RFF REPORT

Impacts of Unconventional Oil and Gas Booms on Public Education

A Mixed-Methods Analysis of Six Producing States

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Abstract

Unconventional oil and gas development has revolutionized the global energy marketplace, particularly in the United States. Rapid industry expansion has also had significant and widespread impacts at the community level. This study provides an in-depth look at pre-K–12 educational impacts across six oil- and gas-producing states—Pennsylvania, Ohio, West Virginia, North Dakota, Montana, and Colorado—to understand the benefits and challenges of the recent resource booms on student enrollment, teachers, public education finances, and student achievement metrics. Understanding the effects of such booms on public education is significant in the short and long term, notably because of their potential influence on educational achievement, career-based decisionmaking, and subsequently, the economic health of a community. A mixed-methods design, coupling difference-in-difference statistical analysis with extensive interviews, reveals a series of key insights across and within states. Broadly, we find divergent trends in student enrollment, student-teacher ratios, and per pupil revenue and expenses between school districts in the eastern versus western United States. In contrast to much of the existing literature, interviews across all regions reported minimal concern with increased dropout rates. Stress from financial uncertainty was also acute and common across all boom districts. Taken together, this analysis underscores the importance of the mixed-methods approach and cautions against overgeneralization of effects across disparate boom regions.

Key Words: shale oil, shale gas, Bakken, Marcellus, fracking, hydraulic fracturing, public education, oil and gas, unconventional oil and gas

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Key Points

- An evaluation of the effect of energy resource booms on preK–12 public schools reveals divergent trends in student enrollment, student-teacher ratios, and per pupil revenue and expenses that split largely between school districts in the eastern versus western United States.
- Student enrollment, particularly in the younger grades, was statistically higher in boom districts than in nonboom districts in North Dakota. Conversely, Marcellus boom districts experienced a statistically significant decline in student enrollment compared with nonboom districts, despite striking increases in natural gas production.
- Notwithstanding the clear challenges of a spiking student population in rural areas, North Dakota interviews revealed that the greater challenge was exceptionally high levels of student mobility—a trend that was commonly referred to as a 'revolving door'. Not knowing when a student might arrive or leave created distinct challenges for budgeting and curriculum planning, with several teachers citing physical and emotional fatigue from constantly working to integrate and connect with new students.
- Financial effects were also divergent between eastern and western districts. North Dakota boom districts experienced a statistically significant decline in per pupil funding, whereas Marcellus boom districts had a statistically positive increase in per pupil revenue.
- From an expense perspective, less money was spent on educational services within North Dakota, while statistically more money was spent on capital projects. Increased capital spending is not overly surprising, given the growth in student numbers in the Bakken; however, the decrease in per pupil educational spending raises red flags for long-term effects.
- Education professionals across all regions expressed several similar themes, including:
    - In contrast to what has been written in some of the historic literature, there was little concern about high school students leaving school early to work in the industry.
    - Despite the disparate regional impacts, nearly all districts reported heightened stress from financial volatility of oil and gas markets.

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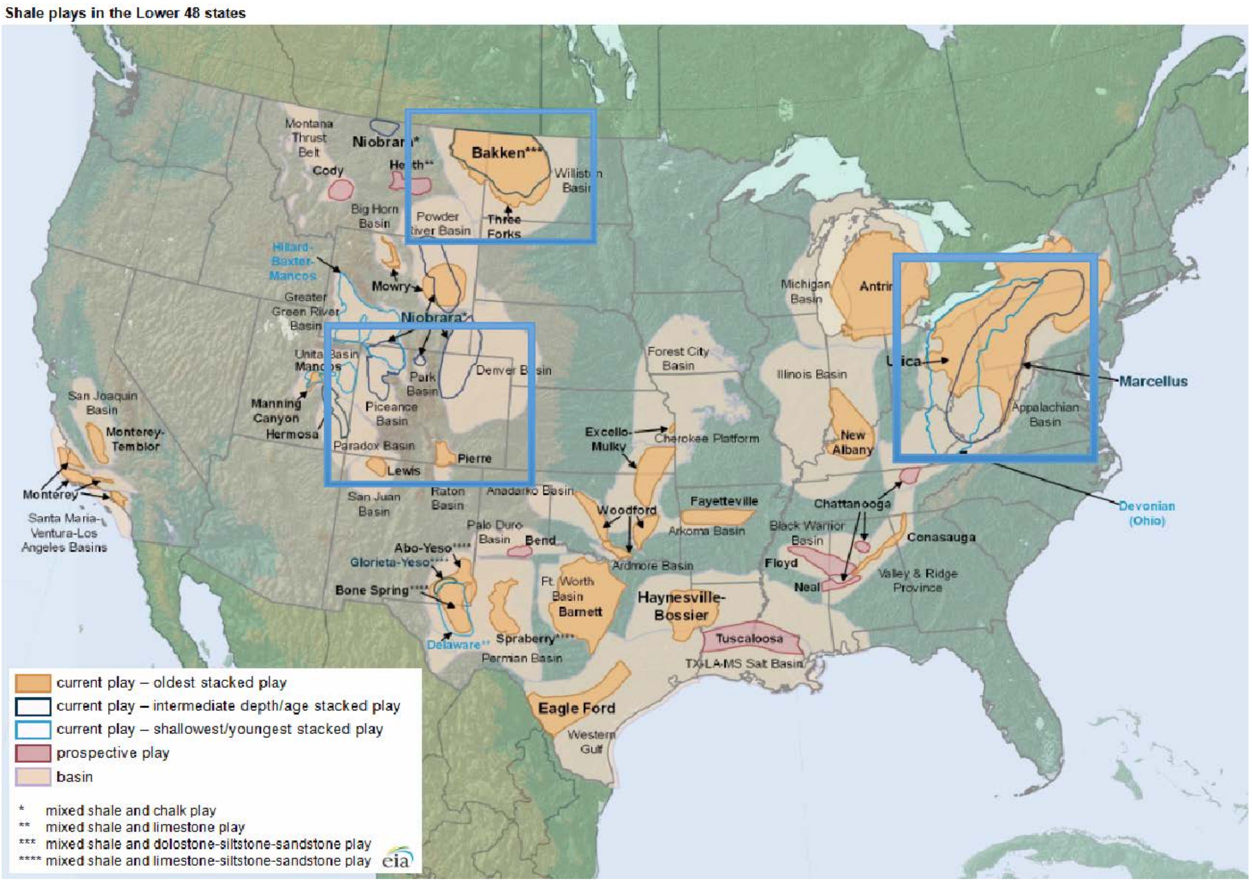
MAP OF US SHALE AND TIGHT ROCK OIL AND GAS BASINS (STUDY REGIONS HIGHLIGHTED IN BOXES)



Source: Energy Information Administration.

1. Introduction

Since its initial expansion in the early 2000s, unconventional oil and gas have fundamentally shifted the international oil and gas marketplace.[1] Unconventional oil—primarily from North Dakota's Bakken field and multiple Texas plays—has helped make the United States one of the most dominant players in the oil market. The abundance of unconventional natural gas has lowered and stabilized domestic natural gas prices, made natural gas exports increasingly cost-effective, placed downward pressure on US coal demand, and caused it to become a driver of climate and renewable energy dialogues. This unexpected energy boom, driven by technological advances rather than new resource discoveries, has also been credited with contributing to the revitalization of the American economy postrecession (Feyrer et al. 2016). The boom's benefits have not come

[1] We use *unconventional oil and gas* to refer to the marriage of hydraulic fracturing, horizontal drilling, and 3D seismic surveys to access previously uneconomic geologic formations to produce oil and gas. Often this is referred to as tight oil, shale oil, shale gas, or fracked gas. We have attempted to use the term *shale* only where the formation is actually a shale play.

without costs. At the national level, concerns about methane leaks and climate change effects are paramount.

Our concern is with local benefits and costs. A community may see revenues rise from severance taxes or other state or local taxes on the sectors causing the boom. These revenues can be spent to increase the quantity and quality of public services or to reduce tax rates. At the same time, the economic boom increases demand for public services such as water, sewage, roads, and schools (Raimi and Newell 2014). Residential housing prices can increase generally with the boom, as can rental housing prices (Price et al. 2014; Jacquet 2009; Headwaters Economics 2008), but for homes that are near wells and rely on groundwater for drinking, housing prices can be heavily discounted (Muehlenbachs et al. 2014).

Oil and gas booms also can have significant short- and long-term impacts on public education. In the short term, educational outcomes can serve as a proxy for community-level economic health. In the long term, resource booms can influence career-based decisionmaking and educational attainment—two drivers of a diverse and robust local economy (Marchand and Weber 2015; Measham and Fleming 2014; Rickman et al. 2017). Therefore, it is in the public interest to ensure that the net effect of a resource boom on education is at worst neutral and ideally a positive factor for individuals and communities.

A limited number of studies focus on the effect of localized resource booms on public school metrics, including budgets, student population, and student-teacher ratios, or on student performance metrics, such as standardized test scores or graduation or dropout rates (Marchand and Weber 2015; Cascio and Narayan 2015; Rickman et al. 2017).

In the broadest sense, this research seeks to answer the following question: Did public school districts in regions with high levels of oil and gas production during the recent unconventional energy booms fare better or worse in terms of financial and educational performance outcomes than comparable school districts in regions that did not experience a boom?

To answer this question, we use a mixed methods research approach, relying on a quasi-experiment combined with semistructured interviews. The quasi-experiment uses a difference-in-difference (DID) design that is employed widely in the resource economics literature. To complement the statistical analysis and probe deeper into related issues, we conducted extended in-person interviews with numerous sources in each of the states included in the study. Importantly, detailed quantitative data analysis at the district level and complementary interview responses allow the statistical outcomes to be reinforced and better explained, providing greater confidence in the results.

This mixed methods research extends the existing body of literature related to US commodity booms and public education. Notably, it is the first study that we are aware of that uses extensive interviews in conjunction with DID analysis to analyze the effects of unconventional oil and gas on public education.

Amid a series of compelling and complex results, several important themes rise to the surface. These include a distinct difference in student population trends between North Dakota and the Marcellus, a difference in *per pupil* school funding among regions, and a common perception of low potential impacts on dropouts and educational achievement across all regions. Generally, interviews did not contradict the statistical results. Although this paper finds little evidence that the recent boom affected student learning outcomes in the short run, we encourage future examination of long-term impacts on student performance. As discussed in section 4, issues such as classroom congestion and high rates of teacher turnover in western rural districts suggest a potential for lower educational achievement in the long run.

Regarding student population, North Dakota had a statistically significant increase during the boom, whereas Pennsylvania and the larger Marcellus regions experienced the opposite effect across most grade levels. Similarly, student-teacher ratios (STR) rose in North Dakota boom districts and dropped in the Marcellus. Importantly, the trend in STR implies that despite budget challenges across Pennsylvania, on average teachers were retained in Marcellus boom area public schools.

Interviews with education professionals revealed important insights that were not apparent when looking only at the official population data. Annual student enrollment totals underestimate the real increase in new Bakken students because of high levels of student mobility throughout the school year, which is not captured in the official population data recorded in October each year. For example, consider a school that reported 20 new students in one year, a significant amount for many rural districts. It would be reasonable to find that in actuality, 40 new students arrived and 20 students left—resulting in the net reported increase of 20. Addressing the needs of 40 new students requires twice as many resources as 20 new students, and yet this is lost in the official numbers. Teachers and staff throughout North Dakota and Montana boom districts reported this revolving door phenomenon as a key challenge for the schools. Education professionals also reported the revolving door effect in Colorado but to a lesser degree than in the Bakken.

Another insight revealed through interviews concerned teacher retention. On one hand, conversations indicated a negligible concern over teachers or staff leaving the educational sector for higher-paying industry jobs in any of the regions. On the other hand, most western districts reported challenges with teacher acquisition and retention because of being so remote. This situation was exacerbated during the boom years.

As with student population estimates, there were parallel though somewhat less pronounced east-west divergent trends in per pupil total revenue. North Dakota boom districts experienced a weakly statistically significant (at a 90 percent confidence level) decrease compared with nonboom districts. Marcellus districts experienced the opposite effect and saw per pupil revenue rise compared with nonboom districts. Statistical results in Colorado were insignificant.

On the spending side of the ledger, total per pupil expenditures show a complementary scenario; however, the analysis did uncover interesting nuances. One notable example is that capital spending increased significantly in North Dakota boom districts versus Marcellus boom districts, which did not exhibit a statistical difference from nonboom districts.

A common interview theme reported across all regions was stress related to uncertainty about the future of school funding. Educational professionals were particularly vocal about this concern in western oil districts, likely because of the salience of the recent downturn in global oil prices. Several administrators suggested it was safer to spend money on onetime investments such as new computers than on recurring costs such as teacher pay raises.

A final theme was the limited concern expressed toward student dropout rates or negative effects on educational attainment in boom districts. Without the retracted quantitative data, interviews provided valuable, if potentially biased, insight.[2] Across almost all districts interviewees did not feel that the boom increased the rate of student dropouts, commonly suggesting that this boom had higher technological demands than previous oil and gas development periods.

Analysis of third- and eighth-grade standardized test data, as well as SAT and ACT scores, in Marcellus states did not reveal any overarching conclusions, as results were largely mixed. (DID analysis in other states was precluded by the limited time series of available data.) Interviews reinforced the statistical outcomes, suggesting there was little impact on student performance in the Marcellus. However, a lack of measurable short-term impacts does not preclude impacts on long-term educational attainment.

The remainder of the paper is structured as follows. Section 2 reviews the existing literature on resource booms, noting relevant statistical designs, and provides an overview of public education funding sources as well as variations in tax policies among the six states included in this study. Section 3 discusses the paper's sample choice, data sources, and methodology. Section 4 reviews the primary econometric results in parallel with interview findings. Section 5 includes a short discussion and conclusions.

2. Background and Literature Review

The literature reviewed for this study encompasses several bodies of research, including resource economics, education, and public finance. The rapid expansion of unconventional oil and gas starting in the early 2000s spurred a new series of research projects assessing the effect on employment and per capita income; however, research on the localized socioeconomic consequences remains relatively limited. Fortunately, a larger body of studies examining the regional or local consequences of historic upticks in conventional energy extraction and mining industries extending back to the 1970s provides a foundation of material for the unconventional oil and gas domain.

In addition to our review of energy extraction literature, Fleming et al. (2015) offer extensive insight on prevailing statistical methods and a comparison of results across quantitative papers that analyze socioeconomic impacts of unconventional fossil fuel development.

2.1. Historic Resource Booms

The oil boom of the 1970s and subsequent bust of the early 1980s gave rise to a series of local impact studies (e.g., Davenport and Davenport 1979; Jones 1982). Work during this period tended to focus on broad social challenges that boomtowns experienced. Few early studies used quantitative methods, nor highlighted specific educational impacts of resource booms (Deller and Schreiber 2012).

Two studies that comment on education as part of broader social analyses are Cortese and Jones (1977) and Freudenburg (1984). Freudenburg compares differences in perceptions between adolescents and adults across communities in western Colorado that experienced rapid industry growth and their peers in neighboring nonboom districts. Highlighting the potential for the booming industry to pull students out of school, Freudenburg finds that adolescents in boom regions felt significantly more negative about their school, teachers, administrators, and

[2] The dropout data source identified for this study was retracted by the National Center for Education Statistics (NCES) during the course of our analysis.

studying than nonboomtown youths. Evaluating a variety of metrics in the northern plains and Rocky Mountain regions affected by energy development, Cortese and Jones (1977) provide wide-ranging insights on school impacts from the 1970s and early 1980s. The authors find that, on the whole, costs related to the boom outweighed the aggregate benefits for schools. Cortese and Jones note that teachers were burdened by increased housing prices in boom communities and that faculty experienced few increases in salaries to make up for the difference in living costs. They also find rapid changes in student enrollment as new families moved to the districts. These unexpected arrivals combined with uncertainty about how long the new students would remain made it a struggle for school administrators to plan ahead. Cortese and Jones also report that classrooms became overcrowded and that boom schools often experienced high levels of student transiency during the school year. As a result, Cortes and Jones conclude that students experiencing numerous disruptions in their education often struggled more than their peers and required more attention from teachers to meet their academic needs. Many of their findings were echoed in our study's interview component, particularly in the Bakken.

Freudenburg and Wilson (2002) provide a comprehensive review of the literature available at that time that looked at mining effects in nonmetropolitan areas. Synthesizing 301 studies, they conclude that roughly half found negative outcomes in mining communities, one-quarter found favorable outcomes, and one-quarter uncovered neutral or indeterminate impacts. The authors note that most of the positive results come from studies conducted before 1982 and that dealt with large western coal regions, such as the Powder River Basin. Overall, their review of the available literature as of 2002 determines that resource booms did not overtly lead to increased local economic development.

A seminal study in the resource economics literature by Black et al. (2005) analyzes Appalachian coal communities from the 1970s to the 1980s. The authors observe positive effects during the boom period. Using a DID analysis, they estimate a net loss to boom communities as a result of the negative impacts of the bust outweighing gains from the boom period, particularly in relation to jobs.

Because of the rapid growth of unconventional oil and gas, several contemporary studies have revisited these historic boom and bust periods. Jacobsen and Parker (2016) explore oil boom and bust counties during the 1970s and 1980s by regressing actual wells drilled on an estimated counterfactual for the number of wells drilled. Similarly to Black and colleagues, Jacobsen and Parker conclude that even though positive employment and income impacts occurred during the growth period, negative income impacts were greater during the bust. Conclusions from an analysis by Haggerty et al. (2014) are consistent with that of Jacobsen and Parker. Using generalized estimating equations to regress 11 metrics on the long-term impacts of oil and gas specialization in six Rocky Mountain states involved in the 1970s and 1980s energy boom, Haggerty and colleagues find that economic specialization in oil and gas over the long term was associated with worse outcomes for communities regarding crime, income, and education.

Broadly, the results from the more recent retrospective work support Freudenberg and Wilson's consensus that resource booms do not necessarily lead to long-term local economic gains. Taken together, these studies note that communities experience positive economic growth during the boom period, but that ultimately the long-term negative impacts are larger. The studies analyzing historic boom and busts also suggest that community outcomes are dependent on how local institutions plan for the boom, including long-term development strategies (Freudenberg and Wilson 2002).

2.2. Unconventional Oil and Gas Boom

A growing catalog of literature is assessing the current and future economic effects of shale oil and gas at the national and state levels (EMF 2013; Haggerty et al. 2014; CBO 2014; Hausman and Kellogg 2015). A separate body of work is beginning to look even more narrowly at the local economic impacts (Weber 2012, 2014; Raimi and Newell 2014, 2016; Weinstein 2014; Paredes et al. 2015).

Weber (2012) is one of the earliest papers to undertake a quantitative analysis of economic effects. Via a DID analysis, Weber looks at counties in Colorado, Texas, and Wyoming and finds modest growth in employment and income, specifically that each $1 million of gas created 2.35 local jobs. Weber (2014) looks for "conditions symptomatic for the resource curse" in Arkansas, Oklahoma, Louisiana, and Texas via a combined DID and two-stage least-squares design (2014, 4). Weber does not find strong evidence of an emerging resource curse, citing a lack of noteworthy increases in average earnings per job and no crowding out of manufacturing. In addition, Weber notes that "human capital is often cited [as] a cause for long-term growth, [and thus] a decline in education attainment is another sign of the making of resource curse." Weber concludes that increased resource extraction did not lead to a less educated workforce in the study states (2014, 9, 4). Although Weber (2014) is assessing the education level of adults, his point also holds for younger generations. Assuming some percentage of students stay in the local area, their level of education (i.e., human capital) could significantly affect the economic health of the community. In fact, Marchand and Weber (2015) take a look at this effect in Texas. Their paper is discussed in depth below.

Paredes et al. (2015) use a propensity score matching approach to analyze the effects of natural gas development on income and employment in the Marcellus region. The authors find a generally negligible trend regarding income effect but a more substantial impact on employment. To explain the latter, the authors hypothesize that many of the higher-paying industry jobs are temporary and taken by outsiders. The interview component of our study further supports these points.

As part of the Shale Public Finance project, Daniel Raimi and Richard Newell (2016) have compiled an extensive body of research from across US oil and gas plays, particularly focusing on the flow of energy-related dollars at the state and local levels. Raimi and Newell generally conclude that local governments have received a net increase in income from development activity—whether from local or state taxation—and that the majority of regional governments had neutral to positive net financial impacts. Looking specifically at conclusions drawn for regions covered in our study, Raimi and Newell find that local governments in the Marcellus have "uniformly net positive" effects and the Bakken had "mixed positive/negative" financial impacts. In Colorado, the Denver-Julesburg is described as positive, while the Piceance is defined as a mix of positive and negative.

In light of Raimi and Newell's findings regarding positive impacts on local revenues, observations in Marchand and Weber's (2015) review of education literature are particularly noteworthy. Not only do greater revenues not always translate to increased school spending, but also "additional revenue from one source may [or may not] crowd out revenue from other sources," such as transfers from the state or local tax collections (Marchand and Weber

2015, 7).[3] In fact, the growth and subsequent shrinking of local tax dollars can create even greater volatility for boomtown schools, as discussed in Section 5.

The income and labor studies discussed here lay an important foundation for community impacts. However, the trends do not necessarily correlate with net public education funding or education outcomes.

2.3. Public Education Finance

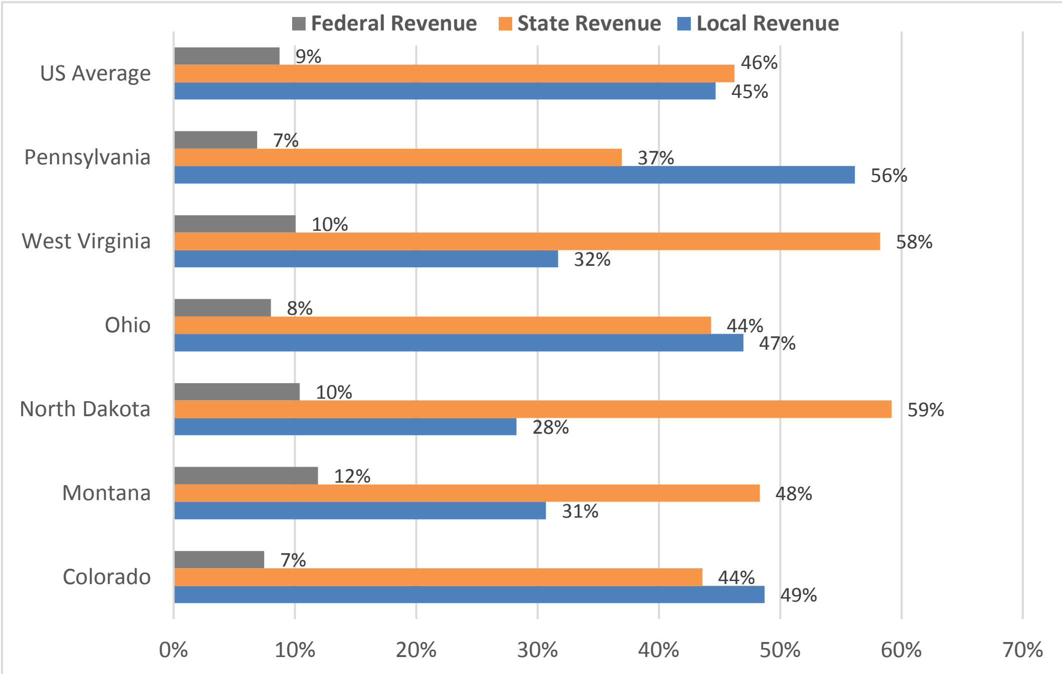
Public school finance is a complicated system of state-based algorithms and local funding mechanisms. In general, local funding is primarily drawn from property values; state-based funding to districts is more reliant on student enrollment numbers. Understanding public school funding becomes even more complex when multiple states are discussed. We do not aim to explain the fine nuances of state-specific educational funding in this paper. Rather, this section is meant to provide an introductory look at the basic sources of school revenue and note important differences among the six states included in the study.

Figure 1 compares sources of educational funding in the 2013–14 school year in the six study states against the national average. The average state's education revenue is composed of 10 percent federal, 45 percent state, and 45 percent local funding. Figure 1 shows that Ohio, Pennsylvania, and Colorado have higher local revenue sources. One key differentiating factor for communities is whether and how local governments generate revenue from oil and gas production or whether those revenues are collected and redistributed by the state. Table 1 provides a broad description of how local governments levy and receive revenue from the oil and gas industry.[4] It is notable that the two largest oil and gas producing states discussed herein do not have the authority to levy local taxes on fuel production. However, comparing the six states in our study, there does not appear to be a clear pattern between local taxing authority and the local percentage of school funding.

[3] Gordon (2004) found that Tile I federal funds did in fact crowd out local and state revenues. On the other hand, a study by Dahlberg et al. (2008) concluded that federal grants did not result in lower local tax rates while also spurring local government spending.

[4] See Raimi and Newell (2016) for further discussion on local funding.

FIGURE 1. PUBLIC EDUCATION FUNDING SOURCES ACROSS SIX STATES, 2013–14



Source: Department of Education (2017)

TABLE 1. OVERVIEW OF LOCAL AND STATE ENERGY PRODUCTION REVENUES

	Local Production Taxes/Fees	Dates	State Production Tax Rate or Fee	Dates
Pennsylvania	No	N/A	Impact fee per well (dependent on $ of gas)	Implemented 2013
Ohio	Average effective tax rate 1–2.6%	Preboom	Effective tax rate 0.5–0.8%	Preboom
West Virginia	Average effective tax rate around 2%	Preboom	5% on wellhead value of oil and gas produced	Preboom
North Dakota	No	N/A	Total rate 10–11.5% (annually adjusted per mcf)	2015: oil rate change 6.5–5%
Montana	No	N/A	0.5–14.8%	Preboom, local distribution modified
Colorado	4–15%	Preboom	2–5% (severance tax can be reduced to credit 87.5% of ad valorem taxes)	Preboom

Note: Stated rates are before deductions, etc. Many states have exemptions or alternative rates for stripper wells.

2.4. Unconventional Oil and Gas and School Impacts

The current literature specifically addressing the influence of unconventional oil and gas development on public education is limited. Some contemporary research studies on local impacts included schooling as a tangential component to a community-wide analysis, but they do little to discuss or quantify the effects (BBC Research & Consulting 2008; Ferrell and Sanders 2013; Oyakawa et al. 2012; Christopherson and Rightor 2012; Perry 2012; Bartik et al. 2016).

An exception comes from a cadre of Penn State University researchers who have published several survey-based analyses over the recent boom, polling educators and school administrators in the Marcellus shale region of Pennsylvania regarding both the opportunities and challenges facing their districts as a result of shale energy development (Schafft et al. 2014a, 2014b; Schafft and Biddle 2014; Kelsey et al. 2012).

Despite concerns that the boom would bring a rapid influx of students to districts overlying the Marcellus play, enrollments in these typically rural districts actually continued on the previous trajectory of a steady, long-term decline (Schafft et al. 2014b). In fact, Kelsey et al. (2012) and Schafft et al. (2014b) find a negative association between oil and gas development in Pennsylvania and slightly larger decreases in student enrollments. Schafft et al. (2014b) report that between 2005–6 and 2010–11, the four top producing counties in Pennsylvania experienced a nearly 8 percent decline in student enrollment compared with a state average decline of around 2 percent.

Looking at Pennsylvania, Schafft et al. (2014b) find little evidence that an increase in unconventional oil and gas development is associated with changes in student demographics or other outcomes, such as changes in the number of English language learner students or the share of students with special education accommodations. However, the study did find that rates of students qualifying for free or reduced-price lunch programs increased at a lesser rate in top producing counties compared with counties in the rest of Pennsylvania, although it is important to note that these counties still had higher poverty rates among students compared with the state averages. Schafft et al. (2014b) find negligible change in dropout rates overall in the four top producing counties in Pennsylvania (the same as our findings). In terms of financial impacts, Kelsey et al. (2012) conduct a survey-based study examining whether local school districts in the Marcellus would see any benefit from increased tax revenues from oil and gas development. The authors note several potential upsides, but they highlight that most interviewees felt that little of the financial benefit had been directed to public schools in Pennsylvania.[5]

2.4.1. School Funding

Ample evidence from the education literature shows that increased funding can lead to increased student outcomes. In a comprehensive review of peer-reviewed quantitative analyses on the impact of money in education, Bruce D. Baker (2016) concludes that per pupil spending is positively associated with improved or higher student outcomes. Baker also finds that on average, “sustained improvements to the level and distribution of funding across local public

[5] The 2012 study was conducted before the new impact fee was implemented.

school districts can lead to improvements in the level and distribution of student outcomes" (2016, i). In a study using nationally representative data to assess the effect of school spending on long-run adult outcomes, Jackson et al. find that a "10 percent increase in per-pupil spending each year for all twelve years of public school leads to 0.27 more completed years of education, 7.25 percent higher wages, and a 3.67 percentage-point reduction in the annual incidence of adult poverty" (2015, abstract). The authors note that effects are far more pronounced for children from low-income families. Further, they assert that exogenous school spending increases were associated with sizable improvements in measurements of school quality, including reductions to student-teacher ratios, increases in teacher salaries, and longer school years.

Weber et al. (2016) report that increased shale development caused a substantial increase in the property tax base and subsequently increased per student revenues and expenditures in the Barnett shale. However, this finding applies to only one play in Texas, which falls in the Dallas–Fort Worth vicinity—a highly populated urban center.

Local governments can treat tax revenue differently. As Marchand and Weber (2015) explain, with substantial revenue coming in relatively rapidly because of resource booms, school districts may find themselves unprepared to use the money in ways targeted to improve educational outcomes in the long run. Essentially, even if school spending increases it may not affect student achievement because of how schools spend additional funds (Baker 2016; Sander 1993, 1999; Chaudhary 2009; Cobb-Clark and Jha 2013).

Furthermore, additional revenue from one source does not mean greater overall school revenue. For example, increased funds for school districts coming from a local severance tax may crowd out revenue from federal or state sources (Gordon 2004). Finally, research from Davis et al. (2016) suggests the importance of the predictability of funding to student achievement by enabling schools to better use funds in ways that improve student outcomes.

2.4.2. Educational Attainment

A review of the literature revealed only a handful of attempts to quantitatively measure the effect of oil and gas development on educational attainment. Three studies relied on the American Community Survey (ACS) to measure dropouts or completions on an individual basis (Weber 2014; Rickman et al. 2017; Cascio and Narayan 2015). We question the robustness of using ACS data because of concerns about insufficient coverage for low population areas. Many of the communities affected by the recent oil and gas boom have small populations, where the ACS historically relied on three- or five-year averages. Furthermore, the three studies have competing results. A fourth paper by Marchand and Weber (2015) focuses solely on Texas and therefore was able to use district-level data from the Snapshot School District Profiles of the Texas Education Agency.

Weber (2014) was the first to use ACS data and did not find that increased shale gas production in nonmetropolitan counties across Arkansas, Louisiana, Texas, and Oklahoma contributed to lower educational attainment of a population. In contrast, Weber reports that shale gas production increased the portion of the population with a high school degree and some college education, and "furthermore, greater extraction did not erode the human capital stock; it may have even improved it by increasing the semi-skilled population (high school and some college)" (2014, 24). It should be noted that Weber's study captures the entire population, rather than those born in the region as attempted by Rickman et al. (2017).

A 2015 National Bureau of Economic Resources (NBER) working paper from Elizabeth Cascio and Ayushi Narayan (2015) relies primarily on a DID approach to assess the effect on educational outcomes in all shale reserve regions covering 30 of the Lower 48 states. Their study focuses on dropout rates and finds that highly developed shale plays saw an increase in dropout rates among 17- and 18-year-olds. In addition to the ACS concern, this paper does not differentiate between oil and gas or offer conclusions among plays. The potential for overgeneralization may be problematic for interpreting the results.

Most recently, Rickman et al. (2017) report significant reductions in both high school and college attainment among native-born residents in Montana, North Dakota, and West Virginia. By including only those born within the specified states in their study, the researchers explain that they "omit in-migration effects on educational attainment outcomes" (2017, 7). Using a synthetic control method instead of a DID approach, Rickman and colleagues examine educational attainment data for persons aged 18–24 from the pooled 2006–13 ACS. The researchers associate educational attainment of an individual with the state in which they were born and the year they turned age 18, which is computed as the survey year minus age at the time of the survey plus 18. Thus an individual is assumed as treated by the fracking boom if he or she turned 18 during the treatment year or later. The researchers therefore consider all individuals who turned 18 before the treatment year as never having been treated.

Joseph Marchand and Jeremy Weber (2015) employ an instrumental variable approach to investigate how the labor market and finance channels of an energy boom could impact teacher quality and student achievement. The authors use shale depth variation and annual oil and gas price variation to find that resource development in Texas school districts slightly decreased student performance on state exams. They note that resource-rich districts often responded to expanded tax bases by lowering tax rates or allocating additional funds to capital projects rather than to teacher pay. Importantly, their study finds that the effect from the labor market pulled teachers out of schools. This pull effect increased teacher turnover and inexperience, resulting in a decline in teacher quality.

Marchand and Weber conclude that "unless funding is allocated disproportionately to districts where the production occurs, and is used to improve teacher quality, rising wages may reduce student performance as districts struggle to retain teachers" (2015, 41). Our work came to dissimilar conclusions regarding teacher attrition, but it does not directly challenge Marchand and Weber's results, as our study does not analyze Texas plays and notes heterogeneity across plays.

Overall, the limited body of existing work and concerns about some data accuracy illustrate the need for further data-based and mixed methods research into school financing and educational attainment. By working with a large sample across states and conducting interviews, we have forwarded this cumulative body of existing education and resource economics literature.

3. Data and Statistical Methods

This section describes the sample selection, lists data sources, and discusses the study's methodology. The maximum time frame of the quantitative data analysis (based on available data) spans school years beginning in 2000–2013; not all metrics cover the entirety of the time series. The 2000–2013 period captures the production boom of both oil and gas in each of the six sample states and the gas price collapse in the late 2000s, but it does not catch the 2014 global oil price collapse. We were able to examine the oil price drop and ensuing production decline via interviews with educators and staff.

3.1. Sample Choice

The quantitative data analysis covers 1,496 nonmetropolitan school districts in six states that overlie major oil and gas formations: Colorado, Montana, North Dakota, Ohio, Pennsylvania, and West Virginia. Together, the six states cover several major plays, including the Marcellus-Utica (Pennsylvania, Ohio, and West Virginia), the Bakken (North Dakota and Montana), and the Denver-Julesburg, Piceance, and San Juan Basin (Colorado). Extensive interviews were conducted in major development regions in each of the study states.

This six-state sample was chosen because it includes important energy development regions and because each of the regions is dissimilar from the others, allowing for intra and interplay comparisons. The Bakken is an oil play, whereas the Marcellus-Utica region is primarily a natural gas play. Colorado produces meaningful quantities of both natural gas and oil. Therefore, this study can compare impacts within the Bakken against general effects in the Marcellus, for example. Although Montana did not ultimately experience a large increase in oil production, we included it in the analysis because of its proximity to North Dakota and to explore spillover effects in neighboring districts.

In contrast to several studies that analyze local economic or public school effects and aggregate to the county level or commuting zone (Jacobsen and Parker 2016 Weber 2012, 2014; Paredes et al. 2015; Maniloff and Mastromonaco 2014; Cascio and Narayan 2015), we chose to evaluate impacts on a more detailed district-specific basis, as districts are smaller than counties in most US states (Marchand and Weber 2015). Data analysis and interviews suggest that differences among districts within the same county or region can be large. Furthermore, using districts has the benefit of increasing the sample size.

Using nonmetropolitan districts precludes districts located in cities (with populations over 250,000) from biasing estimates. In addition, nonmetropolitan districts are more representative of the core population of interest, as the majority of unconventional oil and gas production occurs in rural regions.

3.2. Data Sources

The National Center for Education Statistics (NCES), within the US Department of Education, collects extensive data on students, teachers, and school finances. We use their data on student enrollment by grade, student-teacher ratios, student demographics, and participation in additional programs such as free and reduced lunches, as well as school revenues and expenditures. Unfortunately, NCES retracted dropout and high school completion data during the research phase of this project because of poor data quality and inconsistency across states. We attempted to circumvent this problem by collecting a separate data series on dropouts and completions from state resources but found the data to be similarly inadequate for the difference-in-difference (DID) analysis employed in this study.[6] However, interview results are reported for each region.

The Stanford Education Data Archive (SEDA) aggregates and standardizes a nationwide database of district-level test scores by means and standard deviations to allow for comparisons on a subject and grade-level basis. This paper uses SEDA data to analyze English and math test scores for third through eighth grades. However, we could not include these data for North Dakota's or Colorado's DID analyses because both states lack preboom data within the dataset. Although SEDA was not applicable for all study states, interview responses for each state are reported in the results section.

Additional data from state agencies that catalog education data contributed to supplemental and supporting analysis where appropriate.[7] When data availability permits, the study includes subanalysis of data regarding high school educational attainment (dropouts, graduation, and completion rates) and college entrance exams such as the ACT and SAT.

Local employment, personal income, and total population data come from the Regional Economic Accounts of the US Bureau of Economic Analysis (BEA). Total land area of each county comes from the US Census Bureau, and unemployment statistics come from the US Bureau of Labor Statistics. Oil and gas production were accessed through Drilling Info.[8]

3.3. Empirical Strategy and Difference-in-Difference Estimation

This study uses a mixed methods approach (statistical analysis and interviews) to explore the effects of the resource boom on school finance and education metrics. The statistical analysis relies on a DID regression design that uses binary indicators of boom time periods and boom districts to designate participation in the treatment (Black et al. 2005; Marchand 2012; Weber 2012, 2014; Jacobsen and Parker 2016; Bartik et al. 2016). The DID approach simulates a natural experiment by examining the differential effect (such as participation in a resource boom) on a treatment group compared with a control group. It does so by estimating an unobserved counterfactual for the treatment group and subtracting that estimate from the observed outcome in the control group. Equation 1 describes the mathematical formulation for DID:

$$Y_i = \alpha + \beta + \lambda_t + \delta D_t + x_{it} + \varepsilon_i \qquad (1)$$

Y_i is the dependent variable for district *i*, including, for example, student-teacher ratio or per pupil revenue. α represents a constant, β is the treatment group effect, λ_t is the time trend, x_{it} represents a vector of control variables, and ε_I is the district-specific error term. δD_t is an interaction between group and time variables and represents the treatment effect.

To account for unobserved variation in local characteristics and across years, this study employs a combination of regional fixed effects (Marchand and Weber 2015; Maniloff and Mastromonaco 2014; Cascio and Narayan

6 Several studies (Rickman et al. 2016; Weber 2014; Cascio and Narayan 2015) use the American Community Survey (ACS) to measure dropouts or completions. Because of large gaps in the time series and the use of multiyear averages for populations under 65,000, we question the robustness of using ACS data on dropouts.

7 Supplemental data come from the Pennsylvania Department of Education, Ohio Department of Education, West Virginia Department of Education, Colorado Department of Education, Montana Office of Public Instruction, and North Dakota Department of Public Instruction.

8 See https://info.drillinginfo.com/.

2015) and year fixed effects (Black et al. 2005; Marchand and Weber 2015; Maniloff and Mastromonaco 2014; Cascio and Narayan 2015; Paredes et al. 2015; DeLeire et al. 2014). When adding year and state fixed effects in addition to clustering standard errors by district for each of the runs, the results show generally the same trends but with higher significance.

Several recent studies defined their boom treatment as an interaction between geologic endowments and a time indicator. For the geographic variable, the basic approach was to measure the percentage of an area, such as a county, over an oil or gas play (Weber 2012, 2014; Maniloff and Mastromonaco 2014; Michaels 2011; Fetzer 2014; Cascio and Narayan 2015). This endowment method has the primary benefit of alleviating endogeneity concerns, yet it also represents a problem because it uses somewhat arbitrary cutoffs, such as the top tercile or quintile, to define boom areas (Weber 2014; Bartik et al. 2016).

A series of other papers use production output such as change in British Thermal Units (Btus) (Weber 2014), number of wells (Jacobsen and Parker 2016), a lagged well count (Paredes et al. 2015; DeLeire et al. 2014), or a change in the monetary value of production (Weber 2012). A third group of papers define treatment based on the share of population deriving a majority of income from the resource (Haggerty et al. 2014; Black et al. 2005; Weinstein 2014; Tsvetkova and Partridge 2015). For example, Black et al.'s (2005) seminal study on coal in Appalachia defined their treatment by counties that derived at least 10 percent of income from the coal industry.

In light of varying procedures in the literature, we evaluated a number of methods to classify areas as boom or nonboom. Ultimately, our study defines a boom district based on a district meeting three production metrics: (1) top average producing district during the boom (measured at the top 10 percent and top 20 percent over a four-year average); (2) exceeding national average percentage change in production from preboom to boom; and (3) having a positive change in the number of wells averaged over peak boom years.[9]

A producing district in the top 10 percent is defined as being in the *core treatment* group. *Total treatment* districts include those that are in the top 20 percent of production during the boom. Both top 10 percent and top 20 percent thresholds are used to define treatment groups in the existing literature. Weber (2012) defines a boom county as one in the top 20 percent for the change in gas production during the boom period. Jacobsen and Parker (2016) define boom counties as the set for which the total number of "extra" oil and gas wells drilled in a given county exceeds 200. This cutoff corresponds to 10 percent of counties, and it is robust when the authors use other ways to measure boom counties. In our study, we chose to explore the effects in both the top 10 percent and 20 percent to infer whether impacts were hyperlocalized or more widespread across a region. Using variation in the size of the treatment has been used by other studies, including Weber (2012, 2014), Maniloff and Mastromonaco (2014), Fetzer (2014), and Black et al. (2005).

[9] Average boom production is estimated over a four-year period: the peak production year in each state and the three preceding years. This average is used to identify the top 10 percent and 20 percent of districts based on production.

Exceeding national average percentage change (2000–2003 preboom and the four-year boom average) was chosen to guard against legacy production regions that had high production rates but did not necessarily grow or benefit from the unconventional oil and gas boom. Examples of this scenario are several counties in West Virginia that had high historic natural gas production from coalbed methane. Similar to the second criteria, increasing well numbers over the boom period is meant to winnow away districts that saw production increases during the boom but not from new well development.

To increase confidence in the statistical results, this study ran DID regressions under four primary scenarios.

1. Core treatment, with neighboring districts.
2. Core treatment, dropping neighboring districts.
3. Total treatment, with neighboring district.
4. Total treatment, dropping neighboring districts.

DID regressions with and without neighboring districts are meant to explore the potential for spillover effects. Although specific estimates change within the two treatment levels and when dropping neighboring districts, each of the regressions presents the same general conclusions for the metrics analyzed.

In addition, this study ran each regression with varying controls and found similar trends throughout most runs. For the results shown in section 4, we selected a set of common control variables used in the literature, including population, population density, per capita income, total employment, and unemployment rate.[10] Many of these controls are reported on a county basis. Thus for any district that straddles two or more counties, we attributed controls based on which county contains the largest percentage of the district by land mass. As the general narrative does not change when alterations are made to the parameters (i.e., dropping neighbors), section 4 reports the estimates for regressions for the core treatment (top 10 percent) and drops neighboring districts, unless otherwise noted.

Montana was ultimately not included in the statistical analysis because of irregularities with data aggregation across primary and secondary school districts. Counties in western Colorado's Piceance Basin were also dropped because of increasing levels of natural gas production immediately prior to the introduction of unconventional gas, as defined herein. However, both regions are included in the qualitative analysis and contribute important insights into the effects of rapid oil and gas development on public schools.

3.4. Qualitative Approach

Realizing that a quantitative approach alone can miss nuanced parts of any story, we conducted over 70 interviews across the regions involved in the study between February and August 2016. The interviewees involved teachers, school and district administrators, district staff including chief financial officers, school board members, and

[10] Publicly available BEA data suppress observations where the number of establishments creates confidentiality problems, such as for individual economic sectors. As a result, we chose to use total unemployment in primary regression analysis rather than control for the share of total earnings in the mining, construction, manufacturing, agricultural, and retail sectors.

state government, nonprofit, and community college staff. Some meetings were with single individuals; others were held in a group setting. We used a semistructured interview approach to explore the primary metrics of interest but also allowed for natural, unstructured conversation.

The broad goals of these meetings were to better understand nuances in the data and to incorporate the on-the-ground experience before the boom, during the boom, and during the recent oil price decline (post-2014). The personal perspectives deepened our understanding and also helped triangulate results. For example, some stories, such as heightened student mobility in the Bakken, were not apparent in the standard student population data. In this case, student population growth numbers likely underestimate new arrivals, as many students were moving out of the district as well. Some teachers described this as a revolving door scenario, where in many cases they were not aware a student was leaving or arriving until the day it occurred. As another example, the statistical analysis of revenue and expenditures fails to capture the uncertainty of future income, which many administrators noted as a paramount concern for planning and investment.

Furthermore, the interviews helped build deeper insight into the practices being used among school districts to cope with the resource booms and why their efforts are or are not working in each situation. One illustration of this point is the challenge of acquiring and retaining new teachers. Administrators in many western communities were forced into nationwide searches, offered housing bonuses, and in some cases even became landlords to reduce the cost of housing. Despite these efforts, many young teachers in western districts often left after just a few years. This common scenario increases the soft costs of finding teachers, training them, and integrating them into the school community. Being able to illustrate these types of situations in detail helps confirm or contradict statistical results and aids in understanding the true magnitude of costs and benefits stemming from the unconventional oil and gas boom.

In total, the qualitative component was fundamental in developing a more complete and nuanced understanding of local impacts. It also distinguishes this study from similar analyses.

4. Statistical Results and Interview Responses

Table 2 provides a summary analysis of DID regression results across eight key metrics. It lists estimated effects from pooling five states, the Marcellus as a region and state specific outputs. Regression scenarios for each location can be found in Appendix Tables A1–A7.

Results from the five-state pooled model suggest that on average, boom districts in the sample states experienced a decline in student population compared with nonboom districts. The results also show that per pupil local revenue increased over the boom period, while per pupil state revenue decreased. Differences in four other primary metrics were not statistically significant.

Several of the pooled model results were unexpected. While the pooled results for outcomes such as student population contradicted general findings in western districts, other outcomes such as state revenue per pupil appeared to be in sync with findings in western districts. A simple comparison between the five-state pooled results and the state-specific outputs reveal that many trends had opposite effects between eastern states and North Dakota. Because of this heterogeneity in statistical results across states and the mismatch with interview responses, the remainder of this section focuses on a comparison between the Marcellus and the Bakken.

TABLE 2. SUMMARY OF DID REGRESSIONS (FOR CORE TREATMENT WITH NEIGHBORING DISTRICTS DROPPED)

	Student Enrollment #s	Student-Teacher Ratio	Total Revenue /pupil	Local Revenue /pupil	Property Tax Rev. /pupil	State Revenue /pupil	Education Spending /pupil	Capital Spending /pupil
5 State	↓	−0.0428	−127.6	310.5*	95.3	−367***	−201.5	218.9
		(0.148)	(223.9)	(181.1)	(144.3)	(119.6)	(151.5)	(190.6)
Marcellus	↓	−0.325**	374.8**	138.2	62.56	205.7*	240.3**	127.5
		(0.135)	(176.1)	(117.7)	(109.9)	(123.0)	(112.0)	(208.6)
PA	↓	−0.292*	161.3	−2.188	−29.00	103.7	64.84	90.21
		(0.151)	(162.4)	(130.2)	(117.5)	(93.21)	(122.5)	(267.6)
OH	–	−0.0843	525.5	428.4***	420.9***	75.42	199.9	424.3
		(0.393)	(469.6)	(149.8)	(158.3)	(403.5)	(178.6)	(605.6)
WV	↓	−0.612***	559.3	963.6**	875.4**	−449.2***	532.9**	−182.5
		(0.099)	(474.7)	(461.9)	(410.7)	(123.9)	(211.9)	(198.4)
ND	↑	1.120***	−1,498*	−390.4	−1,195***	−1,212***	−1,451***	872.6*
		(0.365)	(807.2)	(470.2)	(376.1)	(250.7)	(548.4)	(466.4)
CO (D-J)	–	1.391	−1,759	−310.2	88.85	−1,341	−1,112	340.1
		(1.189)	(1,657)	(1,065)	(753.7)	(1,033)	(1,062)	(1,085)

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

Note: For student enrollment numbers, arrows imply statistical significance and direction. Minus signs imply a negative trend direction but no statistical significance. As discussed herein, this report focuses on an analysis of regression results for the Marcellus, North Dakota, and Colorado.

This main generalization about differences between eastern and western outcomes begs for some explanation. Simply, the Bakken—and to a slightly less extent, parts of western Colorado—are truly much more remote than rural regions in the Marcellus. This remoteness likely accounts for much of the growth in total population and the magnitude of industrial expansion, including support services.

Within the Bakken, statistical analysis was possible only for North Dakota; however, interviews are reported from both North Dakota and nearby districts in Montana. Statistical output and interviews are also included for Colorado; generally, Colorado's experience, especially in the western part of the state, is more analogous to the Bakken than to the Marcellus.

4.1. Student Population and Teachers

Student population is a prominent example of the differing impacts among the Bakken, Marcellus, and Colorado regions. North Dakota experienced statistically significant positive changes in student population for grades 1–10. Only preK and kindergarten and the 11th- and 12th-grade groupings in North Dakota did not see significant increases over nonboom districts. Conversely, and despite striking growth in natural gas production, Marcellus districts experienced a statistically significant decline in student population across all grades in boom districts, except preK and kindergarten. Boom districts concentrated in the Denver-Julesburg area of Colorado had a weakly negative but not significant outcome.

Interviewees in each region expressed similar expectations on the front side of the boom, anticipating large influxes of workers and families. The outcomes were clearly much different. Bakken teachers and staff reported an initial heavy influx of young men. Eventually, families and children followed. Interviewees said that most of the new students were clustered in the lower grades. Several interviewees noted either that most men coming to work the fields were not old enough to have children in higher grades or that high-school-age children were often left back home. As a result, some schools reported a "bubble" of students moving through lower grade levels and into the upper grades over time.

Marcellus staff and teachers also had expected a surge of gas workers and began to prepare to accept an associated inflow of children. In their case, the flood never came. Interviewees reported that most new gas workers were temporary workers who never took up full-time residence in the area, choosing instead to base primarily out of Texas or Louisiana. Colorado interviewees revealed an increase in student populations, but conversations suggested that not all new arrivals—especially in western Colorado—came as a result of employment in the oil and gas sector. Interviewees also cited the booming tourism industry surrounding the nearby ski resorts as one cause for new students in the Piceance region. Denver-Julesburg interviewees were also mixed, reporting that some new students had parents tied to the oil and gas sector, but staff also stated that school choice in the region complicated an analysis of the movement of students.[11]

TABLE 3. EFFECT OF BEING A TOP-PRODUCING DISTRICT COMPARED WITH CONTROL DISTRICTS DURING THE BOOM ON PUBLIC SCHOOL POPULATIONS

	# of students							Student-Teacher
	PreK & K	1st & 2nd	3rd & 4th	5th & 6th	7th & 8th	9th & 10th	11th & 12th	Ratio
5-State Pooled	7.021	-7.961	-15.11***	-17.02***	-17.99***	-22.26***	-6.445	-0.0428
	(5.496)	(5.053)	(4.480)	(4.575)	(5.372)	(5.737)	(5.684)	(0.148)
Marcellus Region	7.826	-7.994*	-15.63***	-16.77***	-17.82***	-20.76***	-9.415*	-0.325**
	(6.009)	(4.304)	(4.243)	(4.555)	(5.654)	(6.016)	(5.608)	(0.135)
Pennsylvania	-6.445*	-14.94***	-21.14***	-15.06***	-11.07	-10.04	-21.21***	-0.292*
	(3.717)	(4.904)	(4.947)	(5.335)	(7.099)	(6.948)	(7.044)	(0.151)
Ohio	-4.179	-12.56*	-14.00	-14.33	-11.69	-11.74	-7.279	-0.0843
	(7.707)	(7.360)	(9.362)	(9.317)	(8.257)	(7.474)	(10.01)	(0.393)
West Virginia	-28.98	3.876	-28.76*	-33.74*	-37.50	-43.82**	-24.37*	-0.612***
	(48.12)	(11.51)	(16.99)	(19.53)	(26.26)	(21.65)	(14.06)	(0.0990)
North Dakota	1.946	8.392**	6.965***	5.451*	5.739*	8.164***	2.517	1.120***
	(2.233)	(3.469)	(2.586)	(2.848)	(3.207)	(3.120)	(2.717)	(0.365)
Colorado (D-J)	-16.73	-1.514	-19.61	-18.88	-9.758	-12.41	-32.84	1.391
	(43.40)	(63.80)	(59.34)	(61.02)	(58.85)	(58.72)	(68.62)	(1.189)

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

Note: As discussed herein, this report focuses on an analysis of regression results for the Marcellus, North Dakota, and Colorado.

[11] Colorado law allows students to enroll in schools even in districts outside their original zone. C.R.S. 22-36-101 is referred to as the Public Schools of Choice law or open enrollment. See https://www.cde.state.co.us/choice/openenrollment.

Despite concerns that the boom would cause rapid influxes of students to the top producing districts in the Marcellus, enrollments actually continued on a steady long-term declining trajectory. In fact, similar to the findings of Kelsey et al. (2012), our analysis shows that unconventional energy development was associated with "slightly faster declines in student enrollments" in the Marcellus. Looking at Pennsylvania, Kelsey and colleagues hypothesize that a rise of non-native workers without children, the increasing demand for housing, and the subsequent increase in the cost of rent could have driven lower-income households with children out of these communities. In contrast, many oil workers in North Dakota eventually brought along their families.

An additional explanation for these diverging trends beyond the differing remoteness of the regions is the relative value of oil versus gas and the potential premium for pay in an area like the Bakken. A third potential factor is that the level of secondary development—for roads, facilities, and support activities—was simply that much larger in the Bakken. When we visited the Williston region, the development of industrial parks, corporate headquarters, and supporting businesses was abundantly obvious, which was not the case in the Marcellus.

4.1.1. Student Mobility

In addition to a net increase in student populations, Bakken teacher and staff frequently stated that student turnover (student mobility) was much larger than the commonly reported population statistics made it appear. Several interviewees suggested that the actual number of new students could be twice as large as the net gain, meaning that a significant number of students were leaving the school on a regular basis. A handful of interviewees mentioned that students would come and go without any notice and that in some cases the same student had reappeared later in the year after drilling had resumed following the winter. This heightened level of student mobility was reported to have caused disruption in the classroom and contributed to teacher fatigue. Several teachers commented that it became more difficult to want to get to know the new students. Elevated student mobility was not referenced as a problem in the Marcellus. The mobility concern was reported in interviews in western Colorado, but the phenomenon did not seem entirely related to gas development.

4.1.2. Student-Teacher Ratios

Student-teacher ratio (STR) trends in North Dakota and the Marcellus were also divergent. Across all grades, the coefficient on the STR was 1.12 (at a 99 percent confidence level) in the Bakken. The coefficient on core Marcellus districts was –0.325, significant at the 95 percent level. Essentially, classrooms in North Dakota became relatively more congested compared with nonboom districts, and districts in the core boom of the Marcellus had more teachers per student compared with similar districts. This contradictory trend is important to remember when considering both short- and long-term student achievement. Colorado statistical results, mainly reflecting effects within the Denver-Julesburg, were insignificant.

Interviewees in Montana and North Dakota referenced significantly higher levels of classroom congestion—supporting the empirical evidence—whereas Marcellus teachers did not cite increased classroom size. Educators in several western Colorado districts also noted increasing classroom congestion. As with student population, Colorado teachers and staff felt that gas activity and volatile local revenue were part of the problem but did not account for all of the changes to classroom atmosphere. Interviewees also heavily referenced declining state funding in the postboom period due in large part to the "negative factor"—a state-imposed reduction in school funding stemming from the national recession, discussed later in this section.

4.1.3. Teacher Recruitment and Attainment

Bakken interviews revealed an additional problem related to teachers: the critical challenge of hiring and retaining qualified candidates. In the most extreme case, one North Dakota district reported having to hire 12 full-time teachers within two weeks of the school year commencing.

Finding qualified teachers was problematic given the small population within the Bakken region, and administrators reported conducting nationwide searches for new talent. Finding candidates was just the first hurdle. New teachers and administrators then faced the much-publicized issue of highly elevated housing prices, which most new instructors simply could not afford. To overcome this obstacle, superintendents often offered housing bonuses and in some cases began purchasing district-owned housing, thus becoming landlords themselves. In one dire case, a superintendent reported striking a deal with local homebuilders to house teachers until the new homes were sold.

Once hired, trained, and living in the Bakken, schools were then faced with the challenge of retaining new teachers. With the remote geography and lack of social outlets, numerous interviewees recounted situations in which new teachers left after two to three years. This cycle of finding, hiring, training, and refinding represents significant soft costs to Bakken districts. Given the consistent influx of largely first-year teachers, this situation represents a potential threat to the quality of classroom education.

Pennsylvania districts reported the opposite experience—in most cases, teachers came from the local area and stayed for their entire career. In fact, the only real threat to retention was teachers leaving for nearby districts that offered higher pay. This up-trading occurred across state lines in the Marcellus. West Virginia educators in particular stressed that school districts face competition from districts in southeast Pennsylvania and Ohio—neighboring states that pay higher wages and are only a few miles away. Administrators in West Virginia noted that any increase in teacher pay over the last three years came exclusively from individual districts and not the state.

School staff in the Denver-Julesburg and Piceance Basin reported both a challenging hiring environment and the loss of good teachers to wealthier districts. Western Colorado administrators also noted that the difference in facilities and funding from school foundations made it extremely difficult for Piceance districts to compete with the Aspen or Denver-Boulder districts. Housing prices were also referenced as a limiting factor; although in general, these problems appeared less severe than those experienced in the Bakken.

Significantly, none of the regions reported a concern over teachers leaving for higher-paying oil and gas industry jobs. The only commonly reported threat to school workforce poaching across all regions was related to bus drivers, who could earn significantly more with their commercial driver's licenses.

4.2. Education Finance

This study found that financial effects of energy booms also had diverging trends among school districts in the East versus the West.

4.2.1. Per Pupil Revenue

Revenue trends were opposite in the Marcellus and the Bakken. As shown in Table 4 Marcellus core districts, with a relatively shrinking student body, saw a statistically significant increase in total per pupil revenue at a 95 percent confidence level. When revenue is broken down into local, state, and federal income, state income is statistically higher, but local and federal revenue are not. The significance of state funding is not overly surprising, given that Pennsylvania counties, where many of the boom districts occur, are not able to tax oil and gas production as local property, as is commonly the case. Conversely, North Dakota boom districts had a statistically significant decline in per pupil revenue at a 90 percent level of confidence, which is also not unexpected given the striking growth in student enrollment. Colorado core districts experienced a weakly negative statistical effect.

Table 4. Effect of Being a Top Producing District Compared with Control Districts during the Boom on Public School Finance

	$ per Pupil (in $2014)					
	Total Revenue	Local Revenue	Property Tax Revenue	State Revenue	Education Expenditure	Capital Expenditure
5-State Pooled	-127.6	310.5*	95.30	-367.3***	-201.5	218.9
	(223.9)	(181.1)	(144.3)	(119.6)	(151.5)	(190.6)
Marcellus Region	374.8**	138.2	62.56	205.7*	240.3**	127.5
	(176.1)	(117.7)	(109.9)	(123.0)	(112.0)	(208.6)
Pennsylvania	161.3	-2.188	-29.00	103.7	64.84	90.21
	(162.4)	(130.2)	(117.5)	(93.21)	(122.5)	(267.6)
Ohio	525.5	428.4***	420.9***	75.42	199.9	424.3
	(469.6)	(149.8)	(158.3)	(403.5)	(178.6)	(605.6)
West Virginia	559.3	963.6**	875.4**	-449.2***	532.9**	-182.5
	(474.7)	(461.9)	(410.7)	(123.9)	(211.9)	(198.4)
North Dakota	-1,498*	-390.4	-1,195***	-1,212***	-1,451***	872.6*
	(807.2)	(470.2)	(376.1)	(250.7)	(548.4)	(466.4)
Colorado (D-J)	-1,759	-310.2	88.85	-1,341	-1,112	340.1
	(1,657)	(1,065)	(753.7)	(1,033)	(1,062)	(1,085)

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

Note: As discussed herein, this report focuses on an analysis of regression results for the Marcellus, North Dakota, and Colorado.

While not statistically significant, Colorado school revenue changes provide an important insight into how booms and busts can affect locally funded public institutions. Colorado is unique with respect to taxation because of the Taxpayer's Bill of Rights (TABOR). TABOR principally requires that all tax increases must be approved by the voter, and that the voter must also approve any revenue exceeding the approved amount plus inflation or it is required to be returned to the public. Thus TABOR effectively limits revenue and reduces expenditure flexibility.

Severance tax revenue began to grow in western Colorado with increasing gas production in the mid-2000s. As a result of the increasing revenue per millage, boom district tax rates were automatically ratcheted down to compensate for the higher payments. As a result, many schools in boom districts were unable to capture all the income that would have been generated without the declining tax rates and were also limited from saving all excess funds, unlike a county's rainy day fund, for example.[12] When gas prices declined, production slowed and revenue decreased. Schools then faced lower tax rates, which do not automatically ratchet back up, on lower production—ultimately leaving a significant hole in their budget. This funding shortage left the local governments with two options: go back to the voter to reinstate higher tax rates at a time of local economic hardship or request more funds from the state of Colorado.

The state is normally expected to backfill funds to a foundational level on a per pupil basis. Unfortunately for western Colorado boom districts, the recession and political jockeying had instigated an annual net reduction in education spending, commonly referred to as the "negative factor." The net effect was estimated to be a 10–15 percent reduction in what districts would have expected to receive previously. In total, boom districts were not only suffering the consequences of a local industry decline but also facing a relatively starker financial picture than nonboom districts.

While perhaps extreme, Colorado's situation illustrates the challenging economic situation faced by a public school system that is unable to capture local revenue, save excess funds, and mitigate downturns. Without this ability to smooth spending over time, the western Colorado natural gas boom translated into a desperate bust for many local schools. As a result, several districts have taken the notable step of moving to a four-day school week.

4.2.2. Per Pupil Expenditures

Statistical analysis of per pupil spending in the three regions tells a similarly disparate story between Bakken and Marcellus public schools. Total Marcellus per pupil expenditures saw a weakly positive increase in boom areas. Educational spending, a component of total per pupil spending, was significantly positive at a 95 percent confidence interval (CI). This relative increase in educational spending means that more money per student was being spent on teacher salaries or educational materials than in nonboom counties. North Dakota counties saw a distinctly negative effect on per pupil educational spending, at the 99 percent level. Conversely, capital spending was statistically positive at a 90 percent CI. Together, the

[12] For comparison, in 2010, as gas prices and production declined, Garfield County sat on a $100 million reserve fund that it had amassed during the boom years. https://garfield-county.com/news/finance-2011-budget.aspx.

North Dakota results imply that while expenditures decreased per pupil, available funds were commonly allocated to capital improvements, including school expansions or constructing new buildings.

Near Williston, North Dakota—"Boomtown, USA"—high levels of capital spending were commonly reported in interviews. Given the significant rise in student population, expansions were essential in many cases. However, the largest capital project was a new high school near Watford City, which opened in 2016 with a price tag of $50 million. Pictured in Figure 2, the state-of-the-art school is an example of a distinctly positive impact of the oil boom.

Not all Bakken districts were as successful as Watford City in gaining voter approval for new bonds to support school construction. One district reported being unsuccessful on the ballot three times. While new classrooms are a positive impact, their financing through taxpayer-backed bonds also represents a risk to taxpayers over the long term if oil development slows down over long stretches.

When we visited the Bakken in spring 2016, oil prices had been near record lows for over a year, new well completions were vastly diminished, and industry layoffs had begun. Many teachers and staff wondered aloud what would happen if the drilling did not return. While the acuteness of the global oil glut was clearly felt in the Bakken oil fields, the common refrain of financial uncertainty was a point echoed across the Marcellus and Colorado.

As noted above, Colorado schools had compounding reasons to be concerned with long-term school financing other than simply the oil and gas busts. Pennsylvania districts faced similar uncertainty due to a bitter and prolonged state budget battle that left some schools within weeks of closing their doors. In both cases, as well as in eastern Ohio districts, declining production-based revenue exacerbated the common stress of financial security. In a broad sense, this uncertainty refrain calls into question the design of school funding mechanisms and to what extent they restrict administrators from optimizing financial strategies.

Figure 2. A New $50 Million High School near Watford City, North Dakota

Photo: Nathan Ratledge, 2016.

4.3. Academic Performance and Dropouts

The third chief takeaway from interviews was the lack of reported concern about dropout rates and academic performance. These two trends held true across the Bakken, Marcellus, and Colorado. Unfortunately for the DID analysis, NCES retracted its dropout and high school completion data during the research phase of this project. Efforts to collect dropout data from state agencies did not prove fruitful either, as the data was inconsistent over time in most states. Fortunately, interviews in each region provided valuable insight.

4.3.1. Dropout Rates

Across the Bakken, Colorado, and the Marcellus, there was a consensus that the oil and gas boom had not meaningfully increased dropout rates. When probed on the subject, several interviewees in different regions responded that the oil and gas development was technically advanced compared with prior boom periods and that it was not conducive to high school dropouts looking for employment. The sole exception was western Colorado's Piceance Basin, which was developed before most other unconventional oil and gas regions. In the Piceance, there was a reported marginal increase in dropouts in the mid-2000s, but it was short-lived. In general, the consensus of interviewees across regions runs counter to some previous studies (e.g., Cascio and Narayan 2015; Rickman et al. 2017) and suggests that students were not incentivized to drop out for work in the oil and gas industry during the recent unconventional oil and gas boom.

4.3.2. Student Performance

Interviews across the Bakken and the Marcellus also reported limited concern about impacts on academic performance. Because of poor data quality from state agencies, changing test structures over time, and a limited time series from the Stanford Education Data Archive, DID analysis was possible only in the Marcellus, where third- through eighth-grade standardized test scores were analyzed. Results from English and math scores were mixed, with a weakly negative trend across the five grade levels. Additional DID analysis of SAT and ACT scores in Pennsylvania and Ohio did not return any statistically meaningful difference when compared with nonboom counties.

The exception to the Bakken and Marcellus sentiments came from western Colorado, where several interviewees expressed appreciable concern with student performance related to oil and gas development and the ensuing industry retraction. Unfortunately, reliable data were not ultimately available for comparative analysis.

4.3.3. Academic Attainment

Interestingly, when discussing academic attainment and potential educational effects stemming from the oil and gas boom, interviews in each section of the country referenced the positive impact of community colleges, suggesting that area community colleges were providing training to prepare local candidates for higher-paying work in the oil and gas sector. One specific example is a scholarship fund in North Dakota, stemming from local oil revenue, that provides tuition-free community college to any high school graduate in the five-county region. While the increasing role of community colleges was a constant story, it is unclear whether the community college route is diverting students away from a four-year degree or increasing educational attainment among students that would not have otherwise gone to college.

From the available data and extensive interviews, it is not obvious that the oil and gas boom in the Bakken or Marcellus has had a distinctly negative effect on educational outcomes in the short term. However, it is important to note that interview responses could have been influenced by several common cognitive biases, including the availability heuristic or optimism bias. Furthermore, a lack of evidence in the short term does not preclude long-term impacts, which are not currently measurable (Weber 2014; Haggerty et al. 2014). For example, classroom congestion, higher STRs, and teacher turnover in the Bakken are reasonable red flags for negative long-term effects on educational performance.

The statistical results and interview responses illustrate a general bifurcation between the Bakken and the Marcellus in regard to student populations, teacher demands, and revenue and expenditures. Yet neither region reported concerns with increased dropout rates or effects on academic achievement. Colorado districts generally fell between the two, although they shared more common characteristics with the Bakken despite having robust oil (Denver-Julesburg) and natural gas (Piceance) driven development. This divergence of trends across regions gives us pause about overgeneralizing impacts of resource booms.

5. Discussion and Conclusions

Unconventional oil and gas booms can have diverse impacts on public schools in boom regions. As shown, student enrollment and mobility, student-teacher ratios, and financial trends can vary across development regions. At the same time, other trends, as assessed in this study, can be common across diverse development areas. Examples include a common low concern with dropout rates, infrequent reporting of teachers and school staff leaving for higher-paying industry jobs, and a heightened sense of unease regarding financial volatility.

The primary drivers of the variation across boom regions appear to be growth in population from industry-driven in-migration and the size of industrial and infrastructure expansion in a locality. These two hypotheses account for the divergent trends but do not limit some common effects. For example, it is not surprising to see greater student enrollment in the Bakken, given the remoteness of the region and substantially larger buildout in support services. Conversely, a heightened sense of financial uncertainty could be common across energy regions experiencing volatility in new resource-based income.

Taken together, the divergent trends captured in statistical analysis and interviews between the Bakken and the Marcellus warn against overgeneralization with respect to the effects of natural resource booms. Just as some international analyses of the resource curse are not wholly applicable to the United States, researchers and policymakers should be equally wary of applying broad statements and conclusions across all unconventional oil and gas development areas within the United States. Consider, for example, the stark contrast between the extremely remote and sparsely populated Bakken region and the relatively populated development regions near Pittsburgh (Marcellus), Denver-Boulder (Denver-Julesburg), or at perhaps the farthest extreme, the Barnett Shale, located near the heavily developed and highly populated Fort Worth region in Texas. It would be entirely unsurprising to find that some impacts on schools would be markedly different among regions.

While the differing trends observed herein provide vital insight for school administrators and policymakers in boom states, the commonalities are equally, if not more, insightful when fully understood. The interview results reporting minimal effects of increased high school dropouts across all states contradict the historic resource economics literature, which found increased rates of student dropouts in mining boom regions (Black et al. 2005; Emery et al. 2012; Marchand and Weber 2015). Several interviewees explained that while they worried about decreases in graduation rates as energy development began to increase in their districts, those fears never materialized, concluding that the recent oil and gas booms required a higher level of training than what most potential high school dropouts possess. We find this explanation plausible given the highly technical nature of unconventional oil and gas development, similar responses across regions, and conversations with community college administrators, who cited an increased enrollment in technical training programs related to the oil and gas industry.

However, neither the lack of concern about high school dropouts nor the lack of evidence of an impact on student achievement in the short run alleviates long-term concerns over student educational attainment in some states. In fact, observations of reduced per pupil educational spending, rapid teacher turnover, and low levels of experience for many new teachers in the Bakken raises red flags regarding long-term student success areas. With most of the new boom-related households arriving in the Bakken in the late 2000s, and a majority of these young families having students enrolling in grade school, it may take several more years for potential impacts of the boom on student achievement to become measurable.

Interviews across all states also reported infrequent teacher attrition directly to the oil and gas industry. Despite this conclusion, it does appear that increasing industry wages are indirectly affecting teacher quality via challenges with acquisition and retention of new teachers. In particular, the high housing prices—driven by increasing demand and the high ability of industry workers to pay—made it challenging to hire and retain new teachers that were not already living in rural parts of Montana, North Dakota, and western Colorado. Interestingly, the increase in housing and rental costs in parts of Pennsylvania may have contributed to the more rapid student enrollment declines in boom regions by pushing out lower-income families.

A final commonality across regions may be the most important for policymakers—increased concern with financial volatility. In each region we visited, including those in the Marcellus that did not experience outsize student enrollment increases, many staff expressed concern about future funding and suggested that a decline in fossil fuel–based revenue would be detrimental to school budgets. Notably, interviews stated that this uncertainty was influencing near-term decisions as well as long-term financial commitments. Several interviewees noted that the financial stress was limiting increases in teacher pay and causing reductions in nonessential education programs. Instead, some administrators referenced committing only to short-term expenditures. With the overall growth in revenue generation from fuel production, which remains relatively high in most regions compared with preboom levels, it is a distinctly negative sign for public schools that financial stress from uncertainty has grown with increased production.

From more than 70 interviews, only a handful of interviewees suggested their districts were strictly better off because of the influence of unconventional oil and gas. Although oil and gas revenue has certainly created a variety of new upsides and opportunities for local economies in the short term, this common response from school staff is discouraging for the health of public education in many areas.

Therefore, we encourage local and state policymakers to consider revisions to education funding procedures that would allow for greater savings opportunities in times of excess revenue generation, allow for boom districts to capture larger *net* revenues from local resource extraction, and provide long-term, clearly stated commitments on state-based funding. Each of these updates would allow for consistency in revenue and expenditure smoothing over time, thereby providing districts a better opportunity to allocate resources based on their changing needs.

As a whole, the conclusions reinforce several of the prevailing long-term concerns associated with resource-based economic specialization. Simultaneously, the nuanced and divergent effects noted herein add significant insight into a resource boom's effects on public education and local economic health. However, substantial further research is needed to address several remaining questions.

We suggest three important lines of inquiry for future analysis. First, the varying designations or measurements for defining a boom create ambiguity in interpreting results across studies. Resource economists could work to more clearly define what technically constitutes a resource boom, although consensus seems unlikely. Another approach would be to retroactively compare results of published papers if a different definition for boom were employed. As an example, a paper with a boom defined such as ours would benefit from being reevaluated based on a geographic information system derived boom treatment.

Despite the relative consensus stemming from our inquiries, we also believe further statistical analysis is needed regarding the effect of boom development on dropout rates. On one hand, our study covered only six states. Moreover, the retraction of NCES data in August 2016, poor-quality state data, and potentially insufficient specificity from ACS all raise concerns regarding the validity of past analyses. Notwithstanding states with high-quality data, researchers may need to wait for the data quality and standardization of metrics on a national scale to improve before tackling the dropout question via statistical analysis across a number of producing states.

Recognizing the important role that recent papers have had in evaluating the effects of historic booms, we also recommend that effects on standardized test scores would be good to revisit at some point in the future.

In addition, we encourage future researchers exploring similar questions to consider employing a mixed method analysis that includes an interview- or survey-based component. The interviewees' contributions to this analysis were essential to disentangling details in the data and unearthing hidden stories. Without the interview component, we likely would have misinterpreted the magnitude or nuances of several important storylines.

To conclude, we return to the central question guiding this paper: Did public school districts in regions with high levels of oil and gas production during the recent unconventional energy booms fare better or worse in terms of financial and educational performance outcomes than comparable school districts that did not experience a boom? Although some distinct local benefits from the unconventional oil and gas boom have occurred within public education, the net impact has not been strictly positive. Despite dedicated and sustained efforts by many district staff and communities to mitigate the challenges, it appears that most regions in this study struggled to manage the impacts of uncertainty and volatility to school districts in the short term. Furthermore, with rapidly changing student numbers in the West and prevalent revenue uncertainty across all high-producing regions, students enrolled in boom school districts remain at risk of long-term negative impacts.

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Appendix

Table A1. Marcellus Regional Regression Results

Table A1a. Effect of Being a Top Energy Producing District in the Marcellus Region during the Shale Boom on Education

	Enrollment by Grades							School Staff			Proportion of Qualifying Student Population		
	PreK & Kinder	1st & 2nd	3rd & 4th	5th & 6th	7th & 8th	9th & 10th	11th & 12th	Full-Time Teachers	Student-Teacher Ratio	Instructional Aides	English Language Learners	Free Lunch	Reduced-Price Lunch
Marcellus Core Treatment drop neighbors	7.826	-7.994*	-15.63***	-16.77***	-17.82***	-20.76***	-9.415*	-4.754***	-0.325**	-1.363	-0.000767	-0.0384***	-0.0108***
	(6.009)	(4.304)	(4.243)	(4.555)	(5.654)	(6.016)	(5.608)	(1.842)	(0.135)	(1.001)	(0.000885)	(0.00569)	(0.00201)
Marcellus Core Treatment keep neighbors	4.822	-7.687*	-15.41***	-16.39***	-17.30***	-20.70***	-8.504*	-4.278***	-0.323**	-1.032	-0.000678	-0.0336***	-0.00852***
	(5.869)	(3.959)	(3.886)	(4.167)	(5.276)	(5.613)	(5.123)	(1.642)	(0.127)	(0.924)	(0.000761)	(0.00545)	(0.00203)
Marcellus Total Treatment drop neighbors	3.499	-10.05***	-16.58***	-16.52***	-15.51***	-16.67***	-7.925	-4.314***	-0.362***	-1.467*	-0.000944	-0.0393***	-0.00830***
	(4.636)	(3.839)	(3.823)	(4.176)	(4.830)	(5.011)	(5.369)	(1.656)	(0.122)	(0.880)	(0.000857)	(0.00505)	(0.00186)
Marcellus Total Treatment keep neighbors	-0.796	-9.314***	-15.38***	-15.13***	-13.79***	-15.59***	-7.174	-3.911***	-0.331***	-0.986	-0.000822	-0.0332***	-0.00624***
	(4.670)	(3.514)	(3.521)	(3.863)	(4.534)	(4.728)	(4.797)	(1.476)	(0.116)	(0.802)	(0.000723)	(0.00481)	(0.00179)

Table A1b. Effect of Being a Top Energy Producing District in the Marcellus Region during the Shale Boom on Public Education Finance

	Revenue per Pupil (in $2014)					Expenditures per Pupil (in $2014)				Salaries (in $2014)	
	Total	Local	Property Tax	State	Federal	Total	Education	Instructional	Capital	Teacher	Special Education Teacher
Marcellus Core Treatment drop neighbors	374.8**	138.2	62.56	205.7*	35.32	241.3	240.3**	111.0	127.5	-114,210	-118,233***
	(176.1)	(117.7)	(109.9)	(123.0)	(23.57)	(259.5)	(112.0)	(68.99)	(208.6)	(89,367)	(41,341)
Marcellus Core Treatment keep neighbors	431.2***	177.5	111.1	218.8*	38.25*	408.1*	285.0***	148.9**	206.8	-111,730	-82,921**
	(161.7)	(109.3)	(101.2)	(114.0)	(22.33)	(245.1)	(105.6)	(66.96)	(197.8)	(80,501)	(38,810)
Marcellus Total Treatment drop neighbors	231.9	64.12	15.03	158.6	12.88	184.0	212.5*	109.2*	119.9	-138,897*	-113,362***
	(176.2)	(121.6)	(114.3)	(108.4)	(21.10)	(238.1)	(115.4)	(62.98)	(180.0)	(80,268)	(36,329)
Marcellus Total Treatment keep neighbors	288.1*	120.0	63.46	153.3	17.34	299.6	234.1**	130.0**	183.4	-141,319**	-72,123**
	(154.1)	(105.2)	(98.29)	(99.05)	(20.61)	(218.6)	(102.8)	(59.61)	(170.9)	(70,563)	(33,173)

TABLE A1C. EFFECT OF BEING A TOP ENERGY PRODUCING DISTRICT IN THE MARCELLUS REGION DURING THE SHALE BOOM ON STUDENT PERFORMANCE

	Average English Language Arts Standardized Exams						Average Math Standardized Exams					
	3rd	4th	5th	6th	7th	8th	3rd	4th	5th	6th	7th	8th
Marcellus Core Treatment drop neighbors	-0.0413**	-0.0270	-0.0497**	-0.00637	0.0279*	0.00230	-0.0507**	-0.0177	0.00482	-0.0187	0.00231	-0.0384**
	(0.0184)	(0.0200)	(0.0199)	(0.0163)	(0.0162)	(0.0170)	(0.0202)	(0.0228)	(0.0216)	(0.0220)	(0.0212)	(0.0189)
Marcellus Core Treatment keep neighbors	-0.0387**	-0.0238	-0.0534***	-0.00800	0.0236	0.00318	-0.0524***	-0.0205	0.00231	-0.0217	-0.00133	-0.0380**
	(0.0179)	(0.0195)	(0.0193)	(0.0156)	(0.0156)	(0.0165)	(0.0194)	(0.0220)	(0.0208)	(0.0212)	(0.0208)	(0.0185)
Marcellus Total Treatment drop neighbors	-0.0382**	-0.0119	-0.0242	-0.0115	0.0299**	0.0169	-0.0519***	0.00413	0.0108	-0.00686	0.0165	-0.0179
	(0.0159)	(0.0175)	(0.0166)	(0.0136)	(0.0140)	(0.0149)	(0.0183)	(0.0197)	(0.0188)	(0.0187)	(0.0192)	(0.0172)
Marcellus Total Treatment keep neighbors	-0.0345**	-0.00868	-0.0250	-0.0137	0.0261*	0.0160	-0.0514***	-0.000448	0.0127	-0.00745	0.0104	-0.0209
	(0.0155)	(0.0172)	(0.0164)	(0.0134)	(0.0135)	(0.0146)	(0.0176)	(0.0194)	(0.0182)	(0.0190)	(0.0189)	(0.0168)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A2. Pennsylvania Regression Results

TABLE A2A. EFFECT OF BEING A TOP ENERGY PRODUCING DISTRICT IN PENNSYLVANIA DURING THE SHALE BOOM ON EDUCATION

	Enrollment by Grades							School Staff			Proportion of Qualifying Student Population		
	PreK & Kinder	1st & 2nd	3rd & 4th	5th & 6th	7th & 8th	9th & 10th	11th & 12th	Full-Time Teachers	Student-Teacher Ratio	Instructional Aides	English Language Learners	Free Lunch	Reduced-Price Lunch
Pennsylvania Core Treatment drop neighbors	-6.445*	-14.94***	-21.14***	-15.06***	-11.07	-10.04	-21.21***	-6.500***	-0.292*	-3.157**	-0.000287	-0.0276***	-0.00156
	(3.717)	(4.904)	(4.947)	(5.335)	(7.099)	(6.948)	(7.044)	(1.810)	(0.151)	(1.585)	(0.000332)	(0.00709)	(0.00310)
Pennsylvania Core Treatment keep neighbors	-5.987*	-12.89***	-18.30***	-12.55**	-9.213	-8.851	-19.29***	-6.074***	-0.288**	-2.720*	-0.000179	-0.0248***	-0.00160
	(3.437)	(4.623)	(4.727)	(5.091)	(6.716)	(6.535)	(6.497)	(1.650)	(0.143)	(1.465)	(0.000301)	(0.00663)	(0.00306)
Pennsylvania Total Treatment drop neighbors	-8.570**	-13.00***	-19.02***	-16.11***	-8.797	-4.429	-12.19**	-4.478**	-0.354***	-2.946**	-0.000445	-0.0253***	-0.00163
	(3.755)	(3.273)	(4.752)	(5.237)	(6.583)	(7.032)	(6.176)	(1.908)	(0.130)	(1.377)	(0.000384)	(0.00624)	(0.00250)
Pennsylvania Total Treatment keep neighbors	-6.850**	-15.03***	-19.77***	-17.64***	-13.14**	-13.04**	-18.44***	-6.066***	-0.353***	-3.154**	-0.000301	-0.0205***	-0.00176
	(3.281)	(2.876)	(4.305)	(4.804)	(6.023)	(6.527)	(5.844)	(1.697)	(0.116)	(1.230)	(0.000270)	(0.00550)	(0.00230)

TABLE A2B. EFFECT OF BEING A TOP ENERGY PRODUCING DISTRICT DURING THE SHALE BOOM IN PENNSYLVANIA ON PUBLIC EDUCATION FINANCE

	Revenue per Pupil (in $2014)					Expenditures per Pupil (in $2014)				Salaries (in $2014)	
	Total	Local	Property Tax	State	Federal	Total	Education	Instructional	Capital	Teacher	Special Ed. Teacher
Pennsylvania Core Treatment drop neighbors	161.3	-2.188	-29.00	103.7	66.47**	65.32	64.84	-17.87	90.21	-225,170**	-104,100*
	(162.4)	(130.2)	(117.5)	(93.21)	(31.77)	(360.8)	(122.5)	(87.56)	(267.6)	(109,444)	(56,853)
Pennsylvania Core Treatment keep neighbors	155.8	6.791	-20.56	104.3	50.33	163.2	110.0	11.41	107.7	-199,873**	-103,551*
	(154.6)	(124.4)	(111.7)	(87.25)	(31.24)	(342.5)	(114.9)	(81.80)	(261.9)	(100,885)	(52,918)
Pennsylvania Total Treatment drop neighbors	94.92	-23.83	-94.27	75.56	52.20	97.63	96.39	32.34	116.7	-140,853	-93,924**
	(178.2)	(104.5)	(92.06)	(121.1)	(32.15)	(314.4)	(128.7)	(84.33)	(232.8)	(100,956)	(46,835)
Pennsylvania Total Treatment keep neighbors	116.6	-15.32	-73.54	86.50	50.43*	259.8	76.01	6.905	246.4	-256,101***	-95,578**
	(140.3)	(97.47)	(86.77)	(89.49)	(26.90)	(268.1)	(109.4)	(75.76)	(209.1)	(89,605)	(43,205)

Table A2c. Effect of Being a Top Energy Producing District in Pennsylvania during the Shale Boom on Student Performance

	Average English Language Arts Standardized Exams						Average Math Standardized Exams					
	3rd	4th	5th	6th	7th	8th	3rd	4th	5th	6th	7th	8th
Pennsylvania Core Treatment drop neighbors	-0.0465*	-0.0156	-0.0481	0.00505	0.0550**	0.0156	-0.0968***	-0.0263	0.0297	0.00735	0.0373	-0.0125
	(0.0276)	(0.0295)	(0.0301)	(0.0229)	(0.0254)	(0.0257)	(0.0286)	(0.0339)	(0.0267)	(0.0328)	(0.0302)	(0.0279)
Pennsylvania Core Treatment keep neighbors	-0.0415	-0.0266	-0.0551*	0.0134	0.0525**	0.00827	-0.0916***	-0.0342	0.00987	7.84e-05	0.0344	-0.0151
	(0.0268)	(0.0274)	(0.0289)	(0.0216)	(0.0238)	(0.0258)	(0.0275)	(0.0318)	(0.0264)	(0.0310)	(0.0283)	(0.0288)
Pennsylvania Total Treatment drop neighbors	0.0600***	-0.00546	-0.0553**	-0.0152	0.0656***	0.0184	-0.0997***	0.0117	0.00570	-0.00233	0.0523**	-0.0181
	(0.0210)	(0.0226)	(0.0234)	(0.0197)	(0.0192)	(0.0213)	(0.0242)	(0.0284)	(0.0266)	(0.0262)	(0.0265)	(0.0240)
Pennsylvania Total Treatment keep neighbors	-0.0473**	-0.00201	-0.0429*	-0.0177	0.0555***	0.00962	-0.0860***	0.00944	0.0314	0.00551	0.0425	-0.0334
	(0.0205)	(0.0220)	(0.0227)	(0.0190)	(0.0190)	(0.0201)	(0.0226)	(0.0279)	(0.0246)	(0.0260)	(0.0259)	(0.0223)

Table A2d. Effect of Being a Top Energy Producing District in Pennsylvania during the Shale Boom on Additional Available Education Indicators

	Effect of Being a Top Energy Producing District in Pennsylvania during the Shale Boom on Additional Available Education Indicators											
	College Entrance Exams			PSSA State Exam						7-12th Grade Dropout Rate		
	SAT Average	SAT Average	SAT Average	3rd Reading	3rd Math	**5th Reading**	**5th Math**	**8th Reading**	8th Math	**Total Dropout**	**Male Proportion**	**Female Proportion**
Pennsylvania Core Treatment drop neighbors	0.595	2.964	1.898	-1.185	1.848***	-0.361	1.385	1.162	2.199*	-5.34e-05	0.00783	-0.00783
	(1.564)	(1.809)	(1.756)	(0.764)	(0.572)	(0.933)	(1.197)	(0.912)	(1.186)	(0.000937)	(0.0269)	(0.0269)
Pennsylvania Core Treatment keep neighbors	0.253	3.584*	1.603	-1.007	1.725***	-0.188	1.279	1.097	2.144*	-8.31e-05	0.0203	-0.0203
	(1.485)	(1.857)	(1.675)	(0.739)	(0.590)	(0.882)	(1.118)	(0.855)	(1.157)	(0.000893)	(0.0281)	(0.0281)
Pennsylvania Total Treatment drop neighbors	-0.0684	1.842	1.842	-0.984	1.717***	-0.895	0.652	1.015	1.217	0.000260	-0.00619	0.00619
	(1.235)	(1.641)	(1.499)	(0.628)	(0.562)	(0.790)	(0.973)	(0.652)	(0.958)	(0.000806)	(0.0257)	(0.0257)
Pennsylvania Total Treatment keep neighbors	0.289	2.511	1.809	-0.594	1.430***	-0.724	1.055	0.882	1.259	0.000341	-0.0105	0.0105
	(1.186)	(1.529)	(1.392)	(0.614)	(0.518)	(0.757)	(0.912)	(0.625)	(0.880)	(0.000699)	(0.0234)	(0.0234)

Standard errors in parentheses

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

Table A3. Ohio Regression Results

TABLE A3A. EFFECT OF BEING A TOP ENERGY PRODUCING DISTRICT IN OHIO DURING THE SHALE BOOM ON EDUCATION

	Enrollment by Grades							School Staff			Proportion of Qualifying Student Population		
	PreK & Kinder	1st & 2nd	3rd & 4th	5th & 6th	7th & 8th	9th & 10th	11th & 12th	Full-Time Teachers	Student-Teacher Ratio	Instructional Aides	English Language Learners	Free Lunch	Reduced-Price Lunch
Ohio Core Treatment drop neighbors	-4.179	-12.56*	-14.00	-14.33	-11.69	-11.74	-7.279	-1.925	-0.0843	0.122	-0.00252***	-0.0384***	-0.000232
	(7.707)	(7.360)	(9.362)	(9.317)	(8.257)	(7.474)	(10.01)	(3.591)	(0.393)	(1.074)	(0.000787)	(0.0118)	(0.00489)
Ohio Core Treatment keep neighbors	-4.914	-11.56	-12.43	-12.67	-10.25	-10.12	-7.435	-1.634	-0.0752	0.0953	-0.00253***	-0.0372***	0.000499
	(7.676)	(7.346)	(9.445)	(9.344)	(8.241)	(7.507)	(9.877)	(3.589)	(0.392)	(1.055)	(0.000743)	(0.0117)	(0.00487)
Ohio Total Treatment drop neighbors	-2.862	-10.84*	-10.33	-12.90	-11.99	-11.43	-8.588	-1.483	-0.167	-1.452	-0.00191**	-0.0171	-0.00209
	(5.534)	(5.988)	(7.368)	(8.194)	(8.621)	(7.694)	(11.18)	(3.150)	(0.278)	(0.971)	(0.000777)	(0.0130)	(0.00426)
Ohio Total Treatment keep neighbors	-3.469	-9.199	-8.463	-10.94	-10.51	-9.518	-8.570	-1.091	-0.173	-1.455	-0.00185***	-0.0151	-0.00115
	(5.459)	(5.880)	(7.319)	(8.111)	(8.532)	(7.779)	(11.12)	(3.097)	(0.275)	(0.956)	(0.000714)	(0.0129)	(0.00423)

TABLE A3B. EFFECT OF BEING A TOP ENERGY PRODUCING DISTRICT IN OHIO DURING THE SHALE BOOM ON PUBLIC EDUCATON FINANCE

	Revenue per Pupil (in $2014)					Expenditures per Pupil (in $2014)				Salaries (in $2014)	
	Total	Local	Property Tax	State	Federal	Total	Education	Instructional	Capital	Teacher	Special Education Teacher
Ohio Core Treatment drop neighbors	525.5	428.4***	420.9***	75.42	21.80	529.5	199.9	6.220	424.3	-122,881	-53,784
	(469.6)	(149.8)	(158.3)	(403.5)	(59.31)	(668.8)	(178.6)	(96.84)	(605.6)	(133,397)	(55,653)
Ohio Core Treatment keep neighbors	589.3	431.5***	404.6**	134.6	23.36	630.6	207.4	15.67	518.2	-100,624	-45,199
	(469.1)	(149.5)	(159.1)	(402.6)	(59.08)	(665.3)	(177.5)	(96.00)	(602.6)	(133,954)	(55,041)
Ohio Total Treatment drop neighbors	210.8	212.4	289.8*	4.513	-6.073	-23.62	163.8	43.64	-84.84	-85,535	-80,406*
	(356.1)	(161.3)	(149.1)	(279.4)	(44.04)	(493.2)	(148.5)	(84.91)	(433.7)	(123,910)	(43,195)
Ohio Total Treatment keep neighbors	279.0	217.9	277.1*	64.54	-3.296	83.17	185.1	64.24	-3.125	-48,755	-70,079
	(354.0)	(158.9)	(148.0)	(277.6)	(43.75)	(489.1)	(146.9)	(83.98)	(430.4)	(125,876)	(42,694)

Table A3c. Effect of Being a Top Energy Producing District in Ohio during the Shale Boom on Student Performance

	Average English Language Arts Standardized Exams						Average Math Standardized Exams					
	3rd	4th	5th	6th	7th	8th	3rd	4th	5th	6th	7th	8th
Ohio Core Treatment drop neighbors	-0.0249	-0.0164	-0.00395	-0.0153	0.0278	-0.0148	0.0113	-0.0376	-0.0205	-0.0180	-0.0285	-0.0545
	(0.0365)	(0.0369)	(0.0305)	(0.0280)	(0.0236)	(0.0304)	(0.0465)	(0.0337)	(0.0414)	(0.0355)	(0.0474)	(0.0416)
Ohio Core Treatment keep neighbors	-0.0232	-0.0154	-0.00816	-0.0170	0.0275	-0.0168	0.0114	-0.0340	-0.0231	-0.0187	-0.0258	-0.0565
	(0.0365)	(0.0370)	(0.0304)	(0.0279)	(0.0235)	(0.0302)	(0.0464)	(0.0337)	(0.0413)	(0.0353)	(0.0473)	(0.0416)
Ohio Total Treatment drop neighbors	-0.0202	0.0242	-0.00692	-0.0229	0.0340	-0.0184	0.0269	-0.000727	0.00729	-0.0447	-0.000854	-0.0301
	(0.0286)	(0.0307)	(0.0300)	(0.0203)	(0.0221)	(0.0228)	(0.0367)	(0.0314)	(0.0346)	(0.0328)	(0.0373)	(0.0289)
Ohio Total Treatment keep neighbors	-0.0223	0.0271	-0.0114	-0.0239	0.0335	-0.0219	0.0245	0.00389	0.00665	-0.0465	0.00324	-0.0338
	(0.0285)	(0.0307)	(0.0299)	(0.0201)	(0.0219)	(0.0225)	(0.0365)	(0.0315)	(0.0345)	(0.0327)	(0.0371)	(0.0288)

Table A3d. Effect of Being a Top Energy Producing District in Ohio during the Shale Boom on Additional Available Education Indicators

	College Entrance Exams				Exams									
	ACT Participation Rate	ACT Average	SAT Participation Rate	SAT Average	3rd Reading	3rd math	8th Reading	8th Math	11th Reading	11th Math	Current Graduation Rate	Dropout Rate	Proportion Special Ed.	Property Value
Ohio Core Treatment drop neighbors	-0.563	0.0200	-2.530	-3.662	-0.475	-0.178	-0.655	-1.686	0.305	0.205	-1.078**	0.000665	-0.000868	-21,484
	(1.111)	(0.121)	(1.914)	(19.18)	(1.050)	(1.222)	(1.179)	(1.332)	(0.486)	(0.647)	(0.503)	(0.00107)	(0.00583)	(36,450)
Ohio Core Treatment keep neighbors	-0.447	0.0367	-2.471	-2.514	-0.430	-0.138	-0.807	-1.788	0.315	0.195	-1.061**	0.000712	-0.000982	-17,170
	(1.102)	(0.119)	(1.911)	(19.10)	(1.047)	(1.216)	(1.173)	(1.332)	(0.485)	(0.646)	(0.501)	(0.00105)	(0.00581)	(32,729)
Ohio Total Treatment drop neighbors	-0.728	0.0421	-0.767	-8.614	0.284	0.243	-0.574	-1.714	-0.118	-0.192	-1.198***	0.00114	0.00297	-24,776
	(1.321)	(0.110)	(1.316)	(15.13)	(0.812)	(1.011)	(0.822)	(1.073)	(0.437)	(0.587)	(0.445)	(0.000964)	(0.00447)	(39,216)
Ohio Total Treatment keep neighbors	-0.513	0.0512	-0.694	-6.271	0.225	0.170	-0.758	-1.885*	-0.117	-0.193	-1.174***	0.00126	0.00281	-18,244
	(1.309)	(0.109)	(1.309)	(15.00)	(0.808)	(1.005)	(0.814)	(1.068)	(0.435)	(0.584)	(0.442)	(0.000938)	(0.00445)	(33,684)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A4. West Virginia Regression Results

Table A4a. Effect of Being a Top Energy Producing District in West Virginia during the Shale Boom on Education

	Enrollment by Grades							School Staff			Proportion of Qualifying Student Population		
	PreK & Kinder	1st & 2nd	3rd & 4th	5th & 6th	7th & 8th	9th & 10th	11th & 12th	Full-Time Teachers	Student-Teacher Ratio	Instructional Aides	English Language Learners	Free Lunch	Reduced-Price Lunch
West Virgnia Core Treatment drop neighbors	-28.98 (48.12)	3.876 (11.51)	-28.76* (16.99)	-33.74* (19.53)	-37.50 (26.26)	-43.82** (21.65)	-24.37* (14.06)	11.85 (7.210)	-0.612*** (0.0990)	6.179* (3.464)	0.000782 (0.00116)	0.0110 (0.0110)	0.00179 (0.00782)
West Virgnia Core Treatment keep neighbors	-40.06 (42.50)	4.135 (9.285)	-21.55 (13.97)	-25.33 (16.71)	-26.92 (23.97)	-36.92* (20.01)	-18.46 (13.17)	8.770 (6.212)	-0.718*** (0.170)	4.886 (3.213)	0.00122 (0.00106)	0.0160 (0.0103)	0.00478 (0.00655)
West Virgnia Total Treatment drop neighbors	-2.648 (42.42)	9.716 (7.124)	-3.943 (12.25)	-8.642 (11.92)	-28.86* (16.45)	-48.44** (18.89)	-29.36** (12.62)	-2.503 (8.376)	-0.513** (0.212)	5.270 (3.230)	-0.000256 (0.000721)	-0.0133 (0.0148)	0.00592 (0.00569)
West Virgnia Total Treatment keep neighbors	1.439 (38.47)	15.27** (6.645)	-3.947 (10.75)	-5.711 (11.09)	-19.41 (15.59)	-42.48** (18.14)	-18.39 (12.32)	3.022 (7.671)	-0.486*** (0.178)	6.678* (3.753)	0.000471 (0.000673)	-0.00253 (0.0131)	0.00424 (0.00498)

Table A4b. Effect of Being a Top Energy Producing District in West Virginia during the Shale Boom on Public Education Finance

	Revenue per Pupil (in $2014)					Expenditures per Pupil (in $2014)				Salaries (in $2014)	
	Total	Local	Property Tax	State	Federal	Total	Education	Instructional	Capital	Teacher	Special Education Teacher
West Virgnia Core Treatment drop neighbors	559.3 (474.7)	963.6** (461.9)	875.4** (410.7)	-449.2*** (123.9)	44.87 (67.97)	375.3 (322.0)	532.9** (211.9)	395.6*** (80.01)	-182.5 (198.4)	-244,808 (235,199)	187,427* (105,089)
West Virgnia Core Treatment keep neighbors	681.0* (402.0)	1,301*** (463.5)	1,107*** (393.4)	-731.3** (286.6)	111.0 (76.27)	275.5 (281.4)	744.4*** (220.3)	495.2*** (78.74)	-477.7 (286.9)	-214,452 (188,273)	197,118** (91,228)
West Virgnia Total Treatment drop neighbors	606.1* (300.1)	910.7*** (333.9)	797.5*** (266.7)	-344.2 (210.1)	39.62 (93.79)	541.0 (328.3)	504.0** (216.0)	303.2*** (99.26)	57.91 (297.4)	-118,588 (262,023)	-22,348 (111,738)
West Virgnia Total Treatment keep neighbors	299.4 (309.1)	754.9** (308.7)	656.8** (249.2)	-535.8** (203.0)	80.28 (85.72)	158.3 (357.7)	416.7** (200.7)	289.0*** (95.62)	-223.1 (293.8)	-18,419 (241,048)	10,320 (100,967)

Table A4c. Effect of Being a Top Energy Producing District in West Virginia during the Shale Boom on Student Performance

	Average English Language Arts Standardized Exams						Average Math Standardized Exams					
	3rd	4th	5th	6th	7th	8th	3rd	4th	5th	6th	7th	8th
West Virgnia Core Treatment drop neighbors	-0.0410	0.000748	-0.125	0.0800*	-0.0590	0.0621	-0.0603	-0.0217	-0.122	-0.129	-0.142**	-0.0563*
	(0.0625)	(0.0356)	(0.103)	(0.0467)	(0.0500)	(0.0726)	(0.0549)	(0.0473)	(0.101)	(0.0882)	(0.0692)	(0.0311)
West Virgnia Core Treatment keep neighbors	0.0348	0.104	-0.105	0.0983**	-0.0134	0.0589	0.0380	-0.0324	-0.113	-0.0683	-0.0421	0.0280
	(0.0744)	(0.103)	(0.0853)	(0.0444)	(0.0480)	(0.0636)	(0.0915)	(0.0385)	(0.0819)	(0.0891)	(0.106)	(0.0681)
West Virgnia Total Treatment drop neighbors	-0.00451	-0.0207	-0.0630	0.114**	-0.0203	0.0556	-0.00216	-0.111**	-0.157**	-0.0688	-0.0909	-0.00249
	(0.0489)	(0.0840)	(0.0735)	(0.0465)	(0.0446)	(0.0581)	(0.0584)	(0.0525)	(0.0679)	(0.0692)	(0.0712)	(0.0552)
West Virgnia Total Treatment keep neighbors	-0.0333	-0.0431	-0.0673	0.0894**	-0.0649	0.0489	-0.0341	-0.136**	-0.111*	-0.0562	-0.0944	0.00593
	(0.0539)	(0.0786)	(0.0656)	(0.0432)	(0.0419)	(0.0485)	(0.0621)	(0.0554)	(0.0658)	(0.0623)	(0.0633)	(0.0479)

Table A4c. Effect of Being a Top Energy Producing District in West Virginia during the Shale Boom on Additional Available Education Indicators

	"Mastering" State Exams		Proportion of Students	
	Math	Reading	In Special Education	From Low Socio-economic Households
West Virgnia Core Treatment drop neighbors	-0.0362*	-0.00226	-0.00648	-0.00855
	(0.0183)	(0.0136)	(0.00697)	(0.0101)
West Virgnia Core Treatment keep neighbors	-0.0194	0.00900	-0.00508	-0.00741
	(0.0185)	(0.0134)	(0.00572)	(0.00984)
West Virgnia Total Treatment drop neighbors	-0.00919	0.0207	-0.00578	-0.0190*
	(0.0143)	(0.0135)	(0.00404)	(0.0103)
West Virgnia Total Treatment keep neighbors	-0.0140	0.0114	-0.00650	-0.00725
	(0.0132)	(0.0132)	(0.00416)	(0.00912)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A5. North Dakota Regression Results

Table A5a. Effect of Being a Top Energy Producing District in North Dakota during the Shale Boom on Education

	Enrollment by Grades							School Staff			Proportion of Qualifying Student Population		
	PreK & Kinder	1st & 2nd	3rd & 4th	5th & 6th	7th & 8th	9th & 10th	11th & 12th	Full-Time Teachers	Student-Teacher Ratio	Instructional Aides	English Language Learners	Free Lunch	Reduced-Price Lunch
North Dakota Core Treatment drop neighbors	1.946	8.392**	6.965***	5.451*	5.739*	8.164***	2.517	-0.615	1.120***	-0.205	-0.0140**	-0.0125	-0.00615
	(2.233)	(3.469)	(2.586)	(2.848)	(3.207)	(3.120)	(2.717)	(1.675)	(0.365)	(0.696)	(0.00700)	(0.0127)	(0.00853)
North Dakota Core Treatment keep neighbors	0.269	5.440	4.362	3.409	3.724	7.750***	4.133*	0.0407	0.969**	-0.296	-0.0146**	0.000248	-0.00419
	(3.453)	(4.954)	(3.404)	(2.957)	(3.346)	(2.833)	(2.180)	(1.646)	(0.378)	(0.745)	(0.00680)	(0.0117)	(0.00838)
North Dakota Total Treatment drop neighbors	2.983*	7.248***	5.604***	1.880	2.326	3.490	0.921	-0.707	0.687**	0.0796	-0.00643	-0.0121	-0.0111
	(1.723)	(2.385)	(1.994)	(2.648)	(2.821)	(3.409)	(2.612)	(1.004)	(0.290)	(0.820)	(0.0113)	(0.0122)	(0.00672)
North Dakota Total Treatment keep neighbors	1.100	3.720	2.841	1.029	2.293	4.126	1.622	-1.610	0.722***	0.0597	-0.00719	-0.00704	-0.00854
	(2.325)	(3.204)	(2.525)	(2.466)	(2.765)	(3.270)	(2.597)	(1.213)	(0.273)	(0.772)	(0.00995)	(0.0115)	(0.00622)

Table A5b. Effect of Being a Top Energy Producing District during the Shale Boom in North Dakota on Public Education Finance

	Revenue per Pupil (in $2014)					Expenditures per Pupil (in $2014)				Salaries (in $2014)	
	Total	Local	Property Tax	State	Federal	Total	Education	Instructional	Capital	Teacher	Special Education Teacher
North Dakota Core Treatment drop neighbors	-1,498*	-390.4	-1,195***	-1,212***	283.2	-1,038	-1,451***	-775.0**	872.6*	1,522	-7,533
	(807.2)	(470.2)	(376.1)	(250.7)	(565.4)	(754.6)	(548.4)	(350.1)	(466.4)	(57,457)	(32,237)
North Dakota Core Treatment keep neighbors	-1,311	-800.2	-862.5*	-1,234***	663.0	-1,198	-1,494**	-846.2*	1,167**	-11,417	8,208
	(873.0)	(652.9)	(491.5)	(294.9)	(575.5)	(1,074)	(738.4)	(463.7)	(475.9)	(65,750)	(26,674)
North Dakota Total Treatment drop neighbors	-1,424*	103.2	-787.8*	-900.4***	-365.5	-498.0	-1,100**	-509.9*	330.6	20,476	-654.5
	(758.4)	(645.2)	(424.7)	(220.0)	(474.7)	(884.0)	(520.3)	(302.7)	(351.6)	(44,143)	(22,724)
North Dakota Total Treatment keep neighbors	-1,383*	-15.33	-497.9	-993.7***	-279.6	-1,039	-1,443**	-844.4*	361.6	-8,853	-17,447
	(763.0)	(673.7)	(449.1)	(266.7)	(458.5)	(1,078)	(681.0)	(437.0)	(328.9)	(53,698)	(23,124)

Standard errors in parentheses

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

Table A6. Colorado Regression Results

Table A6a. Effect of Being a Top Energy Producing District in Colorado during the Shale Boom on Education

	Effect of Being a Top Energy Producing District in Colorado during the Shale Boom on Education												
	Enrollment by Grades							School Staff			Proportion of Qualifying Student Population		
	PreK & Kinder	1st & 2nd	3rd & 4th	5th & 6th	7th & 8th	9th & 10th	11th & 12th	Full-Time Teachers	Student-Teacher	Instructional Aides	English Language	Free Lunch	Reduced-Price Lunch
Colorado (D-J) Core Treatment drop neighbors	-16.73	-1.514	-19.61	-18.88	-9.758	-12.41	-32.84	4.064	1.391	-8.572	-0.00721	-0.0322	-0.0109**
	(43.40)	(63.80)	(59.34)	(61.02)	(58.85)	(58.72)	(68.62)	(15.17)	(1.189)	(11.20)	(0.00897)	(0.0219)	(0.00513)
Colorado (D-J) Core Treatment keep neighbors	-38.40	-36.92	-56.06	-51.72	-43.19	-43.45	-56.22	-5.698	1.174	-11.73	-0.00590	-0.0284	-0.00936*
	(43.89)	(64.27)	(60.09)	(59.38)	(58.33)	(57.17)	(65.57)	(15.44)	(1.005)	(10.58)	(0.00882)	(0.0217)	(0.00479)
Colorado (D-J) Total Treatment drop neighbors	9.144	18.12	-11.05	-15.37	-7.370	-21.47	-26.25	5.027	1.289	-8.494	-0.00942	-0.0182	-0.0108**
	(63.01)	(91.17)	(81.30)	(79.96)	(77.34)	(73.79)	(82.35)	(21.14)	(1.338)	(14.15)	(0.00711)	(0.0170)	(0.00465)
Colorado (D-J) Total Treatment keep neighbors	22.02	22.52	-8.046	-14.87	-10.70	-26.78	-12.38	3.623	1.045	-2.309	-0.00897	-0.00861	-0.00925**
	(59.18)	(79.65)	(66.18)	(60.96)	(59.06)	(53.97)	(63.24)	(17.69)	(1.063)	(10.97)	(0.00690)	(0.0165)	(0.00425)

Table A6b. Effect of Being a Top Energy Producing District during the Shale Boom in Colorado on Public Education Finance

	Revenue per Pupil (in $2014)					Expenditures per Pupil (in $2014)			
	Total	Local	Property Tax	State	Federal	Total	Education	Instructional	Capital
Colorado (D-J) Core Treatment drop neighbors	-1,759	-310.2	88.85	-1,341	-108.6*	-1,182	-1,112	-341.9	340.1
	(1,657)	(1,065)	(753.7)	(1,033)	(62.87)	(1,646)	(1,062)	(329.6)	(1,085)
Colorado (D-J) Core Treatment keep neighbors	-1,298	-66.75	232.6	-1,143	-88.82	-801.1	-887.5	-286.3	439.3
	(1,454)	(987.6)	(713.6)	(928.7)	(57.19)	(1,473)	(941.2)	(322.2)	(1,014)
Colorado (D-J) Total Treatment drop neighbors	-1,921	-440.2	70.84	-1,391*	-90.34	-1,118	-881.6	-254.2	110.3
	(1,272)	(795.7)	(545.7)	(772.5)	(60.78)	(1,271)	(839.3)	(244.6)	(819.0)
Colorado (D-J) Total Treatment keep neighbors	-1,158	-126.1	263.3	-968.2	-63.53	-526.2	-627.2	-168.7	358.2
	(1,059)	(704.2)	(504.1)	(668.7)	(53.64)	(1,085)	(693.0)	(235.8)	(739.9)

Standard errors in parentheses
***** p<0.01, ** p<0.05, * p<0.1**

Table A7. Five-State Pooled Regression Results

TABLE A7A. EFFECT OF BEING A TOP ENERGY PRODUCING DISTRICT DURING THE SHALE BOOM ON EDUCATION

	Enrollment by Grades							School Staff			Proportion of Qualifying Student Population		
	PreK & Kinder	1st & 2nd	3rd & 4th	5th & 6th	7th & 8th	9th & 10th	11th & 12th	Full-time Teachers	Student-Teacher Ratio	Instructional Aides	English Language Learners	Free Lunch	Reduced-Price Lunch
5 State Pooled Core Treatment	7.021	-7.961	-15.11***	-17.02***	-17.99***	-22.26***	-6.445	-2.956*	-0.0428	-0.595	-0.00242	-0.0344***	-0.0116***
drop neighbors	(5.496)	(5.053)	(4.480)	(4.575)	(5.372)	(5.737)	(5.684)	(1.768)	(0.148)	(0.897)	(0.00191)	(0.00524)	(0.00194)
5 State Pooled Core Treatment	5.684	-6.710	-13.35***	-14.79***	-15.50***	-19.90***	-4.226	-2.242	-0.0495	-0.309	-0.00274	-0.0299***	-0.0104***
keep neighbors	(5.425)	(4.999)	(4.402)	(4.497)	(5.258)	(5.570)	(5.531)	(1.645)	(0.140)	(0.851)	(0.00183)	(0.00503)	(0.00190)
5 State Pooled Total Treatment	6.689	-3.188	-10.72**	-13.37***	-13.34***	-17.22***	-1.695	-1.842	-0.129	0.0200	-0.00249	-0.0321***	-0.00990***
drop neighbors	(5.540)	(5.935)	(4.873)	(4.714)	(5.140)	(5.060)	(5.755)	(1.724)	(0.139)	(0.927)	(0.00180)	(0.00470)	(0.00172)
5 State Pooled Total Treatment	5.484	-1.839	-8.899*	-11.09**	-10.86**	-15.09***	-0.924	-1.249	-0.130	0.341	-0.00201	-0.0258***	-0.00824***
keep neighbors	(5.422)	(5.738)	(4.665)	(4.508)	(4.954)	(4.877)	(5.523)	(1.610)	(0.126)	(0.884)	(0.00179)	(0.00447)	(0.00167)

TABLE A7B. EFFECT OF BEING A TOP ENERGY PRODUCING DISTRICT DURING THE SHALE BOOM ON PUBLIC EDUCATION FINANCE

	Revenue per Pupil (in $2014)					Expenditures per Pupil (in $2014)				Salaries (in $2014)	
	Total	Local	Property Tax	State	Federal	Total	Education	Instructional	Capital	Teacher	Special Education Teacher
5 State Pooled Core Treatment	-127.6	310.5*	95.30	-367.3***	-27.30	-19.23	-201.5	-103.9	218.9	-275,198***	-118,114***
drop neighbors	(223.9)	(181.1)	(144.3)	(119.6)	(95.55)	(286.1)	(151.5)	(83.90)	(190.6)	(86,206)	(35,964)
5 State Pooled Core Treatment	-55.14	317.1*	142.0	-339.9***	-18.77	-19.56	-220.8	-129.5	257.2	-254,623***	-87,566**
keep neighbors	(226.2)	(187.8)	(141.8)	(116.5)	(102.0)	(307.6)	(167.9)	(99.20)	(185.4)	(83,830)	(34,600)
5 State Pooled Total Treatment	-244.9	141.7	50.47	-357.2***	-15.19	-146.7	-245.5	-111.2	210.2	-263,692***	-109,627***
drop neighbors	(212.6)	(167.1)	(139.2)	(111.0)	(67.84)	(275.1)	(163.3)	(91.57)	(161.0)	(74,276)	(31,399)
5 State Pooled Total Treatment	-137.4	202.2	85.40	-321.3***	-7.701	-46.07	-175.6	-74.59	227.6	-230,620***	-75,594**
keep neighbors	(193.6)	(153.4)	(123.6)	(101.7)	(70.32)	(254.3)	(146.2)	(84.07)	(154.3)	(71,011)	(29,633)

Table A7c. Effect of Being a Top Energy Producing District during the Shale Boom on Student Performance

	Average English Language Arts Standardized Exams						Average Math Standardized Exams					
	3rd	4th	5th	6th	7th	8th	3rd	4th	5th	6th	7th	8th
5 State Pooled Core Treatment drop neighbors	-0.0370*	-0.0158	-0.0456**	-0.0143	0.0313*	0.00150	-0.0544***	-0.0169	0.00667	-0.0157	0.00469	-0.0343*
	(0.0192)	(0.0201)	(0.0204)	(0.0159)	(0.0167)	(0.0169)	(0.0203)	(0.0225)	(0.0208)	(0.0209)	(0.0223)	(0.0196)
5 State Pooled Core Treatment keep neighbors	-0.0312*	-0.0135	-0.0477**	-0.0158	0.0289*	0.00537	-0.0529***	-0.0194	0.00863	-0.0222	0.00108	-0.0323*
	(0.0189)	(0.0199)	(0.0202)	(0.0157)	(0.0164)	(0.0172)	(0.0199)	(0.0225)	(0.0204)	(0.0213)	(0.0220)	(0.0193)
5 State Pooled Total Treatment drop neighbors	-0.0298*	-0.00306	-0.0266	-0.0163	0.0369***	0.00976	-0.0413**	0.00595	0.0108	-0.00106	0.0234	-0.0225
	(0.0160)	(0.0177)	(0.0170)	(0.0139)	(0.0140)	(0.0149)	(0.0180)	(0.0202)	(0.0190)	(0.0193)	(0.0201)	(0.0171)
5 State Pooled Total Treatment keep neighbors	-0.0244	-0.000301	-0.0279*	-0.0179	0.0324**	0.00847	-0.0397**	0.00223	0.0124	-0.00329	0.0194	-0.0242
	(0.0156)	(0.0175)	(0.0168)	(0.0137)	(0.0137)	(0.0147)	(0.0175)	(0.0199)	(0.0185)	(0.0196)	(0.0196)	(0.0167)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1