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Education Reforms and Convergence in Student Performance: Evidence from Arkansas

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Abstract: Arkansas launched a series of far-reaching reforms in 2003 and 2004 aimed at promoting equity and adequacy of education. The education funding system has since directed considerably more school resources to economically disadvantaged and low-performing school districts. This study investigates whether a more equitable allocation of educational resources is followed by more equal student performance. In particular, we examine convergence in student achievements among Arkansas school districts from 2004-05 to 2013-14 academic years. Using traditional convergence tests, we find some degree of overall convergence. We further employ a novel clustering method developed by Phillips and Sul (2007, 2009) to detect convergence clubs. We find that instead of a full panel convergence, school districts' overall academic outcomes converged into three clubs, within which the member districts trend toward their club-specific equilibrium paths. Poorer districts and districts serving a larger proportion of non-white and male students are more likely to end up in the low-performing club. Our results suggest that school finance reforms can reduce but not eliminate student achievement gaps.

Keywords: education reform, education resources, student performance, club convergence

Introduction

Education is recognized as a crucial factor for the development of both individuals and nations (e.g., Hanushek *et al*. 2000; Hanushek and Woessmann, 2011). Furthermore, equity of educational opportunities plays a key role in promoting broader social equality in terms of income, health, and social status (e.g, Dee, 2005; Mirowsky, 2017). Improving student learning and achieving more equitable education, therefore, are fundamental tasks for policymakers.

In the last half-century, school finance reforms have been widely used in the United States to combat inequality in education and are arguably the most important education policy changes (Lafortune *et al.*, 2018). There have been a large number of litigations since the 1960s in which state governments were sued for not providing every child with equal educational opportunities. Between 1971 and 2010, state supreme courts overturned the education system and demanded school finance reforms in as many as 28 states. (Jackson, 2020). These reforms typically focused on the adequacy and/or equity of educational support. That is, they sought to allocate sufficient resources in general, and to low-income districts in particular, in hopes of eliminating disparities across districts.[1] Some reforms, such as the Kentucky Education Reform Act (KERA) and Title-I of New York State's Every Student Succeeds Act (ESSA) Plan, also explicitly aimed at closing educational achievement gaps. Court-mandated reforms often entail a substantial increase in the budget for education. Murray *et al.* (1998) estimate that state spending on K-12 education rose by an average of 23 percent after the reforms.

In response to the state Supreme Court's ruling that Arkansas's education system was unconstitutional, the Arkansas General Assembly passed 73 education-related bills in 2003 and 2004 aiming to provide more adequate and equitable educational opportunities to all students regardless of the size, location, or characteristics of their school districts. In particular, Act 59 of 2003, commonly known as the Public School Funding Act, led to a sharp increase in educational inputs throughout the state and assigned school resources in a way that increasingly favored disadvantaged districts such as those with greater poverty, higher proportions of minority students, and lower academic achievements. We investigate whether the compensatory nature of resource placement is accompanied by a convergence in student outcomes from the Arkansas benchmark examinations, which served as Arkansas's standardized tests from the 2004-05 to 2013-14 school years. Traditional β- and σ-convergence tests suggest that discrepancies across school districts in various measures of student achievements were narrowing during the ten years under study. This implies that low-achieving school districts have been generally catching up since the implementation of the reforms. We further apply a novel club clustering analysis developed by Phillips and Sul (2007, 2009), PS hereafter, and identify three GPA convergence clubs in which

[1] While funding is always the focus, educational resources also include technology, teacher salary, teacher credentials, student/teacher ratio, etc.

school districts converge towards their group-specific equilibrium paths.[2] While the within-club disparities between districts have been declining steadily, the between-club inequality appears to be persistent.

Our paper complements the existing literature on court-ordered education reforms. These reforms are usually found to have immediate and sustained impacts on educational inputs. For example, Murray *et al*. (1998) show that reforms between 1971 and 1996 raised educational spending in poor districts and kept spending in rich districts unchanged, thereby increasing total spending and reducing within-state inequality. Similarly, Card and Payne (2002) find that school finance reforms in the 1980s narrowed the gap in both educational funding and expenditures between richer and poorer districts. However, the evidence is mixed in terms of whether education reforms can improve academic outcomes and reduce achievement gaps. For instance, KERA failed to improve student performance or significantly narrow the gap in test scores between rich and poor districts (Hoyt, 1999; Clark, 2003). Roy (2011) finds that Michigan's school finance reform of 1994 improved student outcomes in the lowest-spending districts in state tests but not in the American College Test (ACT), and the reform had some negative effects on highest-spending districts. Additionally, multiple studies show that New York City's Title-I program of ESSA did not improve student outcomes, even in high-poverty schools that were most likely affected by the policy (Van Der Klaue, 2008; Matsudaira, 2012).

However, there are also many papers, especially recent multi-state studies, that have pointed to reforms' positive impacts on student performance. For example, Guryan (2000) finds that the Massachusetts Education Reform Act of 1993 improved 4th-grade test scores, and the improvement was mainly driven by low-scoring students. Card and Payne (2002) show that spending equalizations that resulted from education reforms in the 1980s narrowed test score gaps between students with highly educated and poorly educated parents. Lafortune *et al*. (2018) present evidence that post-1990 education reforms not only increased academic achievements but narrowed achievement gaps between the poorest and wealthiest districts. Jackson *et al*. (2015) focus on long-run student outcomes and find that increased educational spending induced by school finance reforms led to higher educational attainment, higher incomes after graduation, and lower annual incidence of adult poverty, and the effects are larger for children from low-income families. In this paper, we show that Arkansas's 2003-04 reforms considerably equalized educational spending throughout the state. Students from low-scoring districts were generally catching up with those from high-scoring districts. Nevertheless, we also find that school resource equalization alone is unlikely to eliminate achievement gaps.

[2] Students' performance on the Arkansas benchmark examinations has four categories: Advanced, Proficient, Basic, and Below Basic. We do not observe students' scores, but we do observe the percent of students falling under each of these categories. We create a "GPA" measure that calculates the average grade point at the school district level on a 4-point scale, where Advanced, Proficient, Basic, and Below Basic are assigned the value of 4, 3, 2, and 1, respectively. We further define overall GPA as the average of the math GPA and the literacy GPA.

Our study also adds to the understanding of the determinants of student achievements. Existing research does not provide clear guidance regarding the relationship between educational spending and outcomes. Most observational studies, especially the earlier ones, find that added funds to schools do not translate into better student performance (Coleman *et al.*, 1966; Hanuchek, 1986; Hanushek and Kimko, 2000; Hanushek, 2003; Woessmann, 2003; Hanushek and Luque, 2003). As Hanushek (2003) summarizes, only about 27% of the 163 studies published before 1995 document a significant and positive effect. By contrast, many recent papers, which frequently use quasi-experimental methods to isolate exogenous variation in school expenditures and better establish causal relationships, do find significant effects of school resources on test scores, dropout rates, graduation rates, and college entry (Hyman, 2007; Holden, 2016; Jackson *et al.* 2021). With regard to teachers' role in educational output, some studies document a positive relationship between the quality of teachers and student outcomes, although observable teacher attributes such as teacher education, certification, and experience are generally found to have limited impacts on learning (Aslam and Kingdon; Darling-Hammond, 2000; Dee, 2007; Dolton and Marcenaro-Gutierrez, 2011; Harris and Sass, 2011; Kane *et al.*, 2008; Rivkin *et al.*, 2005;). The evidence about the effects of class size on student performance is quite inconclusive (e.g. Angrist and Lavy, 1999; Hoxby, 2000; Michaelowa, 2001). Among all factors, family background appears to be the most important one to explain the variation in student performance (Hanushek and Luque, 2003; Woessmann, 2004; Woessmann, 2005). This study explores the factors driving the formation of student performance convergence clubs. We find that club memberships are primarily determined by family economic conditions and student demographics: districts with greater poverty, measured by a higher share of students eligible for free or reduced-price lunch (FRL), and those serving more non-white and male students are significantly more likely to end up in the lowest-performing club.

Our paper makes three primary contributions. First, we present the first rigorous analysis of the impact of Arkansas's 2003-04 education reforms on student outcomes. Second, to our knowledge, this is the first study in the literature that uses convergence analyses to investigate the closure of student achievement gaps. Third, although many prior studies have found that school funding reforms may reduce achievement gaps, none of them examined whether those reforms have the potential to eliminate the gaps. Our results uncover three test score convergence clubs in the post-reform period, which implies that school resource equalization alone is unlikely to wipe out achievement gaps because students from poorer districts could be stuck in the low-performing equilibrium in the medium or long run. Our study not only informs Arkansas's policymakers of the effectiveness of education reforms but provides a mechanism for other states to evaluate the accomplishments of their school finance reforms.

The rest of the paper proceeds as follows: Section 2 briefly reviews Arkansas's education reforms; Section 3 describes the data; the patterns of education spending are examined in Section 4; Section 5 shows the results of

convergence tests on student performance and explores potential determinants of convergence club membership; Section 6 concludes the paper.

Arkansas Education and Reforms

Arkansas has historically been a state with low academic achievements. Arkansas students have persistently performed below the national average on the National Assessment of Educational Progress (NAEP) exams. Arkansas has also struggled with education inequality. The achievement gap between economically advantaged and disadvantaged students has ranked in the top half of the nation since 2000.

In addition, the education system has a long history of running into constitutional trouble. The earliest case dates back to 1983 when the Supreme Court ruled in *Dupree v. Alma School District* that the state government had failed to provide a suitable education for all children equally, which prompted then-Governor Bill Clinton to initiate a series of education reform endeavors including setting higher standards, holding school districts accountable for student progress, and implementing a mandatory teacher competence test. In 1992, another lawsuit commonly known as *Lake View* was filed by Arkansas Lake View School District, claiming that there were unconstitutional resource disparities between the wealthy and poor school districts. The Arkansas General Assembly attempted to tackle the problem in 1995 by enacting a new funding formula known as the Equitable School Finance Plan.[3] Despite this effort, a definitive ruling by the Supreme Court came in 2002 that the school funding system was unconstitutionally inequitable. The indictment pointed out considerable between-district disparities in per-pupil expenditures, school facilities, teacher salaries, and curricula quality, among many other problems. This ruling resulted in one of the biggest policy reforms in Arkansas in 2003.

The state adopted a new funding formula established in the Public School Funding Act of 2003. This act established the calculation of the foundation funding (the minimum amount needed to provide an adequate education). Revenue from local sources typically falls short of this base amount, and the state government contributes whatever is needed to close the gap between the local revenue and the foundation amount. This arrangement guarantees adequate funding regardless of local economic conditions. Overall, the new funding rules shifted away from allocation based on affordability to that based on needs, which substantially increased education spending per pupil. In addition, categorical funding was established to accommodate specialized needs such as assisting impoverished students, English language learners, and those in alternative school programs. This supplemental funding ensures that needier school districts will obtain extra resources, and students there will have an equal opportunity to thrive in school. Other policies included raising teachers' base salaries, granting more funds for teacher professional development, consolidating small districts, and increasing

[3] The Equitable School Finance Plan was a shift from allocation based on expenditure to that based on revenue. The amount of funding was determined by the local property tax revenue, state's miscellaneous funds from the previous year, and state equalization funding. Additional funding was assigned to poor districts to ensure that they could receive at least 80% of the per-student funding that the state's 95th percentile district received.

school accountability. Part of the increase in spending was facilitated by raising the state sales tax rate and expanding the list of taxable items. In the 2004-05 school year, the year immediately after the reforms, the state budget for elementary and secondary education was almost 25% more than that in the previous year (Ritter, 2005). The fast-growing funding has also reduced the gap in per-pupil expenditures between Arkansas and the national average (Swanson *et al*., 2015).

Data and Descriptive Facts

Our data come from three main sources. We obtained data on test results of the Arkansas benchmark examinations from the Office for Education Policy's Arkansas School Databases from the 2004-05 school year through 2013-14.[4] The exams provide assessments in math, literacy, and science for students in Grade 3 through 8.[5] The information on education inputs and most school district characteristics is from the National Center for Education Statistics. Among different measures of school expenditures, we mainly focus on the current expenditures, which exclude expenditures on capital outlays, debt services, school facilities, community services, adult education, and many other miscellaneous items that are not closely related to grade students' educational experiences. Data on teacher quality such as the percentage of teachers with a master's degree and average teaching experience are drawn from the Arkansas Department of Education Data Center.

The summary statistics are available in Table 1. Both public and charter districts are included. All the dollar values have been adjusted for inflation with 2014 as the benchmark year, and all the averages have been weighted by the enrollment of each school district such that they are more representative of what a typical Arkansas student experiences. The overall GPA averaged about 2.89. The GPA of the literacy tests was slightly higher than that of the math tests. Approximately two-thirds of students achieved the proficient level in either the math or literacy test.[6] Real current expenditures per pupil rose substantially since the reforms, and about 60% of the spending went to instructions. The largest source of funding was the state government, which contributed 55% of the total revenue. Revenue from the Federal government accounted for a small share (about 10%) but grew rapidly. Another noticeable change is the size of school districts. The average enrollment increased by about 1000 students due to district consolidations. Finally, the share of students eligible for free or reduced-price lunch rose considerably from 46% to 58%, which likely reflected the adoption of the new funding algorisms, as opposed to growing poverty.

Table 1: Summary Statistics

	Before Reform	After Reform

[4] The benchmark exams were replaced in the 2014-15 school year by the Partnership for Assessment of Readiness for College and Careers (PARCC) tests, which were subsequently replaced by ACT Aspire in 2015-16. To compare test outcomes over time, our analyses will only focus on the benchmark exams.
[5] Information on science tests is only available for the school year 2010-2011 and 2011-2012, and therefore will not be included in our analyses.
[6] Arkansas School for the Deaf and Arkansas School for the Blind are excluded from the sample.

Variables	Mean	SD.	Mean	SD.
Panel A: Student Performance				
Overall GPA			2.89	0.34
Math GPA			2.88	0.38
Literacy GPA			2.91	0.31
Percent of Students Proficient or Better in Math Tests			0.68	0.15
Percent of Students Proficient or Better in Literacy Tests			0.69	0.14
Percent of Students Scoring Advanced in Math Tests			0.35	0.14
Percent of Students Scoring Advanced in Literacy Tests			0.30	0.13
Panel B: Educational Inputs				
Real Current Expenditures per Pupil	7,620	988	9,345	1,244
Real Current Expenditures per Pupil on Instruction	4,698	516	5,491	622
Real Revenue per Pupil	8,636	1,087	10,678	1,491
Real Revenue per Pupil from Federal Government	823	399	1,282	591
Real Revenue per Pupil from State Government	4,889	714	5,789	1,150
Real Revenue per Pupil from Local Government	2,923	1,246	3,607	1,542
Pupil/Teacher Ratio	15.38	1.95	14.25	2.53
Teacher Experience			12.28	2.72
Percent of Teachers with Master's Degree or Higher			0.46	0.12
Panel C: School District Characteristics				
Enrollment	5,689	6,618	6,394	7,076
Percent of Students FRL-Eligible	0.46	0.15	0.58	0.17
Percent of Male Students	0.51	0.01	0.51	0.01
Percent of Students of Color	0.29	0.27	0.34	0.27

Note: The averages and standard deviations are weighted by the enrollment of each school district each year. All dollar values have been adjusted for inflation using 2014 as the base year. Data on student performance are only available for the post-reform period 2005-2014. Data on educational inputs cover 1998-2014 except teacher quality for which the pre-reform data are not available. School district characteristics are from 1999-2014.

Source: Data on learning outcomes are derived from the University of Arkansas's Office for Education Policy. Information on education resource and spending as well as most school district characteristics is obtained from National Center for

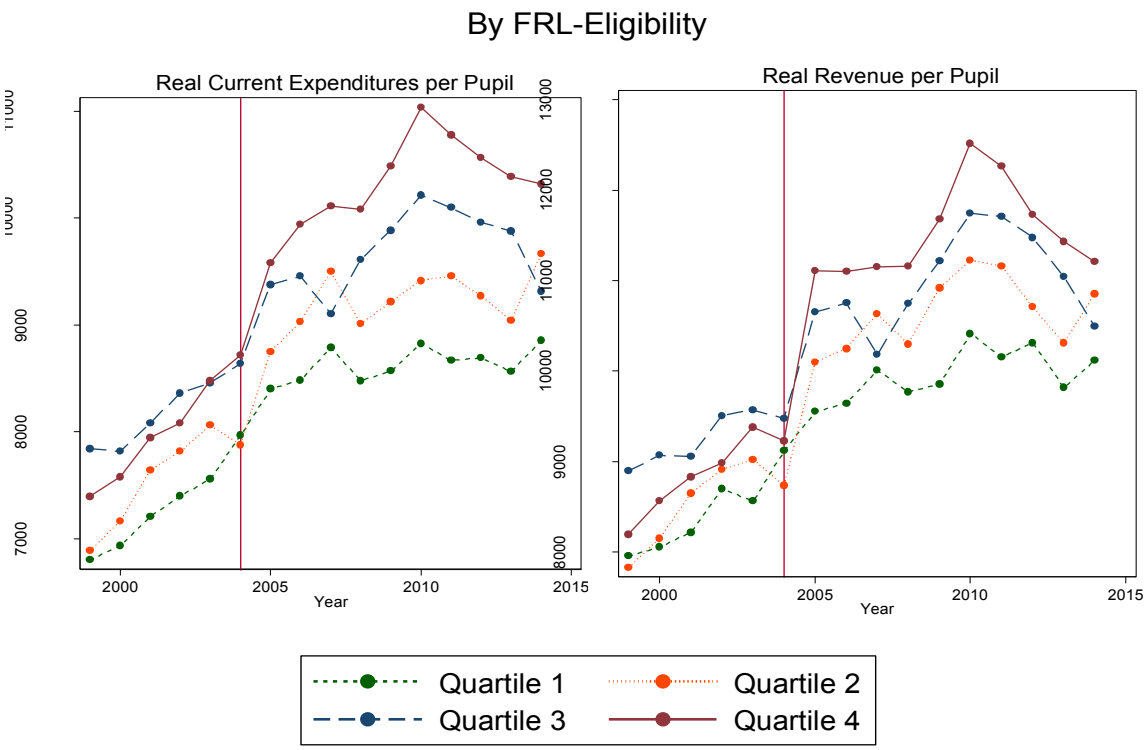
Education Statistics. Data on teacher quality are drawn from Arkansas Department of Education Data Center.

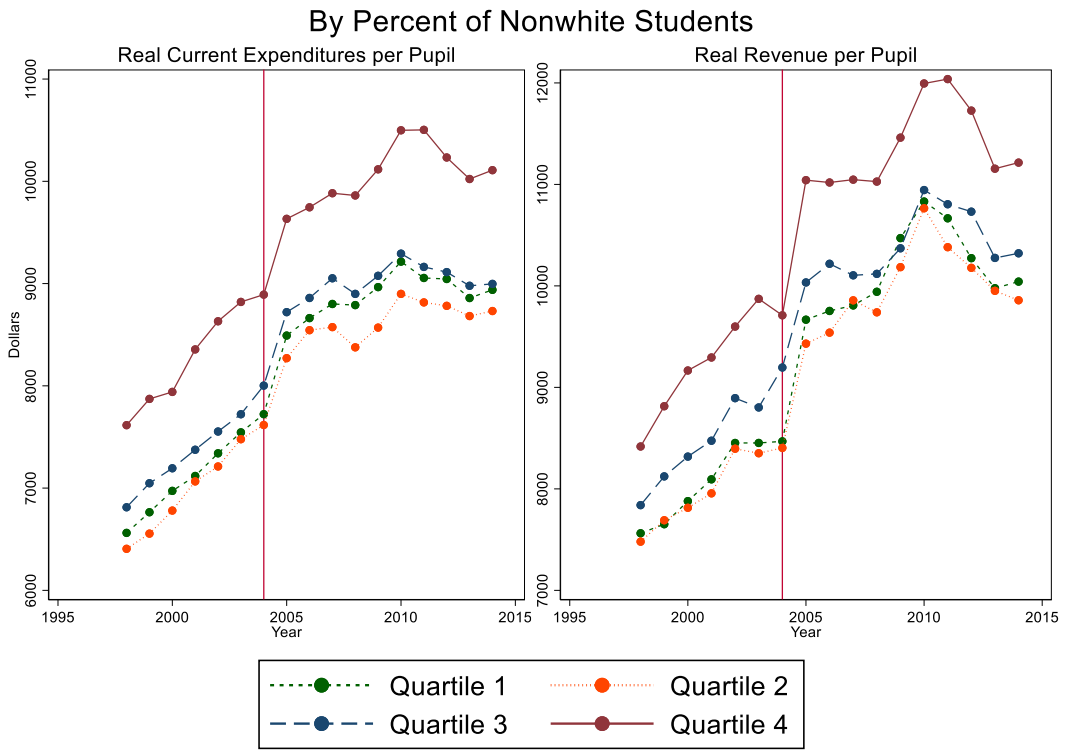
In the following analysis, we include both traditional and charter school districts that existed throughout the analyzed period. Although charter schools differ in many ways from traditional public schools such as independent management and greater autonomy on the curricula, all results are highly robust to dropping them.

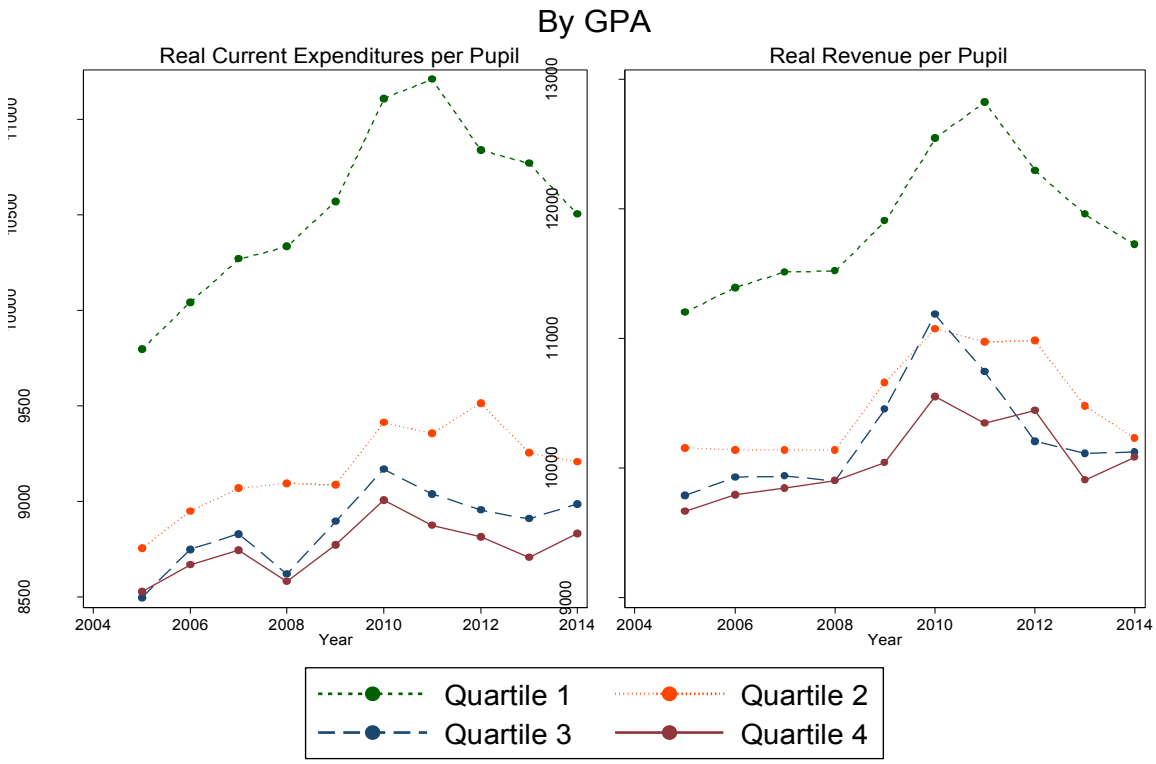
Distribution of Education Spending

Since the implementation of the Public School Funding Act, Arkansas school funding has been more equitable in the sense that the neediest districts received the most resources and were able to make the highest educational expenditures on a per-student basis. This helped narrow the opportunity gaps among students with differential needs and socioeconomic conditions. Following Swanson *et al*. (2015), we present how real current expenditures per pupil and real revenue per pupil are related to various characteristics of school districts in Figure 1. We show trends both before and after the reforms whenever possible and trace as far back as data permit. The average expenditure and revenue are weighted by the enrollment.

Figure 1: Distribution of Education Inputs by FRL-Eligibility, Percent of nonwhite students, and GPA




By Percent of Nonwhite Students
Real Current Expenditures per Pupil
Real Revenue per Pupil
Dollars
Year
Quartile 1
Quartile 2
Quartile 3
Quartile 4


By GPA
Real Current Expenditures per Pupil
Real Revenue per Pupil
Year
Quartile 1
Quartile 2
Quartile 3
Quartile 4

In the first panel of Figure 1, we decompose the sample into quartiles according to the percentage of students eligible for free or reduced-price lunch. Districts with the highest percentages are in the 4th quartile (poorest) and those with the lowest percentages are in the 1st quartile (wealthiest). The vertical line denotes the year of reforms, which unsurprisingly, was the turning point: prior to the 2004-05 school year, the districts with the highest proportion of needy students (4th quartile) neither received nor spent the most, and the differences between the groups were relatively small. After the reform, the poorest quartile consistently had the highest expenditures and revenue, and the discrepancies rose quickly until the 2009-10 school year, after which the gaps between the quartiles appeared to be more stable.

The second panel illustrates the relationship between expenditures or revenue per pupil and the share of non-white students. Since minority students are more likely to be associated with unfavorable socioeconomic conditions, schools enrolling higher proportions of minority students were more heavily funded. The neediest districts (4th quartile)'s trajectory is far above everyone else. This is probably because the proportion of non-white students in the 4th quartile is 61%, much larger than that in other quartiles.

The third panel plots school inputs by overall-GPA quartiles. The 1st quartile in this panel represents districts serving the lowest-performing students. We find that more funds were typically allocated to lower-scoring districts after the reforms, and the major difference lies between the 1st quartile and the others. Since the formula for the foundation funding and categorical funding do not directly involve student achievements, the negative correlation between test outcomes and education resources likely reflects the fact that economically disadvantaged students tend to perform worse.

All these graphs show that needier regions received more education funding and spent more per pupil since the inception of the reforms. Given more equitable educational inputs, it is of substantial interest to examine whether student performance has also become more equal.

5. Convergence in Student Performance

5.1. *Traditional Convergence Tests*

This section seeks to uncover the convergence patterns of student achievements. β-convergence and σ-convergence are the two most common convergence types examined in early studies. In this context, β-convergence denotes a process where the growth rate of a variable such as GPA is negatively correlated with its past values, such that the low-performing districts will eventually catch up. σ-convergence refers to a reduced dispersion in student performance across the school districts over time, which is often reflected by a declining coefficient of variation (CV).[7]

[7] CV is defined as the ratio of the standard deviation to the mean and is widely used as a measure of dispersion in data. An alternative to CV is the standard deviation. While standard deviation measures the typical distance from the mean,

β-convergence can be empirically tested using the following regression function (Young *et al*., 2008):

$$\ln\left(\frac{Y_{i,t}}{Y_{i,t-1}}\right) = \alpha + \beta \ln(Y_{i,t-1}) + \varepsilon_{it}, \qquad (1)$$

where $Y_{i,t}$ denotes some student performance in school district i and year t. The left-hand side represents the growth rate of Y from year $t-1$ to year t. A negative β implies an inverse relationship between growth rate and the value of Y in the previous period, and thus β-convergence. An alternative regression (Canova, 2004) is:

$$\frac{1}{T-1} ln\left(\frac{Y_{i,T}}{Y_{i,1}}\right) = \alpha + \beta ln(Y_{i,1}) + \varepsilon_i, \qquad (2)$$

where T denotes the final year in the sample. Compared with Equation (1), this function emphasizes the relationship between the growth rate and the initial value of Y.

Table 2 reports the results of the β-convergence tests for a variety of student outcomes, including overall GPA, math GPA, literacy GPA, and the percent of students scoring "proficient" or "advanced" on the benchmark math and literacy exams. We find that estimates of β are negative and statistically significant at the 1% level for all measures of achievements, suggesting that districts that lagged behind have been catching up in the analyzed period.

Table 2: β-convergence Tests

	Overall GPA (1)	Math GPA (2)	Literacy GPA (3)	Percent of Students Proficient or Advanced on Benchmark Math (4)	Percent of Literacy Proficient or Advanced on Benchmark Literacy (5)
Panel A: Equation (1)					
$\hat{\beta}$	-0.221***	-0.317***	-0.131***	-0.280***	-0.173***
	(0.008)	(0.009)	(0.008)	(0.006)	(0.007)
Obs	2151	2142	2151	2149	2149
Panel B: Equation (2)					
$\hat{\beta}$	-0.045***	-0.050***	-0.042***	-0.068***	-0.067***
	(0.004)	(0.004)	(0.004)	(0.003)	(0.002)
Obs	239	239	239	239	239

CV measures the relative magnitude of the dispersion by allowing for the fact that larger means are often accompanied by larger variation. In cases of comparison between different points in time when the mean changes, CV is better-suited (Heckelman, 2013). We only report results for CVs, but the results are similar if the standard deviation is used.

Notes: This table reports the results of β-convergence tests for the period 2005-2014.

*** p<0.01, ** p<0.05, * p<0.1

Figure 2 presents the evidence of σ-convergence. The CVs of all test outcomes declined steadily after 2004. The CV of the proficiency rate in either math or literacy benchmark exams in the 2013-14 school year was approximately 45% lower than that in 2004-05. The drop in the CVs of different GPA measures is smaller, ranging from 18% to 25%. More rigorously, we perform simple linear regressions of the CVs on the time trend as follows:

$$CV_t = \beta_0 + \beta_1 Year_t + \varepsilon_t \qquad (3)$$

and the results are reported in Table 3. we find that the slope coefficient is negative and statistically different from zero at the 1% level in all cases, confirming the existence of σ-convergence.

Figure 2: σ-convergence in Learning Outcomes

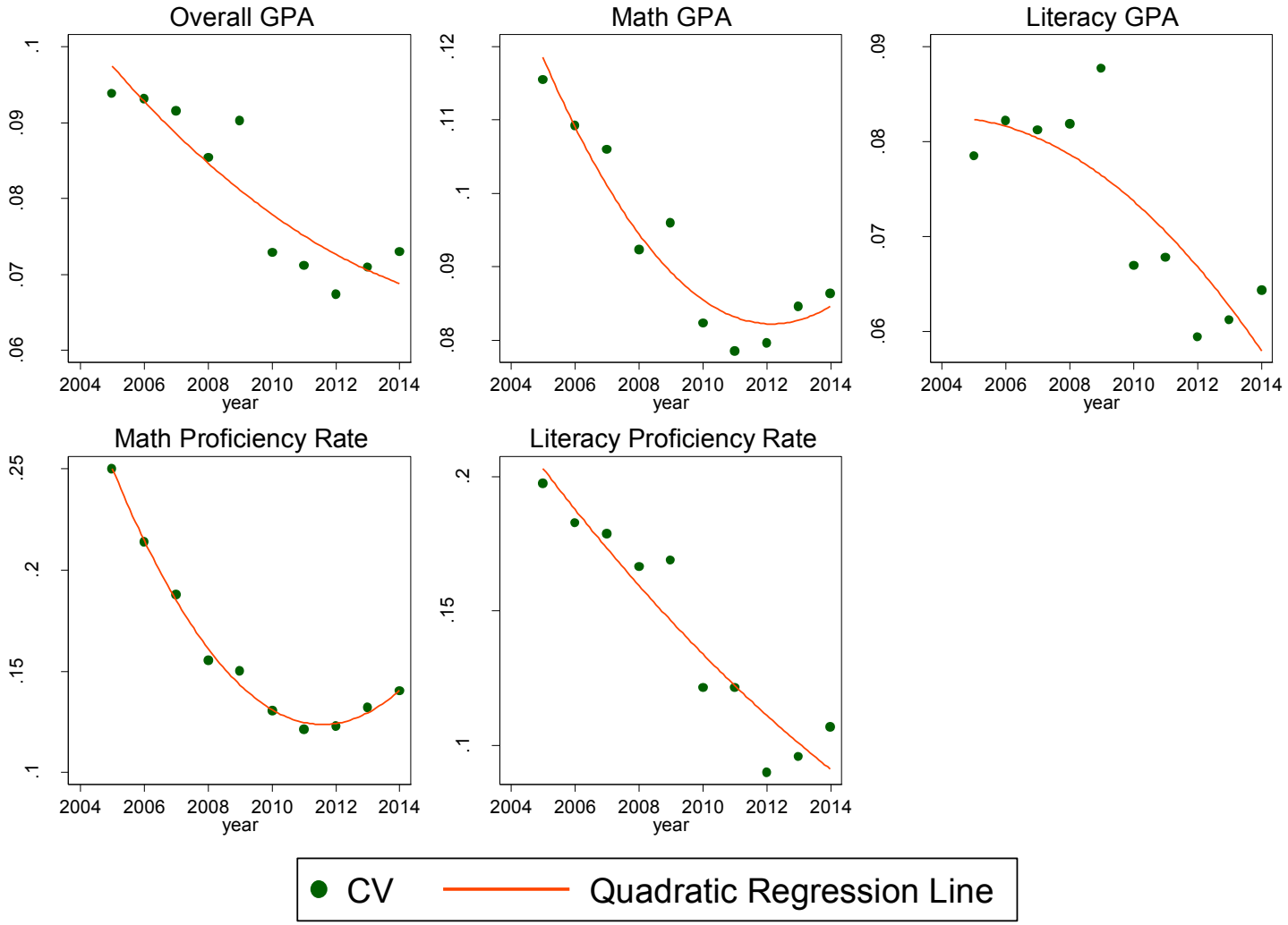


Table 3: σ-convergence Tests

Dependent Variable: Coefficient of Variation					
Variable	Overall GPA (1)	Math GPA (2)	Literacy GPA (3)	Percent of Students Proficient or Advanced on Benchmark Math (4)	Percent of Literacy Proficient or Advanced on Benchmark Literacy (5)
t	-0.0032***	-0.0038***	-0.0027***	-0.0122***	-0.0124***
	(0.0006)	(0.0008)	(0.0007)	(0.0026)	(0.0016)
Obs	10	10	10	10	10

Notes: This table reports the results of β-convergence tests for the period 2005-2014.

*** p<0.01, ** p<0.05, * p<0.1

The presence of β- and σ-convergence points to the effectiveness of the education reforms because the low-achieving school districts have been catching up since then. However, β- and σ-convergence do not ensure a full panel convergence where all individual districts move towards a common steady-state path. There could be a few different convergence clubs, in which the members converge among themselves toward club-specific equilibria. We empirically identify convergence clubs for students' overall performance in the next subsection.

5.2. *Club Convergence*

We apply a novel clustering algorism proposed by Phillips and Sul (2007, 2009) to explore the club convergence pattern of school districts' overall GPA. This technique exploits the evolution of transition paths and repeatedly runs a convenient time series regression test called *log t test* to detect convergence and to cluster individuals with similar transition paths into the same clubs. The PS approach is completely data-driven and endogenizes both the number of clubs and the members in each club. This method has been implemented in a wide range of topics such as economic growth (Phillips and Sul, 2009; Herrerias and Ordones; 2012; Tian et al., 2016), corporate tax (Regis et al., 2015), housing prices (Kim and Rous, 2012; Montanes and Olmos, 2013; Montagnoli and Nagayasu, 2015), innovation activity (Barrios et al, 2019) and environment and resources (Panopoulou and Pantelidis, 2009; Camarero et al., 2013). To our knowledge, this is the first application of the PS approach to educational outcomes. We briefly describe the PS methodology in Appendix A.

Panel A of Table 4 shows the results of the log t tests. Based on the negative and highly significant t-statistic for the full sample, the null hypothesis of full panel convergence toward a single steady-state path is firmly rejected. Instead, we find three clubs within which school districts display converging trends. Summary statistics for each club are reported in Panel B of Table 4 and all club members are listed in Table B1 in the appendix. About two-thirds of the districts form the top

group, with an average GPA of about 2.97. Roughly one-tenth of districts are grouped into the worst-performing club. Their GPA averaged around 2.50. The remaining districts comprise the middle tier, of which the mean GPA was 2.77.

Table 4: Convergence Club Classification (overall GPA)

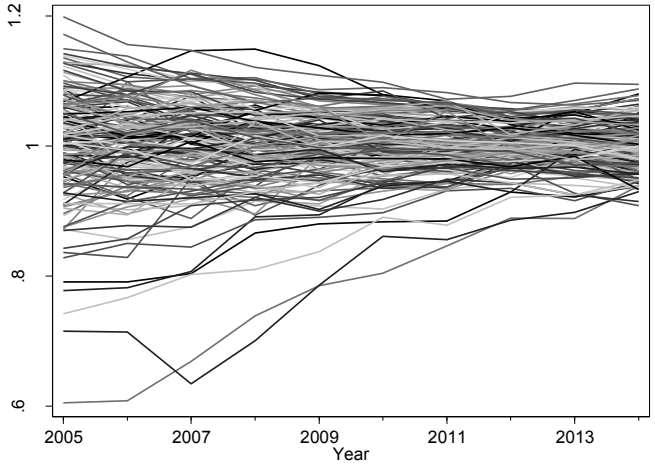
Panel A: Log t regression results				
log(t)	Full Panel	Club 1 (high)	Club 2 (medium)	Club 3 (low)
Coef ($\widehat{\beta_1}$)	-0.71	-0.08	0.70	0.17
T-Stat	-31.95	-1.42	3.97	1.79

Panel B: Summary statistics			
	Number of Club Members	Mean	Std. Dev.
Club 1	162	2.97	0.30
Club 2	53	2.77	0.26
Club 3	24	2.50	0.29

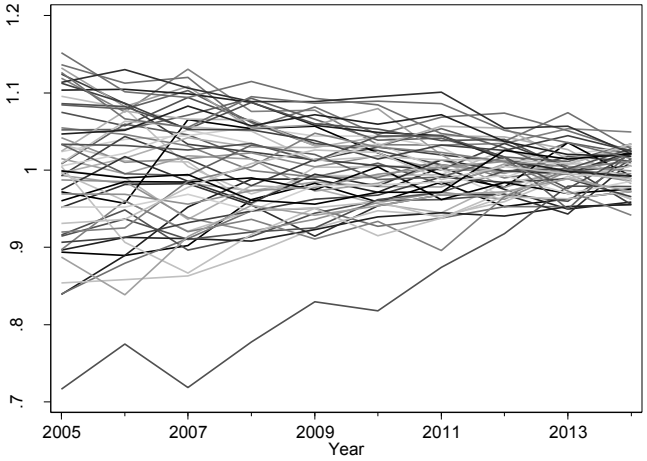
Note: Club 1, Club 2, and Club 3 are high, medium, and low spending clubs, respectively

Figure 3 plots the relative transition parameters for each club and the full panel. For the full panel, we demonstrate club averages rather than every school district for clarity purposes. The relative transition paths will trend towards one if there is convergence. Otherwise, individual paths move toward different values. We find that districts within each club are converging toward one, along with a notable decrease in the dispersion of curves. It suggests that the within-club disparities in student performance have decreased.

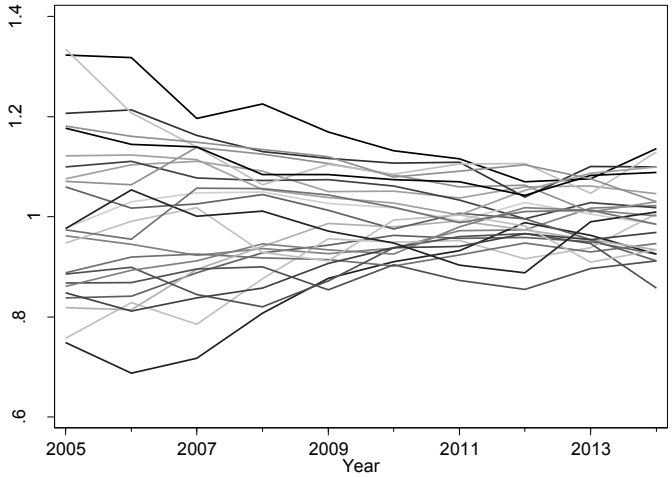
Figure 3: Relative Transition Curves for Overall GPA



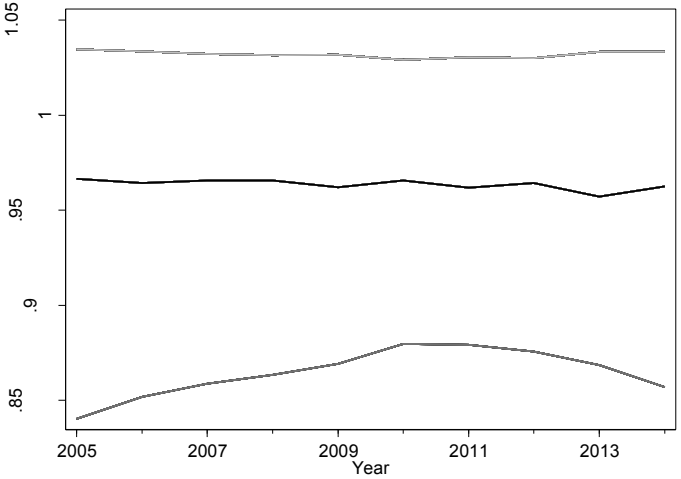
Club 1



Club 2



Club 3



Full panel

Note: Club 1, 2, and 3 represent the clubs with the highest, medium, and lowest student performance, respectively. The lower right graph shows the evolution of average transition parameters for each convergence club.

However, the three clubs stayed in their own equilibria and were not converging toward each other, as is shown in the lower right graph of Figure 3. It implies that the between-club achievement gaps are persistent. This should concern Arkansas education policymakers because some school districts are stuck in an unfavorable steady-state and may fall behind permanently if no major changes are made to them. Thus, it is of great importance to examine the driving forces of club determination such that effective policies can be formulated to help the most underperforming districts.

5.3. *Factors Driving Convergence Club Membership*

Table 5 provides descriptive statistics of a variety of factors that may affect club membership for each club. The lowest-performing club has advantages in some school inputs due to the compensatory nature of resource allocation following the reforms. The real current expenditures for this club are $12,119 per pupil, which is $846 more than the middle club and $1354 more than the high-performing club. The low-performing club also enjoys a lower pupil/teacher ratio. On average this club assigns one teacher to every 12 students. The ratio in the other two clubs is close to or higher than 13.

Table 5: Descriptive Statistics by Club

Variables	Club 1 (High GPA)	Club 2 (Middle GPA)	Club 3 (Low GPA)
% FRL-Eligibility	0.55	0.65	0.79
% Rural Districts	0.60	0.64	0.54
Enrollment	1,969	2,201	1,451
Real Current Exp per Pupil	10,765	11,273	12,119
Real Instructional Exp per Pupil	5,336	5,537	5,977
Teacher Experience	11.98	10.99	11.61
% Teachers with a master's degree	0.44	0.39	0.37
Pupils/teacher Ratio	13.31	12.93	11.95
% Black Students	0.09	0.22	0.52
% White Students	0.83	0.73	0.42
% Asian Students	0.01	0.01	0.01
% Male Students	0.51	0.51	0.52
% Adults with a bachelor's degree	0.16	0.13	0.11
Number of club members	162	53	24

While the highest-scoring club has fewer school resources to utilize, it boasts higher teacher quality. Teachers in this club have 12 years' work experience on average, which is about 1 year higher than the middle group and 0.4 year higher than the bottom club. Furthermore, 44% of teachers in the top club have earned a master's degree or better. This proportion is at least five percentage points higher than in the other two groups. The top club also benefits from a better family

economic status. About half of the students in this club are eligible for free or reduced-price lunch. By contrast, there are almost 80% of such students in the bottom club.

The student racial composition differs considerably between clubs as well. For example, non-white students account for 58% of the total student population in the lowest-scoring club, which is more than twice that of the middle club and more than three times that of the highest-scoring club.

Finally, people in the high-performing club districts are far better educated. Roughly 16% of the population age 25 or older has a bachelor's degree, which is at least 3 percentage points higher than in the other two clubs.

To uncover the factors driving the formation of convergence clubs we perform an ordered logit regression, which is appropriate for this purpose because the three convergence groups have a natural ordering (Club 1 has the highest GPA and Club 3 has the lowest GPA). Explanatory variables include district characteristics (FRL-eligibility, enrollment, a dummy variable indicating rural areas, and the percent of adults with a bachelor's degree), school resources (per student real current expenditures, pupil-teacher ratio, average teacher experience, and the percent of teachers with a master's degree), and student demographics (the share of non-white students and the share of male students). All explanatory variables are ten-year averages over the period from 2005 through 2014.[8]

Table 6 presents the estimated marginal effects from the ordered logit model. In each row, we report the average marginal effect of a factor on the probability that a school district belongs to a particular convergence club. We find that a one-percentage-point increase in the share of students eligible for FRL lowers the probability of fitting in the high-GPA club by 0.94 percentage point and increases the likelihood of falling into the low-GPA group by 0.43 percentage point. This suggests that poverty is a significant obstacle to academic achievements. With a one-percentage-point increase in the proportion of non-white students, a school district is 0.37% less likely to be in the top tier and 0.17% more likely to end up in the bottom tier. Students' gender composition also matters. Female students on average outperform male students, and a one percentage point increase in the share of male students is associated with a 3.49 percentage points decrease in the likelihood of being in the high-performance group.

Table 6: GPA Club Membership Determination: Marginal Effects

Variables	Low GPA Club	Middle GPA Club	High GPA Club
Rural	0.10	0.12	-0.22
	(3.03)	(3.64)	(6.67)
Enrollment	1.25	1.50	-2.75

[8] To obtain a better sense of the economic significance of the explanatory variables, we have normalized per pupil real current expenditures, teacher experience, and enrollment.

	(1.43)	(1.65)	(3.06)
Share of Adults bachelor's degree (%)	-0.38	-0.45	0.83
	(0.35)	(0.41)	(0.75)
Real Current Exp per Pupil	0.12	0.15	-0.27
	(1.53)	(1.84)	(3.37)
Pupils/teacher Ratio	-0.59	-0.71	1.31
	(0.94)	(1.11)	(2.04)
Teacher Experience	-1.21	-1.45	2.67
	(1.40)	(1.65)	(3.03)
Share of Teachers master's degree (%)	-0.08	-0.10	0.18
	(0.10)	(0.11)	(0.21)
Share of FRL-Eligible Students (%)	0.43**	0.51***	-0.94***
	(0.17)	(0.18)	(0.33)
Share of Students of Color (%)	0.17**	0.20**	-0.37**
	(0.07)	(0.09)	(0.16)
Share of Male Students (%)	1.59*	1.90**	-3.49**
	(0.83)	(0.94)	(1.72)
Number of Observations: 234			

Note: This table reports the results of Ordered Logit Regressions. The coefficients represent the marginal effects on the probability of being in one of the three clubs. All regressors are the 10-year average for the period 2005-2014. Per pupil real current expenditures, teacher experience, and enrollment have been normalized.

*** p<0.01, ** p<0.05, * p<0.1

To summarize, family conditions and student demographics are important factors related to club memberships. Furthermore, poverty is a significant barrier to good academic outcomes. Since low-income students probably face out-of-school disadvantages, they may still be stuck in the low-achieving equilibrium even after school resources are distributed more equally. This suggests that the governments can help achieve more equitable education by stepping up their efforts to fight poverty.

6. Conclusion

In the past 50 years, state supreme courts overturned the education system and demanded school finance reforms in more than half of US states. Those reforms strived to provide sufficient educational resources to low-income districts and eliminate disparities across districts. Some of them also explicitly aimed at closing educational achievement gaps. Such court-mandated reforms are found to be very effective at school resource equalization. However, there is more debate concerning the impact of the reforms on student achievements. Some scholars are skeptical of resource-based education policies in general (Hanushek, 2003; Woessmann, 2003). They believe that school inputs are not closely related to student performance. Others find that the reforms failed to improve test scores or reduce achievement gaps in some states such as Kentucky and New York but succeeded in other states

such as Massachusetts and Michigan (Guryan, 2000; Clark, 2003; Papke, 2008; Van Der Klaue, 2008). Interestingly, most recent multi-state studies find education reforms highly effective. In this paper, we present new evidence from Arkansas.

Following the Supreme Court's ruling in 2002 that the school funding system was unconstitutionally inequitable, Arkansas launched a series of influential educational reforms in 2003 and 2004 aimed at creating a more adequate and equitable education system. Since then, Arkansas's overall educational spending has increased considerably, and the distribution of educational inputs has become more compensatory in nature. That is, not only school funding was equalized, but poorer districts have been receiving more resources than richer districts. From policymakers' perspective, the ultimate goal of the reforms is to improve student performance in general, and especially in low-scoring districts, so as to close achievement gaps. Accordingly, this paper investigates whether the more equal resource allocation was followed by more equal student outcomes.

In particular, we test for convergence in various measures of student performance in the post-reform period. Traditional β- and σ-convergence tests reveal a certain degree of overall convergence. It means that low-achieving school districts were generally catching up. We further employ a novel clustering algorism and identify three convergence clubs, within which the school districts converge to their club-specific steady-state paths. While we observe narrowing within-club achievement gaps, the disparities between clubs are persistent. Districts with greater poverty or higher percentages of non-white and male students are significantly more likely to be in the lowest-performing club.

Our results carry important policy implications. First, money does matter in education. Although many economists and policymakers are still unsure of the effectiveness of resource-based education policies, we show that school spending equalization led to a narrowing of test scores between high-achieving and low-achieving districts. In this regard, school finance reforms at least achieved some success in Arkansas. This finding is consistent with Card and Payne (2002), Jackson *et al*. (2015), and Lafortune *et al*. (2018), which also show that court-ordered school finance reforms are an important way to improve education quality for students in low-income districts. Second, we point out that school finance reform alone is unlikely to eliminate achievement gaps. There are other important factors driving the differences in student performance and determining districts' long-run equilibrium. Our analysis shows that family background plays a critical role. Students from poorer districts probably face out-of-school disadvantages and may be trapped in the low-achieving equilibrium even after school resources are equalized. This suggests that poverty relief efforts may contribute to more equitable education.

Much remains to be done to thoroughly understand the effects of education reforms on student achievement gaps. A possible extension is to apply the convergence analysis to education reforms in other states. Are there heterogeneous impacts across states? This is left for future work.

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Appendix A: Major Steps of the PS Methodology

A.1 Time-varying factor representation

Our variable of interest X_{it} (overall GPA) can be decomposed into a systematic component (g_{it}) and a transitory component (a_{it}) as follows:

$$X_{it} = g_{it} + a_{it} . \quad (1)$$

Separating the common component from the idiosyncratic component, we have the following:

$$X_{it} = (\frac{g_{it} + a_{it}}{\mu_t})\mu_t = \delta_{it}\mu_t , \quad (2)$$

where δ_{it} is a time-varying idiosyncratic element and μ_t is a common component. According to Phillips and Sul (2007), if μ_t represents a common trend component in the panel, then δ_{it} measures the relative share of individual i in μ_t at time t. Thus, δ_{it} represents individual distance between the common trend component μ_t and X_{it}.

Relative convergence is defined as

$$\lim_{t\to\infty} \frac{X_{it}}{X_{jt}} = 1, \text{ for all } i \text{ and } j. \quad (3)$$

This is equivalent to the convergence of factor loading coefficients:

$$\lim_{t\to\infty} \delta_{it} = \delta, \text{ for all } i. \quad (4)$$

Therefore, testing for convergence in X_{it} is equivalent to testing for convergence in δ_{it}. Furthermore, relative transition parameter (h_{it}) is defined as follows:

$$h_{it} = \frac{X_{it}}{\sum_{i=1}^{N} X_{it}/N} = \frac{\delta_{it}}{\sum_{i=1}^{N} \delta_{it}/N} . \quad (5)$$

h_{it} measures how school district i compares with the cross-section average at time t, or a school district's relative departure from the common steady state growth path μ_t. By definition, the cross-sectional mean of h_{it} is one. If convergence exists among school districts, then the relative transition parameter converges to one and the cross-sectional variance of h_{it} converges to zero:

$$H_t = \frac{1}{N} \sum_{i=1}^{N} (h_{it} - 1)^2 \to 0 \text{ as } t \to \infty. \quad (6)$$

This property is used to test convergence and form convergence clubs.

A.2 The log t regression test

The loading coefficient, δ_{it}, is further modelled as

$$\delta_{it} = \delta_i + \frac{\sigma_i}{L(t)t^{\alpha}}\xi_{it}, \; t \geq 1, \; \sigma_i > 0 \text{ for all } i, \quad (7)$$

where δ_i is fixed, ξ_{it} is i.i.d.(0,1) across i but weakly dependent over t, and $L(t)$ is a slowly varying function for which $L(t) \to \infty$ as $t \to \infty$. This formulation ensures that δ_{it} converges to δ_i for all $\alpha \geq 0$. Based on the Monte Carlo simulations, Phillips and Sul (2007) determine that L(t) = log (t) produces the best results. A log t test, which is based on regression, is proposed to conveniently test the null hypothesis of convergence H_0: $\delta_i = \delta$ and $\beta_1 \geq 0$:

$$\log(\frac{H_1}{H_t}) - 2\log(L(t)) = \beta_0 + \beta_1 \log(t) + \varepsilon_t, \quad (8)$$

where $H_t = \frac{1}{N} \sum_{i=1}^{N} (h_{it} - 1)^2$, $h_{it} = \frac{X_{it}}{\sum_{i=1}^{N} X_{it}/N}$, and $\beta_1 = 2a$. The regression is run after a fraction (r) of the sample is removed.[9] Convergence exists when β_1 is positive or zero, whereas divergence is associated with negative values of β_1. A one-sided t test is appropriate in this case. At the 5% significance level, if the t-statistic is

[9] PS recommends setting r = 0.3 for small and moderate samples (T ≤ 50).

smaller than -1.65, we should reject the null hypothesis and conclude that there is no full panel convergence. In the absence of full convergence, other convergence patterns may emerge, including club convergence, divergence, or a mixture of both.

A.3 Club convergence

Phillips and Sul (2007) propose a four-step clustering algorism to empirically identify the convergence clubs using the log t test repeatedly.

- Step 1 (Ordering): Individuals are sorted based on the final observation (or the average of final observations) in the time series. Intuitively, convergence will generally be most evident towards the end of the sample period.
- Step 2 (Creating the Core Group): Pick the first k highest individuals, where $2 \leq k \leq N$, and conduct the log t regression to obtain the convergence test statistic t_k for each k. Among the (N-1) possibilities choose the group size k^* that maximizes t_k according to the criterion:
  $k^* = \text{argmax}\{t_k\}$, s.t. $\min\{t_k\} > -1.65$ (9)
  The condition $\min\{t_k\} > -1.65$ ensures that the null hypothesis of convergence is not rejected by data for each k, and the maximization step diminishes the chance of type II error. At one extreme, if every t_k is larger than -1.65, then all individuals belong to the same group, there is a universal convergence toward a common steady state. At the other extreme, if the condition $\min\{t_k\} > -1.65$ does not hold for k=2, then the highest individual diverges from everyone else and can be discarded from the core group. The process would then attempt to form a core group starting from the second highest individual. If the condition is not satisfied for all such sequential pairs, a core group cannot be found, suggesting that every individual is diverging from each other.
- Step 3 (Determining the First Convergence Club): Once the core group is established, every other individual that is not in the core group is added to the core group, one at a time, and the log t test is run for each of them. An individual is absorbed into the core group if and only if the convergence t statistic is greater than c, where c is some arbitrary critical value.[10] Once all units satisfying this criterion are added, the log t test if performed for this expanded group. If the t statistic is greater than -1.65, all individuals in this group converge, and the first club is claimed to be found. Otherwise, the critical value c is increased so that fewer individuals will be included. This procedure continues until the t statistic exceeds -1.65.
- Step 4 (More Clubs and Stopping Rule): All individuals not selected in the first club form a complement group. Conduct the log t test for these individuals. If the t statistic is higher than -1.65, they converge and constitute the second club, and we can conclude that there are two convergence clubs. Otherwise, repeat step 1 through 3 for the complement group to find more clubs. The iteration stops when it is impossible to form a core group in Step 2, and the remaining individuals are said to be divergent.

In Phillips and Sul (2009), the authors admit that the above grouping algorithm may overstate the number of convergence clubs. They propose to address this

[10] Phillips and Sul (2009) recommend setting c=0 for small samples ($T \leqslant 50$) to ensure that it is highly conservative.

issue by attempting to combine the existing clubs if they exhibit similar trends. More specifically, we will run the log t test pairwise for all neighboring clubs and merge those clubs that meet the convergence hypothesis jointly.

Appendix B: Converge clubs for overall GPA

Table B1
Convergence Clubs for Overall GPA

Club	# of Members	Districts
Low GPA	24	Blytheville School District Camden Fairview School Dist. Clarendon School District Decatur School District Deer/Mt. Judea School District Dermott School District Dollarway School District Dumas School District Forrest City School District Hampton School District Helena/ W. Helena School Dist. Hope School District Hughes School District Izard Co. Cons. School Dist. Lead Hill School District Lee County School District Mineral Springs School Dist. Mountain Pine School District Osceola School District Pine Bluff School District South Pike County School District Stephens School District Strong-Huttig School District Watson Chapel School District Westside School District
Middle GPA	53	Barton-Lexa School District Bearden School District Bradford School District Cedar Ridge School District Cross County School District East Poinsett Co. School Dist. England School District Fordyce School District Greenland School District Hackett School District Harmony Grove School District (Ouachita) Harrisburg School District Hartford School District Hazen School District Hermitage School District Hillcrest School District Hot Springs School District Jonesboro School District Junction City School District Kipp Delta Public Schools Lakeside School District (Chicot County) Little Rock School District Magazine School District Magnolia School District Malvern School District Marmaduke School District Marvell School District Mayflower School District Maynard School District Mcgehee School District Midland School District Mountainburg School District Mulberry School District N. Little Rock School District Norphlet School District Palestine-Wheatley Sch. Dist. Paragould School District Piggott School District Pulaski Co. Spec. School Dist. Quitman School District Rivercrest School District Riverview School District Rose Bud School District Shirley School District Sloan-Hendrix School Dist. South Side School District Texarkana School District Trumann School District Van Buren School District Waldron School District Warren School District West Fork School District West Side School District
High GPA	162	Academics Plus Charter School Alma School District Alpena School District Arkadelphia School District Armorel School District Ashdown School District Atkins School District Augusta School District Bald Knob School District Batesville School District Bauxite School District Bay School District Beebe School District Benton County School Of Arts Benton

		School District Bentonville School District Bergman School District Berryville School District Bismarck School District Blevins School District Booneville School District Brinkley School District Brookland School District Bryant School District Buffalo Is. Central Sch. Dist. Cabot School District Caddo Hills School District Calico Rock School District Carlisle School District Cave City School District Cedarville School District Centerpoint School District Charleston School District Clarksville School District Cleveland County School Dist. Clinton School District Concord School District Conway School District Corning School District Cotter School District County Line School District Crossett School District Cutter-Morning Star Sch. Dist. Danville School District Dardanelle School District Dequeen School District Des Arc School District Dewitt School District Dierks School District Dover School District Drew Central School District Earle School District East End School District El Dorado School District Elkins School District Emerson-Taylor School District Eureka Springs School District Farmington School District Fayetteville School District Flippin School District Foreman School District Fort Smith School District Fouke School District Fountain Lake School District Genoa Central School District Gentry School District Glen Rose School District Gosnell School District Gravette School District Green Forest School District Greenbrier School District Greene Co. Tech School Dist. Greenwood School District Gurdon School District Guy-Perkins School District Hamburg School District Harmony Grove School District (Saline) Harrison School District Heber Springs School District Hector School District Highland School District Horatio School District Hoxie School District Huntsville School District Jackson Co. School District Jasper School District Jessieville School District Kirby School District Lafayette County School District Lake Hamilton School District Lakeside School District Lamar School District Lavaca School District Lincoln School District Lisa Academy Charter Lonoke School District Magnet Cove School Dist. Mammoth Spring School District Manila School District Mansfield School District Marion School District Marked Tree School District Mccrory School District Melbourne School District Mena School District Monticello School District Mount Ida School District Mountain Home School District Mountain View School District Mt. Vernon/Enola School Dist. Nashville School District Nemo Vista School District Nettleton School District Nevada School District Newport School District Norfork School District Omaha School District Ouachita River School District Ouachita School District Ozark Mountain School District Ozark School District Pangburn School District Paris School District Parkers Chapel School Dist. Pea Ridge School District Perryville School District Pocahontas School District Pottsville School District Poyen School District Prairie Grove School District Prescott

		School District Rector School District Riverside School District Rogers School District Russellville School District Salem School District Scranton School District Searcy County School District Searcy School District Sheridan School District Siloam Springs School District Smackover School District So. Conway Co. School District Southside School District Spring Hill School District Springdale School District Star City School District Stuttgart School District Two Rivers School District Valley Springs School District Valley View School District Vilonia School District Viola School District West Memphis School District Western Yell Co. School Dist. Westside Cons. School District White Co. Central School Dist. White Hall School District Wonderview School District Woodlawn School District Wynne School District Yellville-Summit School Dist.