Does Location Matter? Spatial Variation in School Performance and Spending

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Abstract. Whether an increase in school spending leads to improvements in student achievement is a debated topic in educational policy research. Previous literature has found that overall increases in school spending are associated with higher student achievement. However, the traditional Ordinary Least Squares (OLS) model provides a universal explanation between school funding and academic performance, ignoring nuances across different geographical contexts. This study employs Multiscale Geographically Weighted Regression (MGWR) to examine the heterogeneous spatial relationships between funding and student academic outcomes in the greater Phoenix area, Arizona, United States. The findings from the MGWR model suggest that the impact of school spending varies across regions. In more affluent areas of northern Phoenix, increased spending correlates positively with proficiency, indicating that these schools may benefit from continued or increased investments in personnel resources. Conversely, in resource-limited areas, where the relationship is negative, different strategies may be required to address unique local challenges.

Keywords: School Finance; Student Achievement; Education Policy; Geographics Analysis

1. Introduction

Whether an increase in school spending can improve student outcomes has been a longstanding debate in economics and education policy literature. The investigation into the effectiveness of school resources on student achievement began in the 1960s with the Coleman Report (Coleman et al., 1966), one of the first large-scale U.S. studies to measure the relationship between academic performance and students' socioeconomic status and school characteristics. The report concluded that "socioeconomic factors bear a strong relation to academic achievement, and when these factors are statistically controlled, the differences between schools account for only a small fraction of the difference in achievement" (Coleman et al., 1966).

However, later scholars criticized this earlier literature for using simple regression techniques that failed to account for confounding factors between spending and student characteristics. Contemporary education finance research, benefiting from richer standardized data and school finance data in recent decades, is now able to design studies that capture the causal effects of spending on achievement (Angrist & Pischke, 2010; Handel & Hanushek, 2022a; Jackson, 2018). In a recent and comprehensive review, Jackson et al. (2024) conducted a meta-analysis of experimental and quasi-experimental studies published between 2009 and 2022. This analysis identified 31 studies that explored the effect of changes in school spending on learning achievement, demonstrating strong first-stage F-statistics. Jackson (2024) noted that this new body of literature employs clear comparison groups rather than simple variations in school spending; these studies leverage the effects of school finance reform to explore the relationship between resources and achievement, often finding different results. The pooled meta-analytic average estimate indicates that, on average, a $1,000 per-pupil increase in school spending sustained over four

years increases test scores by 0.0316 standard deviations ($p < 0.001$). For educational attainment, increasing school spending by $1,000 is associated with a 2.05 percentage increase in high school graduation rates (with a standard deviation of 0.357).

While increasing school spending has been found to positively impact on student learning, studies show that other factors also play an important role in improving student's learning outcome. For instance, variation in teacher quality accounts for at least 7.5% of the total variation in student achievement (Rivkin et al., 2005). Public schools have historically been funded by local sources, with approximately 40% of revenue coming from these sources nationally. Conceptually, the spending behavior of one school district may affect neighboring districts. An example is the tendency of nearby districts to match teacher compensation levels. If neighboring districts influence each other's spending decisions, but these spatial effects are not accounted for, models may produce unexplained variation due to the exclusion of location factors (Slagle, 2010).

This study analyzed the spending behavior of 366 public schools in the greater Phoenix area in the state of Arizona, Unites States. Employing an Ordinary Least Squared (OLS) and a Multiscale Geographically Weighted Regression (MGWR) , this paper found that overall, school spending is positively associated with school performance. However, the strength and direction of this relationship vary by location. The OLS model found a positive association between personnel spending and proficiency rates, explaining 64% of the variation in achievement. However, the MGWR model provides deeper insights, showing that the relationship between spending and proficiency is not uniform across regions. While some areas, in the northern part of greater Phoenix such as Scottsdale, exhibit a strong positive impact of spending on proficiency, other areas eastern part of greater Phoenix such as Mesa, display a negative relationship. Additionally, MGWR uncovers spatial variability in the effects of demographic factors, such as student's race ethnicity and special needs, on proficiency, suggesting the need for geographically targeted educational policies to address these disparities effectively. The findings from the MGWR model highlight the importance of geographically targeted policies in education. The spatial variability in the impact of school spending suggests that a one-size-fits-all approach may not be effective. Regions like Scottsdale, where increased spending correlates positively with proficiency, may benefit from continued or increased investments in personnel resources. However, areas like Mesa, where the relationship is negative, may require different strategies to address unique local challenges. This localized research approach facilitates the identification of spatial patterns where certain predictors have stronger or weaker effects, informing region-specific strategies and interventions for policymaking.

2. Literature Review

Summarizing the older literature on school finance and achievement reveals an inconclusive relationship between spending and students' learning outcomes (E.

A. Hanushek, 2003). Historical research on school inputs and outputs varies greatly in quality, particularly in methodology and data adequacy, making it challenging to draw definitive conclusions between these two factors. It was not until the enactment of Every Student Succeeds Act (ESSA), which mandated the release of spending data, that the public gained access to comprehensive spending data for every public school in the nation. Before that, scholars can only use aggregated spending data or data in available states or districts for analysis (Betts, 1995). Estimates of the impact of expenditures did not come from the classroom or school level because spending data were often measured at districts, county, or state level back in 1990s. A similar situation was observed in student performance measures; before the implementation of the No Child Left Behind (NCLB) Act, there was no universal state accountability, resulting in a variety of measures for student performance used in analyses. Reviewing these studies published before 1995, Hanushek (2003) conducted a thorough review of research on school finance and student learning outcomes. At least a quarter of studies relied on an inconsistent measure including things like continuation in school, dropout rate, and subsequent labor market earnings. Nevertheless, these early studies are not viewed as reliable for causal inference by today's research standard, the correlation identified between school spending and student achievement builds a solid foundation for subsequent research (Jackson, 2018).

Contemporary school finance research differs significantly from earlier literature, offering more precise data and advanced research designs to capture the causal effect of spending on achievement (Angrist & Pischke, 2010; Handel & Hanushek, 2022; Jackson, 2018). The authorization of the No Child Left Behind Act (NCLB) marked a pivotal moment, providing access to large-scale standardized testing and spending data (NCLB, 2001). Subsequently, Every Student Succeeds Act (ESSA) mandated districts to annually publish educational expenditure data at the school level (ESSA, 2015). Researchers are now able to measure the causal effect of resources on achievement with more accurate data and capture the heterogeneous effects of spending on students.

Regarding research methodology, there's a distinct difference between older and more recent studies. Earlier analyses typically compared the marginal contributions of inputs (such as schools, families, peers, etc.) without accounting for variables that correlate both spending and achievement. Ideally, to draw a causal conclusion, one would observe a school under different spending levels simultaneously. However, a significant challenge to causal estimation arises because only one of the two possible outcomes can be observed at a time. (Hahn & Herren, 2022; Rubin, 1974). A simple comparison between the treated and untreated units would not be able to capture the effect of the treatment--- the treatment effect is said to be confounded with other factors. Overall, contemporary empirical evidence suggests a quantitatively more positive relationship between school resources and student achievement than a negative one. Jackson et al. (2024) conducted a meta-analysis of experimental and quasi-experimental research published between 2009 and 2022. This study intends to add geographic location as an additional feature to the analysis of school funding and student achievement.

3. School Funding in Arizona

The public education system in the United States has a tradition of education localism, broadly defined as the belief that decentralized and independent local governments are preferable to a centralized government structure (McDermott, 1999). The current school funding system consists of a roughly "40-40-20 structure," where local and state governments each account for approximately 40%, and the federal government accounts for 20% (NCES, 2023). This dependence on local contributions has created geographical differences in funding across school districts. Linda Darling-Hammond (2012) found that in the 1990s, there was at least a three-to-one ratio between per-pupil spending in the richest and poorest districts.

Arizona, located in the southwestern region of the United States, is characterized by its diverse population and varying socioeconomic landscapes. The research focuses on Greater Phoenix area which is home to a significant proportion of minority groups, including Hispanic/Latino, African American, and Asian communities. The region exhibits substantial socioeconomic disparities. Affluent neighborhoods such as Scottsdale and Paradise Valley contrast sharply with lower-income areas like eastern Phoenix and Mesa. These disparities influence access to educational resources and student achievement levels.

For decades, the Arizona state government has underfunded public schools compared with the national average. Arizona ranks 49th in the nation, spending $25.42 on K-12 education for every $1,000 of personal income, while the national average is $36.13. According to the Annual Survey of School Finance and Systems (US Census, 2021), only 48% of school funding in Arizona comes from the state before the pandemic. Arizona's heavy reliance on local revenue in public schools provides a prime example to examine the relationship between funding and achievement in an underfunded state.

The state of Arizona adopted a primarily student-based formula, which assigns a base cost to the education of a student with no special needs or services. As depicted in Figure 1, state aid per pupil aims to equalize funding disparities across counties. The highest-poverty school districts receive the highest amount of state funding; however, it is local investment that creates inequalities. The average revenue from the local share is 41% for the most impoverished school districts, while it reaches nearly 50% in the most affluent school districts.

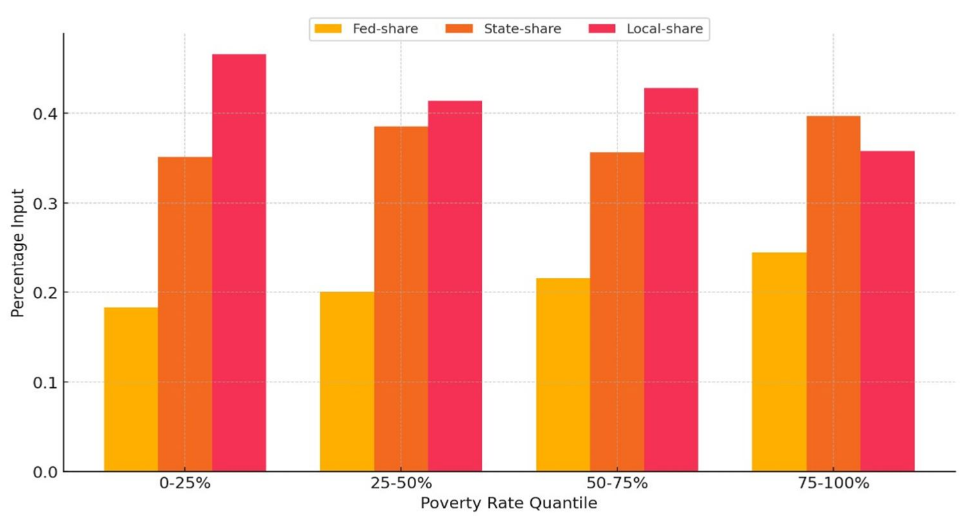

Figure 1: Arizona School Funding Average Revenue Source by Poverty Quantile, FY 2018

4. Theoretical Framework

Hanushek (1986) conceptualized the questions of resources allocation and achievement in the framework of education production function. Similar to a production function in economics, the Education Production Function describes the relationship between inputs (like labor, capital, and materials) and outputs (goods or services). In the context of education, the inputs include factors like teacher quality, class sizes, school facilities, and family background, while the output is typically measured in terms of student performance through test scores or graduation rates. School output includes both short term learning outcome such as test score, curriculum completion and long-term outcomes often refers to human capital resource such as employment and earnings (Betts, 1996; Bishop, 1991) The formula is defined as follows:

$$Y\,Y_{i\,i} = S\,S_{i\,i} + F\,F_{i\,i} + P\,P_{i\,i} + A\,A_{i\,i}$$

Where:

Y = Educational outcomes or student achievement

S = School resources (facilities, teachers, technology, etc.)

F = Family inputs (parental education, household income, etc.)

P= Peer (demographics of peers)

A= Other factors

Together with school factors, family influences and peer effects on student's achievement, education production function controls for Student's socioeconomic status which has been to be one of most important predictors of one's achievement (Coleman et al., 1966; Hanushek, 2003). Therefore, this study will entangle the spatial variability of the school expenditure controlling for average school-level students demographics including race ethnicity, household income, gender, and English proficiency.

5. Data

This research will include the following sources of data for analysis

5.1 School-Level Demographics

The state of Arizona has over 2,000 public schools (Figure 2), in the greater Phoenix area, which is also the Maricopa County, the most populous county in Arizona. It has a population of 4.5 million and serves more than 470,000 students across 700 public schools. Approximately 70% of these schools are concentrated in the Greater Phoenix and Tucson areas, while schools are sparsely located in other regions. Due to the unique characteristics of Multiscale Geographically Weighted Regression (MGWR), which conducts regression based on proximity to each point iii, schools located in areas with no nearby schools must borrow weights from distant points, leading to potential statistical bias. Therefore, this study only includes public schools in the metropolitan area of Greater Phoenix, as shown in Figure 3. This graph is plotted using American Census data for FY2018-2019. All lines and boundaries represent census tracts, which typically contain between 1,200 and 8,000 people. Each red dot represents a public school.

This dataset contains demographic characteristics of individual schools such as aggregated student socio-economics status information and annual spending. The Arizona Department of Education provides publicly available datasets on school-level information, including race/ethnicity, English language learner status, special education status, and income eligibility. A student is considered "income eligible I" or "income eligible II" if they live in a household with an income below 185% or 130% of the federal poverty line, respectively, or if they participate in specific means-tested nutrition assistance programs or are identified as homeless, migrant, or runaway. Income eligibility is used to determine qualifications for federal programs such as free or reduced-price lunch (detailed poverty line information by household size and income is provided in the appendix). The data is collected at the school site level and is based on the October headcount of the current academic year. As listed in Table 1, the majority of students are Hispanic/ Latino with 53.79% of the population, followed by 28.88 percent of white students and 8.1 percent of African American students. Summary statistics listed in Table 1 show a large variety of outcome variables: the passing rate (mean: 40.77; SD: 16.42) as well as focal independent variables --- school personnel expenditure; personnel spending has a mean of 700,000 and SD of 232,500. All variables are tested for independence and normality using Variance Inflation Factor (VIF) test and do not find the presence of multicollinearity.

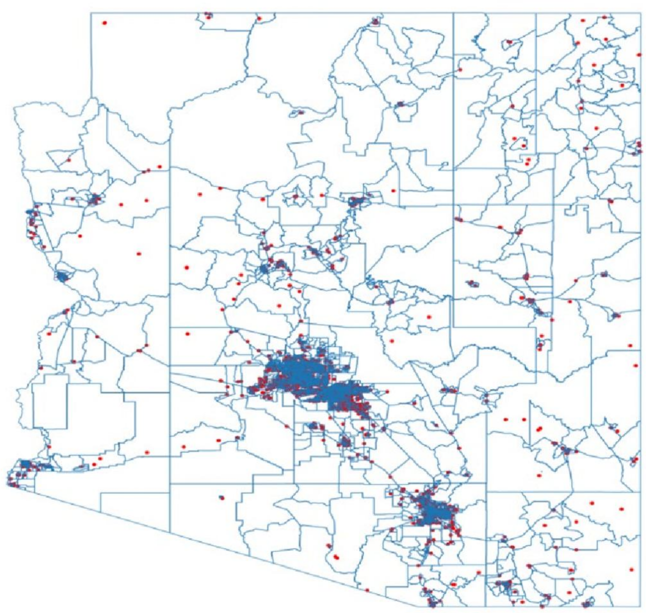
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Figure 2 Spatial Distribution of Public School in Arizona

5.2 School-Level Spending Data

School expenditure data is provided by the NERD data set from Edunomics at Georgetown University (Edunomics Lab at Georgetown University, n.d.). Starting in 2020, school-by-school financial data became publicly available thanks to a provision in Every Student Succeeds Act (ESSA) requiring school financials on every state and district report card. Edunomics tracks annual school-level spending data from fifties states in the nation. However, due to the data restriction in the state of Arizona, NERDS is only able to publish the data by the following category:

1. Personnel spending: expenditure on school staff and employee related costs. This category typically includes:
    a. Salaries and Wages: Payments to teachers, administrators, support staff, and other school personnel. This is often the largest portion of personnel spending.
    b. Employee Benefits: Costs for health insurance, retirement contributions, life insurance, and other benefits provided to employees.
    c. Professional Development: Expenses related to training, workshops, and courses aimed at improving the skills and qualifications of school staff.
    d. Contracted Services: Payments to contractors or consultants for specialized services that may not be handled by full-time

[*] *The graph is plotted using data from the AY 2018- AY 2019 US. Census data. The blue line border represents the census tract which has population between 1,200 to 8, 000.*

staff, such as psychologists, speech therapists, or special education aids.

2. Non personnel spending:

The final sample included into analysis are 366 public schools in the greater Phoenix area (Figure 3); after exclusion of schools with no information and charter schools; charter schools operated by third-party nonprofit organizations traditionally receive funding directly from the state or donation whereas public schools are funded by local districts through property tax. Due to financial sources and reporting differences, school spending at charter schools varies tremendously from public schools.

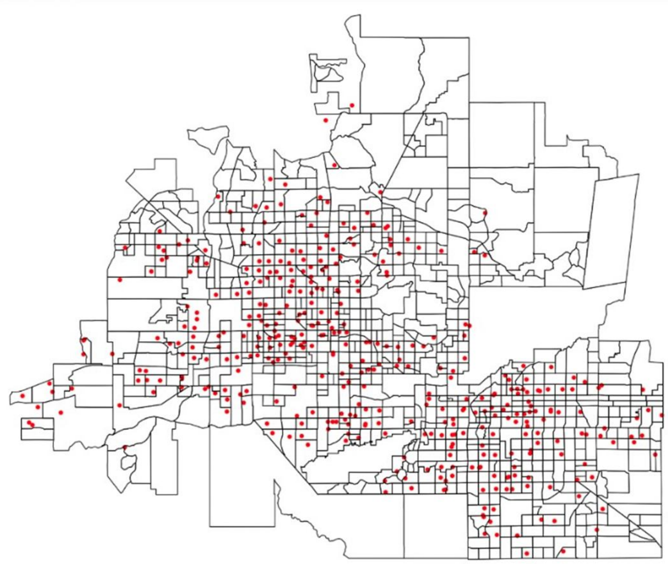

Figure 3 Spatial Distribution of Public School in Greater Phoenix

5.3 Academic Achievement

The outcome measures for this research are estimates of students' learning achievement. The dataset includes observations from the pre-pandemic period, specifically FY 2018 to FY 2019, obtained from the Arizona Department of Education. Due to the nature of Multiscale Geographically Weighted Regression (MGWR), the analysis can only include a single year of observations for onetime analysis. MGWR models the spatially varying relationships between a dependent variable and one or more independent variables by allowing regression coefficients to vary across locations. It assumes that the observed spatial relationships exist within a single, relatively stable time period, as combining data from multiple time periods could obscure or distort the spatial patterns due to temporal variations. Furthermore, because the funding structure changed significantly after the pandemic due to increased federal funding through the Elementary and Secondary School Emergency Relief Fund (ESSER), this study includes only pre-pandemic data.

Proficiency rates are derived from the AZ Merit assessment, an annual test designed to measure students' progress toward meeting the Arizona Common Curriculum Standards (Arizona Department of Education, 2020). AZ Merit is the only statewide mandated assessment conducted at all public schools every year. The standardized tests measure student's progress in meeting the Arizona Common Curriculum standards. The data provides the testing proficiency rate of English and mathematics disaggregated by grade from grades 3 to 12 at each school. The proficiency level is divided into 4 levels; proficient 1 to proficient 4 represent minimal proficient, partially proficient, proficient and highly proficient. However, the Arizona Department of Education masks proficiency rates when a group contains 10 or fewer students or when 100% of students in a group fall into the same proficiency category. For the purposes of this research, the analysis is limited to mathematics proficiency rates for grades 3–8. This decision is based on the inconsistency of annual testing across all high school grades.

Table 1: Student Demographics FY 2018-19

Variables	Mean
Math Proficiency	40.77
School Personnel Spending	1417.10
Percentage of African American	8.1
Percentage of Hispanics	53.79
Percentage of Students of Other Race Ethnicity	2.3
Percentage of Free Reduced Lunch Recipient	57.08
Percentage of English Language Learner	10.22
Percentage of Special Education Student	11.3

6. Method

Under education production function, one's achievement can be predicted by school inputs. School inputs typically include school resources such as financial resources and personnel input such as teachers, staff, and the community in which a school is located. An OLS regression model is conventionally defined as follows:

$$Y_i = \beta_0 + \beta_1 * Spending_i + \beta_2 * X_i + \varepsilon$$

Y_i : Mathematics proficiency rate as a measure of the educational outcome at school i.

β_0: Intercept term

$Spending_i$: Proportionate annual expenditure on personnel

X_i : school-level student demographics including:

1. Percentage of low-income students at school.
2. Percentage of English language learners at school.
3. Percentage of African American students at school.
4. Percentage of Hispanic/Latino students at school.
5. Percentage of Asian students at school.
6. Percentage of special education students at school.

To explore the spatial heterogeneity of the relationship between spending and achievement, this research will run the model via Multiscale Geographically Weighted Regression (MGWR). MGWR is designed to estimate the spatial dependence on the relationship between dependent and independent variable given the unique geographic distribution of school districts in the state of Arizona(Fotheringham et al., 2017). Instead of producing a global average model, MGWR produced local regression coefficients at each location. MGWR adds additional information by explicitly examining the relationship between the ESSER expenditure and district's characteristics with their locations. The model is defined as follows:

$$Y_i = \beta_0(u_i, v_i) + \beta_1 \sum_{k=0}^{n} (u_i, v_i) * Spending_i \quad + \beta_2 \sum_{k=0}^{n} (u_i, v_i) * X_i \quad + \varepsilon$$

Where (u_i, v_i) represents the geographic location of the $i\,i$ th observation which is longitude and latitude of a school. Thus, the parameter β_0 and β_1 are both functions of (u_i, v_i). X_i is a set of covariates including student racial composition, the percentage of students eligible for free-reduced lunch, teacher-student ratio as well as neighborhood characteristics. MGWR generates a set of location-specific parameter estimates for each variable in the model. It is important to assess the spatial variability of parameters estimated, whether spatial variation in these estimates. MGWR generates a set of location-specific parameter estimates for each variable in the model. It is important to assess the spatial variability of parameters estimated; whether spatial variation in these estimates may be due to noise, or it is large enough to represent intrinsically spatially varying processes (Sachdeva et al., 2020). To do this, a Monte Carlo test available in MGWR 2.0 is conducted. Monte Carlo test is designed to measure the extent to which the variables included in the model vary (Mrkvička et al., 2016). This approach is able to determine whether the observed spatial pattern is significantly different from what would be expected by chance (Fotheringham et al., 2017). As listed in the Table 3, most of variables included into the model are statistically significant at 0.05 level., except for the percent of male students, percent of students of other race ethnicity, students from low income and English language learner. For variables which are not statistically significant, I will consider excluding when analyzing.

Table 2: Monte Carol Test

Independent Variable	P-Value
Intercept	0.038*
Personnel Spending	0.000**
Percent of Male Students	0.850
Percent of Hispanic/Latino	0.000**
Percent of African American	0.030*
Percent of American Indian	0.007*
Percent of Students of Other Race Ethnicity	0.204
Economics Disadvantaged Students	0.751
Percent of English Language Learner	0.595
Percent of Special Ed Student	0.027*

In addition, to verify if the data has a statistically significant spatial pattern, an autocorrelation test is conducted. If the data have a random spatial relationship—that is, no statistically significant pattern exists—then the data set is said to have zero spatial autocorrelation (Goodchild, 1986). Spatial autocorrelation is measured using a statistic known as Moran's I. Moran's I is similar in interpretation to the Pearson's Product Moment correlation statistic in that both statistics range between -1.0 and 1.0, depending on the degree and direction of correlation. A diagnostic test for spatial autocorrelation using the Moran's Index has a value of 0.001 for OLS which is significant at 0.01 level and a value of 0. 47 for MGWR which is significant at 0.05 level. Finally, all variables are tested for independence and normality results listed in Appendix 1 and do not find the presence of multicollinearity.

7. Results

The OLS model shows that all variables have a significant impact on students' achievement at the 0.05 significance level, except for the percentage of male students and the percentage of low-income students. The focal variable, the amount of personnel spending, has a positive coefficient of 0.08. This means that for each standard deviation increase in school spending, there is an associated 0.08 standard deviation increase in students' mathematics proficiency rates. This finding is consistent with previous scholars' research, which indicates that an increase in per-pupil expenditure leads to an increase in students' academic achievement (Handel & Hanushek, 2022b; Jackson & Mackevicius, 2024). Notably, for students of color, the results indicated a significant negative association with school performance, particularly for

Hispanic/Latino (-0.55, $p < 0.01$), African American (-0.21, $p < 0.01$), and American Indian students (-0.14, $p < 0.01$). Similarly, for English language learners (-0.13, $p < 0.01$) and special education students (-0.25, $p < 0.01$), a significant negative relationship has been detected. All variables are standardized so that the parameter estimates reflect the effect of a one standard deviation change in the variables on the percentage of passing rates. The R^2 of the OLS model is 0.64, which suggests that 64% of the variation in mathematics proficiency rates can be explained by the included variables. The global parameter estimates from the OLS model are presented in Table 3.

While the OLS model provides an overall estimate of the relationship between school expenditure and performance, MGWR adds additional information by explicitly examining the effect of spatial dependence on the relationship between annual personnel spending and its covariates. The MGWR model results, shown in Table 5, indicate a better model fit, improving the R^2 from 0.64 for OLS to 0.772.

In addition, the MGWR model presents a lower AICc value (AICc for OLS is 700 and AICc for MGWR is 648). The Akaike Information Criterion (AIC) is an estimator of prediction error that assesses the quality of a statistical model, particularly for small sample size datasets (Hurvich & Tsai, 1989). The MGWR model assumes that the relationship between factors influencing spending and each school's spending behavior differs by location and by the proximal influences of neighboring schools. The model coefficients of personnel spending are plotted in Figure 4. Each observation in the dataset has its own unique regression equation. By mapping the statistically significant parameters of these individual regressions, regional patterns of spatially varying parameter estimates can easily be identified. Parameters that are statistically significant at the 0.05 level are identified in the graph. Schools represented by red dots (0.29 to 0.70) indicate a positive relationship between school spending and students' achievement; schools with orange dots (-0.13 to 0.29) indicate an inverse relationship; and schools with green dots (-0.45 to -0.13) indicate a negative relationship between school spending and students' achievement. The enhancement of model predictivity provides more comprehensive information of the relationship between school spending and student achievement.
Overall, the MGWR model produces a range of local regression coefficients for the amount of personnel spending, ranging from -0.43 to 0.69, with a local bandwidth of 73. This relatively smaller bandwidth indicates only the spending of nearby schools affects student outcomes, highlighting more localized spatial relationships.

As shown in Figure 4-6, MGWR allows for the mapping of spatially varying parameters. This level of detail is not possible with OLS. For example, in the per-pupil school spending map (Figure 4) areas to the north of the Phoenix area—such as Scottsdale—are statistically significant and positively related to school-level mathematics proficiency rates. Schools in this area display the highest impact of personnel spending on achievement, with a range of 0.29 to 0.70 after controlling students' demographics. In contrast, areas in the southeastern part of the region—such as Mesa—exhibit a negative relationship with educational spending.

Table 3: OLS & MGWR Model Estimates

Independent Variable	OLS Parameters Estimates	MGWR Parameters Estimates	MGWR Bandwidths
Personnel Spending	0.08*	-0.44, 0.67	77.00
Percent of Hispanic/Latino	-0.55**	-1.17, -0.07	365.00
Percent of African American	-0.21**	-0.41, -0.10	49.00
Percent of Students of Other Race Ethnicity	0.10*	0.04, 0.11	148.00
Economics Disadvantaged Students	0.06	0.00, 0.03	157.00
Percent of English Language Learner	-0. 13**	-0.25, -0.20	365.00
Percent of Special Education Students	-0.25**	-0.80, 0.01	59.00
Adjusted R^2	0.64	0.70	
AICc	700.40	648	

In addition, the model shows that the effect of students of color on achievement varies across locations. In Figure 5 and 6, the percentage of Hispanic/Latino students has a local bandwidth of 49, indicating that the proportion of Hispanic/Latino students on campus has a varying effect on students' academic performance. The percentage of African American students has a larger negative effect on achievement in the eastern area compared with the northern area, which consists of more impoverished school districts.

This finding is meaningful as the percentage of students of color at a school is often found to be negatively associated with students' standardized test scores in educational research. A high percentage of students of color is typically associated with lower socioeconomic status within a school. However, results from MGWR show that a high percentage of students of color has a varying effect on achievement. For example, the percentage of Hispanic/Latino students is not necessarily associated with lower academic performance. In Paradise Valley and northern Scottsdale, particularly in local school districts that are served with sufficient resources, students are able to achieve high performance. This finding is significant and provides another perspective for assessing the relationship between students' academic outcomes and their socioeconomic status.

To sum up, MGWR produces a set of local parameter estimates that can be mapped, instead of producing a single global average parameter estimate for each relationship. For instance, the global parameter estimate for the relationship between school performance and the percentage of special education students is significantly negative, and most of the local parameter estimates are also negative. However, there are parts of the region, particularly in north Phoenix and Scottsdale, where there appears to be a positive relationship between the percentage of special education students and performance, holding all else constant. Special education students have traditionally been found to perform worse compared with students without disabilities. Schools in areas like Scottsdale are able to close the achievement gap through sufficient investment in school resources.

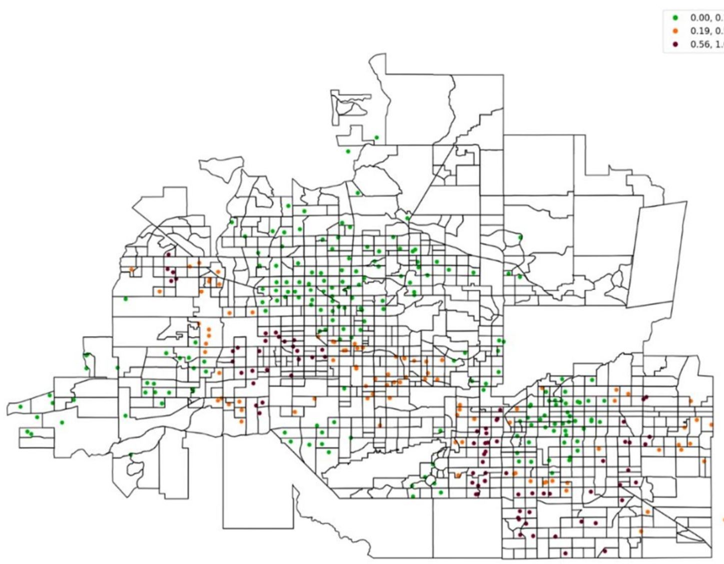

Figure 4 MGWR Parameters Estimates for Percent of Personnel Spending

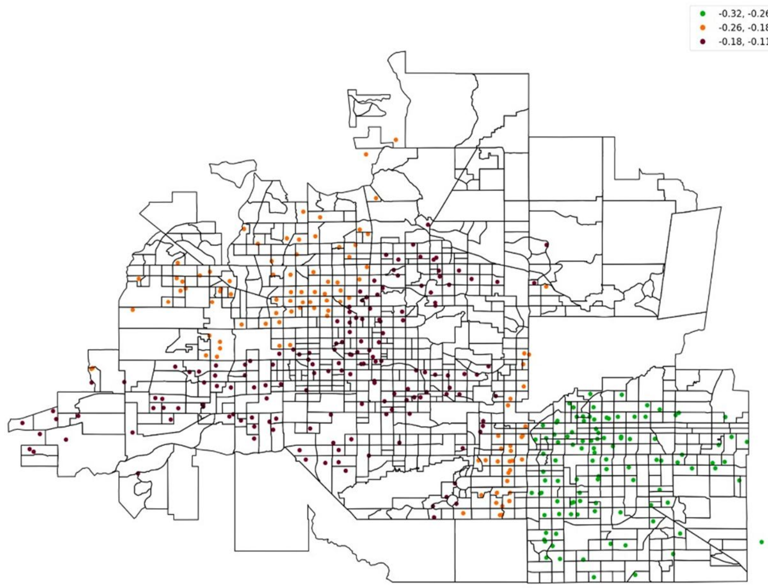

Figure 5 MGWR Parameters Estimates for Percent of African American Students

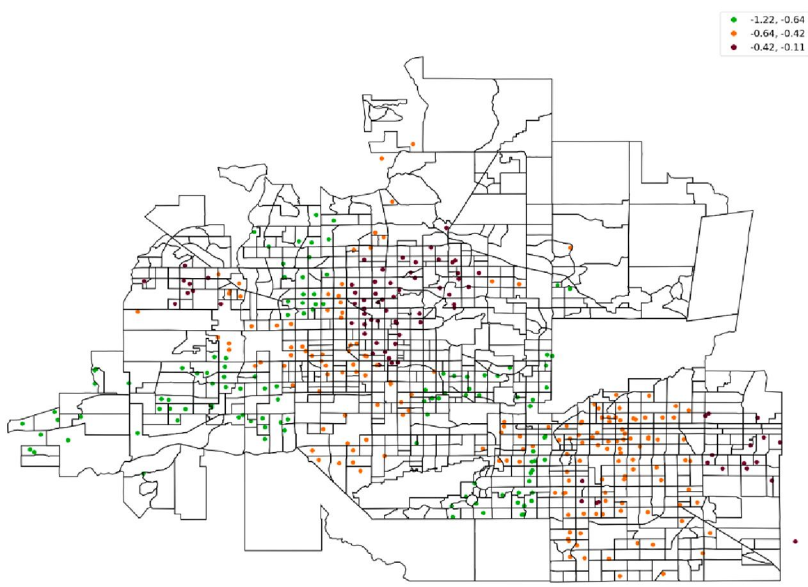

Figure 6 MGWR Parameters Estimates for Percent of Hispanic / Latino Students

8. Conclusion

Education is a driving engine for social mobility. A better understanding of the determinants of school performance is essential to reduce achievement gaps. Previous research has examined student academic performance in relation to school funding and socioeconomic status. Multiscale Geographically Weighted Regression (MGWR) further reveals the spatial heterogeneity of these determinants and highlights significant differences between the northern and southern parts of Maricopa County.

In the Scottsdale school district, which has a higher percentage of White students, higher household income, and higher levels of education, student performance responds positively to increases in school personnel spending. In contrast, in the southern region, where household income and education levels are lower, student performance responds negatively to school spending.

There is also a significant amount of variation in school performance that is not explained by the global regression framework. The global modeling results provide only averages across regions, potentially masking interesting spatial variations in relationships that are illuminated through local analysis (Fotheringham et al., 2017). The maps of parameter surfaces allow for a comprehensive understanding of the stationarity or nonstationary of relationships, revealing dynamics between spending and performance that would not be discovered through traditional OLS analysis.

These findings highlight the importance of adopting location-specific strategies in education funding and policy-making. By recognizing that the impact of school spending varies geographically, policymakers can tailor interventions to address the unique needs of different regions. For instance, increasing personnel spending in affluent areas like Scottsdale may further enhance student achievement, while alternative strategies might be necessary in lower-income southern regions to effectively bridge the achievement gap. Additionally, focusing on factors such as teacher quality in underperforming districts can complement financial investments, leading to more comprehensive improvements in student outcomes. Overall, utilizing MGWR provides a more nuanced and actionable understanding of the factors influencing educational outcomes, paving the way for more effective and equitable education policies.

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Appendix 1

Multicollinearity Check of Variables

Independent Variable	VIF
Personnel Spending	1.17
Percent of Hispanic/Latino	3.41
Percent of African American	1.24
Economics Disadvantaged Students	2.45
Percent of English Language Learner	2.69
Percent of Special Education Students	1.52
Mean VIF	1.80