

Counting the Cost of Human Capital

School Funding Adequacy, Achievement, Attainment and State Economic Growth, 1997–2024

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ABSTRACT

The international literature treats schooling as an investment in human capital and finds high returns to years of schooling, larger returns to measured skills, and strong links between skills and economic growth. U.S. state-level studies, by contrast, often find little relationship between school spending and outcomes. I argue that much of this gap reflects how the investment is measured. Using a 50-state panel collapsed to long-run cross-sections, I compare two measures of K-12 investment: spending per pupil adjusted for regional labor costs, and spending relative to the modeled cost of reaching national-average outcomes, from the School Finance Indicators Database's National Education Cost Model. Controlling for initial income, the cost-adjusted measure predicts higher 8th-grade achievement (about 2.1 NAEP scale points per standard deviation), smaller income-based achievement gaps, and, through achievement and attainment, faster growth in real income and GDP per capita over 1997–2024. A standard deviation of 2003 achievement predicts 1.75 points more adults with a bachelor's degree; a standard deviation of 2009 attainment predicts 0.21 points faster annual real income growth and 0.43 points faster GDP per capita growth. The labor-cost-adjusted measure predicts none of these and, entered jointly with the cost-adjusted measure, carries a negative sign. Scaled to student-level units, the achievement–growth relationship across states falls within the range implied by cross-country estimates. Human capital across states is diverging at the extremes, with implications for national economic and scientific capacity. The estimates are associations; I discuss migration, reverse causality and the embedding of student need in cost measures.

Keywords: human capital; school finance; educational adequacy; education cost functions; economic growth; NAEP; state policy

JEL codes: I22, I24, I26, H75, O47, R11

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Counting the Cost of Human Capital

1. Introduction

Few propositions in economics are better supported than the claim that human capital pays. Across more than a thousand estimates from 139 countries, a year of schooling raises earnings by about 9% (Psacharopoulos & Patrinos, 2018), and causal estimates are higher still (Patrinos & Psacharopoulos, 2025a). Measured skills pay more than years: a standard deviation of test performance is worth about 15% in earnings (Patrinos & Psacharopoulos, 2025b). Cross-country differences in cognitive skills account for a large share of differences in long-run growth (Hanushek & Woessmann, 2012), and once learning is measured directly, human capital explains between one-fifth and one-half of income differences across countries (Angrist, Djankov, Goldberg & Patrinos, 2021).

U.S. policy debates about school funding proceed as if this evidence did not exist. A recent state-level analysis concludes that state spending bears little relationship to student outcomes once state poverty and income are controlled (Reber & Goodman, 2025). That conclusion echoes a long tradition of production-function studies that find weak or inconsistent associations between resources and outcomes (Hanushek, 2003). Yet quasi-experimental studies of school finance reforms consistently find that sustained increases in spending raise achievement, attainment and adult earnings, especially for low-income children (Jackson, Johnson & Persico, 2016; Lafortune, Rothstein & Schanzenbach, 2018; Jackson & Mackevicius, 2024).

This paper argues that a central reason for the disconnect is measurement. Most cross-state analyses treat the investment as spending per pupil, adjusted at most for inflation and regional wages. Such a measure ignores the largest source of variation in what it costs to produce a given level of skills: the needs of the students served. A dollar spent in a state with high child poverty, many English learners and dispersed rural districts buys less human capital than a dollar spent in an affluent, low-need state. Controlling for poverty in a regression does not fix this. It treats need as a confounder to be removed, rather than as a component of cost to be priced into the investment

measure.

I compare two measures of K-12 investment across the 50 states. The first is spending per pupil adjusted for labor costs using the NCES Comparable Wage Index for Teachers. The second is spending relative to the modeled cost of reaching U.S.-average outcomes, from the National Education Cost Model in the School Finance Indicators Database (SFID). I then trace a three-link human capital chain: from investment to 8th-grade achievement, from achievement to adult attainment, and from attainment and achievement to growth in real income and GDP per capita over 1997–2024.

Four findings emerge. First, the cost-adjusted measure predicts achievement, low-income achievement and income-based achievement gaps; the labor-cost-adjusted measure does not. Second, achievement predicts later attainment, and attainment and achievement predict growth, with low-income students' achievement as predictive as the state average. Third, entered jointly, the two investment measures carry opposite signs, so the choice of measure reverses the apparent relationship between school investment and growth. Fourth, once state-level variation is rescaled to student-level units, the achievement–growth relationship across U.S. states falls within the range implied by cross-country estimates. I close by documenting divergence in human capital across states and discussing its implications.

The contribution is threefold. The paper connects the international human capital literature to U.S. school finance by applying the same production logic to states. It shows that the measurement of educational investment, specifically whether the investment is priced against the cost of producing outcomes, materially changes conclusions about whether school funding matters. And it provides a transparent, fully documented set of estimates that can be replicated from public data. The estimates are cross-sectional associations rather than causal effects; Section 10 discusses the main threats to interpretation.

2. Related literature

2.1 Human capital and growth

The modern study of education as investment begins with Becker (1964) and Mincer (1974), who framed schooling as a costly investment that raises lifetime earnings. At the aggregate level, Lucas (1988) placed human capital at the center of endogenous growth, and Mankiw, Romer and Weil (1992) showed that augmenting the Solow model with human capital greatly improves its fit to cross-country income differences. Early growth regressions using years of schooling produced fragile results (Barro, 1991; Pritchett, 2001), which Krueger and Lindahl (2001) attributed in part to measurement error in schooling data.

The shift from years to skills resolved much of this fragility. Hanushek and Kimko (2000) showed that international test scores, as measures of labor-force quality, are strongly related to growth. Hanushek and Woessmann (2012) extended the analysis, finding that a one standard deviation difference in cognitive skills is associated with roughly two percentage points of annual growth over four decades, a relationship robust to instrumental-variable, difference-in-differences and longitudinal designs. An update through 2016 finds a smaller but still large coefficient of 1.3 points (Heller-Sahlgren & Jordahl, 2021). Angrist et al. (2021) harmonized learning data for 164 countries and found that human capital, measured with learning, accounts for one-fifth to one-half of cross-country income differences, and that enrollment growth has outpaced learning gains. Gust, Hanushek and Woessmann (2024) estimate that at least two-thirds of the world's youth lack basic skills (24% in North America), with a present value of lost output exceeding \$700 trillion this century.

Within the United States, Hanushek, Ruhose and Woessmann (2017) apply development accounting to states and find that knowledge capital accounts for 20–30% of variation in state GDP per capita, divided roughly evenly between attainment and cognitive skills. Moretti (2004) documents spillovers from college graduates to the wages of other workers, implying social returns beyond private ones.

2.2 Returns to schooling and skills

Psacharopoulos and Patrinos (2018) review 1,120 estimates from 139 countries over 1950–2014 and find an average private return of 9% per year of schooling; harmonized estimates from 819 household surveys in 139 economies confirm the pattern (Montenegro & Patrinos, 2014). A meta-analysis of 182 instrumental-variable estimates from 55 countries finds an average return of 9.7%, about 38% above OLS (Patrinos & Psacharopoulos, 2025a). Returns to measured skills are larger: a standard deviation of test scores raises earnings by about 15%, roughly one and a half times the return to a year of school (Patrinos & Psacharopoulos, 2025b). Among adults in 23 countries, a standard deviation of numeracy is associated with 18% higher wages, and the U.S. return of 28% is the highest (Hanushek, Schwerdt, Wiederhold & Woessmann, 2015). Human capital can also be lost: pandemic school closures reduced learning by about 0.17 standard deviations on average (Patrinos, Vegas & Carter-Rau, 2022), while U.S. returns to education rose after the pandemic (Patrinos & Rivera-Olvera, 2024). The World Bank’s Human Capital Index Plus places the United States at 252 of a possible 325, below the high-income average (World Bank, 2026; Stacy et al., 2026).

2.3 Does school spending matter?

Education production-function studies have long reported weak associations between resources and outcomes (Hanushek, 2003), although Card and Krueger (1992) found that state school quality predicted the returns to schooling of the cohorts educated there. Quasi-experimental studies exploiting court-ordered and legislative school finance reforms find consistent positive effects. Jackson, Johnson and Persico (2016) find that a 10% increase in per-pupil spending sustained over all 12 school years raises completed education by 0.27 years and adult wages by 7.25%, with larger effects for low-income children. Lafortune, Rothstein and Schanzenbach (2018) find that post-1990 reforms raised achievement in low-income districts. Pooling evaluations, Jackson and Mackevicius (2024) estimate that \$1,000 more per pupil sustained for four years raises test scores by 0.032 standard deviations and college-going by 2.8 percentage points.

Cross-state analyses remain mixed. Reber and Goodman (2025) find little relationship between state spending and outcomes after controlling for poverty and income, using spending adjusted for inflation and regional wages; Weber (2025) critiques the design.

2.4 Measuring the cost of educational outcomes

A separate literature estimates education cost functions: the spending required to reach a given outcome level as a function of input prices, scale and student needs (Downes & Pogue, 1994; Duncombe & Yinger, 2005). These models consistently find that children in poverty, English learners and students with disabilities require substantially more resources to reach common outcomes. The SFID’s National Education Cost Model applies this approach nationally, producing for each district and state the per-pupil cost of reaching U.S.-average outcomes and the gap between that cost and actual spending. Baker (2018) and Baker and Losen (2026) show that conclusions about the equity of school funding change markedly when spending is measured against cost; Baker (2026a, 2026b) illustrates how spending-versus-outcome comparisons mislead when cost is ignored. This paper brings that measurement approach to the human capital and growth question.

3. Conceptual framework

3.1 Pricing the investment

Let a state’s schools produce achievement Y with per-pupil spending E . Following the education cost-function literature, the minimum per-pupil spending required to reach outcome level Y^* is

$$C_s(Y^*) = c(Y^*, W_s, S_s, N_s),$$

where W is the price of educator labor, S captures scale and density, and N is the needs of the student population (poverty, English learners, disability). Define adequacy as the ratio of actual to required spending, $A_s = E_s / C_s(Y^*)$. Adequacy is the human capital analogue of an investment rate measured in real terms: it asks how much of the investment needed to produce a benchmark

level of skills a state actually makes.

The conventional labor-cost-adjusted measure is E_s / W_s . Taking logs,

$$\ln(E_s / W_s) = \ln A_s + \ln(C_s / W_s).$$

The second term is a cost index net of wages, driven by scale and, above all, student need. Labor-cost-adjusted spending therefore mixes the true investment rate with a need index that is itself negatively related to outcomes. Two implications follow. Alone, the wage-adjusted measure should be a weak predictor of outcomes, because its two components push in opposite directions. Entered jointly with adequacy, its coefficient captures the cost index and should be negative. Both patterns appear in the data.

3.2 The human capital chain

I treat the link from investment to growth as a chain of three reduced-form relationships, each estimated across states with a control for initial income:

1. **Investment** → **skills**. Adequacy raises achievement, Y_s , and especially the achievement of low-income students, for whom need-driven cost is highest.
2. **Skills** → **attainment**. Higher achievement raises the share of each cohort that completes college, B_s , with a lag as cohorts reach adulthood.
3. **Human capital** → **growth**. Attainment and achievement raise the growth of income and output, g_s , as in the cross-country literature.

The timing is imperfect: the achievement measures predate the adequacy measure, so the chain is assembled from overlapping cohorts rather than estimated as a single causal path. The aim is to test whether each link holds in the direction the human capital literature predicts, and whether the conclusion depends on how investment is measured.

4. Data and measures

The unit of analysis is the state (the District of Columbia is excluded). Data come from five public sources; Appendix Table A1 gives full definitions.

Economic outcomes. Real GDP by state (chained 2017 dollars), personal income per capita and population are from the Bureau of Economic Analysis via FRED. Annualized growth over 1997–2024 is $100 \times [(X_{2024} / X_{1997})^{(1/27)} - 1]$. Personal income is deflated with the CPI-U. The control for initial conditions is log real personal income per capita in 1997.

Labor-cost-adjusted spending. SFID modeled current spending per pupil for a district at 10% child poverty, converted to 2023 dollars, averaged over 1993–2002 and divided by the state value of the NCES ACS Comparable Wage Index for Teachers (CWIFT). This mirrors the wage-adjusted measure common in cross-state work.

Adequacy. From the SFID National Education Cost Model (NECM), the log ratio of actual per-pupil spending to the predicted cost of reaching U.S.-average outcomes, averaged over 2009–13, for all districts and for the highest-poverty fifth of districts in each state. The 2009–13 window is the earliest available and precedes the 2019 and 2024 achievement outcomes; Appendix A of the companion policy paper shows results for later windows. I also report the 2021–23 per-pupil adequacy gap.

Achievement. State mean NAEP grade 8 scale scores in mathematics and reading (averaged) for 2003, 2013, 2019 and 2024, for all students and for students eligible for the National School Lunch Program, and the gap between non-eligible and eligible students.

Attainment. The share of adults 25 and older with a bachelor’s degree or higher, from the American Community Survey, for 2009 and 2024 (via FRED) and 2019–23 (Table B15003), along with the graduate-degree share.

Table 1 summarizes the main measures. States vary widely in adequacy: in 2009–13, actual spending ranged from about half of required cost (Mississippi, 51%) to more than one and a half times it (Connecticut, 174%). They vary much less in average achievement: one standard deviation

of state 2003 NAEP is 6.5 points.

Table 1. Descriptive statistics, 50 states

Measure	n	Mean	SD	Min	Max
Real GDP per capita growth, 1997–2024 (%/yr)	50	1.36	0.51	0.29	3.15
Real personal income per capita growth, 1997–2024 (%/yr)	50	1.40	0.31	0.79	2.32
Real personal income per capita, 1997 (2024 \$)	50	48,613	6,681	37,558	68,430
Wage-adjusted spending per pupil, 1993–2002 (2023 \$)	49	11,704	2,020	7,991	15,718
Adequacy, $\ln(\text{actual} \div \text{required})$, 2009–13	48	0.03	0.31	−0.67	0.80
Adequacy, highest-poverty fifth, 2009–13	48	−0.34	0.38	−1.23	0.69
Adequacy gap per pupil, 2021–23 (\$)	47	693	4,464	−9,292	10,876
NAEP grade 8, 2003 (math & reading)	50	270.1	6.5	257.4	279.7
NAEP grade 8, 2019	50	271.9	5.1	260.2	283.8
NAEP grade 8, low-income, 2019	50	258.0	3.4	248.3	264.3
NAEP gap, low-income vs. other, 2019	50	26.0	4.0	17.0	34.3
Adults with BA+, 2009 (%)	50	27.2	4.7	17.3	38.2
Adults with BA+, 2019–23 (%)	50	34.0	5.4	23.3	46.6
Change in BA+, 2009–2024 (pts)	50	8.6	1.4	6.2	12.0

Sources: BEA and BLS via FRED; SFID 2026; NCES; NAEP Data Service; ACS. Hawaii lacks the SFID spending measure; Alaska and Hawaii lack adequacy; Vermont also lacks the 2021–23 gap.

5. Empirical strategy

Each link is estimated by OLS across states:

$$y_s = \alpha + \beta \cdot z(x_s) + \gamma \cdot z(\ln \text{Income}_{s,1997}) + \varepsilon_s,$$

where y is the outcome, $z(\cdot)$ denotes standardization across the states with data, and the 1997 income control absorbs initial differences in prosperity and, for the growth models, conditional convergence. β is the change in the outcome per standard deviation of the predictor. Standard errors are heteroskedasticity-robust (HC1); Section 7 reports HC3 errors, which perform better in small samples.

To contrast the two measures of investment, I also estimate

$$y_s = \alpha + \beta_1 \cdot z(A_s) + \beta_2 \cdot z(\ln E_s/W_s) + \gamma \cdot z(\ln \text{Income}_{s,1997}) + \varepsilon_s.$$

Section 3.1 predicts $\beta_1 > 0$ and $\beta_2 < 0$.

With 47–50 observations, the analysis is necessarily parsimonious. I add one control at a time rather than many, and I check sensitivity in three ways: dropping resource-dependent states (AK, ND, WY, WV, NM, OK, LA), whose GDP swings with commodity prices; dropping the Northeast (CT, ME, MA, NH, RI, VT, NJ, NY, PA), which combines high spending and slow growth; and replacing state income with the income of public-school families. I also report leave-one-out ranges for every key coefficient. Figures show added-variable plots, in which both axes are residualized on the income control, so each fitted slope equals β .

6. Results

6.1 Link 1: investment and achievement

Table 2 shows that adequacy predicts 8th-grade achievement in every year, while labor-cost-adjusted spending does not. A standard deviation of adequacy in 2009–13 is associated with 2.1 more NAEP points in 2019, about 0.4 of the cross-state standard deviation. For low-income students the association is 1.1 points, a third of their cross-state spread, and the gap between low-income and other students is 1.5 points smaller. Adequacy in the highest-poverty districts is the strongest predictor of the gap (–1.9 points).

Table 2. Investment and grade 8 NAEP (scale points per SD, controlling for 1997 income)

Predictor	2013	2019	2024	Low-income, 2019	Gap, 2019
Wage-adjusted spending, 1993–2002	+1.2 (0.9)	+0.5 (0.8)	+0.0 (0.9)	+0.2 (0.6)	–1.0 [†] (0.6)
Adequacy, all districts, 2009–13	+3.3** (0.8)	+2.1** (0.6)	+1.8* (0.7)	+1.1* (0.5)	–1.5** (0.5)
Adequacy, high-poverty districts, 2009–13	+2.8** (0.8)	+1.7** (0.6)	+1.4* (0.7)	+1.3* (0.5)	–1.9** (0.4)

NAEP math and reading averaged. HC1 standard errors in parentheses. ** p<.01, * p<.05, [†] p<.10. n = 48–49.

6.2 Link 2: achievement and attainment

States whose 8th graders scored a standard deviation higher on 2003 NAEP have 1.75 percentage points more adults with a bachelor's degree in 2019–23 and added 0.49 points more BA holders between 2009 and 2024, the period in which those cohorts reached adulthood (Table 3). Low-income students' 2003 scores show the same pattern. Neither investment measure predicts attainment directly once income is controlled, consistent with investment operating through achievement. No K-12 measure predicts the graduate-degree share.

Table 3. Achievement and adult attainment (percentage points per SD)

Predictor	BA+, 2019–23	Change in BA+, 2009–24	Graduate degree share	BA+, excl. resource states
NAEP grade 8, 2003	+1.75** (0.56)	+0.49** (0.18)	+0.34 (0.36)	+1.88** (0.62)
NAEP grade 8 math, low-income, 2003	+1.24** (0.43)	+0.27 [†] (0.16)	+0.02 (0.26)	+1.48** (0.45)
Adequacy, 2009–13 (direct)	+0.91 (0.76)	+0.07 (0.24)	+0.38 (0.37)	+1.95* (0.76)
Wage-adjusted spending (direct)	–0.65 (0.67)	–0.23 (0.24)	–0.14 (0.32)	–0.17 (0.77)

Controls for 1997 income. HC1 standard errors. n = 48–50 (42–43 excluding resource states).

6.3 Link 3: human capital and growth

Table 4 and Figure 1 show the growth relationships. A standard deviation more adults with a BA in 2009 is associated with 0.21 points faster annual real income growth and 0.43 points faster GDP per capita growth over 1997–2024. A standard deviation of 2003 achievement is associated with 0.12 and 0.23 points. Low-income students' achievement is as predictive as the state average and, unlike the all-student measure, remains significant when resource states are excluded. Adequacy predicts income growth (0.15 points) but not GDP growth. Labor-cost-adjusted spending predicts slower GDP growth, largely reflecting the slow-growing, high-spending Northeast against fast-growing, low-spending Sunbelt and energy states.

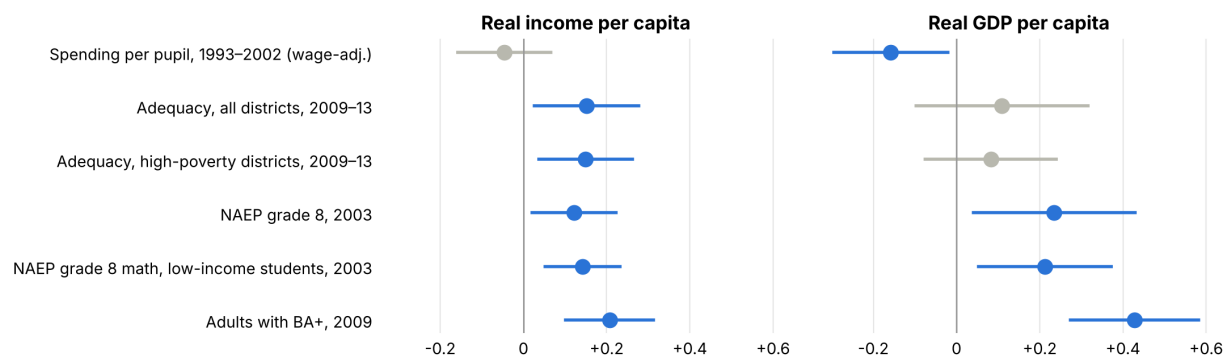
Table 4. Human capital, investment and growth, 1997–2024 (percentage points per year per SD)

Predictor	Income growth	GDP per capita growth	Income growth, excl. resource states	GDP per capita growth, excl. resource states
Wage-adjusted spending, 1993–2002	−0.05 (0.06)	−0.16* (0.07)	−0.09 [†] (0.05)	−0.14 [†] (0.08)
Adequacy, all districts, 2009–13	+0.15* (0.06)	+0.11 (0.11)	+0.10 (0.06)	+0.10 (0.11)
Adequacy, high-poverty districts, 2009–13	+0.15** (0.06)	+0.08 (0.08)	+0.11* (0.06)	+0.09 (0.08)
NAEP grade 8, 2003	+0.12* (0.05)	+0.23* (0.10)	+0.09 (0.06)	+0.16 [†] (0.09)
NAEP grade 8 math, low-income, 2003	+0.14** (0.05)	+0.21** (0.08)	+0.10* (0.05)	+0.16* (0.07)
Adults with BA+, 2009	+0.21** (0.05)	+0.43** (0.08)	+0.24** (0.04)	+0.35** (0.06)

Each cell is a separate regression controlling for 1997 income. HC1 standard errors. n = 48–50 (42–43 excluding resource states).

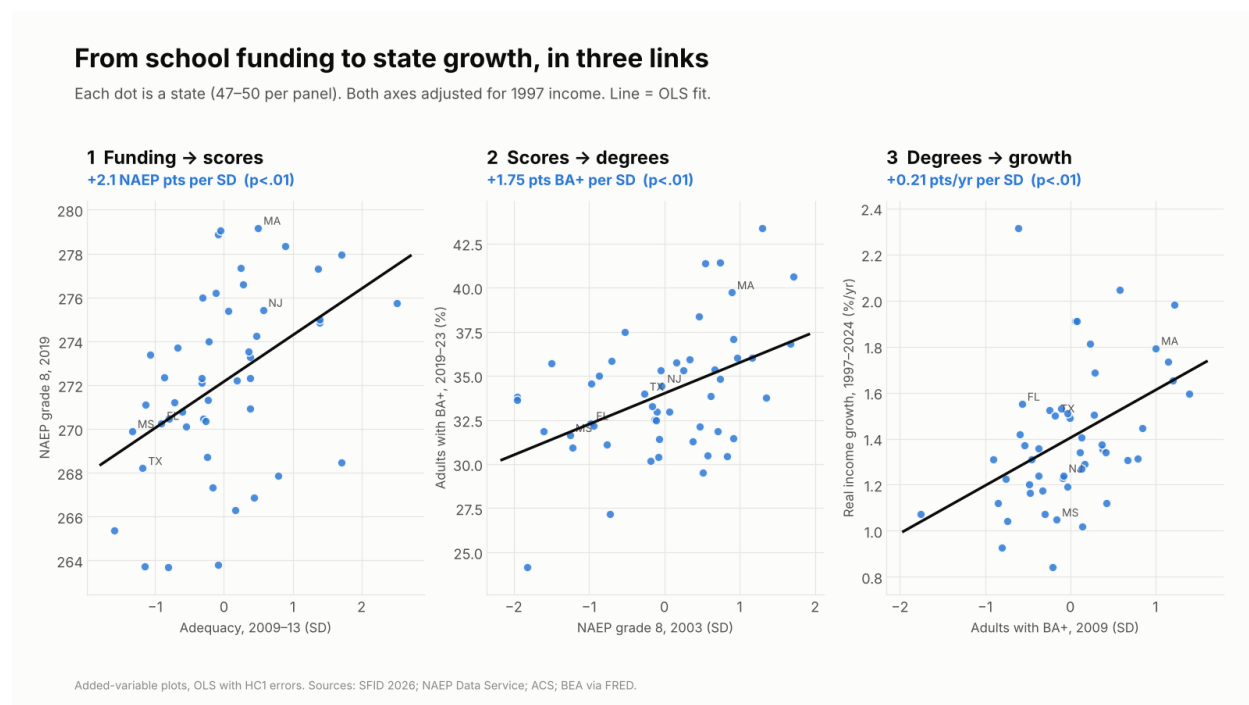
Figure 1. Per-SD associations with annual growth in real income per capita and real GDP per capita, 1997–2024, controlling for 1997 income. Blue: 95% interval excludes zero.

Achievement, adequacy and attainment predict faster growth; spending alone does not
Change in annual growth rate, 1997–2024 (pct. pts), per 1 SD, controlling for 1997 income; 95% CI



Blue = 95% CI excludes zero. 47–50 states; robust (HC1) standard errors. Replicated from state_growth3.csv.

Figure 2. The three links as added-variable plots. Each dot is a state; both axes are net of 1997 income, so each slope equals the coefficient in Tables 2–4.



6.4 The measurement contrast

Table 5 enters both investment measures together. As Section 3.1 predicts, adequacy is positive and labor-cost-adjusted spending is negative in every model. For real income growth, a standard deviation of adequacy is associated with 0.39 points faster annual growth and a standard deviation of wage-adjusted spending with 0.31 points slower growth. For BA attainment the coefficients are +2.75 and –2.42 points. Figure 3 illustrates the contrast for achievement: the same states and the same scores yield a flat relationship with wage-adjusted spending and a clearly positive one with adequacy.

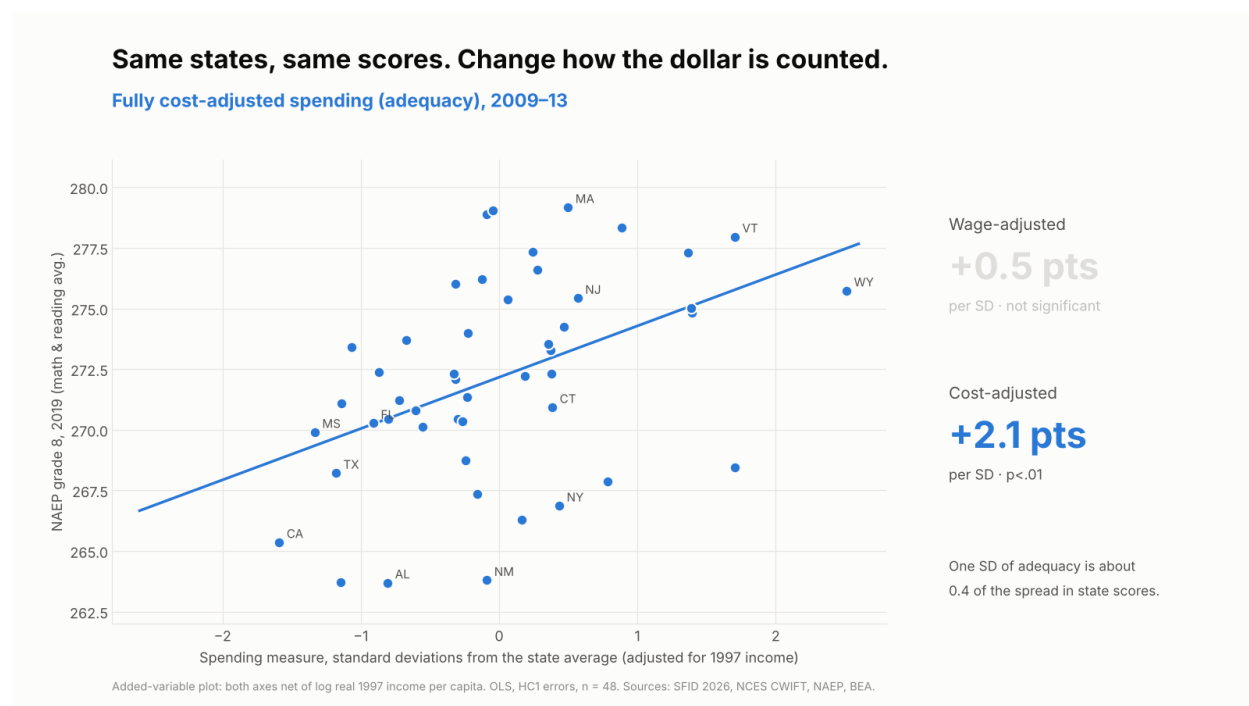
7. Robustness and sensitivity

Small-sample inference and influential states. Table 6 reports, for each key coefficient, p-values under HC1 and HC3 errors and the range of the coefficient when each state is dropped in turn. Every key estimate remains significant at the 5% level under HC3, and no single state reverses a sign or

Table 5. Both investment measures in the same model (per SD, controlling for 1997 income)

Outcome	Wage-adjusted spending	Adequacy
Real income growth, 1997–2024 (pts/yr)	−0.31** (0.05)	+0.39** (0.05)
Real GDP per capita growth (pts/yr)	−0.45** (0.11)	+0.45** (0.13)
Adults with BA+, 2019–23 (pts)	−2.42** (0.55)	+2.75** (0.90)
NAEP grade 8, 2019	−1.5 (1.0)	+3.3** (0.8)
NAEP grade 8 math, low-income, 2019	−1.7 [†] (0.9)	+2.6** (0.8)

HC1 standard errors. n = 48.

Figure 3. 2019 grade 8 NAEP against adequacy (2009–13), both net of 1997 income. Against wage-adjusted spending, the slope is +0.5 (not significant); against adequacy, +2.1 (p<.01).

moves an estimate to zero. The most influential states vary by link (West Virginia for achievement, Nevada for attainment, California and Wyoming for growth) and none drives the results.

Table 6. Inference and leave-one-out sensitivity for key coefficients (per SD, controlling for 1997 income)

Outcome	Predictor	b	p (HC1)	p (HC3)	Leave-one-out range	n
NAEP grade 8, 2019	Adequacy, all districts	+2.12	<.001	.001	+1.91 to +2.53	48
NAEP low-income, 2019	Adequacy, all districts	+1.15	.022	.035	+0.93 to +1.44	48
NAEP gap, 2019	Adequacy, high-poverty	-1.92	<.001	<.001	-2.06 to -1.81	48
BA+, 2019–23	NAEP 2003	+1.75	.002	.003	+1.43 to +1.92	50
Change in BA+, 2009–24	NAEP 2003	+0.49	.005	.006	+0.41 to +0.55	50
Income growth	BA+ 2009	+0.21	<.001	<.001	+0.18 to +0.24	50
GDP per capita growth	BA+ 2009	+0.43	<.001	<.001	+0.38 to +0.46	50
Income growth	NAEP 2003	+0.12	.018	.029	+0.10 to +0.16	50
GDP per capita growth	NAEP 2003	+0.23	.018	.029	+0.18 to +0.31	50
Income growth	NAEP low-income, 2003	+0.14	.002	.003	+0.12 to +0.17	50
GDP per capita growth	NAEP low-income, 2003	+0.21	.009	.016	+0.15 to +0.26	50
Income growth	Adequacy, all districts	+0.15	.018	.036	+0.11 to +0.19	48
GDP per capita growth	Wage-adjusted spending	-0.16	.023	.038	-0.19 to -0.11	49

Joint human capital models. Entering 2003 achievement and 2009 attainment together, attainment carries most of the association with growth (income: BA +0.16, $p=.02$; NAEP +0.08, $p=.18$; GDP per capita: BA +0.34, $p<.001$; NAEP +0.15, $p=.14$). Adding adequacy to that model, its direct coefficient falls to +0.12 for income growth ($p=.14$) and -0.04 for GDP growth ($p=.59$), while attainment remains significant. This pattern is what the chain implies: once the skills and attainment that investment produces are held constant, little direct association between investment and growth remains. Attainment and initial income are highly correlated ($r = 0.78$), so the attainment coefficients should be read as conditional on a strong correlate of initial prosperity.

Sample and control changes. The adequacy–achievement link holds with the Northeast excluded (+2.2 points, $n = 39$) and when the income of public-school families replaces state income as the control (+1.2 overall, $p\approx.08$; +1.2 for low-income students, $p<.05$). The low-income achievement–growth links hold with resource states excluded (Table 4).

Timing. Using the full 2009–23 adequacy series, or 2014–18 or 2019–23 averages, yields estimates as large or larger; state adequacy positions are highly persistent ($r = 0.92$ between 2009–

13 and 2019–23). These window estimates are computed from the SFID workbook and reported in the companion policy paper (Baker, 2026c).

Levels versus gains. Adequacy predicts achievement levels, not gains: from 2003 to 2019, less adequately funded states gained more on NAEP (about 2 points per SD of underfunding), reflecting catch-up from low bases and accountability and reading reforms, with Mississippi the leading example.

8. Calibration against international estimates

Are the state estimates plausible in magnitude? Cross-country growth estimates are expressed per student-level standard deviation of test scores, while the estimates here are per standard deviation of state means, which vary far less. Grade 8 NAEP mathematics spans about 100 points between the 10th and 90th percentiles, implying a student-level standard deviation of roughly 39 points under normality. One state-level standard deviation on 2003 NAEP (6.45 points) is therefore about 0.17 student standard deviations.

The per-dollar figure divides the 2019 NAEP coefficient, converted to student SD units, by the cross-state standard deviation of the 2021–23 adequacy gap (about \$4,500 per pupil). All conversions are approximate: state NAEP here averages math and reading, while the student-level spread uses mathematics; international estimates use a PISA-scale standard deviation of about 100 points.

Two conclusions follow. The achievement–growth association across U.S. states is the size the cross-country literature predicts: +0.23 points a year compounds to a GDP per capita level about 6% higher over 27 years. And the funding–achievement association is, per dollar, roughly a third of the pooled causal estimate from U.S. school finance evaluations. Even if student need inflates the cross-state funding coefficient, the coefficient is not implausibly large.

9. Divergence across states

If human capital drives growth and investment drives human capital, the persistence of adequacy gaps matters for the trajectory of the states, not only their levels. Three patterns suggest divergence

Table 7. State estimates in international units

Relationship	International or causal benchmark	Implied for one state SD	This paper
Achievement → GDP per capita growth	+1.86 pts/yr per student SD (Hanushek & Woessmann); +1.3 (Heller-Sahlgren & Jordahl, 2021)	+0.22 to +0.31 pts/yr	+0.23 pts/yr (95% CI 0.04 to 0.43)
Achievement → earnings	+15% per SD (Patrinos & Psacharopoulos, 2025b); +28% per SD of U.S. adult numeracy (Hanushek et al., 2015)	+2.5% to +4.6%	+0.12 pts/yr real income growth, about 3.3% after 27 years
Spending → achievement	+0.032 SD per \$1,000 per pupil for four years (Jackson & Mackevicius, 2024)	—	About +0.012 SD per \$1,000 of adequacy gap
Human capital → income differences	One-fifth to one-half across countries (Angrist et al., 2021); 20–30% across U.S. states (Hanushek, Ruhose & Woessmann, 2017)	—	Attainment and achievement predict growth conditional on initial income

at the extremes.

Table 8. Indicators of divergence

Indicator	Earlier	Later
BA+ share, five most-educated states	36.0% (2009)	46.1% (2024)
BA+ share, five least-educated states	19.6% (2009)	26.8% (2024)
Gap between them	16.4 pts	19.3 pts
GDP per capita, Massachusetts ÷ Mississippi	1.63 (1997)	2.15 (2024)
Personal income per capita, Massachusetts ÷ Mississippi	1.61 (1997)	1.84 (2024)

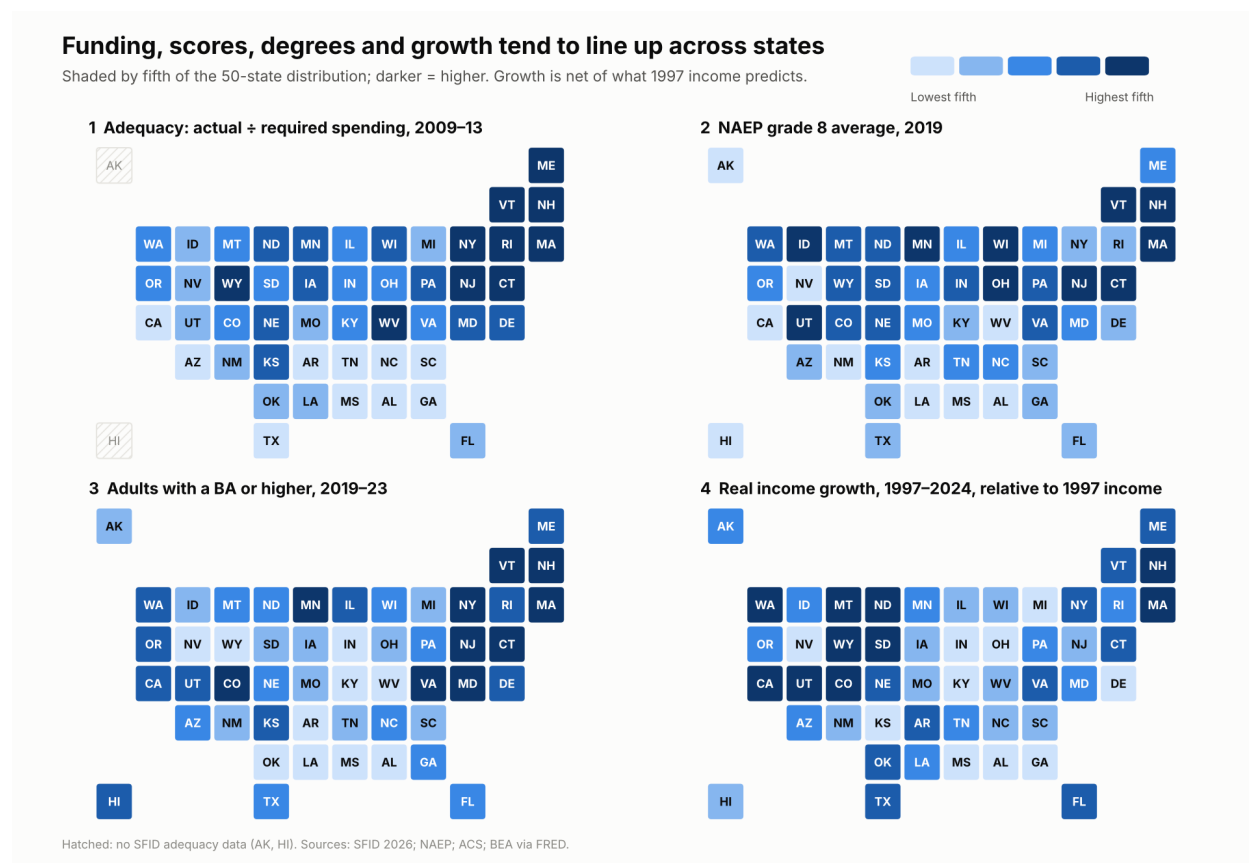
Sources: ACS and BEA via FRED. Five-state averages are unweighted and identified separately in each year.

First, attainment is diverging: states with more college graduates in 2009 added more by 2024 ($r = 0.45$ between the 2009 level and the 2009–2024 change). Second, while the overall dispersion of log GDP per capita across states barely changed between 1997 and 2024 (standard deviation 0.18 in both years), the extremes moved apart, consistent with the decline in regional income convergence documented by Ganong and Shoag (2017). Third, the achievement gap between the highest-

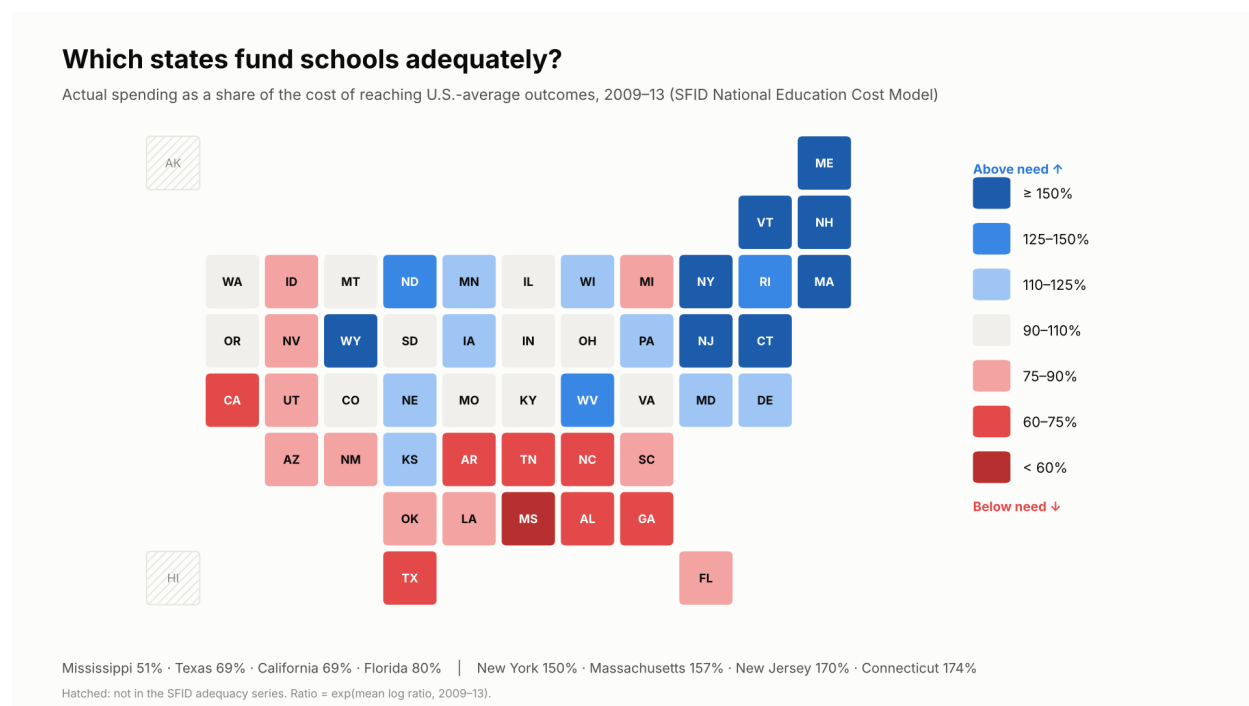
and lowest-performing states is international in scale. In the 2011 NAEP–TIMSS linking study, Massachusetts’s 8th graders scored 561 in mathematics, behind only five of 47 education systems, while Alabama scored 466, statistically indistinguishable from Turkey and Armenia (NCES, 2013). The 95-point difference approaches a full international standard deviation, a gap associated across countries with 1.3 to 1.9 points of annual growth.

The funding gaps that underlie these patterns are persistent. Adequacy positions correlate at 0.92 across a decade, and Mississippi, at about half of required spending in 2009–13, remained about \$9,300 per pupil short in 2021–23 and \$25,100 short in its highest-poverty districts.

Figure 4. States shaded by fifth of the 50-state distribution on adequacy (2009–13), NAEP (2019), BA attainment (2019–23) and real income growth relative to that predicted by 1997 income. Hatched: no adequacy data.



The pattern is not uniform, and California is an important exception to the persistence of positions. California ranked 45th of 48 states on adequacy in 2009–13 (69% of required spending) but was near the middle of the states on the 2021–23 adequacy gap (23rd of 47). In the author’s

Figure 5. Actual spending as a share of NECM required spending, 2009–13.

analyses, its highest-poverty districts rose from 65% to 79% of adequate funding between 2009 and 2024, most of it after the Local Control Funding Formula began phasing in after 2013, although they remain about \$5,600 per pupil short (Baker, 2026d). California’s starting point reflects the 1978 tax revolt, Proposition 13, which capped property taxes at 1% of assessed value and cut the local revenue that had supplied about two-thirds of school funding (EdSource, n.d.). The California case suggests that positions can change when states make sustained, need-targeted investments.

These patterns do not imply that lagging states will fall to developing-country income levels; Mississippi’s GDP per capita of about \$41,300 in 2024 remains far above most of the world’s, supported by a national labor market and federal transfers. They do imply that, on skills, the lowest-performing states already resemble upper-middle-income countries while the highest-performing states compete with the leading Asian systems. Because knowledge-intensive industries and scientific talent concentrate where human capital is deep, persistent investment gaps are likely to compound.

10. Discussion and conclusion

10.1 Interpretation and limitations

The estimates are cross-sectional associations across 47–50 states, and four threats to causal interpretation deserve emphasis.

Migration. College graduates move toward high-wage labor markets, so a state’s adult attainment reflects whom it attracts as well as whom it educates. Cross-state associations will overstate the payoff to schooling for net importers of talent and understate it for exporters. The 2009–2024 change in attainment, which partly reflects a state’s own cohorts reaching adulthood, is a cleaner measure, and it too is predicted by earlier achievement.

Reverse causality and common causes. Faster-growing states can afford more adequate funding, and the same civic and economic conditions may produce both strong schools and strong growth. Adequacy is measured in 2009–13, inside the 1997–2024 growth window. The 1997 income control removes part of this concern, not all of it.

Need embedded in cost. NECM required cost is estimated from a cost function that links spending to outcomes conditional on student need. Needier states have higher required costs and, for the same reasons, lower outcomes, so adequacy carries some of the influence of need. This could inflate the adequacy–achievement association. The per-dollar calibration in Section 8, which places that association below causal estimates, suggests the inflation is limited.

Timing and industry mix. Students schooled in the 1990s and 2000s are only now a large share of the workforce, so a 27-year window captures the early part of any payoff. Energy-producing states’ output swings with commodity prices; the main human capital–growth relationships hold when they are excluded.

The strongest causal evidence comes from within-state variation in funding driven by school finance reforms (Jackson et al., 2016; Lafortune et al., 2018; Jackson & Mackevicius, 2024), and from the international finding that causal returns to schooling exceed OLS estimates (Patrinos & Psacharopoulos, 2025a). Both point in the same direction as the associations reported here. Natural

extensions include an event-study design exploiting the timing of state finance reforms and a cohort-aligned design linking adequacy at ages 6–17 to adult outcomes by state of birth.

10.2 Conclusion

The international human capital literature and the U.S. school finance debate have largely proceeded on separate tracks. This paper brings them together. When investment in schooling is measured against the cost of producing a common level of skills, the cross-state evidence lines up with the global evidence: investment predicts achievement, achievement predicts attainment, and attainment and achievement predict growth, in magnitudes consistent with cross-country estimates. When investment is measured as wage-adjusted spending, the relationships vanish or reverse. Conclusions that school spending does not matter across states are, to a large degree, artifacts of measuring the investment without its cost.

The stakes are national. States supply most K-12 funding, adequacy positions are persistent, and human capital is diverging at the extremes. A country whose scientific and economic capacity depends on skilled workers cannot draw them from a handful of states. Sustained, need-based state investment in human capital, measured against what it costs to build it, is central to the nation's long-run prosperity.

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Appendix

Table A1. Variable definitions and sources

Variable	Construction	Source	Years
Real GDP per capita growth	$100 \times [(GDP \text{ per capita } 2024 \div GDP \text{ per capita } 1997)^{(1/27)} - 1]$; real GDP in chained 2017 dollars $\div$ population	BEA via FRED ([ST]RGSP, [ST]POP)	1997–2024
Real personal income per capita growth	Same formula; 1997 income converted to 2024 dollars with CPI-U	BEA via FRED ([ST]PCPI); BLS CPIAUCSL	1997–2024
Initial income (control)	Log real personal income per capita, 1997 (2024 \$), standardized	BEA, BLS via FRED	1997
Wage-adjusted spending	SFID modeled current spending per pupil at 10% child poverty, 2023 dollars, averaged 1993–2002, $\div$ state ACS-CWIFT; logged, standardized	SFID 2026; NCES EDGE ACS-CWIFT 2022	1993–2002
Adequacy, all districts	Mean of $\ln(\text{actual per-pupil spending} \div \text{NECM predicted cost of U.S.-average outcomes})$, state totals; standardized	SFID NECM	2009–13
Adequacy, high-poverty districts	Same, highest-poverty fifth of districts	SFID NECM	2009–13

Variable	Construction	Source	Years
Adequacy gap	Mean NECM funding gap per pupil (actual – required)	SFID NECM	2021–23
NAEP grade 8	Mean of state math and reading scale scores	NAEP Data Service	2003, 2013, 2019, 2024
NAEP low-income	State mean score of students eligible for the National School Lunch Program	NAEP Data Service	2003, 2019
NAEP gap	Non-eligible minus eligible mean score	NAEP Data Service	2019
Adults with BA+	Share of adults 25+ with a bachelor's degree or higher	ACS via FRED (2009, 2024); ACS 5-year Table B15003 (2019–23)	2009–2024
Graduate degree share	Share of adults 25+ with a master's, professional or doctoral degree	ACS Table B15003	2019–23
Public-school family income (robustness)	Log income of families with children in public schools, standardized	Analysis file	—

Table A2. Full results (per SD of predictor; all models control for standardized log real 1997 income; HC1 standard errors)

Model	Outcome	Predictor	b	SE	95% CI	p	n	R ²
1	NAEP grade 8, 2019	Wage-adjusted spending	+0.50	0.77	–1.00 to +2.00	.513	49	0.24
1	NAEP grade 8, 2019	Adequacy, all	+2.12	0.58	+0.99 to +3.25	<.001	48	0.43
1	NAEP grade 8, 2019	Adequacy, high-poverty	+1.75	0.57	+0.63 to +2.87	.002	48	0.40
1	NAEP low-income, 2019	Wage-adjusted spending	+0.19	0.56	–0.90 to +1.29	.731	49	0.00
1	NAEP low-income, 2019	Adequacy, all	+1.15	0.50	+0.16 to +2.13	.022	48	0.10
1	NAEP low-income, 2019	Adequacy, high-poverty	+1.30	0.54	+0.24 to +2.37	.017	48	0.14
1	NAEP gap, 2019	Wage-adjusted spending	–1.03	0.57	–2.15 to +0.10	.073	49	0.33
1	NAEP gap, 2019	Adequacy, all	–1.48	0.53	–2.51 to –0.45	.005	48	0.38
1	NAEP gap, 2019	Adequacy, high-poverty	–1.92	0.38	–2.67 to –1.17	<.001	48	0.46
2	BA+, 2019–23	NAEP 2003	+1.75	0.56	+0.65 to +2.84	.002	50	0.65

Model	Outcome	Predictor	b	SE	95% CI	p	n	R ²
2	BA+, 2019–23	NAEP low-income 2003	+1.24	0.43	+0.39 to +2.09	.004	50	0.61
2	BA+, 2019–23	Adequacy, all	+0.91	0.76	−0.58 to +2.41	.232	48	0.61
2	BA+, 2019–23	Wage-adjusted spending	−0.65	0.67	−1.97 to +0.66	.332	49	0.57
2	Change in BA+, 2009–24	NAEP 2003	+0.49	0.18	+0.15 to +0.84	.005	50	0.15
2	Change in BA+, 2009–24	NAEP low-income 2003	+0.27	0.16	−0.04 to +0.59	.085	50	0.08
2	Change in BA+, 2009–24	Adequacy, all	+0.07	0.24	−0.39 to +0.53	.777	48	0.06
2	Change in BA+, 2009–24	Wage-adjusted spending	−0.23	0.24	−0.69 to +0.24	.335	49	0.06
3	Income growth	Wage-adjusted spending	−0.05	0.06	−0.16 to +0.07	.424	49	0.07
3	Income growth	Adequacy, all	+0.15	0.06	+0.03 to +0.28	.018	48	0.22
3	Income growth	Adequacy, high-poverty	+0.15	0.06	+0.04 to +0.26	.009	48	0.23
3	Income growth	NAEP 2003	+0.12	0.05	+0.02 to +0.22	.018	50	0.19
3	Income growth	NAEP low-income 2003	+0.14	0.05	+0.05 to +0.23	.002	50	0.26
3	Income growth	BA+ 2009	+0.21	0.05	+0.10 to +0.31	<.001	50	0.23
3	GDP per capita growth	Wage-adjusted spending	−0.16	0.07	−0.30 to −0.02	.023	49	0.09
3	GDP per capita growth	Adequacy, all	+0.11	0.11	−0.10 to +0.32	.301	48	0.04
3	GDP per capita growth	Adequacy, high-poverty	+0.08	0.08	−0.07 to +0.24	.305	48	0.03
3	GDP per capita growth	NAEP 2003	+0.23	0.10	+0.04 to +0.43	.018	50	0.21
3	GDP per capita growth	NAEP low-income 2003	+0.21	0.08	+0.05 to +0.37	.009	50	0.19
3	GDP per capita growth	BA+ 2009	+0.43	0.08	+0.27 to +0.58	<.001	50	0.30
Joint	Income growth	Wage-adjusted spending	−0.31	0.05	−0.40 to −0.22	<.001	48	0.61
Joint	Income growth	Adequacy, all	+0.39	0.05	+0.28 to +0.49	<.001	48	0.61
Joint	GDP per capita growth	Wage-adjusted spending	−0.45	0.11	−0.66 to −0.25	<.001	48	0.39
Joint	GDP per capita growth	Adequacy, all	+0.45	0.13	+0.19 to +0.71	.001	48	0.39
Joint	BA+, 2019–23	Wage-adjusted spending	−2.42	0.55	−3.51 to −1.34	<.001	48	0.68
Joint	BA+, 2019–23	Adequacy, all	+2.75	0.90	+0.97 to +4.52	.002	48	0.68

R² includes the income control. NAEP outcomes in scale points (math and reading averaged), BA+ in percentage points, growth in percentage points per year.

Replication. All estimates reproduce from the state analysis file and Python code (pandas, statsmodels): build.py constructs the file from FRED, SFID, NCES, NAEP and ACS; replicate.py and wp_robustness.py estimate every model in the paper; graphics.py produces the figures. Adequacy-window estimates and NECM required-cost dollar figures use the SFID State Indicators Database workbook directly. Files are available from the author.