test score gains so large as to be considered implausible. Several subsequent analyses called into

[17] In fact, the Tennessee Supreme Court ruled in October 2002 that previous efforts to equalize teacher salaries across rich and poor districts had been unsuccessful and had failed to comply with State's constitutional obligation to provide equal educational opportunity to all students (*Tennessee Small School Systems v. McWherter,* 2002 WL 31247076 Tenn., 2002).

question the validity of the KIRIS exam. Koretz and Barron (1998) present a variety of evidence indicating that KIRIS scores were not a reliable gauge of student achievement student, including findings that the large gains in KIRIS scores between 1992 and 1995 were not reflected in NAEP or ACT scores, which changed little over this period.

Concerns over the validity of KIRIS prompted the state to adopt the revised Commonwealth Accountability Testing System (CATS), which included as one of its components a norm-referenced standardized test. Most subsequent evidence of KERA's impact on student achievement is from reports published by the Kentucky Department of Education, such as Kentucky Department of Education (2000). These reports typically present average test scores without controls for demographic characteristics of the students, schools, or districts that are likely to be correlated with test performance. Furthermore, results from the CATS assessment are only available from 1998 onward, so these scores do not permit comparisons to student performance pre-KERA.

Some evidence on the effects of school finance reform on student achievement is available from other states. Guryan (2000) studies the impact of the Massachusetts Education Reform Act of 1993 on student test scores, exploiting discontinuities in the state aid formula to identify the effect of increased spending on student achievement. He finds that increased funding led to improvements in the test scores of 4th grade students but not of 8th grade students. Card and Payne (2002) is one of the few studies that has examined the impact of school finance equalizations on the *gap* in achievement between rich and poor students. They examine SAT scores of students from different parental education groups in the late 1970s and early 1990s and find that states with court-ordered school finance reforms during this

period saw a significant decrease in the gap between the scores of children from high and middle parental education groups. Card and Payne are unable to link students to their districts, however, so they cannot fully determine the extent to which the school finance reforms reduced the gap in achievement between rich and poor districts.

In the remainder of this analysis, I examine changes in test scores of Kentucky students over the course of the decade since KERA's implementation using data from the ACT and the NAEP. I examine whether KERA improved the test scores of Kentucky students, whether it differentially affected the scores of black and white students, and whether it reduced the gap in test scores between students from rich and poor districts.

A. KERA's Effect on Student Achievement: ACT Data

To examine KERA's effects on student achievement, I analyze ACT scores for all graduating seniors in Kentucky and Tennessee for 1989 (pre-reform) and 1999 and 2000 (post-reform). The ACT is a college entrance exam similar to the SAT, although the ACT is designed to be more curriculum-based than the SAT, so it is likely to be a particularly good measure of what students have learned in school (Wilgoren, 2002). It is made up of four separate exams in English, mathematics, reading, and natural science reasoning. Each section is scored on a scale of 1 to 36, and a composite score, the average of the scores on the four sections, is also reported.[18] The exam is taken by the majority of college-bound seniors in

[18] In 1989, the ACT comprised English, mathematics, social studies reading and natural science reading sections. The ACT Corporation developed a concordance for the math, English, and composite scores (but not for the individual reading scores, science, or social studies scores) so they can be compared across the years.

Kentucky, Tennessee, and several other Midwestern and Southern states, and scores are accepted at virtually all colleges and universities in the country.

While I have student-level ACT scores, I do not have information on the school or district the students attend. I do, however, have information on the students' home zip codes, which I use to match students to their districts by overlaying school district and zip code cartographic boundary files. In cases in which a zip code spans multiple school districts, I assign the zip code to the district which contains the largest fraction of that zip code's area. I also construct a variable equal to the proportion of the zip code's area that falls within the matching district, as a measure of the quality of the match. The zip code-school district matching procedure is described in further detail in the appendix.

Table 5 presents sample statistics for all public school students in the ACT data set, for test takers graduating in 1989 (pre-reform) and 1999 and 2000 (post-reform). The racial and ethnic distribution of ACT takers closely mirrors the racial and ethnic distribution of all enrolled students in each state. A considerably higher percentage of ACT takers are black in Tennessee than in Kentucky. In both states the percentage of black ACT takers is just slightly lower than the percentage of enrolled students who are black according to the 1990 Census data presented in Table 1. The percentage of Asian and Hispanic test takers is less than 2 percent in both states in all years, reflecting the low percentage of Asians and Hispanics in these states. Average family income, interpolated from the categorical family income

variable, is higher among Tennessee test takers than Kentucky test takers.[19] The fraction of test takers enrolled in public schools is slightly lower in Kentucky than in Tennessee in all years.

Table 5 also presents estimated ACT-taking rates for Kentucky and Tennessee, among all students and separately by race. Ordinarily, as the ACT is a college entrance exam, changes in ACT participation rates could be interpreted as a proxy for changes in college attendance rates and thus examined as an outcome of the KERA reforms. In the mid-1990s, however, Tennessee began requiring all seniors to take either the ACT, the SAT, or the WorkKeys (a vocational exam) in order to graduate. Since this policy may have encouraged Tennessee students not applying to college to take the ACT, it would be inappropriate to compare ACT taking rates of Kentucky students to those of students in Tennessee as an outcome of KERA. Similarly, it will be important to control for changes in test taking rates in my analysis of ACT scores, as the policy in Tennessee may have induced lower performing students to take the exam.

To calculate ACT test taking rates, I divide the number of students in each district and year who took the exam by the number of 17 year olds residing in each district in that year, interpolated from the 1990 and 2000 Censuses. Using Census population data in the denominator is preferable to using district-level enrollment data in the sense that enrollment

[19] To interpolate family income, I aggregated family income data from the Current Population Survey for Kentucky and Tennessee in each relevant year and computed the mean family income for each income bracket. In practice, this essentially amounted to assigning each bracket its midpoint, except for the top income brackets ("> $60,000" was assigned a value of $81,000 in 1989 and "> $100,000" was assigned a value of $162,000 in 1999 and $157,000 in 2000). I then converted these values to 2001 dollars using the consumer price index.

data exclude high school dropouts. With the population of 17 year olds as the denominator, my estimate reflects the test-taking rate among the potentially eligible population.[20] As measurement error in test-taking rates is likely to be most severe for very small populations, I calculate the rates for black students only in districts with ten or more black 17 year olds (no district has fewer than ten white 17 year olds). As shown in the table, overall ACT test taking rates increased by 5 percentage points between 1990 and 1999–2000 in Kentucky, and by 12 percentage points in Tennessee. Among white students, the test taking rate in Kentucky increased by 5 percentage points in Kentucky and 8 percentage points in Tennessee. Among black students, the corresponding increases were 9 percentage points in Kentucky and 18 percentage points in Tennessee.

B. KERA's Effect on Student Achievement: NAEP Data

My analysis of student-level ACT scores is complemented by an analysis of state-level NAEP scores. The NAEP is a national assessment of student achievement and is administered to a representative sample of students in each state. The exam covers various subject areas in different years and for different grade levels, but I specifically focus on the 8th grade mathematics assessment, which is the only component that was administered to a representative sample of Kentucky students in both 1990 and 2000. Scores are available only at the state level and for various subgroups (e.g. race and parental background).

[20] In fact, the correlation between the number of 17 year olds from the Census data and the number of students in grade 12 from the Common Core of Data is quite high — the correlations in Kentucky are over .98 in all three years and in Tennessee range from .95 in 1999 to .98 in 1989.

Unfortunately, NAEP results for this exam are not available for Tennessee in 1990. They are, however, available for several other Southeastern and Midwestern states. I therefore construct a group of control states for this analysis, based on geographic proximity to Kentucky as well as lack of major education reform initiatives or finance equalizations (as estimated from the F-33 data using the same techniques applied in section three of this paper) during the 1990s. The control group consists of Alabama, Arkansas, Indiana, Louisiana, and Ohio.

C. KERA's Effect on Student Achievement: Methodology

To evaluate KERA's effect on student achievement, I pursue a difference-in-differences strategy, using test scores from students nearby states (Tennessee with the ACT data; Alabama, Arkansas, Indiana, Louisiana, and Ohio with the NAEP data) to control for potentially confounding trends in test scores. Tennessee shares a long border with Kentucky, has a very similar school system structure to Kentucky (with districts organized primarily on the county-level), is demographically similar, and, like Kentucky, has a high ACT participation rate. As discussed in section two, Tennessee, like almost all states, also implemented education reforms during the 1990s, although not on as large as scale as KERA and later in the decade. As shown in section three, Tennessee's finance equalization policies were considerably less effective than Kentucky's in reducing the expenditure gap between rich and poor districts. Similarly, none of the NAEP control states implemented education reforms as early in the decade or on as large a scale as KERA, and none experienced reductions in income gradient in school spending on the scale of Kentucky's. Nonetheless, to the extent

that reform efforts in these states were driving improvements in students' test scores over the decade, my difference-in-differences methodology may understate KERA's impact on student achievement.

To examine KERA's effects on student achievement, I estimate the following model:

$$SCORE_{idt} = \beta_0 + \beta_1(KY_{dt}) + \beta_2(POST_{dt}) + \beta_3(POST_{dt} \times KY_{dt}) + \beta_4 \boldsymbol{X}_{idt} + \varepsilon_{idt} \qquad (4.1)$$

where $SCORE_{idt}$ represents the math, English, or composite ACT score of individual *i* in district *d* graduating in year *t*, KY_{dt} is an indicator variable equal to one if the student lives in Kentucky and zero otherwise, $POST_{dt}$ is an indicator variable equal to one if the exam was taken in 1999 or 2000 (post-KERA) and zero if it was taken in 1989 (pre-KERA), and $\boldsymbol{X}_{idt}$ is a vector of individual and district-level covariates. In this model, β_3 is the coefficient of primary interest, indicating how the performance of Kentucky students changed over the decade relative to that of students in Tennessee. With the NAEP data, I estimate the same model, but with no covariates, at the state level for 8th grade math scores.

To examine KERA's effect on the district income *gradient* in ACT scores, I modify the above model to include interactions with median household income in each district, a specification similar to the one I used to examine the income gradient in district expenditures in section three:

$$\begin{aligned} SCORE_{idt} = \gamma_0 + \gamma_1(KY_{idt}) + \gamma_2(POST_{idt}) + \gamma_3(POST_{idt} \times KY_{idt}) + \gamma_4(MEDINC_d) \\ + \gamma_5(KY_{idt} \times MEDINC_d) + \gamma_6(POST_{idt} \times MEDINC_d) + \gamma_7(POST_{idt} \times KY_{dt} \times MEDINC_d) \\ + \gamma_8 \boldsymbol{X}_{idt} + \varepsilon_{idt} \qquad (4.2) \end{aligned}$$

In this model, $MEDINC_d$ represents the median household income in 1989 in district d. γ_4 then represents the income gradient in ACT scores in the base year (1989) and base state (Tennessee). A positive value for γ_4 indicates that test scores are positively correlated with a district's median income. γ_5 represents the difference in the income gradient between Kentucky and Tennessee in 1989, and γ_6 represents the change in the gradient in Tennessee between 1989 and 1999–2000. Finally, γ_7 represents the difference-in-differences in the income gradient — that is, how the income gradient in Kentucky changed over the decade relative to the control state of Tennessee. A positive coefficient indicates that the income gradient in test scores increased in Kentucky relative to Tennessee over this period; a negative slope indicates that test scores became more equalized over the period. γ_7 will be the main coefficient of interest in this model. Biases from increases in ACT test taking rates in model 4.1 are likely to be lessened in model 4.2, to the extent to which changes in ACT taking rates over the 1990s were uncorrelated with districts' median household income within each state.

D. KERA's Effect on Student Achievement: Effects on ACT Scores

Table 6 examines KERA's effects on student test scores on the math and English sections of the exam, as well as their composite scores. For comparability across ACT and NAEP results, in the analyses that follows the dependent variable for each exam (or section of the exam) is the raw score on that exam (or section) divided by the standard deviation of the raw score on that exam (or section) for the full sample. Model 1 presents a difference-in-differences estimate of KERA's effect with no demographic or district-level controls. The coefficient on the interaction of post-reform and Kentucky indicates the change in test scores

in Kentucky between 1989 and 1999–2000 relative to Tennessee. This basic specification indicates that Kentucky test scores increased relative to Tennessee scores, but the coefficients are small in magnitude (ranging from .04 to .05 standard deviations for the full sample) and are statistically significant at the 5 percent level only for composite scores.[21] However, this model does not control for student- and district-level covariates that are likely to be correlated with test performance.

Model 2 adds dummy variables for the test-taker's gender, race, grade, and whether the student was going to graduate from a public high school. It also includes a control for family income, as well as school district-level controls for urban/suburban/rural location, log district enrollment, district governance (county versus independent), and median household income in the district in 1989. In this model, the difference-in-differences coefficients fall to about one third the magnitude of the corresponding coefficients in model 1 and are no longer statistically significant at conventional levels.

As discussed above, ACT taking rates increased more in Tennessee than in Kentucky over this period, introducing a potential sample selection problem. To the extent that the increase in ACT taking rates in Tennessee was driven by more marginal, lower-performing students taking the exam in 1999 and 2000 than in 1989, there may be an increase in the proportion of relatively low scores in Tennessee relative to Kentucky, which would lead me to overstate gains in Kentucky scores relative to Tennessee. To account for this potential

[21] Results are similar if this model is estimated on the full sample of ACT-takers rather than just those who were successfully matched to a district. In this case, the coefficients on the interaction of Kentucky and post-reform are .042 (SE=.026), .035 (SE=.022), and .043 (SE=.022) for the math, English, and composite scores, respectively.

selection bias, in model 3 I add controls for a quartic in the estimated ACT taking rate. The difference-in-differences coefficients actually increase very slightly relative to those in model 2, but are still small in magnitude (.02 to .03 standard deviations) and statistically insignificant, suggesting that differential test-taking rates were not substantively biasing the results in model 2.[22] Taken together, these results suggest that KERA's effect on Kentucky students' ACT scores was, if positive, very small in magnitude and not statistically distinguishable from zero.

E. KERA's Effect on Student Achievement: Effects on ACT Scores by Race

Some previous literature suggests that education reforms may have differential impacts by race; achievement improvements are often greater among black students than white students.[23] In Kentucky, as well as in Tennessee, black students tend to be concentrated in the wealthier urban districts rather than the poorer rural districts that received the largest increase

[22] To insure that my procedure to match students to districts was not biasing my results, I estimated two additional specifications, both of which yielded similar results. The first limited the sample to students for whom at least 80 percent of the area of their zip code fell into the matched districts (so there was less possibility of error in the match). With this specification, the coefficients on the interaction of Kentucky with post-reform were .040 (SE=.024), .026 (SE=.020), and .036 (SE=.018) for the math, English, and composite scores, respectively. The second specification estimated the same model using county- rather than district-level covariates, as there is likely to be less error in the student-county match than the student-district match. In this model, the coefficients on the interaction of Kentucky and post-reform were .031 (SE=.027), .010 (SE=.020), and .026 (SE=.021) for the math, English, and composite scores, respectively.

[23] For instance, Krueger and Whitmore (2001) find that, among students who were randomly assigned to small classes in grades 1–3, black students experienced greater short- and long-term achievement gains than white students.

in funding under KERA.[24] Table 7 presents difference-in-differences estimates of KERA's effect on ACT scores separately for black and white students. As in Table 6, model 1 of Table 7 presents a simple difference-in-differences estimate with no controls for other covariates, model 2 adds controls for student- and district-level covariates, and model 3 adds a quartic in race-specific ACT-taking rates. The top panel of Table 7 displays results for white students. The difference-in-differences estimate is extremely small in magnitude (ranging from –.001 to –.005 standard deviations in model 3), negative in all of the models that include covariates, and not significant in any of the models, implying KERA had no effect on the test scores of white Kentucky students.

The bottom panel of Table 7 presents results for black students. In striking contrast to the results for white students, the difference-in-differences coefficient is positive, significant, and of considerable magnitude (ranging from .11 to .14 standard deviations for the full sample in model 3) in all three models for all three sections of the exam, suggesting that KERA did improve the achievement of black students over this period.[25] To put this effect size in perspective, it suggests that KERA narrowed the gap in test scores between observationally similar black and white Kentucky students by about a third, even while the black-white gap in Tennessee *increased* over this period, by about one-fifth. These results may be somewhat surprising, given that black students in Kentucky are predominantly located in the wealthier,

[24] In fact, Carr and Fuhrman (1999) suggest that one of the primary reasons for KERA's overwhelming political success was that its equalization policies were not perceived to be targeted at racial minorities, thereby removing racial politics from the debate.

[25] The sample size for blacks falls in model 3 because, as noted above, black test-taking rates are only calculated for districts with 10 or more black 17 years olds.

urban districts that received smaller funding increases under KERA. They may indicate that black students were positively impacted by some of the non-finance-reform elements of KERA.

E. KERA's Effect on Student Achievement: The Income Gradient in ACT Scores

Table 8 examines KERA's effect on the income gradient in ACT scores, represented by the coefficient on median income. The positive coefficient on median income in all models indicates that test scores are increasing with median income in the district in 1989, as expected. The coefficient on the interaction of median income with post-reform indicates how the gradient changed between 1989 and 1999–2000 in Tennessee, and the coefficient on the interaction of median income with post-reform and Kentucky indicates how the gradient changed between 1989 and 1999–2000 in Kentucky relative to Tennessee. If KERA's resource equalization across the districts equalized student achievement, one would expect the coefficient on this interaction to be negative, indicating that the district's median income became a less important determinant of student achievement post-KERA. I find this coefficient to be negative in all models for math and composite scores, although not significantly different from zero. Both positive and negative coefficients are also very small in magnitude; for instance, the estimates in model 3 suggests that KERA narrowed the

composite test score gap between a district with a median income of $20,000 and a district with a median income of $40,000 by only .04 standard deviations.[26]

F. KERA's Effect on Student Achievement: Effects on NAEP Scores

Table 9 presents difference-in-differences results from the NAEP 8th grade mathematics exam between 1990 and 2000. In accord with estimates from ACT scores, NAEP gains among white Kentucky students relative to their peers in the control states, although generally positive, were small in magnitude (the difference-in-differences estimate for white test takers represents about a .03 standard deviation increase) and not statistically distinguishable from zero. The gains for black students, although also not statistically significant, are roughly comparable in magnitude to the gains found for black students in the ACT data, representing a .12 standard deviation increase in the 8th grade math scores of black Kentucky students relative to their peers in the control states. Estimates by parental education category are generally positive but statistically insignificant. Taken together, the results from the ACT and NAEP suggest that KERA had a somewhat positive effect on the achievement of black students, but that its effects on white students' test scores were quite small.

[26] If the sample is limited to students for whom at least 80 percent of the area of their zip code fell into the matched districts, the coefficients on *POST* x *KY* x *MEDINC* are similar: –.001 (SE=.002), .000 (SE=.018), and –.003 (SE=.002) in model (3) for math, English, and composite scores, respectively. When I estimate the model using county- rather than district-level covariates, these coefficients are .008 (SE=.003), .003 (SE=.002), and .004 (SE=.003). Finally, if I examine the gradient in family income rather than median district income, the coefficient on family income interacted with post-reform interacted with Kentucky is negative and generally insignificant for all models/exams, and of a magnitude similar to that in the results presented in Table 8.

5. Instrumental Variables Estimates of the Effect of School Spending on Student Achievement

A primary motivation for KERA's school finance reform component, as well as education finance reforms in other states, is the assumption that increasing school spending in the poorer (typically lower achieving) districts will raise student achievement in these districts.[27] The evidence on the efficacy of increases in school spending is mixed, however.[28] One well-known difficulty in estimating the effects of spending on achievement is the likely endogeneity of school spending. For instance, districts that spend more on education may be those that possess otherwise unobservable preferences for education that are likely to be correlated with students' test scores. A sharp change in the relationship between district wealth and school spending, such as that induced by KERA's finance reform, produces variation in school spending that, although likely correlated with overall state preferences for education, is arguably exogenous to individual districts' preferences for education.

A natural extension of my estimates of KERA's effect on the income gradient in school spending and student test scores is then to use the change in the school finance formula under KERA as an instrument for school spending in order to estimate the effects of per-pupil expenditures on student achievement. Guryan (2000), described earlier, pursues a similar strategy, using discontinuities in the school finance formula under the Massachusetts

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[27] For instance, the Kentucky Supreme Court stated in *Rose v. Council for Better Education* that "the achievement test scores in the poor districts are lower than those in the richer districts, and expert opinion clearly established that there is a correlation between those scores and the wealth of the district….Uniform testimony of the expert witnesses at trial, corroborated by data, showed a definite correlation between the money spent per child on education and the quality of the education received."

[28] See Hanushek (1986), Hanushek (1997), and Krueger (2000) for an overview of the literature.

Education Reform Act (MERA) as an instrument for school spending, and finds that spending increases under MERA had mixed results, increasing test scores of 4th grade, but not 8th grade students after three years under the new formula. My analysis can provide complementary evidence on the effects of school spending, for a different state, a different grade level (11th and 12th), and cumulated over a longer time span (ten years). For consistency with the previous two sections of this paper, I calculate the instrumental variables estimates within a difference-in-differences framework, using Tennessee as a comparison state.[29]

A. Instrumental Variables Estimates of the Effect of School Spending on Student Achievement: Methodology

Rather than using the change in the actual school finance formula, which gave districts discretion in the amount they spent, I instead use a post-reform dummy variable interacted with a Kentucky dummy variable interacted with median household income in district (*POST* x *KY* x *MEDINC*) as an instrument for school spending. This is conceptually equivalent to rescaling my reduced-form estimates of the income gradient in test scores by the income gradient in school spending. (In practice, the instrumental variables (IV) estimates in this section will not be exactly equal to the rescaled coefficients of the previous two sections, as the first-stage regression in school spending will be calculated only for the subset of districts that were matched to a zip code in the ACT data.) The first-stage regression is then similar to that estimated in section three:

[29] See McClellan and Newhouse (1997) for a discussion of instrumental variables models in a difference-in-differences framework.

$$SPEND_{dt} = \gamma_0 + \gamma_1(KY_{dt}) + \gamma_2(POST_{dt}) + \gamma_3(POST_{dt} \times KY_{dt}) + \gamma_4(MEDINC_d) + \gamma_5(KY_{dt} \times MEDINC_d) + \gamma_6(POST_{dt} \times MEDINC_d) + \gamma_7(POST_{dt} \times KY_{dt} \times MEDINC_d) + \gamma_8 \boldsymbol{X}_{dt} + v_{dt} \quad (5.1)$$

where $SPEND_{dt}$ is current expenditures per pupil in district *d* in year *t*, and, as before, $MEDINC_d$ is median household income in district *d*, $POST_{dt}$ is an indicator variable equal to one in 1999 or 2000 (post-KERA) and zero in 1990 (pre-KERA), KY_{dt} is an indicator for Kentucky, and $\boldsymbol{X}_{dt}$ is a vector of district-level covariates. I then use the predicted value of school spending from the first stage in the second-stage regression of test scores on school spending:

$$SCORE_{idt} = \beta_0 + \beta_1(KY_{idt}) + \beta_2(POST_{idt}) + \beta_3(POST_{idt} \times KY_{idt}) + \beta_4(MEDINC_d) + \beta_5(KY_{idt} \times MEDINC_d) + \beta_6(POST_{idt} \times MEDINC_d) + \beta_7(SPEND_{dt}) + \beta_8 \boldsymbol{X}_{idt} + \varepsilon_{idt} \quad (5.2)$$

where $SCORE_{idt}$ again represents the English, math, or composite ACT score of student *i*.

For *POST* x *KY* x *MEDINC* to be a valid instrument for school spending, the following assumptions must hold. First, school spending must be correlated with the interaction of district resources and the reform (i.e., γ_7 must be nonzero), a condition I showed to be satisfied in section three. Second, the interaction of the reform with district resources must be uncorrelated with unobservable determinants of student achievement. The difference-in-differences framework will, in principle, control for changes in the relationship between median income and test scores over the course of the decade that would have occurred

independently of KERA, to the extent that Kentucky and Tennessee would have experienced similar trends in the absence of the reform. The assumption will be violated, however, if the non-finance reform aspects of KERA had differential effects on districts' test scores that were systematically related to district resources. For instance, if poorer districts had more difficulty implementing the new curricula mandated by KERA because the teachers were less well trained, the second assumption will be violated, and the effects of non-finance aspects of the reform will be incorrectly attributed to the spending increases. Because of this potential threat to the validity of the instrument, the estimates that follow should be interpreted with caution.

B. Instrumental Variables Estimates of the Effect of School Spending on Student Achievement: Results

Table 10 presents ordinary least squares (OLS) and IV estimates of the effects of expenditures on test scores. All models include controls for district- and student-level covariates and a quartic in the estimated test-taking rate in the district. In the OLS models, the coefficient on current expenditures per pupil is fairly small (for instance, the coefficient in the model for ACT math scores suggests a spending increase of $1000 per pupil is associated with a .05 standard deviation increase in ACT math scores) and not significantly different from zero except for math scores. The IV estimates of the current expenditure coefficient are also small and insignificant for all three tests. Taken together, the IV estimates suggest that the increase in spending induced by KERA did not improve test scores. It is important to keep in mind the limitations of the IV estimates, however. In particular, the estimates may confound the actual effects of increased expenditures with the effects of non-finance-reform aspects of KERA. If any of these reforms had a differential effect on student achievement across

districts that was positively correlated with the districts' median income, the IV estimates will understate the true effect of expenditures on test scores.

6. Conclusions

As several states consider strategies to reform their public education systems, Kentucky's experience with KERA can provide valuable evidence on the effectiveness of comprehensive education reform. In this paper I have examined KERA's effect on school-spending equalization across the districts as well as KERA's effects on student achievement (as measured by ACT and NAEP scores) and on the gap in student achievement across rich and poor districts. I also present instrumental variables estimates of the effects of school-finance-reform-induced spending on student test scores.

I find that the state did substantially increase funding to lower-income districts immediately after the reform was implemented. These increased revenues from the state were not offset by decreases in spending at the local level, even ten years after KERA was first put in place, suggesting that KERA's minimum-local-contribution requirement and tax rate equalization scheme for the districts were in fact effective. Current expenditures per pupil increased dramatically in the lower-income districts after KERA was first implemented, and in KERA's early years low-income districts were spending considerably more per pupil than the wealthier districts. By the end of KERA's first decade, high-income districts had increased local funding for schools, but per-pupil expenditures in the poorest districts still, on average, exceeded those in the wealthiest districts. Much of the increase in expenditures in the poorer districts was directed towards increasing teacher salaries.

KERA's effects on student achievement are more mixed. My analysis of ACT scores suggests that KERA somewhat improved the achievement of black students in Kentucky relative to their peers in Tennessee. These results may be somewhat puzzling, given that black students in Kentucky tend to be located in wealthier urban districts that did not receive large increases in school funding under the reform. This suggests blacks students' test scores may have been positively impacted by non-finance-reform aspects of KERA, such as the curriculum reforms. Further exploration of test score data linked to schools rather than districts could shed additional light on the mechanisms through which black students' ACT scores improved.

I find that white students in Kentucky did not experience meaningful gains in ACT or NAEP scores relative to their peers in neighboring states. Despite the fact that KERA successfully equalized resources across rich and poor districts, it seems not to have been effective in significantly narrowing the gap in ACT scores across these districts. Instrumental variables estimates of the effects of school spending on test scores, using the sharp change in the school finance formula under KERA as an instrument, suggest that the additional spending induced by KERA did not lead to improvements in test scores.

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Chapter 1 Appendix: Procedure to Match Students to School Districts by Zip Code

In my analysis of ACT data, I match students to school districts according to their home zip code. Zip codes are service areas defined by the U.S. Postal Service, and they do not always correspond to school district (or city, county, census tract or block, or other geographic) boundaries. In fact, some zip codes don't have clearly defined geographic boundaries, but are defined simply as a network of streets or a single post office. The U.S. Census Bureau has developed Zip Code Tabulation Areas (ZCTAs), which assign geographic boundaries to zip code service areas. The Census Bureau constructs each ZCTA by aggregating the Census blocks whose addresses use a given zip code into a ZCTA with the same code. ZCTAs are approximate in the sense that a given Census block may contain addresses with different zip codes, in which case the block is assigned to the ZCTA that represents the majority of addresses in the block. [30]

To match zip codes to school districts, I overlay 2000 school district cartographic boundary files and 2000 ZCTA cartographic boundary files from the Census Bureau. Appendix Figure 1 shows the overlaid ZCTA and school district boundaries for Kentucky. As discussed above, the ZCTA boundaries (the lightly colored lines) do not correspond precisely to the district boundaries (the dark lines). In cases where the ZCTA boundary spans one or more districts, I assign each zip code to the district that contains the largest fraction of that ZCTA's area. Some districts, particularly smaller districts, will not be matched to any zip

[30] For more information about ZCTAs, see U.S. Census Bureau (2002).

code if they don't comprise the majority of any ZCTA's area. I also construct a variable equal to the proportion of the zip that falls within the matching district, as a measure of the quality of the match.

Appendix Table 1a presents information on the zip-district matching procedure. In both Kentucky and Tennessee, I successfully match at least one zip code to about three-quarters of the districts. I match all of the larger, county-level districts and am unable to match the majority of the smaller, independent districts. However, the unmatched districts represent less than 10 percent of enrolled students in both states. The unmatched districts tend to have fewer students and slightly higher per-pupil expenditures than the matched districts in both states and in both years. The average median income in the unmatched districts in 1989 is slightly lower than that in the matched districts. The average fraction of each ZCTA area that lies in its matched district is 91 percent in Kentucky and 86 percent in Tennessee.

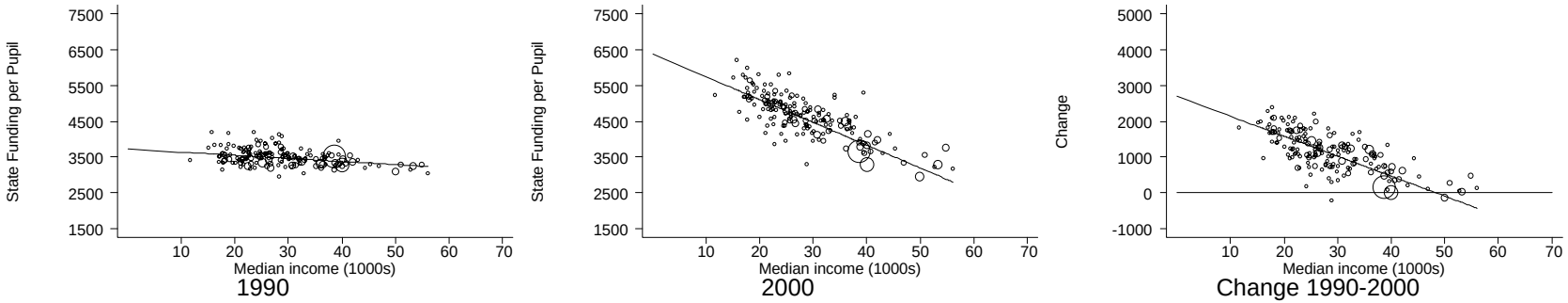
After mapping each zip code to a district, I match ACT takers to districts according to their zip codes.[31] I am able to match over 98 percent of all test takers in my data set in all years and in both states, as shown in Appendix Table 1b. The few test takers that I am unable to match either do not list a zip code in the ACT data or else list a zip code that is not matched to a ZCTA (because it is an invalid zip code or is not included in Census Bureau's ZCTA files for some other reason). The unmatched test takers, although few in number, do differ

[31] Some zip codes, typically those representing single post offices, are "enclosed" within other zip codes; these enclosed zips do not have a corresponding ZCTA. If a test taker's zip code is unmatched in the ZCTA files but is enclosed in another zip code, I assign that zip code to the enclosing ZCTA and the corresponding school district.

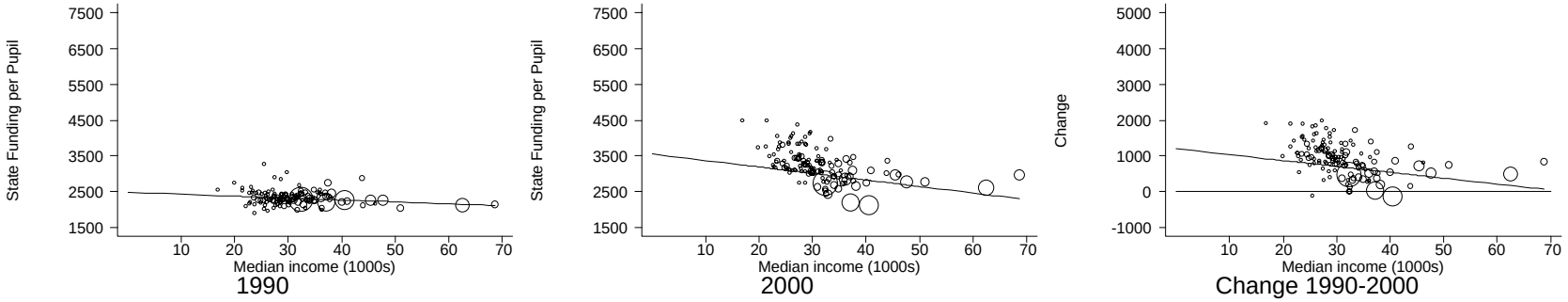
somewhat from the matched test takers. In particular, they tend to have lower composite ACT scores than the matched test takers. In Kentucky, the unmatched test takers are less likely to be black and have lower average family incomes; in Tennessee the opposite is generally true, although the differences tend not to be significant.

Figure 1: State Funding per Pupil, 1990 and 2000

Panel 1A: Kentucky



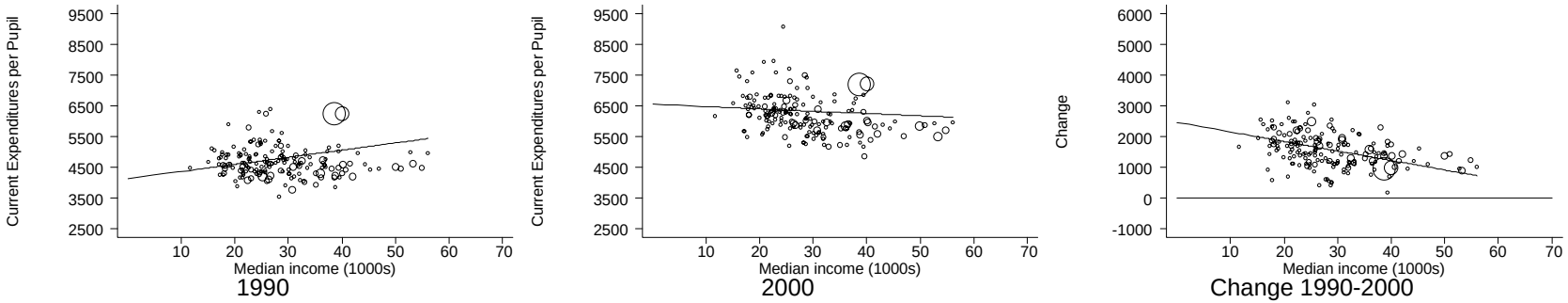
Panel 1B: Tennessee



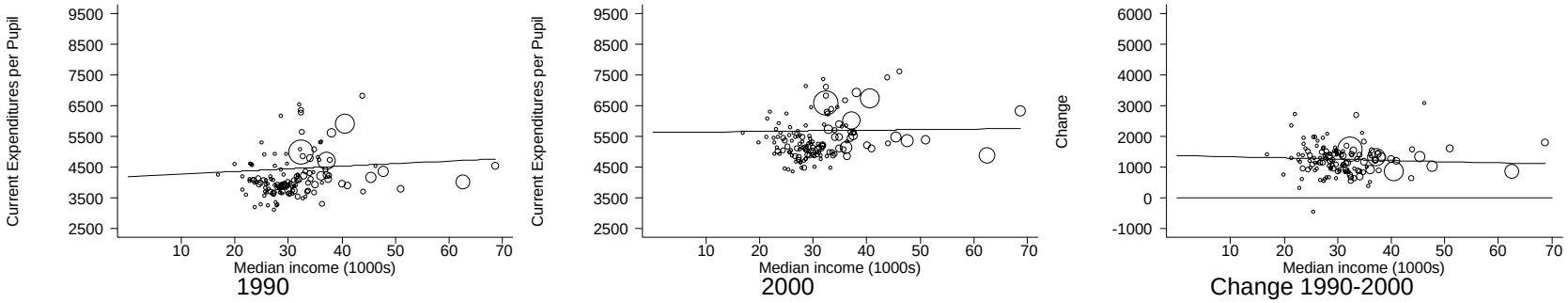
Notes: Diameters of circles are proportional to district enrollment. Median income is 1989 value from 1990 Census, state funding per pupil is from F-33 Survey of Local Government Finances. All numbers in 2001 dollars.

Figure 2: Current Expenditures per Pupil, 1990 and 2000

Panel 2A: Kentucky

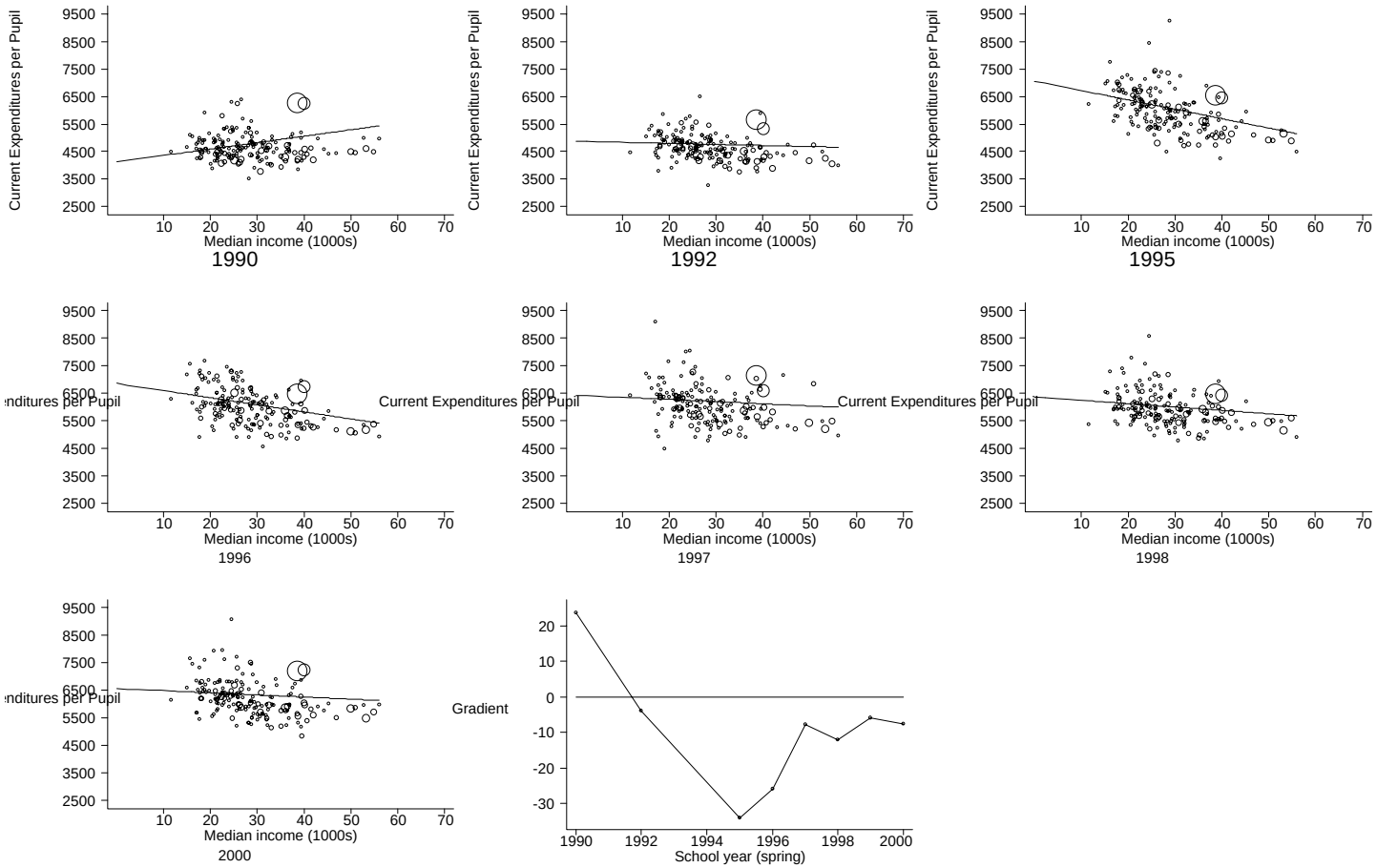


Panel 2B: Tennessee



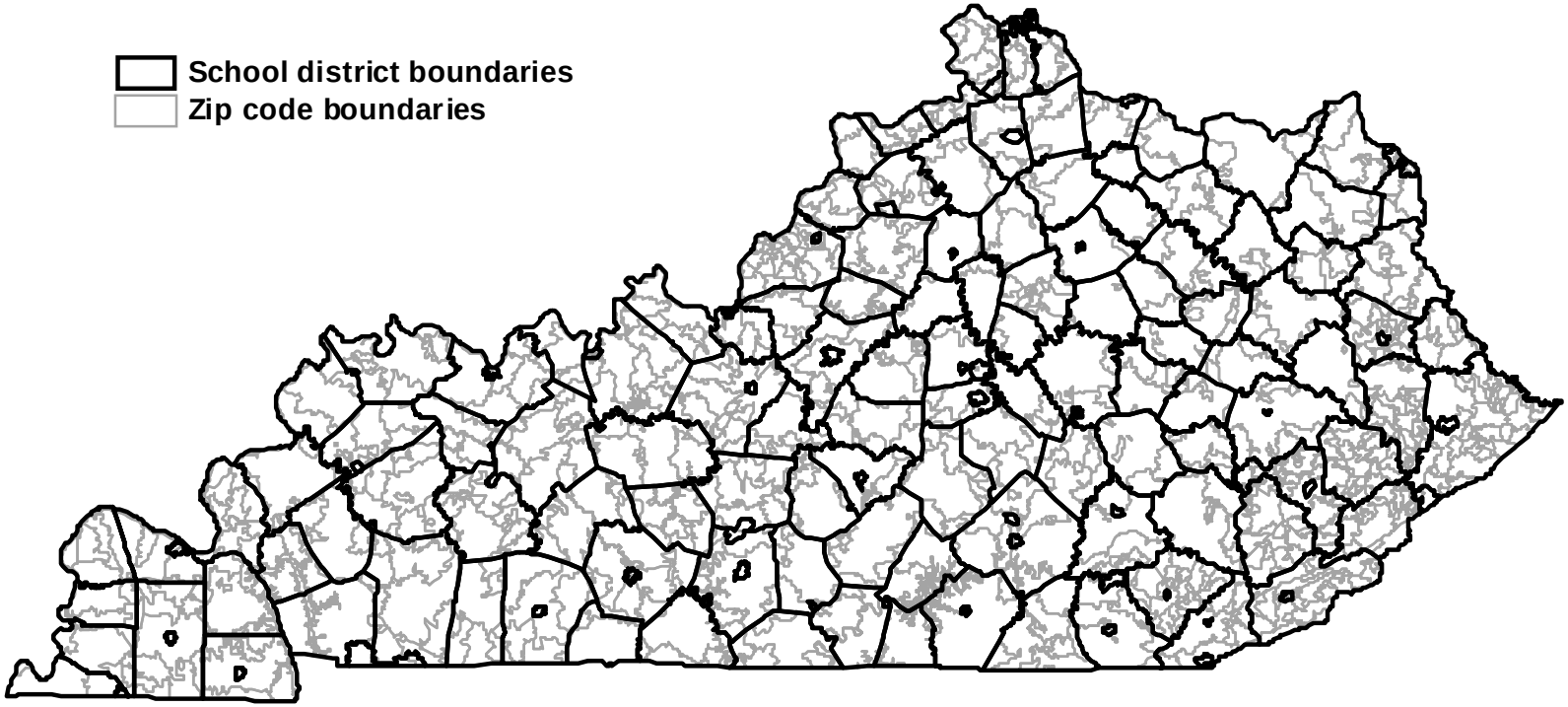
Notes: Diameters of circles are proportional to district enrollment. Median income is 1989 value from 1990 Census, current expenditures per pupil are from F-33 Survey of Local Government Finances. All numbers in 2001 dollars.

Figure 3: Current Expenditures per Pupil, Kentucky, 1990–2000



Notes: Diameters of circles are proportional to district enrollment. Median income is 1989 value from 1990 Census, current expenditures per pupil are from F-33 Survey of Local Government Finances. All numbers in 2001 dollars.

Appendix Figure 1: Kentucky School District and Zip Code Boundaries



Notes: Zip code (ZCTA) and school district boundary files from Census Bureau.

Table 1
School District Summary Statistics

	1990			2000			Difference
	Kentucky (std. dev.)	Tennessee (std. dev.)	Difference [p-value]	Kentucky (std. dev.)	Tennessee (std. dev.)	Difference [p-value]	in differences [p-value]
Number of regular operating districts	173	133	40	173	133	40	0
County-Level	118	91	27	118	91	27	0
Independent	55	42	13	55	42	13	0
Unified	169	119	50	169	120	49	-1
Elementary	4	14	-10	4	13	-9	1
Percent urban	1.7	0.8	1.0	2.9	6.7	-3.8	-4.8
Percent suburban	18.5	27.1	-8.6	20.8	23.1	-2.3	6.2
Percent rural	79.8	72.2	7.6	76.3	69.4	6.9	-0.7
Average number of students per district	3619.44 (7466.83)	5786.20 (11948.64)	-2166.76 [.05]	3713.05 (7928.23)	6384.56 (12981.66)	-2671.51 [.03]	-504.75 [.76]
Average school size	486.79 (119.16)	573.82 (156.08)	-87.04 [.00]	453.25 (110.27)	609.18 (176.70)	-155.92 [.00]	-68.88 [.00]
Average pupil-teacher ratio	17.67 (1.19)	19.19 (2.14)	-1.52 [.00]	15.61 (1.63)	16.14 (1.46)	-0.54 [.00]	0.98 [.00]
Percent black students	9.36 (11.44)	21.63 (26.46)	-12.27 [.00]	10.29 (12.74)	23.22 (28.17)	-12.93 [.00]	-0.66 [.00]
Percent of children below poverty line	25.22 (10.93)	20.92 (8.54)	4.30 [.00]	--	--	--	--
Median family income in state (2001 dollars)	32,184	35,430	-3,246	43,519	46,260	-2,741	505

Source: Common Core of Data, 1989-90 and 1999-2000.

Notes: Data for average school size, average pupil-teacher ratio, percent nonwhite, and percent of children below poverty line are weighted by number of students in district. "Urban" school districts are those that primarily serve the central city of a Metropolitan Statistical Area; "suburban" districts serve an MSA but not primarily its central city; "rural" districts do not serve an MSA. Percent black students are 1990 and 1999 values, since 2000 values are not available for Tennessee. Percent children below poverty line and median income are from Decennial Census. Table excludes districts that merged between 1990 and 2000 (2 in Kentucky and 4 in Tennessee), districts with missing data (1 in Kentucky and 1 in Tennessee), and districts that are tremendous outliers in median income or current expenditures per pupil (Anchorage Independent District and Owsley County School District in Kentucky. Standard deviations in parentheses; p-values in brackets.

Table 2
Summary of District Revenues and Expenditures, 1989-90 and 1999-2000

	Kentucky			Tennessee		
	1990	**2000**	**% Change**	**1990**	**2000**	**% Change**
			Revenue per Pupil			
Level (2001 dollars)	5139	7120	38.53	4753	6233	31.15
	1232	2123	72.36	2041	2814	37.89
	3439	4295	24.86	2281	2880	26.27
	468	702	49.95	431	539	25.13
Percent	100.0	100.0	--	100.0	100.0	--
	24.0	29.8	--	42.9	45.1	--
	66.9	60.3	--	48.0	46.2	--
	9.1	9.9	--	9.1	8.6	--
			Current Expenditure per Pupil			
Level (2001 dollars)	4872	6307	29.45	4491	5698	26.88
Gini coefficient	0.084	0.060	-28.68	0.091	0.072	-21.18
Standard deviation	773.46	670.00	-13.38	744.14	727.88	-2.19
Percentile						
	4064	5397	32.78	3602	4840	34.37
	4154	5500	32.41	3695	4866	31.69
	4299	5822	35.44	3940	5095	29.31
	4589	6199	35.08	4221	5476	29.72
	5181	6870	32.60	4994	6578	31.71
	6254	7202	15.15	5895	6732	14.20
	6254	7213	15.33	5895	6732	14.20
Ratio 10th to 50th percentile	.91	.89	-1.98	.88	.89	1.52
Ratio 25th to 50th percentile	.94	.94	0.26	.93	.93	-0.31
Ratio 75th to 50th percentile	1.13	1.11	-1.84	1.18	1.20	1.54
Ratio 90th to 50th percentile	1.36	1.16	-14.76	1.40	1.23	-11.96
Number of districts		173			133	

Source: Calculations from F-33 survey data, 1989-90 and 1999-2000.

Notes: Current expenditures are expenditures for the day-to-day operation of schools and school districts (instruction, support services, food services, and enterprise operations). Funding and inequality measures are computed from district-level data, weighted by district enrollment.

Table 3
Effect of 1989 Median Income on State Funding per Pupil and District Spending per Pupil

	(1)			(2)		
	Kentucky	Tennessee	Difference	Kentucky	Tennessee	Difference
	State funding per pupil					
Intercept	3,717.78*	2,476.47*	1,241.32*	4,116.50*	3,544.01*	572.48*
	(77.34)	(117.53)	(137.46)	(109.40)	(162.33)	(189.81)
Post-reform (1=yes)	2,666.32*	1,075.19*	1,591.12*	2,651.89*	1,082.03*	1,569.86*
	(109.32)	(158.68)	(190.11)	(105.16)	(138.42)	(171.96)
Median income (1000s)	-8.68*	-5.42	-3.26	-4.23	2.56	-6.79
	(2.32)	(3.16)	(3.92)	(2.39)	(2.98)	(3.81)
Median income x post	-55.22*	-12.84*	-42.38*	-54.78*	-12.72*	-42.06*
	(3.25)	(4.22)	(5.39)	(3.13)	(3.68)	(4.87)
Controls for district-level covariates	No	No	No	Yes	Yes	Yes
Sample size	346	266		346	266	
R-squared	0.83	0.50		0.84	0.63	
	Current expenditures per pupil					
Intercept	4,120.23*	4,188.26*	-68.03	1,670.82*	2,443.15*	-772.33*
	(201.30)	(263.47)	(326.38)	(203.16)	(325.61)	(369.79)
Post-reform (1=yes)	2,435.07*	1,445.30*	989.77*	2,528.45*	1,434.16*	1,094.28*
	(284.54)	(355.73)	(451.38)	(195.30)	(277.65)	(335.01)
Median income (1000s)	23.44*	8.41	15.02	-4.38	0.44	-4.82
	(6.04)	(7.09)	(9.31)	(4.44)	(5.97)	(7.42)
Median income x post	-31.03*	-6.66	-24.38	-33.89*	-6.98	-26.91*
	(8.46)	(9.47)	(12.79)	(5.81)	(7.39)	(9.49)
Controls for district-level covariates	No	No	No	Yes	Yes	Yes
Sample size	346	266		346	266	
R-squared	0.52	0.41		0.78	0.64	

Source: Calculations from F-33 and Common Core of Data, 1990 and 2000.

Notes: Model 2 includes controls for log district enrollment and dummy variables for districts serving only elementary grades and districts organized at the county level. Median income is from 1989 (from 1990 Census). All models computed by weighted least squares, using district enrollment as weights. Standard errors in parentheses.

Table 4
KERA's Effect on Income Gradient in Pupil-Teacher Ratios and Average Teacher Salaries

	Pupil-Teacher Ratio			Average Teacher Salary		
	Kentucky	Tennessee	Difference	Kentucky	Tennessee	Difference
Intercept	15.24*	17.89*	-2.65*	3,824.24*	26,668.79*	-22,844.55*
	(0.53)	(0.98)	(1.06)	(1,497.78)	(2,079.18)	(2,498.82)
Post-reform (1=yes)	-4.18*	-4.63*	0.45	11,059.06*	-5,841.10*	16,900.15*
	(0.51)	(0.83)	(0.96)	(1,439.82)	(1,772.92)	(2,263.81)
Median income (1000s)	-0.00	0.04*	-0.04	73.09*	114.17*	-41.08
	(0.01)	(0.02)	(0.02)	(32.70)	(38.13)	(50.16)
Median income x post	0.06*	0.04	0.02	-173.17*	58.84	-232.01*
	(0.02)	(0.02)	(0.03)	(42.83)	(47.18)	(64.14)
Controls for district-level covariates	Yes	Yes	Yes	Yes	Yes	Yes
Sample size	346	266	612	346	266	612
R-squared	0.48	0.48	0.51	0.74	0.62	0.69

Source: Calculations from F-33 and Common Core of Data, 1990 and 2000.

Notes: Average teacher salaries are in 2001 dollars. All models include controls for log district enrollment and dummy variables for districts serving only elementary grades and districts organized at the county level. Median income is from 1989 (from 1990 Census). All models computed by weighted least squares, using district enrollment as weights. Standard errors in parentheses.

Table 5
ACT Summary Statistics, Kentucky and Tennessee

	1989		1999-2000	
	Kentucky	**Tennessee**	**Kentucky**	**Tennessee**
Test scores				
Math	19.14	19.08	19.35	19.08
	[5.19]	[5.06]	[4.61]	[4.66]
English	20.99	21.30	19.84	19.88
	[5.68]	[5.73]	[5.55]	[5.77]
Composite	20.07	20.09	20.14	19.93
	[4.73]	[4.73]	[4.51]	[4.70]
Student characteristics				
Percent female	54.66	55.64	56.53	55.64
	[49.78]	[49.68]	[49.57]	[49.68]
Percent black	6.40	15.25	6.49	17.48
	[24.47]	[35.95]	[24.64]	[37.98]
Percent Asian	.82	1.03	.96	1.63
	[9.02]	[10.08]	[9.77]	[12.67]
Percent Hispanic	.21	.22	.32	.47
	[4.62]	[4.64]	[5.62]	[6.83]
Average family income	50,762	53,486	55,659	55,956
	[31,657]	[33,244]	[40,040]	[42,405]
Percent in public school	86.30	88.41	85.89	88.98
	[34.38]	[32.02]	[34.81]	[31.31]
ACT-taking rates				
ACT-taking rate, all students	49.03	49.23	54.17	60.53
	[17.55]	[14.97]	[17.55]	[19.72]
ACT-taking rate, white students	46.67	51.33	52.90	58.72
	[16.27]	[17.86]	[15.49]	[17.10]
ACT-taking rates, black students	43.03	45.83	51.73	64.17
	[48.25]	[38.50]	[47.67]	[41.47]
Sample size	22,421	27,300	46,372	64,864

Source: ACT, graduating classes of 1989, 1999, and 2000.
Notes: Family income interpolated from categorical variables and reported in 2001 dollars.
Standard deviations in brackets.

Table 6
Difference-in-Differences Estimates of KERA'S Effect on ACT Scores
(Dependent variable is ACT score divided by standard deviation of score for full sample)

	(1)			(2)			(3)		
	Math	**English**	**Composite**	**Math**	**English**	**Composite**	**Math**	**English**	**Composite**
Intercept	3.979*	3.725*	4.317*	3.694*	3.286*	3.983*	3.676*	3.386*	3.975*
	(0.043)	(0.038)	(0.050)	(0.155)	(0.076)	(0.110)	(0.215)	(0.137)	(0.173)
Post-reform (1=yes)	0.000	-0.248*	-0.034	0.005	-0.239*	-0.023	-0.009	-0.247*	-0.033*
	(0.024)	(0.021)	(0.021)	(0.015)	(0.012)	(0.013)	(0.015)	(0.013)	(0.014)
Kentucky (1=yes)	0.012	-0.054	-0.005	0.046	-0.049*	0.002	0.046	-0.050*	0.002
	(0.053)	(0.043)	(0.057)	(0.027)	(0.018)	(0.023)	(0.026)	(0.018)	(0.022)
Kentucky x post	0.042	0.048	0.050*	0.019	0.013	0.018	0.025	0.017	0.023
	(0.029)	(0.025)	(0.023)	(0.023)	(0.018)	(0.017)	(0.023)	(0.019)	(0.018)
Controls for student and district-level covariates	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Controls for ACT-taking rates	No	No	No	No	No	No	Yes	Yes	Yes
Observations	160,957	160,957	160,957	160,957	160,957	160,957	160,957	160,957	160,957
R-squared	0.00	0.01	0.00	0.14	0.14	0.15	0.14	0.14	0.15

Source: ACT, graduating public school classes of 1989, 1999, 2000 in Kentucky and Tennessee. School district data from 1990 Census and Common Core of Data.

Notes: Base group is 1989, post-reform is 1999 and 2000. Models (2) and (3) include individual-level controls for family income, race, gender, grade in which student took exam, and whether student would graduate from a public or private high school as well as district-level controls for urban/suburban/rural location, percent minority students, log district enrollment, district governance (county versus independent) and median household income in 1989. Model (3) includes controls for a quartic in estimated test-taking rate in district. Robust standard errors, adjusted for clustering at the district level, in parentheses.

Table 7
Difference-in-Differences Estimates of KERA'S Effect on ACT Scores by Race
(Dependent variable is ACT score divided by standard deviation of score for full sample)

	(1)			(2)			(3)		
	Math	**English**	**Composite**	**Math**	**English**	**Composite**	**Math**	**English**	**Composite**
					White				
Intercept	4.081*	3.858*	4.458*	3.666*	3.297*	3.979*	3.589*	3.356*	3.934*
	(0.029)	(0.026)	(0.025)	(0.135)	(0.079)	(0.093)	(0.201)	(0.150)	(0.173)
Post-reform (1=yes)	0.024	-0.225*	-0.008	0.023	-0.226*	-0.007	0.012	-0.231*	-0.014
	(0.024)	(0.020)	(0.021)	(0.022)	(0.016)	(0.019)	(0.024)	(0.019)	(0.022)
Kentucky (1=yes)	-0.045	-0.128*	-0.087*	0.063*	-0.040	0.013	0.065*	-0.040	0.014
	(0.044)	(0.032)	(0.038)	(0.028)	(0.021)	(0.024)	(0.028)	(0.021)	(0.024)
Kentucky x post	0.010	0.016	0.017	-0.006	-0.007	-0.002	-0.003	-0.005	-0.001
	(0.031)	(0.025)	(0.025)	(0.027)	(0.021)	(0.022)	(0.029)	(0.023)	(0.024)
Controls for student and district-level covariates	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Controls for ACT-taking rates	No	No	No	No	No	No	Yes	Yes	Yes
Observations	135,492	135,492	135,492	135,492	135,492	135,492	135,492	135,492	135,492
R-squared	0.00	0.01	0.00	0.10	0.08	0.08	0.10	0.08	0.08
					Black				
Intercept	3.391*	3.057*	3.570*	3.394*	2.693*	3.441*	3.406*	2.678*	3.449*
	(0.030)	(0.020)	(0.034)	(0.164)	(0.141)	(0.155)	(0.171)	(0.153)	(0.164)
Post-reform (1=yes)	-0.026	-0.244*	-0.028	-0.045*	-0.263*	-0.048*	-0.045*	-0.266*	-0.049*
	(0.026)	(0.023)	(0.018)	(0.022)	(0.017)	(0.013)	(0.022)	(0.017)	(0.013)
Kentucky (1=yes)	-0.036	-0.094*	-0.027	-0.090	-0.115*	-0.078*	-0.089	-0.113*	-0.075*
	(0.052)	(0.031)	(0.047)	(0.050)	(0.028)	(0.037)	(0.050)	(0.027)	(0.037)
Kentucky x post	0.132*	0.113*	0.102*	0.142*	0.116*	0.110*	0.138*	0.114*	0.105*
	(0.036)	(0.034)	(0.031)	(0.033)	(0.026)	(0.027)	(0.034)	(0.027)	(0.029)
Controls for student and district-level covariates	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Controls for ACT-taking rates	No	No	No	No	No	No	Yes	Yes	Yes
Observations	19,945	19,945	19,945	19,945	19,945	19,945	19,898	19,898	19,898
R-squared	0.00	0.01	0.00	0.08	0.09	0.08	0.08	0.09	0.08

Source: ACT, graduating public school classes of 1989, 1999, 2000 in Kentucky and Tennessee. School district data from 1990 Census and Common Core of Data.

Notes: Base group is 1989, post-reform is 1999 and 2000. Models (2) and (3) include individual-level controls for family income, gender, grade in which student took exam, and whether student would graduate from a public or private high school as well as district-level controls for urban/suburban/rural location, percent minority students, log district enrollment, district governance (county versus independent) and median household income in 1989. Model (3) includes controls for a quartic in estimated race-specific test-taking rate in district. For blacks, this rate is only computed for districts with more than 10 black 17-year olds. Robust standard errors, adjusted for clustering at the district level, in parentheses.

Table 8
Difference-in-Differences Estimates of KERA'S Effect on Income Gradient in ACT Scores
(Dependent variable is ACT score divided by standard deviation of score for full sample)

	(1)			(2)			(3)		
	Math	**English**	**Composite**	**Math**	**English**	**Composite**	**Math**	**English**	**Composite**
Intercept	3.600*	3.374*	3.938*	3.816*	3.358*	4.077*	3.729*	3.418*	4.022*
	(0.110)	(0.077)	(0.120)	(0.134)	(0.081)	(0.099)	(0.190)	(0.136)	(0.163)
Post-reform (1=yes)	-0.153*	-0.371*	-0.168*	-0.090	-0.317*	-0.107*	-0.075	-0.317*	-0.096*
	(0.057)	(0.058)	(0.048)	(0.048)	(0.026)	(0.033)	(0.043)	(0.032)	(0.033)
Kentucky (1=yes)	-0.251*	-0.025	-0.161	-0.301*	-0.102	-0.255*	-0.288*	-0.079	-0.244*
	(0.123)	(0.093)	(0.133)	(0.072)	(0.061)	(0.064)	(0.069)	(0.064)	(0.063)
Kentucky x post	0.115	0.047	0.166*	0.076	-0.001	0.122*	0.049	-0.014	0.102*
	(0.073)	(0.071)	(0.063)	(0.065)	(0.047)	(0.051)	(0.063)	(0.051)	(0.051)
Income gradient									
Median income (1000s)	0.010*	0.009*	0.010*	0.006*	0.006*	0.006*	0.005*	0.006*	0.005*
	(0.003)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Post-reform x median income	0.004*	0.003*	0.003*	0.003	0.002*	0.002*	0.002	0.002*	0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Kentucky x median income	0.009*	0.000	0.005	0.010*	0.001	0.007*	0.009*	0.001	0.007*
	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Kentucky x post x median income	-0.002	0.001	-0.003	-0.001	0.001	-0.003*	-0.001	0.001	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
Controls for student and district-level covariates	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Controls for ACT-taking rates	No	No	No	No	No	No	Yes	Yes	Yes
Observations	160,957	160,957	160,957	160,957	160,957	160,957	160,957	160,957	160,957
R-squared	0.03	0.03	0.02	0.15	0.14	0.15	0.15	0.14	0.15

Source: ACT, graduating classes of 1989, 1999, 2000 in Kentucky and Tennessee. School district data from 1990 Census and Common Core of Data.

Notes: Base group is 1989, post-reform is 1999 and 2000. Median income is 1989 median household income in the district, in thousands of 2001 dollars. Models (2) and (3) include individual-level controls for family income, race, gender, grade in which student took exam, and whether student would graduate from a public or private high school as well as district-level controls for urban/ suburban/rural location, percent minority students in district, log district enrollment, district governance county versus independent) and median household income in 1989. Model (3) includes controls for a quartic in estimated test-taking rate in district. Robust standard errors, adjusted for clustering at the district level, in parentheses.

Table 9
Difference-in-Differences in NAEP 8th Grade Math Scores by Subgroup
(Dependent variable is NAEP score divided by standard deviation of scores for national sample)

	Kentucky			Control States			Difference in differences
	1990	2000	Difference	1990	2000	Difference	
Total	7.14	7.56	0.42	7.14	7.47	0.33	0.08
	(0.03)	(0.04)	(0.05)	(0.01)	(0.02)	(0.02)	(0.06)
White	7.22	7.64	0.42	7.39	7.77	0.38	0.03
	(0.03)	(0.04)	(0.05)	(0.01)	(0.02)	(0.02)	(0.05)
Black	6.67	7.03	0.36	6.47	6.71	0.24	0.12
	(0.07)	(0.08)	(0.10)	(0.02)	(0.03)	(0.03)	(0.11)
Parental education: less than high school	6.67	7.08	0.42	6.72	7.06	0.34	0.08
	(0.05)	(0.10)	(0.11)	(0.03)	(0.04)	(0.04)	(0.12)
Parental education: high school	7.03	7.33	0.31	6.97	7.18	0.21	0.10
	(0.04)	(0.04)	(0.06)	(0.02)	(0.03)	(0.03)	(0.06)
Parental education: some college	7.47	7.64	0.17	7.36	7.69	0.33	-0.16
	(0.04)	(0.05)	(0.06)	(0.02)	(0.02)	(0.03)	(0.07)
Parental education: college or more	7.44	7.89	0.44	7.44	7.78	0.33	0.11
	(0.05)	(0.06)	(0.08)	(0.02)	(0.03)	(0.03)	(0.09)

Source: Nation's Report Card, National Assessment of Educational Progress, 1990 and 2000.
Notes: Each row represents a separate regression for the specified subgroup. Control states are Alabama, Arkansas, Louisiana, Ohio, and Indiana. Standard errors in parentheses.

Table 10
Estimates of the Effect of Current Expenditures per Pupil on ACT Scores
(Dependent variable is ACT score divided by standard deviation of score for full sample)

	Ordinary Least Squares			Instrumental Variables		
	Math	**English**	**Composite**	**Math**	**English**	**Composite**
Intercept	3.644*	3.415*	3.949*	3.679*	3.516*	3.823*
	(0.163)	(0.135)	(0.153)	(0.214)	(0.205)	(0.256)
Post-reform (1=yes)	-0.157*	-0.347*	-0.125*	-0.117	-0.233	-0.268
	(0.055)	(0.036)	(0.047)	(0.186)	(0.144)	(0.162)
Kentucky (1=yes)	-0.317*	-0.112	-0.219*	-0.298*	-0.058	-0.287*
	(0.067)	(0.062)	(0.062)	(0.086)	(0.083)	(0.074)
Kentucky x post	0.024	0.023	0.022	0.027	0.030	0.013
	(0.026)	(0.018)	(0.018)	(0.030)	(0.018)	(0.029)
Median income (1000s)	0.006*	0.006*	0.006*	0.006*	0.005*	0.006*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Post-reform x median income	0.009*	0.001	0.005*	0.009*	0.001	0.006*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Kentucky x median income	0.003*	0.002*	0.002	0.002	0.001	0.003
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
Current expenditures per pupil (1000s)	0.049*	0.008	0.033	0.027	-0.054	0.111
	(0.024)	(0.013)	(0.019)	(0.099)	(0.075)	(0.090)
Controls for student and district-level covariates	Yes	Yes	Yes	Yes	Yes	Yes
Controls for ACT-taking rates	Yes	Yes	Yes	Yes	Yes	Yes
Observations	160,957	160,957	160,957	160,957	160,957	160,957
R-squared	0.15	0.14	0.15	--	--	--

Source: ACT, graduating public school classes of 1989, 1999, 2000 in Kentucky. School district data from F33, 1990 Census, and Common Core of Data.

Notes: Base group is 1989, post-reform is 1999 and 2000. All models individual-level controls for family income, race, gender, grade in which student took exam, and whether student would graduate from a public or private high school as well as district-level controls for urban/suburban/rural location, percent minority students, log school size, log district enrollment, district governance (county versus independent) and median household income in 1989 and a quartic in estimated test-taking rate in district. IV models use the interaction of a post-reform dummy variable with median household income in district as an instrument for school spending. Robust standard errors, adjusted for clustering at the district level, in parentheses.

Appendix Table 1a
Characteristics of Matched vs. Unmatched Districts in Zip Code-District Merge

	Kentucky			Tennessee		
	Unmatched	**Matched**	**Total**	**Unmatched**	**Matched**	**Total**
Number of districts	41	132	173	29	104	133
Number county-level districts	0	118	118	0	90	90
Number independent districts	41	14	55	29	15	44
Percent of all districts	23.70	76.30	100.00	21.80	78.20	100.00
Percent of county-level districts	0.00	100.00	100.00	0.00	100.00	100.00
Percent of independent districts	74.55	25.45	100.00	65.91	34.09	100.00
Percent of total students, 1989-1990	8.13	91.87	100.00	7.08	92.92	100.00
Percent of total students, 1999-2000	7.82	92.18	100.00	6.81	93.19	100.00
	Unmatched	**Matched**	**[p-value of difference]**	**Unmatched**	**Matched**	**[p-value of difference]**
Avg. number of students, 1989-1990	1,242	4,358	[.000]	1,880	6,875	[.000]
Avg. number of students, 1999-2000	1,225	4,486	[.000]	1,994	7,609	[.000]
Current expenditure per pupil, 1989-1990	4,924	4,592	[.003]	4,427	4,100	[.046]
Current expenditure per pupil, 1999-2000	6,419	6,131	[.035]	5,742	5,295	[.008]
Average median income, 1989	25,397	29,481	[.006]	29,085	31,520	[.060]
Average percentage of zip code area that lies within matched district	--	91.16	--	--	86.36	--

Source: Common Core of Data 1989-90 and 1999-2000.
Notes: Median income and expenditures in 2001 dollars.

Appendix Table 1b
Characteristics of Matched vs. Unmatched ACT-Takers in Zip Code-District Merge

	Kentucky			Tennessee		
	Unmatched	**Matched**	**Total**	**Unmatched**	**Matched**	**Total**
Test-takers (number)						
1989	344	22,538	22,882	78	29,477	29,555
1999	68	22,892	22,960	23	34,364	34,387
2000	63	23,763	23,826	27	35,226	35,253
Test-takers (percent)						
1989	1.50	98.50	100.00	0.26	99.74	100.00
1999	0.30	99.70	100.00	0.07	99.93	100.00
2000	0.26	99.74	100.00	0.08	99.92	100.00
	Unmatched	**Matched**	**[p-value of difference]**	**Unmatched**	**Matched**	**[p-value of difference]**
Average composite score						
1989	19.13	20.06	[.000]	19.33	20.11	[.140]
1999	18.99	20.15	[.016]	17.70	19.93	[.017]
2000	19.84	20.14	[.563]	19.22	19.98	[.428]
Percent black						
1989	2.91	6.38	[.000]	15.38	15.45	[.988]
1999	7.35	6.47	[.782]	30.43	17.71	[.208]
2000	0.00	6.53	[.000]	22.22	18.03	[.612]
Average family income						
1989	41,547	51,011	[.000]	54,009	50,250	[.977]
1999	40,518	55,423	[.000]	31,760	50,190	[.004]
2000	38,907	56,324	[.000]	60,925	51,042	[.695]

Source: ACT, graduating classes of 1989, 1999, 2000 in Kentucky and Tennessee.
Notes: Family income interpolated from categorical variables and reported in 2001 dollars.