A "Resource Curse" for Education?: Deepening Education Disparities in Pennsylvania's Shale Gas Boomtowns

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Abstract: In Pennsylvania's Marcellus Shale region, the recent shale gas boom profoundly reshaped communities, local institutions, and living circumstances for many residents. We focus on one particular local institution – the public school – to investigate the relationship between unconventional gas development and education funding. Using geographic information systems software, we identify unconventional drilling activity between 2007 and 2015 and link unconventional drilling point data with district-level state and federal data. We then use techniques from the matching literature to explore the relationship between unconventional drilling and the distribution of educational resources and opportunities. Evidence from our analysis suggests that, on average, districts experiencing unconventional drilling had lower per pupil revenues, locally-raised per pupil funding for schools, per pupil income, and per pupil property wealth than very similar districts that did not experience unconventional drilling.

Keywords: Marcellus shale; hydraulic fracturing; shale gas; economic development; spatial inequality; school funding

Introduction

In the mid-2000s the physical and economic landscape of much of Pennsylvania was dramatically altered by unconventional gas development (Jacquet, et al. 2018). Unconventional gas extraction is an industrially intensive process that involves drilling a wellbore to the energy resource-bearing geologic layer, then turning the bore to drill horizontally along the layer, often for a mile or more. Explosive charges are laid along the horizontal wellbore to perforate the geologic layer, after which fracturing fluid, containing a mixture of water, sand, lubricants and biocides, is injected at high pressure. This fractures the geology, releasing the gas, which then flows to the surface (Wilber 2012).

Pennsylvania sits atop the Marcellus Shale formation, understood to be among the largest gas bearing shale formations in the world with much of the prime extraction area located in largely rural parts of the state that have long experienced economic contraction and underdevelopment (Schafft, McHenry-Sorber, Hall, and Burfoot-Rochford 2018). Unconventional oil and gas development in Pennsylvania began in earnest in 2007, reaching peak drilling in 2011, although drilling continues to the present time (see Figure 1).

(Figure One About Here)

Unconventional oil and gas development has not been without its controversy. Opponents have largely pointed to negative environmental and community impacts, including the potential for contaminated ground and surface water, overburdened public institutions, public health concerns, impacts on public lands, and the effects of dramatically increased heavy vehicle traffic on smaller roads. Others have raised concerns about the potential for negative impacts of boom-bust economic development (Buday 2017; Jacquet 2014; Schafft, Glenna, Borlu, and Green 2014; Vasi, Walker, Johnson, and Tan 2015). Much of this work is broadly consistent with earlier "boomtown" literature (see, e.g., Freudenberg 1992; Freudenberg and Gramling 1998), although some more recent scholarship on unconventional gas development impacts has tended to pay greater attention to spatiality and localized spatial scales of development (Jacquet and Kay 2014; Mayer, Olson-Hazboun and Malin 2018; Schafft Brazier and Hesse 2019).

Proponents within Pennsylvania, however, supported the development of unconventional oil and gas drilling primarily with economic arguments, describing it as a fiscal windfall for economically lagging communities. As development accelerated, gas and oil lobbyists, and industry-funded groups such as the Marcellus Shale Coalition, spearheaded public relations campaigns across the state in support of shale gas development (Smith and Ferguson 2013). Communities experiencing unconventional drilling, advocates argued, would experience higher employment rates, increased economic opportunities, and new governmental revenues from oil and gas leasing. Economic development was also rhetorically tied with the argument that natural gas development would increase "energy independence," framing industry support in terms of the broader benefits of U.S. energy security (Jerolmack and Walker 2018; Sica and Huber 2017).

Assessing Local Economic Impacts: The Resource Curse?

Despite economic benefit arguments for shale gas development in Pennsylvania, a relatively substantial literature suggests how increased economic dependency on natural resource extraction is often associated with relatively lower economic growth than in areas that have little or no natural resource development. Often termed the "resource curse," much of the research on the relationship between natural resource development and economic underdevelopment has been conducted at the national, regional, or state level (e.g., Papyrakis and Gerlagh 2007; Sachs and Warner 2001).

This literature stems from the observation that despite assumptions that countries with ample energy and mineral resources should be able to translate these assets into long-term economic development, the reality has often proved different. Indeed, some economists have found that counties with energy and mineral resources often experience economic growth at slower rates than similar counties without such resources. Badeeb, Lean and Clark (2017) argue that there are two broad explanations offered. The first is economic and suggests that natural resource booms can create national-level market distortions of non-natural resource sectors because of inflation and cost increases. Further, natural resource base economies can be vulnerable to volatile global commodity prices, placing natural resource economies at risk of sudden economic shocks. The second explanation is political and suggests that windfall natural resource revenues increase the power and influence of political elites, increasing income inequality, corruption and clientelism.

Other studies have been conducted at the subnational level at geographic levels such as counties. James and Aadland (2011) for example examine U.S county-level growth and find that resource-dependent counties show consistently weaker economic growth after controlling for state-specific characteristics, socio-demographic factors, and spatial correlation. Weber (2014) however, examining counties in the south-central U.S. finds little evidence of a resource curse from natural gas production. To the contrary, he finds that each mining job was associated with the creation of one new non-mining job, and that there was no effect on human capital in the form of educational attainment.

Given the economic arguments of gas industry proponents and the economic underdevelopment that characterizes much of Pennsylvania that experienced rapid unconventional gas development, now that the buildout in Pennsylvania has peaked, we argue it is important to systematically examine local-level impacts such as the effects on key local institutions such as public education. There is, for example, strong evidence to suggest that buildout was associated with local disruption to housing availability, resulting in strains on social services and increases in homelessness, as well as impacts on physical infrastructure such as roads (Schafft, Glenna, Borlu, and Green 2014; Schafft, McHenry-Sorber, Hall, and Burfoot-Rochford 2018). Others have noted how significant numbers of skilled out of state employees were taking advantage of gas industry jobs in Pennsylvania rather than native Pennsylvanians (Hardy and Kelsey 2014). At the same time, others have pointed to the local economic benefits associated with leasing revenues and job creation (Hardy and Kelsey 2015). How and to what extent have these different community effects been reflected in the economic status of local schools?

School District Fiscal Resources as Indicators of Community Wealth and Opportunity

In this study we examine school district fiscal resources within Pennsylvania to investigate the association between natural resource development and local economic outcomes. While many states contain school districts that are contiguous with county-level geographies, Pennsylvania has 500 public school districts. Especially within Pennsylvania's more rural areas, school districts are often directly associated with specific municipalities. As such, they help to define local communities and create a sense of shared, often inter-generational, identity. Residents pay property taxes which accrue to school districts, and within rural areas in particular, school districts are often an area's largest employer, the schools themselves functioning as important sites of civic engagement and interaction. Additionally, schools play important economic roles beyond providing employment, including being positively associated with earnings and housing values (Sipple, Francis, and Fiduccia 2019).

The fiscal resources of these districts, moreover, reflect both wealth and opportunity within a community. Since local taxes play an important role in education funding, changes in local wealth can be viewed in relation to changing patterns in education funding. School districts in Pennsylvania were more reliant on local taxes for education funding than districts in 47 other states in 2015, with the vast majority of local funds derived from taxes on real estate (U.S. Census Bureau 2017). These real estate taxes provided 77% of local revenue in 2015, with a locally-raised earned income tax providing 8% of local revenue in that same year (Pennsylvania Department of Education 2015).

School funding is also an important indicator of opportunity within a community. District-level education funding shapes long-term academic and economic outcomes for children educated in that district (e.g., Baker 2018). For example, research shows that increases in district-level education funding reduce poverty and increase future adult earnings (Jackson, Johnson, and Persico 2016). Research also indicates that increased school spending improves academic outcomes associated with social and economic mobility. Candelaria and Shores (2019), for example, provide evidence from a natural experiment that increased education funding improves high school graduation rates. Secondary school completion is critical, in turn, because dropping out of high school adversely impacts future employment, earnings, physical health, and chances of experiencing incarceration (Belfield and Levin 2007; Lleras-Muney 2005). Although intergenerational mobility has declined overall in recent years (Chetty et al. 2017), recent work finds that school funding equalization between 1980 and 2004 had a large effect on mobility of low-income students (Biasi 2019).

In Pennsylvania, unconventional drilling has disproportionately affected smaller, poorer, and more rural school districts (Kelsey, Hartman, Schafft, Borlu, and Costanzo 2012; Schafft, McHenry-Sorber, Hall, and Burfoot-Rochford 2018). In Table 1 (below) we disaggregate Pennsylvania school districts by National Center for Education Statistics (NCES) spatial designations and indicate the relative distribution of unconventional well drilling across school districts along Pennsylvania's urban-rural continuum[1] between 2007 and 2015. Using 2007 data, we further compare school districts by relative wealth. To measure relative wealth, we use a state specific measure—the "aid ratio"—calculated by the Pennsylvania Department of Education (PDE). The ratio compares each school district's total income and property wealth with the state average.[2]

(Table 1 About Here)

Table 1 indicates the spatial distribution of unconventional drilling activity in Pennsylvania between 2007 and 2015, as well as how drilling has differentially occurred in poorer versus wealthier school districts. Notably, although there are 20 school districts classified as "city," only one urban district (five percent of all in the category) had experienced unconventional drilling. Among suburban districts, that percentage increased to slightly less than 12 percent. However, nearly 40 percent of districts classified as towns had experienced unconventional drilling, and the same was true for over 56 percent of rural districts. Furthermore, over two thirds of all unconventional wells drilled during the time period were drilled in rural districts, as compared to town districts within which slightly over 22 percent of wells were drilled, suburban districts where about ten percent of wells were drilled and city school districts which accounted for less than one percent of all unconventional drilling. Unconventional drilling also occurred disproportionately in Pennsylvania's poorest districts[3]. Of school districts in the wealthiest quintile, only about seven percent experienced unconventional drilling, as compared to about 45 percent of districts in the poorest quintile. Drilling within the wealthiest districts accounted for about three percent of all unconventional wells, as compared to drilling within the poorest districts which accounted for about 32 percent of all wells. Poverty and economic disadvantage typically concentrate in rural areas (Brown and Schafft 2019). This is the case in Pennsylvania where of the 99 school districts in the wealthiest quintile, only 13 are

[1] For spatial category definitions, see: https://nces.ed.gov/surveys/ruraled/definitions.asp.

[2] For more information on the calculation of this measure and its use, see: https://www.education.pa.gov/Teachers%20-%20Administrators/School%20Finances/Finances/FinancialDataElements/Pages/default.aspx

[3] Here we draw from 2007 data to identify relative district wealth.

classified as rural, while of the 100 school districts in the poorest quintile, 50 are classified as rural.

Therefore, it is important to better understand the relationship between shale gas development in Pennsylvania and the fiscal well-being of schools in the most immediate proximity to unconventional energy development. Has unconventional oil and gas extraction represented a windfall opportunity for local schools? Or alternately do we see evidence of a "resource curse," and an association between resource development and community disadvantage?

To date, little work has investigated how unconventional gas development affects school funding (see, however, Kelsey, Hartman, Schafft, Borlu, and Costanzo 2012 and Marchand and Weber 2019). Our analysis provides the first comprehensive analysis of this question within the Pennsylvania context. First, what is the impact of unconventional drilling on three indicators of income and wealth: resident income per pupil, district property wealth per pupil, and the percentage of children living in poverty within a school district? Second, what is the impact of unconventional drilling on total, federal, state, and local public school per pupil revenues?

Data and Methods

We utilize spatial analyses to better understand how place characteristics may affect development impacts (Schafft, Brasier and Hesse 2019). We bring together data on the location of unconventional drilling sites operating between 2007 and 2015 (Pennsylvania Department of Natural Resources [PDNR]); the location of school districts (U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing data on school district boundaries from 2015 [TIGER]); and district-level data on education funding, community wealth, and socioeconomic disadvantage. Due to constraints on the availability of our federal data sources for the period after 2015, we concentrate our analysis on the period between 2007, the start of the Marcellus Shale boom, and 2015.[4] This time frame, however, coincides with the major build-out of the industry within Pennsylvania (e.g., see Figure 1). Figure 2 (below) shows a map of Pennsylvania school districts with point data indicating drilling activity between 2007-2015. Figure 2 illustrates the spatial concentration of drilling as well as the variability in the relative exposure of school districts to drilling activity.

(Figure 2 About Here)

To assemble our data set, we first identified school districts experiencing unconventional drilling activity within their boundaries between 2007 and 2015. We do this by combining point data from the Pennsylvania Department of Natural Resources (PDNR) and district boundary files from TIGER. We then merge this information with district-level data from the US Census of Governments School System Finance File (F-33) for 2007 and 2015.

To assess the economic status of localities, we use data on the total income of residents in each school district provided by Pennsylvania Department of Education (PDE). Income data reported by PDE is derived from the personal income tax returns of residents reported to the Pennsylvania Department of Revenue. Since most local revenue is derived from taxes on property, changes in property wealth can also impact the ability of districts to cover their costs. We use data on the value of property in each

[4] Federal education and poverty data for 2015 were the most recently available when we conducted our analysis.

district in 2007 and 2015 from the Pennsylvania State Tax Equalization Board (STEB). These values are generated by state officials to adjust for the way county-level variations in assessment practices impact property valuation. As is customary in analyses of education funding, we concentrate on per pupil figures and weight district observations by their fall enrollment in our analysis (Verstegen, 2013). To capture variations in educational costs between labor markets, we use values from the Comparable Wage Index (CWI) for 2007 and 2015 reported in the school funding fairness data system (Baker, Srikanth, and Weber 2016).

Researchers often use free and reduced-price lunch data to assess socioeconomic disadvantage within a school district. However, some researchers have questioned the validity of this measure (Domina et al. 2018). Recent policy changes in reporting requirements through community-wide eligibility for free and reduced-price lunch further complicate the use of this measure as a proxy for economic disadvantage (Koedel and Parsons 2019). As a result, we assess economic disadvantage using 5-year estimates from the U.S. Census Bureau's American Community Survey on the number of 5-17 years old children falling below the federal poverty threshold within each district.

Analysis

We begin our analyses with descriptive statistics shown in Table 2, examining the change between 2007 and 2015 across a number of district-level socioeconomic indicators, subclassifying districts according to their relative exposure to unconventional drilling activity. As we noted earlier (and as suggested by Table 1), within Pennsylvania unconventional gas development occurred disproportionately in poorer and more rural districts. Secondly, the period between 2007 and 2015 generally marked the recovery period for the Great Recession, and all per pupil funding measures, with the exception of federal revenue, showed increases. However, it is notable that districts with unconventional drilling showed markedly lower economic gain than those without wells. This is the case with regard to income, property values, total income, state revenue, local revenue and local property tax. These figures, however, do not control for systematic differences across school districts with and without drilling.

(Table 2 About Here)

School districts and the communities they serve cannot be randomly assigned unconventional drilling above Marcellus shale deposits. Since drilling disproportionately impacts poorer and more rural school districts, efforts to quantitatively assess the impact of unconventional gas development must account for the impact these underlying differences can have on analysis. To deal with this methodological challenge, we use methods from the matching literature to estimate the relationship between unconventional drilling and education funding (Angrist and Pischke 2008; Imbens and Rubin 2015).

Conceptually, matching techniques allow researchers to compare cases in a study receiving a "treatment" with equivalent control cases that have not received that treatment. Districts that experienced unconventional drilling within their borders are "treated" cases that we compare to otherwise identical "control" cases that did not experience natural gas extraction. Theoretically, when the only differences between treatment and control groups is their treatment status, researchers can interpret differences in outcomes between these groups as an effect of treatment (Rosenbaum and Rubin, 1983). In this way, matching techniques can mimic a randomized control trial.

Indeed, researchers have found that estimates of treatment effects from matching can have the same accuracy as estimates from randomized control trials (Fortson, Verbitsky-Savitz, Kopa, and Gleason 2012).

Of course, matching can only support causal inference when matched cases are identical. In our main analysis, we use entropy balanced matching to create treatment and control groups that can satisfy this assumption (Hainmueller 2012). Similar to propensity score matching, entropy balancing can be used to preprocess data by creating treatment and control samples that are indistinguishable from one another along a number of predetermined covariates. In propensity score matching, those covariates would be used to calculate propensity scores—the conditional probability of receiving a treatment (Rosenbaum and Rubin, 1983). Then, researchers would engage in an iterative process of matching along propensity scores and checking that matching produced groups that are actually equivalent by assessing covariate balance. In contrast, entropy balancing uses an entropy maximization algorithm to create weights that satisfy prespecified balance conditions along the covariates selected by researchers. Researchers can then use this weighted sample to estimate the effect of a treatment. Entropy balancing has been shown to be more robust than conventional propensity score matching (Zhao and Percival 2017). As one of our robustness checks, we also conduct a conventional propensity score matching analysis.

Our main analysis followed three steps: (1) selecting covariates for balancing our treatment and control cases; 2) generating weights through entropy balancing and confirming that our weighted treatment and control groups are now indistinguishable on pretreatment characteristics; (3) calculating the average effect of treatment on the treated.

Covariates

Using data from 2007, we decided to balance on a number of covariates that impact the fiscal health of school districts. We included factors that are known to impact the resource needs of districts, including the percentage of low-income students within a district, the size of the district's enrollment, property values per pupil, income per pupil, and index values from NCES CWI (Baker 2018). In addition, we also included funding data from 2007. This funding data reflects both the financial resources districts possessed before the spread of unconventional drilling and the willingness and/or ability of local communities—for a number of reasons that we might not be able to observe with existing data—to generate revenue for schools. In developing our model, then, we create comparison districts that are extremely similar along both the observed and unobserved factors that impact per pupil funding within a school district.

Entropy Balancing and Confirming Balance

We used the ebal package in R written by Hainmueller (2015) to generate our entropy balancing weights. To ensure that the treatment and control groups in our matched sample were equivalent, we examined absolute standardized mean differences on our pretreatment covariates. According to the Institute of Education Sciences guidelines provided through the What Works Clearinghouse (2014), groups with standardized mean differences below .05 are equivalent without statistical adjustment. We applied this standard, with none of the standardized mean differences in our weighted samples above .01.

Average Treatment Effect on the Treated

In working with a matched sample that meets the threshold for equivalence, researchers can calculate the average treatment effect on the treated (ATT) by comparing differences in average outcomes for treatment and control groups. Since equivalence through entropy balancing involves a weighting scheme, these weights must be incorporated into the calculation of the ATT. We used the survey package in R written by Lumley (2019) to incorporate the weights into our analysis and report robust standard errors recommended by Robins, Hernán, and Brumback (2000) and Hainmueller (2012).

Results

Results comparing districts experiencing unconventional drilling and otherwise equivalent districts without drilling show statistically significant differences along our measures of wealth and socio-economic disadvantage. The estimated ATTs for unconventional drilling on income and property wealth per pupil were negative and statistically significant ($p < .001$). In other words, we estimate that districts experiencing unconventional drilling had lower incomes and property wealth per pupil than we would expect them to have had if they had not experienced unconventional drilling. This average treatment effect on the treated was largest on the value of property, suggesting that properties in districts with unconventional drilling sites are either rapidly losing market value or being systematically underassessed by the state of Pennsylvania. Some differences were statistically significant, but slight. For example, districts experiencing unconventional drilling saw a statistically significant increase of 2% in the proportion of students in poverty within their district.

(Table 3 About Here)

Our results also show that we estimate a negative, statistically significant average treatment effect on the treated for total per pupil revenues. On average, this effect was -$1,550.50 per pupil. An effect of this size can have large consequences for the fiscal health of public-school districts and translate, in turn, into lost tangible resources known to increase outcomes and opportunities for children like smaller class sizes (Baker and Welner 2011).

One contribution to the decline in total per pupil revenues was the reduction in revenue from local taxes. Unconventional drilling had an average treatment effect of -$2,445.02 per pupil on local property tax revenues. Districts can supplement their property tax revenue with a number of other local taxes, though the average treatment effect of unconventional drilling on all local taxes was similar in magnitude, reducing per pupil revenues by -$2,491.93 in local property taxes and all other local taxes for education combined. The state and federal governments did increase their appropriations to local districts experiencing unconventional drilling, as shown by the ATT estimate for state funding per pupil ($885.79) and federal funding per pupil ($55.64). Since state and federal governments often provide additional funding to school districts enrolling large numbers of students from low-income families, the increase in poverty, albeit small, may help explain increased state and federal funding. These increases were not large enough to counterbalance the average negative effects that unconventional drilling had on local revenue, however.

Since districts with a higher concentration of wells may experience the impact of unconventional drilling differently, Table 4 displays results from additional models that examine the association between the number of natural gas wells within a district and our outcome variables. We examine this association on an entropy balanced sample and we include labor market-fixed effects. By examining the frequency of drilling, we are able to consider spatial variation in the relationship between drilling and educational resources. Labor market-fixed effects also help us adjust for the possibility that some districts experienced the 2008 financial crisis differently. Although we balance on several measures of income and wealth in our main model, it is possible that districts with equivalent wealth but different labor markets recovered faster or slower following the recession.

These results are consistent with the findings of our main model for total revenue, income per pupil, and property values per pupil. Here, a one unit increase in the number of wells within a district is associated with a decline in income per pupil and property values per pupil that would have a small effect on districts with few wells and a much larger effect on districts with a greater concentration of wells. A one unit increase in the number of drills within a district is also associated with a small decline in local property tax revenue per pupil and all local revenue per pupil (.01 when rounded) is associated with a small increase (.01 when rounded) in state revenue per pupil. This suggests that districts with the largest number of wells would feel these impacts on education funding the most, while the impact of drilling was less noticeable in districts with fewer wells. The association between poverty and federal revenues per pupil and the number of wells within a district was negligible, in this case too small to be captured in the table after rounding.

Robustness Checks and Sensitivity Analysis

To ensure that our results were not spurious, we also estimated treatment effects on the treated using conventional propensity score matching. With propensity score matching, we found that nearest neighbor matching with replacement and a caliper of .25 standard deviations created an equivalent sample. Detailed results, including balance statistics for our sample generated through propensity score matching, are available upon request from the first author.

Our results were consistent and similar across all of these specifications for the average effect unconventional drilling had on income per pupil, property values per pupil, local property tax revenue per pupil, total local revenue per pupil, and total revenue per pupil. Across all of our estimation techniques, we consistently estimated that unconventional drilling had a negative and statistically significant average treatment effect on these indicators of the financial resources communities have to support their schools.

Our estimates of the effect unconventional drilling had on poverty were less consistent. While our main analysis estimated an ATT of +2%, our other model found a decrease of 1-2%. We also found small differences in the direction of our estimates for federal education funding. Overall, all of these effects were smaller in magnitude which may help explain their variability. Another important factor that may account for variations between our estimates might be the fact that entropy balancing produces more balance than conventional propensity score matching while also retaining the full sample. Given the importance of covariate balance for the reliability of ATT estimates overall, we consider our entropy balancing results more reliable.

One major assumption of our study is that our covariates capture factors unrelated to unconventional drilling that could explain our outcomes. To assess this assumption, we conducted a sensitivity analysis of our main results following the procedures proposed by Altonji et al. (2005) and Oster (2017). This approach is often used in studies using entropy balancing (e.g., Freier et al. 2019). Table 1 reports Oster's δ for each of our ATT estimates from our main entropy balancing analysis. Oster's δ

expresses how much more informative unmodeled factors would have to be to explain away our ATT estimates. Our estimated δ's varied by ATT, with income having the smallest δ and local revenue per pupil the highest δ. For income, unmodeled factors would have to be nearly twice as important as modeled factors to make our estimates zero or explain our ATT. For local revenue per pupil, unmodeled factors would have to be at least 22.8 times as important as modeled factors to make our estimates zero or explain our ATT. These results suggest that our results are robust to unmodeled factors.

There are limits to our analysis worth noting. Entropy balancing allows for a strong causal design, and our results are robust to alternative matching methods, unmodeled factors, and spatial differences related to the economic composition of communities. Readers should nevertheless keep in mind that it is possible unmodeled factors might influence the relationship between unconventional drilling and educational resources we have identified, even if it appears unlikely given the results of our sensitivity analysis. Readers should also keep in mind the differences between public school finance policies across American states when interpreting our results. Merchand and Weber (2019) find, for example, that unconventional drilling increased educational revenues in Texas because of the way oil and gas wells are taxed in that state. Given these policy differences, our results may not generalize to other states where policy differences could mediate the relationship between unconventional drilling and educational resources in distinct ways.

Discussion and Conclusion

In sum, evidence from our analysis suggests that, on average, districts experiencing unconventional drilling had lower per pupil revenues, locally-raised per pupil funding for schools, per pupil income, and per pupil property wealth than otherwise similar districts that did not experience unconventional drilling. Our calculated ATTs were robust to alternative approaches to estimating effects using an alternate matching technique. Our results related to state funding, federal funding, and poverty were less stable. Nevertheless, across specifications we find consistent casual evidence suggesting that unconventional drilling has a negative effect on the financial resources available for public education.

That the expansion of shale gas in Pennsylvania has had, on average, a negative impact on school district fiscal resources seems counterintuitive. In theory, gas development and increased economic activity should have increased the value of local wealth in affected school districts. Since the state of Pennsylvania provides a lower share of total education funding than most other states, we might expect these increases in local wealth to result in additional revenues for schools. Instead, we estimate that districts experiencing unconventional drilling had relatively lower per pupil revenues and less local wealth from which to generate these revenues, relative to otherwise similar districts that did not experience drilling. The wealth generated during the gas boom, then, does not appear to have remained within communities along the indicators of wealth and opportunity examined in this analysis.

We interpret this in large part as a consequence of the nature of the industry and the public policies spurring its growth. First, Pennsylvania imposes an impact fee which collects revenue each time a well is drilled, as opposed to a severance tax which collects revenue based on the amount of the energy resource produced. The Kleinman Center for Energy Policy at the University of Pennsylvania has estimated that the impact fee revenues are one-third the potential revenues of a severance tax proposed by Governor

Tom Wolf whose 2015-16 budget proposal was developed with the intention of raising $2 billion for public education (Pachon and Weber 2015).

Second, in Pennsylvania about 77% of local school district revenues come from property taxes, with most of the remainder generated from an earned income tax. Property values showed relatively little impact from shale gas development within Pennsylvania (Kelsey, Adams and Milchak 2012). This was likely a consequence of the nature of the industrial development which was sudden and intensive, with a highly mobile labor force comprised (and especially in the earlier years of build-out) largely by non-Pennsylvania workers looking to rent but not buy housing (Wrenn, Kelsey, and Jaenicke 2015). On the other hand, rental prices increased dramatically as housing demand by mobile workers strained existing housing stock, often placing low and fixed income residents in unanticipated housing insecurity (Jacquet and Kay 2014; Schafft, et al. 2018). While rental prices increased, often several-fold, real estate values overall did not show any dramatic change in association with shale gas development (Muehlenbach, Spiller and Timmins 2015). Locally, some residents were able to benefit from leasing revenues, but those revenues don't fall under "earned income" and as a consequence don't contribute towards school revenues (Kelsey, Adams and Milchak 2012; Kelsey, Hartman, Schafft and Costanzo 2012).

When viewed in relation to fiscal resources for education, our analysis suggests that shale gas development appears to have disproportionately exposed rural communities in Pennsylvania to the costs of unconventional drilling rather than the economic benefits cited by advocates. Similar patterns have been documented in other studies of unconventional gas development. For example, other research has suggested that shale gas development may depress high school and college attainment of young people in resource extractive areas (Rickman, Wang, and Winters 2017), and still further research has failed to find appreciable impacts of unconventional oil and gas development on reversing the loss of human capital from rural non-amenity counties (Mayer, Malin, and Olson-Hazboun 2018).

Economic inequality has risen sharply across the United States since the 1970s, and data suggest children living in rural communities have been disproportionately impacted (Piketty 2014; USDA 2018). Proposals for state action to address poverty often focus on indirect alternatives to helping struggling families like promoting economic growth (Katz 2013). After the 2008 recession, many states focused on incentives for economic development by limiting corporate taxation (Baker 2018). Is there a "resource curse" effect for education, as associated with unconventional gas development? While our analyses utilize causal inference techniques, more detailed analyses are likely warranted to rule out potential confounding factors. At the same time, these results suggest an absence of clear economic benefits to affected school districts. Given research suggesting that school funding can be particularly important for long-term economic opportunities, our analysis suggests that unconventional drilling may help to maintain and entrench spatial inequality across school districts if school finance mechanisms and natural resource public policies don't take into account the often profoundly uneven economic outcomes of natural resource development.

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Table 1. Spatial and Socioeconomic Distribution of Unconventional Oil and Gas Development in Pennsylvania 2007-2015

	Total Districts	**Districts with Unconventional Wells**	**Total Unconventional Wells**
Urban-Rural			
City			
Large	2	0	0
Midsize	2	0	0
Small	16	1	81
City, Total	**20**	**1**	**81**
Suburb			
Large	197	23	756
Midsize	17	0	0
Small	22	5	192
Suburb, Total	**236**	**28**	**948**
Town			
Fringe	29	9	877
Distant	38	13	1,105
Remote	9	8	153
Town, Total	**76**	**30**	**2,135**
Rural			
Fringe	88	41	1,850
Distant	69	43	3,930
Remote	10	10	477
Rural, Total	**167**	**94**	**6,257**
All, Total	**499**	**153**	**9,421**
Relative Wealth			
Wealthiest Quintile	99	7	285
Poorest Quintile	100	45	3,051

Note: Data from Pennsylvania Department of Education and Pennsylvania Department of Natural Resources. Well locations within school districts calculated using geographic information systems software. Community classifications are based on designations used by the National Center for Educational Statistics.

Table 2. Change 2007-2015 in School District Wealth Indicators in Pennsylvania by Exposure to Unconventional Gas Drilling (Terciles)

Per Pupil	**0 wells**	**1-5 wells**	**6-34 wells**	**35+ wells**	**All Districts**
Income	$61,589.40	$22,578.47	$28,315.77	$35,049.77	$56,066.46
Property Values	$175,444.47	$103,832.80	$86,438.15	$130,505.60	$163,936.58
Total Revenue	$5,162.10	$2,412.40	$2,212.80	$2,271.70	$4,683.50
State Revenue	$2,026.70	$1,477.70	$1,349.10	$1,362.50	$1,921.40
Federal Revenue	$186.60	-$35.40	$28.60	-$36.50	$153.10
Local Revenue	$2,948.80	$970.10	$835.10	$945.80	$2,609.10
Local Property Tax Revenue	$2,481.80	$818.00	$669.80	$803.70	$2,194.50
Total N	346	47	56	50	499

Note: Data from Pennsylvania Department of Education and Pennsylvania Department of Natural Resources. Well locations within school districts calculated using geographic information systems software. All dollar amounts are expressed in 2015 dollars.

Table 3. Average Treatment Effect on the Treated of Unconventional Drilling on Financial Resources for Educational Opportunity using Entropy Balancing

	Average Treatment Effect on the Treated	**Oster's δ**
% Poverty	.02(.00)***	4.7
Federal Revenue Per Pupil	55.64(0.00)***	3.33
Income Per Pupil	-27,228.61(123.54)***	1.8
Property Values Per Pupil	-157,650.7(431.00)***	4.8
Property Tax Revenue Per Pupil	-2,445.02(1.64)***	4.9
All Local Revenue Per Pupil	-2,491.93(1.58)***	22.8
State Revenue Per Pupil	885.79(0.811)***	11.3
Total Revenue Per Pupil	-1,550.50(.88)***	5.2

Note. Robust standard errors for ATT in parentheses. * $p < .05$, ** $p < .01$, *** $p < .001$

Table 4. Association Between Frequency of Unconventional Drilling on Financial Resources for Educational Opportunity on Entropy Balanced Data

% Poverty	-.00 (.00) ***
Federal Revenue Per Pupil	-.00 (.00)***
Income Per Pupil	-137.38(2.26) ***
Property Values Per Pupil	-439.863(5.75) ***
Property Tax Revenue Per Pupil	-.01(7.89e-05) ***
All Local Revenue Per Pupil	-.01(7.65e-05) ***
State Revenue Per Pupil	.01 (6.76e-05) ***
Total Revenue Per Pupil	-3.47(5.45e-05) ***

Note. * $p < .05$, ** $p < .01$, *** $p < .001$ Model includes labor market fixed effects.

Figure 1. Pennsylvania unconventional wells drilled by year 2007-2018, Pennsylvania Department of Environmental Protection, Office of Oil and Gas Management Spud Data.

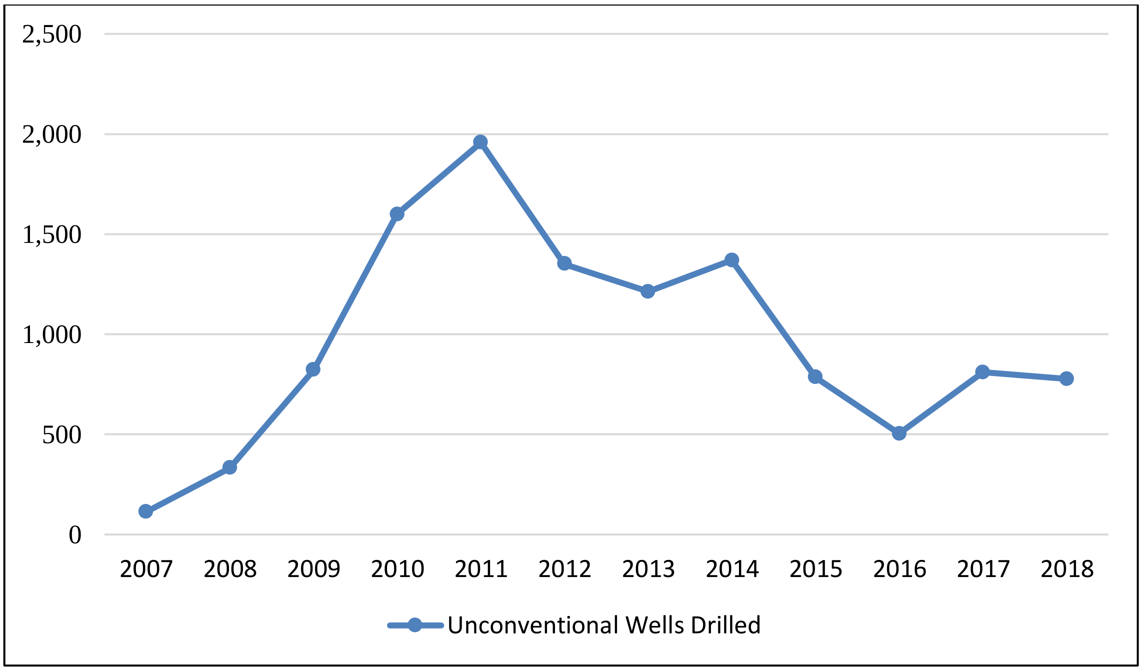

Figure 2. Unconventional wells drilled in Pennsylvania 2007-2015, with school district boundaries.