UNIVERSITY OF ALBERTA
FACULTY OF ARTS
Department of Economics

Working Paper No. 2017-12

# The Local Effects of the Texas Shale Boom on Schools, Students, and Teachers

**Joseph Marchand**
**University of Alberta**

**Jeremy Weber**
**University of Pittsburgh**

Revised January 2019

Copyright to papers in this working paper series rests with the authors and their assignees. Papers may be downloaded for personal use. Downloading of papers for any other activity may not be done without the written consent of the authors.

Short excerpts of these working papers may be quoted without explicit permission provided that full credit is given to the source.

The Department of Economics, the Institute for Public Economics, and the University of Alberta accept no responsibility for the accuracy or point of view represented in this work in progress.

# The Local Effects of the Texas Shale Boom on Schools, Students, and Teachers *

Joseph Marchand †
University of Alberta

Jeremy G. Weber ‡
University of Pittsburgh

Revised January 2019

**Abstract**

This study explores how the Texas shale boom affected schools, students, and teachers. Using variation in geology across school districts, the evidence shows that test scores and attendance in the average shale district declined despite the boom tripling the tax base and creating a revenue windfall. Greater spending went to capital projects and servicing debt, not to teachers. Although higher wages did not affect completion rates, a growing gap in wages between the private and education sectors accompanied greater teacher turnover and more inexperienced teachers, which help explain the decline in student achievement.

Keywords: local labor markets, local public finances, resource booms, schools, students, teachers.

JEL codes: H70, I22, J24, J40, Q33, R23.

*This paper was re-titled following an extensive revision, after previously being circulated under the title, "The Labor Market and School Finance Effects of the Texas Shale Boom on Teacher Quality and Student Achievement" (Marchand and Weber, 2015). The authors would like to thank the participants of the following conferences and seminars for their feedback: American Economic Association, Canadian Economic Association, Eastern Economic Association, Ryerson University, Society of Labor Economists, Syracuse University, University of Pittsburgh, University of Toronto, and West Virginia University. Comments from Jeanette Winn, superintendent of Karnes City school district in Karnes County, Texas, were also appreciated. As a part of the University of Alberta's Future Energy Systems research initiative, this research was made possible thanks to funding from the Canada First Research Excellence Fund.

†Marchand: Associate Professor, Department of Economics, University of Alberta, 7-29 HM Tory, Edmonton, AB, T6G 2H4, Canada. E-mail: joseph.marchand@ualberta.ca.

‡Weber: Associate Professor, Graduate School of Public and International Affairs and Department of Economics, University of Pittsburgh, 3601 Posvar Hall, 230 S. Bouquet Street, Pittsburgh, PA, 15260, USA. E-mail: jgw99@pitt.edu.

# 1 Introduction

High energy prices and innovations in horizontal drilling and hydraulic fracturing caused an oil and gas drilling boom in shale formations across the United States. The effects of the shale boom on communities are widely debated and have increasingly captured the interest of economists (e.g. Muehlenbachs et al., 2015; Feyrer et al., 2017). The Texas shale boom, in particular, permits studying several questions of broad interest that span the areas of education, labor markets, and public finance. As this study will show, the Texas boom was large and localized, tripling the tax base of the average shale school district and increasing private sector wages by almost 20 percent.

How do schools, students, and teachers respond to a localized economic shock that provides resources to schools, but also increases private sector wages, and therefore the opportunity cost for students and teachers to stay in the classroom? Greater revenue could improve student achievement by allowing schools to purchase equipment that enhances learning or to pay higher salaries to attract better teachers. Spending additional revenues in productive ways may prove difficult, however, when they come rapidly, temporarily, and in large sums, as can happen during an economic boom. An economic boom can also create jobs and increase private sector wage rates. Higher wage rates, especially for low-skill labor, could encourage students to miss class or drop out of school. Teachers may also leave for higher paying jobs, especially if no commensurate increase in teacher salaries occurs. The overall effects on school-wide student achievement will therefore depend on how any additional money is spent and whether high or low performing students or teachers are pulled from the classroom.

Empirically, this study exploits variation in shale geology across Texas school districts and temporal variation in drilling caused by changing energy prices and the introduction of improved technologies for shale development. Home to four major shale formations, Texas has been the epicenter of the U.S. shale boom and, in Texas. It is also a state where local schools and governments tax producing oil and gas wells as property. Independent appraisers assign value to a well based on the discounted flow of profits that it is expected to generate, with wells reassessed annually as they mature and prices change. Texas is one of fifteen U.S. states that subject oil and gas wells to property taxes, which explains why the drilling boom increased the property tax base and revenues to schools in at least some areas of the state (Raimi and Newell, 2015; Weber et al., 2016).[1]

For the 2001-2014 period, the percentage of students passing standardized tests in the average shale oil district declined relative to districts outside of any shale formation and even relative to districts with below-average shale geology or those with only shale gas. The decline occurred despite an increase in the property tax base of over a million dollars per student in shale districts, which led school districts to lower property tax rates, borrow more, and spend more. Most of the additional spending went to capital projects or to service debt, and none of it went to teachers. Despite the shale boom increasing the private market wage by nearly 20 percent, attendance rates declined only slightly and completion rates were unaffected. However, the boom widened the gap between private and education sector wages, increased teacher turnover, and led to more inexperienced teachers in the classroom. The overall negative effect of shale development on student achievement may therefore stem in part from the disruption of turnover and the decline in teacher quality.

# 2 Relevant Literature

Despite potentially large effects of resource booms on school finances and labor markets, no comprehensive study documents how booms affect schools, students, and teachers through both of these channels. That said, numerous studies of resource booms show how they generally affect local labor markets (for a review, see Marchand and Weber, 2018). Increased resource extraction can create jobs and raise incomes, drawing workers from near and far, which can also spillover into other local sectors, as found by Black et al. (2005a) for coal areas in Appalachia and by Marchand (2012) for oil and gas areas in Western Canada. For the U.S. shale boom, Weber (2012) found that expanded oil and gas drilling led to substantial increases in wage and salary earnings across counties of Colorado, Texas, and Wyoming. Other recent studies have also documented increased earnings per worker and wages, as well as spillover effects (Brown, 2014; Fetzer, 2014; Weber,

[1] According to each state's publicly-available information, states that tax oil and gas wells as property in some form include Arkansas, California, Colorado, Illinois, Indiana, Kansas, Kentucky, Nebraska, New Mexico, Ohio, Oklahoma, Texas, Utah, West Virginia, and Wyoming.

2014; Jacobsen and Parker, 2016).

For students, higher wages from a boom may encourage them to work (or work more), especially when students heavily discount future income and returns to education are low, leading some to miss class or drop out. For the U.S., a coal mining boom increased the returns to unskilled labor, causing youth to leave school (Black et al., 2005b), and an oil boom slowed growth in the relative demand for skills (Kumar, 2017). In Alberta, Canada, an oil boom caused males to delay their education, but not decrease their eventual attainment (Emery et al., 2012). Similarly, high school and college attainment among local residents in Montana, North Dakota, and West Virginia fell during a shale boom, (Rickman et al., 2016). More recently, Cascio and Narayan (2017) found that a shale boom increased the dropout rate among males across U.S. commuting zones, an effect that others show is largest for states where students 17 and older are legally allowed to drop out (Texas has a compulsory age of 18) (Zuo et al., 2019).

For teachers, the labor market effects from an energy boom have not been previously explored. However, Boyd et al. (2005) showed that teacher labor markets are geographically small, enhancing the credibility of finding localized impacts. And, improved labor market conditions for talented women in the U.S. have previously been linked to a decline in teacher quality (Stoddard, 2003; Corcoran et al., 2004; Eide et al., 2004; Bacolod, 2007). In a more recent study, Nagler et al. (2015) used business cycle variation in outside opportunities at the start of a teacher's career to show that individuals entering teaching during a recession were more effective in raising student test scores and to suggest that higher teacher salaries might attract more effective teachers. In Texas specifically, teacher quality has been shown to have large positive effects on reading and math achievement (Rivkin et al., 2005). Teacher turnover also matters and can be especially harmful for student achievement (Ronfeldt et al., 2013), mainly because the first few years of teaching experience matter the most (Buddin and Zamarro, 2009; Harris and Sass, 2011) and experienced teachers are typically replaced with inexperienced ones (Staiger and Rockoff, 2010). Of course, teachers could be leaving schools due to other boom-related reasons, such as increased earnings of other household members (Scafidi et al., 2006) or sizable royalty payments (Brown et al., 2017).

For schools, a drilling boom should improve school finances in states like Texas where oil and gas wells are taxed as real property and such taxes are a major revenue source for schools. Raimi and Newell (2015) document the various revenues generated by shale development in eight states and to whom they accrue (schools, municipalities, counties, or the state). Depending on tax and revenue-sharing polices, oil and gas drilling may have no effect on revenues to schools (Pennsylvania), a modest effect on revenues to all schools (Colorado), or a large effect on revenues of schools where drilling occurs (Texas). Unsurprisingly, Weber et al. (2016) showed that the development of the core area of the Barnett Shale in the Dallas-Forth Worth region caused a large increase in the property tax base, which subsequently increased school revenues.[2] While Cascio and Narayan (2017) found no effect of shale reserves on local, state, or federal revenues to schools at the commuting zone level (i.e. economically-linked counties), their result is hard to interpret because of the large differences in tax policy across states.

Even if school spending increases due to an energy boom, it may not improve student achievement. Meta-analyses of spending effects have previously proven inconclusive, as either being a clearly positive (Krueger, 2003) or insignificant (Hanushek, 2006) relationship. However, earlier studies concluding that greater school spending had no effect often lacked proper identification, while more recent studies with better research designs generally show that spending matters (Gibbons and McNally, 2013). The best natural resource example of this is from Haegeland et al. (2012), who found that additional revenues provided by nearby hydro-power plants improved the achievement of 16 year olds. More recent contributions, from Jackson et al. (2016), Hyman (2017), and Lafortune et al. (2018), also show that school funding improved various student outcomes. Temperature may also help explain why school infrastructure funding was successful for performance in Connecticut (Neilson and Zimmerman, 2014), where schools without air conditioning were targeted, but unsuccessful for performance in Texas (Martorell et al., 2016), where most schools already had air conditioning (Goodman et al., 2018).

[2]Weber et al. (2016) focuses on the effect of natural gas drilling–and the associated property tax base effects–on housing values, not on school spending decisions or other education-related outcomes. In addition, the study focuses only on several counties in and around the Dallas-Fort Worth region, not the entire Barnett Shale or other formations in Texas.

## 3 Empirical Strategy

Across the education literature, the unit of observation ranges from students to classrooms, schools, school districts, counties, and states. A district-level analysis best suits the resource shock of the current study because school finances vary across districts, not within them.[3] Texas has roughly five million primary and secondary school students, in more than one thousand school districts, with the full sample including 1,012 independent school districts for which shale geologic data were available (98.1 percent of the available 1,031 districts).[4] The districts are followed for 14 years, from 2001 to 2014.[5]

Figure 1 shows the delineation of Texas school districts and the location of the state's four major shale formations, with forty percent of districts overlying one of the formations. The Barnett and Haynesville produce natural gas in the north and east of the state, and the Eagle Ford and Permian primarily produce crude oil in the south and west of the state, respectively. The figure also shows variation in shale depth across districts. Spatially disaggregated data on depth come from Los Alamos National Laboratories and permit calculating each district's average depth, which is defined as the average distance in kilometers from the surface to the formation.

Shale depth provides a continuous measure of shale richness and proxies for the district's resource endowment. Because deeper shale tends to have greater pressure, it generally has more productive and profitable wells (EIA/ARI, 2013).[6] Across the major shale formations in the U.S., Brown et al. (2016) found that a ten percent increase in average depth is associated with a seven percent increase in the ultimate recovery of a typical county well. In this study, each district's depth is normalized by the average depth of the entire formation in which it lies. The average shale district therefore has a normalized depth of about one, and districts outside any shale (non-shale districts) are given a depth of zero.

[3]Previous studies have also used variation across school districts (ex. Unnever et al., 2000).

[4]Districts in a small shale formations across three counties, and for which geologic data were unavailable, have been excluded.

[5]Although the data for 2000 are also available, the changes from 2001 to 2014 are used because, in some regression specifications, baseline characteristics in 2000 are controlled for.

[6]Allcott and Keniston (2018) instead used the amount of recoverable resources, but because of the periodic discovery of new resources and the fact that extraction can happen at any time, shale depth is arguably more exogenous.

## 3.1 Drilling, Prices, School Finances, and Labor Markets

Substantial variation in drilling and energy prices occurred in shale districts over the study period, with key differences between the oil formations (Eagle Ford and Permian) and gas formations (Barnett and Haynesville). The differences between formations motivates and justifies the empirical approach and aids in the interpretation of the estimates. Data on wells drilled, used for descriptive purposes only, come from the proprietary data provider, Drillinginfo. Energy prices are from the Energy Information Administration, using national first-purchase price for crude oil and national wellhead price for natural gas, both in 2010 dollars.

Figure 2 shows the real price of crude oil (column a, row 1) growing steadily from 2003 to 2008, and then sharply declining in the Great Recession from 2008 to 2009, before returning to higher levels from 2009 to 2014. The onset of horizontal drilling and hydraulic fracturing can be seen most clearly in the Eagle Ford, where drilling increased slightly during the 2000-2008 period, but then grew by about 400 percent from 2009 to 2012. The number of wells drilled in the Permian more closely follows oil prices, with the 2000-2008 expansion reflecting conventional oil production from strata above the shale, and the 2009-2014 expansion coming mostly from shale, which serves as the source rock for hydrocarbons closer to the surface.[7]

Similar to wells drilled, the oil and gas tax base (in row 2) is a measure of the shale boom, because it depends on the number of producing wells and their profitability. Consistent with its lack of growth in conventional oil drilling, districts in the Eagle Ford saw almost no change in this base during the 2000s. As fracking expanded from 2010 to 2014, however, the oil and gas tax base expanded from under \$200,000 to nearly \$1,000,000 per student. Districts in the Permian saw large increases in the oil and gas tax base over the entire study period, going from below \$400,000 per student in the early 2000s to over \$1,200,000 per student in 2012. All of the increase came after 2004, initially because of higher oil prices and greater conventional drilling, and later because of fracking-related drilling. The value of the tax base tracked the price of crude oil, which more than doubled in real terms over the same time. This is unsurprising, because higher oil prices

[7]The role of horizontal wells, as opposed to vertical wells, is an indicator of conventional versus unconventional (shale) development. Growth in shale development in the Permian and Eagle Ford can be seen by the ratio of vertical to horizontal wells documented in the EIA Today In Energy report from March 17, 2015: http://www.eia.gov/todayinenergy/detail.php?id=20392.

increase the value of existing wells and encourage the drilling of new wells, which enter the tax base upon commencement of production.

The natural gas prices and well drilling (column b, row 1), on the other hand, follow more of a boom and bust over the period, with prices increasing from 2002 to 2005, remaining high until 2008, and then plummeting in 2009 and remaining low afterward. Drilling followed prices in both gas formations, peaking in 2008 and declining thereafter. Districts in the natural gas formations experienced much smaller expansions in the oil and gas tax base (row 2), which followed the price of natural gas. The smaller increase in the tax base in the gas formations likely reflects the fewer number of wells drilled and the lower profitability of gas wells.

Turning to wages (row 3), measured as private sector compensation per job, Eagle Ford districts began with a more than 15 percent lower wage relative to non-shale districts, and the difference remained constant until 2010, but with the growth in drilling, this difference disappeared by 2014. The average shale district in the Permian had a wage roughly 10 percent less than the wage of the average non-shale district in 2000. A general increase in drilling over most of the study period led to wage growth relative to non-shale districts, and by 2014, the difference had switched, with Permian districts now having an average wage roughly 10 percent higher than non-shale districts. For both gas formations, the difference in wages between shale and non-shale districts remained fairly constant over the study period. The weaker drilling growth in a more densely-populated region helps to explain the lack of wage effects in the gas formations.

The regression analyses that follow focus on school districts only in the oil formations and districts outside of any formation (non-shale districts). The focus on the oil formations is due to the small (or non-existent) changes in the tax base and wages observed in the natural gas formations. Without school finance or labor market effects, there is no reason to expect shale development to have important effects on education outcomes, such as student achievement or the composition of students and teachers.[8]

[8]Focusing on the most productive parts of the Barnett Shale, Weber et al. (2016) found that development had a modest effect on revenues and because of a contemporaneous decline in the property tax rate, as well as the state's "Robin Hood" policy, which captures revenue from property-rich districts and redistributes it. This redistribution policy helps explain why the spending increase in oil districts was proportionally smaller than the increase in the property tax base, as shown in Figures 3 and 4.

### 3.2 Regression Specifications

Two empirical approaches provide a robust description of the effects of shale development on outcomes related to school finance and spending, wages, student achievement, and the composition of students and teachers. The first approach uses a district fixed effects model to quantify how outcomes evolved year-by-year based on shale geology:

$$Outcome_{dy} = \sum_{2002}^{2014} \beta_y \left(Depth_d \cdot Year_y\right) + District_d + Year_y + \epsilon_{dy} \tag{1}$$

The coefficients of interest, $\beta_y$, are on the interaction between *Depth* and *Year,* as they show how the outcome changed over time based on shale depth. The year indicator variables within the interaction implicitly capture the timing of the booms. For example, 2008 saw high oil prices and substantial drilling in the Permian formation, but not in the Eagle Ford, which had little drilling until widespread fracking began there in 2010. The district fixed effect, $District_d$, accounts for time-invariant differences across districts, while the year fixed effect, $Year_y$, accounts for temporal shocks.

Interacting the year variables with the normalized depth makes it easier to interpret the coefficients: an increase in normalized depth from 0 to 1 corresponds to going from a district with no shale (*Depth*=0) to a district with the average shale depth (*Depth*=1). So, the coefficient ($\beta_y$) gives the difference in the outcome in year $y$ between the average shale district and non-shale districts, all relative to the difference in the reference year (2001). If depth were not normalized, this coefficient would be the effect of an additional kilometer of shale depth, which is less meaningful.[9]

As shown in prior figures, the drilling booms varied enormously across the Eagle Ford and Permian formations. Equation (1) is therefore estimated separately for each formation, with the $\beta_y$ estimates show graphically. Separate estimates for each formation reveal if there were differences in prior trends across shale and non-shale districts, as well as whether changes in outcomes occur when expected (e.g. rising wages during the booms in each formation).

[9] An alternative specification is to use the log of depth for districts with positive depth values. However, the associated coefficient would also be less interpretable than when depth is normalized, because it would represent the effect of a proportional increase in depth.

The second approach, the long difference (LD) approach, summarizes the change over the entire study period by looking at the difference between the first and last years of the study period, 2001 and 2014, with normalized shale depth as the lone explanatory variable:

$$\Delta_{2014-2001}Outcome_d = \alpha + \beta_{LD} \cdot Depth_d + \Delta_y \epsilon_d \tag{2}$$

As before, normalizing depth makes its coefficient easy to interpret: the Long Difference coefficient ($\beta_{LD}$) gives the average change in the outcome over the study period for districts with average depth relative to non-shale districts.[10] Because shale depth is time invariant, including it in the Long-Difference regression allows the relationship between depth and each outcome to change over the study period. This is expected: in the early 2000s, technologies for shale development were in an experimental stage and oil prices were low, both of which were not true in 2014.

The LD coefficient from Equation (2) will not isolate the effect of the shale boom if *Depth* is correlated with prior trends in the outcomes. This is what makes the estimates based on Equation (1) so important, as they should help reveal such trends, especially in the case of the Eagle Ford, which was largely unaffected by the 2004-2008 increase in oil prices.

The LD model is first estimated with all shale oil districts and non-shale districts (n=751). In the following sections, the differences in baseline characteristics across shale and non-shale districts are discussed and substantial comparability is found along most dimensions. Non-shale districts, however, may be quite far from oil districts and experience different regional shocks during the study period. To address such a possibility, the LD model is also estimated using a within-shale sample, where only districts in counties with an oil formation are included (n=299). Robust standard errors are reported.

[10] The coefficient on normalized depth is conceptually similar to an average shale effect, but it is not mathematically identical to a coefficient that would result from replacing shale depth with a binary shale indicator variable. This is because the depth variable varies within each formation and is therefore not perfectly correlated with a binary shale indicator.

# 4 School Finance, Spending, and Labor Outcomes

Table 1 displays the baseline values for all of the school finance, school spending, and labor market outcomes in 2000. The tax base and school spending data come from the Public Education Information Management System of the Texas Education Agency. School district property tax rates and debt data come from the Texas Bond Review Board. All wage data come from the Bureau of Economic Analysis, except for the teacher wage, which is from the Snapshot School District Profiles of the Texas Education Agency. The 2000 mean values for all variables are shown separately for shale oil and non-shale districts. The table also provides the difference in means across the two groups (normalized by the standard deviation) and the p-value for the null hypothesis that the difference in means is zero.

## 4.1 Local Finances

The local finance variables (shown in panel 1 of Table 1) are the total tax base ($100,000 per student), also shown separately for oil-and-gas and non-oil-and-gas property, the property tax rate (percentage), total debt ($1,000 per student), and the log of total revenues per student. Figure 3 (rows 1-3) and Figure 4 (row 1) show the $\beta_y$ coefficients from Equation (1), which depict how differences in these finance variables evolved over time based on shale depth. Results are shown separately for the Eagle Ford (column a) and the Permian (column b). Table 2 (panel 1) shows the Long Difference estimates of the coefficient on normalized depth using the full sample (a) and within-shale samples (b).

Oil districts initially had tax rates similar to non-shale districts but much larger oil and gas tax bases and also a larger total tax base and more revenue per student. More importantly, Eagle Ford districts had tax base, tax rate, debt, and revenue trends similar to non-shale districts from in the 2000s, prior to its shale boom. When shale development boomed in the Eagle Ford in 2010 and afterward, the total tax base significantly expanded, almost entirely because of growth in the oil and gas tax base. For Permian districts, the tax base expansion occurred from about 2004 to 2014, albeit by less than the boom in the Eagle Ford.[11]

[11] The small role of the non-oil-and-gas tax base in the tax base expansion indicates that the national housing boom, bust, and recovery was not positively correlated with shale depth and oil prices. Otherwise, the value of residential property and land, which are included in the non-oil-and-gas tax base, would have accounted for larger changes in the total tax base. The modest

Over the entire period, the total tax base of an oil district with average depth grew by over one million dollars more per student relative to non-shale districts according to the Long Difference estimate. The increase is roughly double the mean baseline tax base for shale districts. Nearly all (87 percent) of the increase came through the increased oil and gas tax base. The remaining 13 percent reflects growth in the non-oil-and-gas tax base, which consists of residential property, commercial property, and land. The within-shale results show even larger increases in the oil and gas and total tax base.

Oil districts responded to the expanded tax base by lowering property tax rates, qualitatively similar to what Weber et al. (2016) found for the Barnett Shale, with tax rates declining by 0.03 percentage points in oil districts relative to non-shale districts (LD). The effect represents a 4 percent decline over the baseline tax rate. The tax rate decrease is most pronounced in the Eagle Ford during the latter years of the shale boom (2013 and 2014) and during the beginning of the conventional boom in the Permian (roughly 2004 to 2008).

The large increases in the tax base overcame the relatively small decline in tax rates, leading to a 15 percent increase in revenues per student in the average oil district.[12] The increase for the within-shale sample was even larger, at 21 percent. Oil districts also borrowed about $10,000 more per student according to the LD results, which is three times higher than their initial debt level. For the Eagle Ford, the increase only occurred during its shale boom, while the increase in the Permian began with the rise in oil prices in the mid-2000s.

The large increase in capital spending may stem from the state's focus on equalizing operational spending across districts but not spending on facilities. Unlike with operational spending, districts must fund facilities almost entirely through local property taxes that pay the principle and interest on bonds issued for capital projects, which must be approved by voters (Martorell et al., 2016). Without expansions in the tax base, issuing a new bond would normally require a politically-

changes in the non-oil-and-gas tax base are expected during boom times, because more drilling increases the demand for commercial property, as well as for labor and therefore housing. In the Eagle Ford, which had little drilling and oil production in 2008 and 2009, shale and non-shale districts experienced similar changes in their total tax base and in its components. Unsurprisingly, districts in the Permian had a large decline in the oil and gas tax base from 2008 to 2009, when oil prices fell precipitously.

[12] For coefficients on logged variables and cases where the coefficient is larger than 0.10, the exact percentage change is calculated using the transformation $e^{\beta} - 1$.

unpopular increase in property tax rates, as additional revenue would be needed to service the debt.

However, with an expanded tax base, districts could issue bonds and service them without a concurrent increase in property tax rates. It is also worth noting that the state imposed a cap on property tax rates set in 2006. For districts bound by the cap, the expanded tax base would have allowed them to support new bond issuances and address deferred investments in facilities.[13] These institutional details help explain why capital and debt spending both increased, while tax rates did not (and instead decreased).

## 4.2 School Spending

The school spending variables are total spending, payroll spending, and non-payroll spending (also shown separately for capital, debt, and other), all of which are per student and logged. The other spending category includes all non-payroll operating expenditures, such as supplies and materials, professional or contracted services, and other operating costs.[14] The 2000 mean values of the variables are reported in panel 2 of Table 1, the evolution of differences shown in Figure 4, and the regression results shown in panel 2 of Table 2.

Eagle Ford districts and non-shale districts had similar trends in spending prior to its shale boom that began in 2010. The same is true of Permian districts prior to the increase in oil prices in the mid-2000s. Afterward, and in line with expansion of the tax base and revenue growth, spending per student grew substantially more in shale oil districts relative to non-shale districts, with the full sample results showing a 20 percent increase.

Strikingly, none of the spending growth occurred in the payroll category, even though the average school district in 2000 had slightly less than two-thirds of their total spending going to payroll. Non-payroll spending, in contrast, increased by 50 percent. The breakouts of non-payroll expenditures reveal that capital accounted for the largest proportional non-payroll increase, with oil districts more than doubling their capital spending relative to non-shale districts.[15] The increase in capital

[13] In 2010, more than 200 school districts were at the maximum rate. The 2006 law also required voters to approve certain property tax increases by school districts. See the "History of Tax Rates" by the Texas Education Agency.

[14] See http://misdtx.schoolwires.com/cms/lib/TX21000394/Centricity/Domain/917/AbtBud13.pdf.

[15] Davis and Ferreira (2017), in an analysis of housing price increases, also documented that

spending was sharply pronounced in the Eagle Ford during the shale boom years, but larger in magnitude in the Permian, given that the conventional and shale booms were both contributing. Consistent with the finding that outstanding debt increased, spending to service debt also grew, but the percentage increase was less important, because debt is the smallest of the non-payroll categories.

To summarize, the shale boom set in motion various changes in school finances: more and higher-valued wells expanded the oil and gas tax base, and therefore the total tax base, increasing revenues to schools and encouraging greater spending per student. Districts spent additional revenues on capital and debt expenses and by reducing property tax rates. None of the additional spending went to payroll (i.e. teachers). This is not to say that the money was mismanaged. Districts may have had deferred maintenance and saw the property tax windfall as a way of addressing long-term facility needs.

## 4.3 Labor Market

The labor market variables include compensation per private sector job (private wage), compensation per public sector job (public wage) which includes all state and local government jobs, and compensation per teacher job (teacher wage). All are reported as the natural log of dollars per job. While the average teacher wage is reported at the district level, all other wage variables are at the county level. The wage gaps are then calculated as the teacher wage subtracted from the private wage or the public wage, all in log form.

According to the logged baseline values (Table 1, panel 3), the average teacher wage was slightly above the average public sector wage, but greatly above that of the private sector wage. The higher public and teacher wages could be due to primarily being full-time, whereas many private jobs may be part-time. The private sector wage is most relevant for the opportunity costs faced by students, as it better measures what they could earn by dropping out. The average teacher wage difference with the private sector best represents what a teacher could gain by leaving her teaching job.[16]

much of the additional spending available to schools went to capital projects. In their case, however, this was paired with an increase in spending on instruction.

[16]This differs slightly from Hanushek et al. (2019), which used "the wage position of public sector employees (excluding all teachers) in the distribution of all employees" for this purpose.

Shale districts initially had lower private wages but slightly higher teacher wages and similar public sector wages. Prior to the shale boom, the difference in wages for Eagle Ford and non-shale districts was flat, with a clear divergence only after 2010 (Figure 4, panel 3). Wages in the Permian began diverging in 2004 as oil prices increased, and the divergence grew over the study period, with the exception of a sharp decline in 2009 with the recession and the associated sharp drop in oil prices.

Table 2 (panel 3) displays the LD estimates for wage outcomes, which show that the average shale district experienced a 19 percent increase in the private sector wage and a 2 percent increase in the public wage from 2001 to 2014. The teacher wage, on the other hand, saw no growth in shale districts when compared to non-shale districts, which matches the lack of increased payroll spending documented in the previous sub-section. The stagnant teacher wage, combined with the growing private wage, caused the wage gap to increase by 20 percent. Despite the general stickiness of public sector wages, even the public-teacher wage gap widened by 3 percent. The within-shale results are very similar.

# 5 Education Outcomes (Students and Teachers)

Table 3 displays the summary statistics for variables related to student achievement and the composition of students and teachers, all for the year 2000. All variables come from the Snapshot School District Profiles of the Texas Education Agency, which is based on school administrative records, not surveys. As with the other descriptive table, mean values for oil and non-shale districts are provided along with normalized differences in means and p-values. In general, oil and non-shale districts had similar mean values for most variables. For 13 of the 17 variables related to achievement and student and teacher composition, the difference in means was a 0.12 standard deviation or less. As for larger differences, oil districts had a higher percentage of vocational/technical and economically-disadvantaged students but a lower percentage of inexperienced teachers and fewer students per teacher.

## 5.1 Student Composition

The student composition variables include the percentages of students that are economically-disadvantaged, enrolled in vocational/technical (votech) programs, enrolled in English as a Second Language (ESL) programs, or are in gifted programs, as well as the logged number of students in the district. Economically-disadvantaged students are those eligible for free or reduced-price meals under the National School Lunch and Child Nutrition Program. To be eligible for a reduced-price lunch, the household of the student must have an annual income less than 185 percent of the poverty line.[17] Gifted students are those participating in state-approved academically gifted and talented programs. As shown in Table 3 (panel 1) for 2000, disadvantaged students accounted for roughly half of all students, votech students accounted for a quarter, and ESL students and gifted students both accounted for less than ten percent.

Prior to the shale boom, Eagle Ford districts had slightly lower growth in the student population compared to non-shale districts (Figure 5, row 1), with a roughly 3 percent decline over nearly a decade. This gap then dissipated during the boom years. The Eagle Ford also appeared to have a weak trend towards fewer ESL, votech, and economically-disadvantaged students (row 2). The most clear change in student composition, however, occurred after 2010, with a sharp decline in the percentage of economically-disadvantaged students. The Permian also had slower growth in its student population in the early 2000s, but this difference flattened over the rest of the period. It also had a weak trend in student composition in the early 2000s, but the largest changes occurred with the rise of oil prices in the mid-2000s, when the percentage of economically-disadvantaged students began a precipitous decline.

The LD estimates in Table 4 (panel 2) establish magnitudes for the overall changes. They show a 5 percent decline in enrollment relative to non-shale districts from 2001 to 2014. And, as shown graphically, the largest change in composition was the decline in economically-disadvantaged students, which fell by about 7 percentage points relative to non-shale districts. The percentage of votech and ESL students also declined (3.9 and 1.8 percentage points), while the percentage

[17] In 2014, a student from a household of four with less than $43,568 in annual income would be eligible for a reduced lunch program, which would put the student in the economically-disadvantaged category. See www.gpo.gov/fdsys/pkg/FR-2013-03-29/pdf/C1-2013-06544.pdf.

of gifted students remained similar to that of non-shale districts. The within-shale estimates show a similar pattern.

The results suggest that, in both Eagle Ford and Permian districts, drilling helped stem a secular decline in the student population relative to non-shale districts. This is consistent with the empirical literature on natural resource booms, which generally shows population increases as wages increase during boom times (e.g. Marchand and Weber, 2018). In addition, the higher wages documented in a prior section are the most plausible explanation for the decline in the percentage of economically-disadvantaged students. The extra income would have pushed some households to earn more than 185 percent of the poverty line, thereby lifting their children out of the economically-disadvantaged category. Similarly, an increase in household income could have caused some parents to consider funding post-secondary education for their children, shifting their academic focus away from vocational programs.

## 5.2 Teacher Composition

The teacher composition variables include the percentage of teachers with less than five years of teaching experience, the percentage with an advanced degree (Masters or Doctorate), the teacher turnover rate (the percentage of teachers from the prior year that did not return in the current year), the natural log of the student-teacher ratio, and the natural log of the number of teachers. Baseline values in 2000 are shown in Table 3 (panel 2), with the evolution of oil and non-shale differences shown in Figure 5 (panels 1 and 3), and the regression results shown in Table 4 (panel 2).

The number of teachers in the Eagle Ford roughly followed the number of students, with a small decline prior to the boom and then a slight reversal during the boom. Trends in teacher characteristics, however, match those of non-shale districts prior to the boom and then diverged afterwards, with more teachers with an advanced degree and a higher turnover rate, student-teacher ratio, and percentage of teachers with less than fives years experience. For Permian districts, notable differences only emerge during the post-2010 shale boom, when all variables increased except the percentage of teachers with advanced degrees.

The LD estimates in Table 4 (panel 2) show that the total number of teachers in oil districts declined by 7 percent relative to non-shale districts. Concurrently, the percentage of inexperienced teachers increased by 3.2 percentage points, the turnover rate by 1.7 percentage points, and the student-teacher ratio by 2 percent. The within-shale results are even more pronounced, with a 5.3 percentage point increase in inexperienced teachers and a 2.9 percentage point higher turnover rate.

The lack of wage growth and school spending on teachers, combined with increased private sector wages, may have encouraged some teachers to leave classroom or never enter it in the first place. The trends for students and teachers (Figure 5, row 1) suggests that teacher numbers actually began rising (relative to non-shale districts) during the shale boom but not as much as for the student population. A larger wage gap between the education and private sectors, along with increased teacher turnover, does not necessarily imply that teachers were leaving. To catch up with a growing student population, districts may have found it easier to attract inexperienced teachers fresh out of college.

To the extent that some teachers did leave and needed to be replaced, they may not have taken higher-paying, non-teaching jobs. Instead, a spouse or other household member may be earning more business or wage income due to the boom, reducing the household's marginal utility of additional income and encouraging teachers to leave schools, at least temporarily, to possibly spend more time at home with their families (see Scafidi et al., 2006). Similarly, royalty payments to teacher households could have encouraged early retirement, as such royalty payments can be large and widespread (Brown et al., 2017). Alternatively, disamenities associated with drilling, including noise, traffic, or real wage decline brought about by greater living costs, would also encourage teachers to move elsewhere for jobs, even for similar nominal wages.

## 5.3 Student Achievement

Measures of student achievement include the percentages of students passing state standardized tests, attending school on a given day, completing high school, taking college entrance exams, and meeting college entrance exam requirements. Baseline values are shown in Table 3 (panel 3). The standardized test was the Assessment of Academic Skills (2001-2002), the Assessment of Knowledge and Skills (2003-2012), and then the Assessment of Academic Readiness (2012-present). The percentage of students passing state standardized tests, shown overall and separately for reading and math, may include students enrolled in grades 3-12, although not all grades take all tests in every year. The attendance rate is based on daily attendance for grades 1-12 over the entire academic year. The completion rate is based on a longitudinal cohort of all non-repeating ninth graders and students who transfer into the district in their second, third, or fourth year of high school. The numerator of the completion rate is the number of graduates and continuers from the cohort; the denominator is the number of graduates, continuers, GED recipients, and dropouts, also of the same cohort. The percentage of students taking college entrance exams is based on the SAT and ACT, with required thresholds of 1110 and 24 respectively.

Figure 6 shows how the achievement variables evolved over time based on shale geology. Before the shale boom, the Eagle Ford and non-shale districts (column a) had similar trends in pass rates for state exams, with a clear divergence only occurring after the shale boom began in 2010, when overall pass rates and rates for reading and math all declined relative to non-shale districts. Attendance rates followed a similar pattern, with a divergence only emerging after 2010. In contrast, there were no clear shifts in completion rates or in participation and performance on college entrance exams before or after 2010. The results indicate that the weak trend towards fewer ESL, votech, and economically-disadvantaged students prior to the shale boom (as discussed in sub-section 5.1) did not affect pass rates in the Eagle Ford as compared to non-shale districts.

The Permian and non-shale districts (column b) also had similar trends in pass rates prior to the rise of oil prices in the mid-2000s. Afterward, pass rates declined in Permian districts relative to non-shale districts. The same occurred with attendance rates, albeit with only a small divergence across the two groups. As with Eagle Ford districts, there were no clear shifts in completion rates or participation and performance in college entrance exams before or after the oil price rise.[18]

Table 4 (panel 3) shows the Long-Difference regression estimates for the coefficient on shale depth, both with and without controlling for changes in student

[18]The lack of a decline in the completion rate indicates that students were not enticed by increased wages to drop out of school for full-time work. This result is also is consistent with Texas policy, which has compulsory schooling until age 18.

composition. From 2001 to 2014, overall pass rates declined by 2.3 percentage points, which represents a 2.8 percent decline in the baseline pass rate for oil districts.[19] To further put the decline in perspective, it would cause a district at the median pass rate to move from the 50th percentile to the 57th percentile. The decline in pass rates was largest in math but reading pass rates also fell. The percentage of students meeting college entrance exam criteria also declined, as did the attendance rate, although only by 0.3 percentage points for the latter. All of the results are sseen in the within-shale sample except for the decline in performance in college exams, which becomes much less precisely estimated with the smaller sample (though the point estimate is larger).

The estimated effects of shale depth on achievement represent the net or combined effect of the previously documented changes in oil districts, including more school spending, higher labor market wages, and various shifts in student and teacher composition. Oil districts had large increases in their tax base over the study period, so their relative decline in student pass rates is not due to a lack of resources. The decline may instead stem from capital spending on better gyms and football fields that distracted students from academics or from classroom renovations that interrupted instruction. A more plausible contributor, however, is the increase in teacher turnover and the percentage of inexperienced teachers in the classroom. Other shale-related explanations are also possible. The decline in attendance could affect scores, with less attendance potentially stemming from some students missing school days to work part-time and take advantage of high labor market wages. In addition, shale development has also been linked with declines in air quality, which can itself affect cognitive ability (e.g. Ebenstein et al., 2016).

Initial or subsequent differences in student composition across shale oil and non-shale districts do not account for the decline in achievement. Oil districts initially had a higher percentage of votech and economically-disadvantaged students; they also saw a decline in the percentage of these students (and ESL students) during the boom. The change in composition likely worked against the decline in achievement. To test if this is the case, the LD model is estimated for achievement controlling for initial student composition and their changes over time. Specifically, every student

[19] Pass rates for shale and non-shale districts were generally flat over the shale boom period, meaning that, in absence of the shale boom, shale districts would have likely seen improvements in test scores.

composition variable enters the LD regression in two forms, one as the 2000 level and one as the change from 2001 to 2014. The results, also shown in Table 4, are as expected, with shale depth now leading to even larger declines in pass rates. For example, controlling for student composition causes the effect on reading pass rates to go from -1.53 to -1.93, a more than 25 percent increase. Math pass rates also decline more when controlling for composition. A similar pattern is observed when controlling for student composition using the within-shale sample.

# 6 Robustness

The evidence presented relies on variation between shale oil and non-shale districts, as well as variation within shale oil districts, both of which use shale depth as the explanatory variable. Neither approach exploits variation across shale oil and shale gas districts, nor do they explore alternative forms of shale measurement. Appendix Tables A1 and A2 remedy this by showing the Long Difference estimates based only on shale oil and shale gas districts, and by using shale thickness instead of shale depth as the explanatory variable (method d). These tables respectively mimic the order of outcomes and structure of the previous Tables 2 and 4.

As shown in Figure 2 and explained in sub-section 3.1, gas districts also experienced shale development, but without the clear improvements in school finances or labor market wages like oil districts. Shale gas districts are therefore now used as placebos–control observations that received a type of treatment (they had shale) but that lacked a mechanism (finances or wages) to induce effects. Under this method, gas districts are treated as having no shale (*Depth*=0), making them the control group.

Using gas districts as the control group provides results very similar to those using non-shale districts as the control group or when limiting the analysis to districts in oil counties. Relative to gas districts, oil districts had large increases in their tax bases, leading to more revenue and spending. Spending growth only occurred in non-payroll spending, which increased by more than 50 percent. Private and public sector wages increased relative to teacher wages, and the percentage of inexperienced teachers in the classroom increased by more than 5 percentage points. As before, the most significant change in the student body was the decline in economically-disadvantaged students, which fell by 8 percentage points. The effect on achievement was a 2.9 percentage point decline in the overall pass rate, which was also accompanied by a decline in the attendance rate, both of which are robust to controlling for student composition (results not shown). Interestingly, the percentage of students taking college entrance exams increased at the same time, which is consistent with the finding that votech students declined in oil districts relative to gas districts.[20]

All approaches thus far have used shale depth as a proxy for oil and gas endowments. But, other dimensions of geology also matter, including shale thickness, with thicker shale holding more oil and gas (Brown et al., 2016). Data on shale thickness, also from Los Alamos Laboratories, permit defining each district's average shale thickness. Thickness is then normalized in the same way as depth, meaning that the average shale district has a normalized depth of about one, and non-shale districts are treated as having a thickness of zero.

The LD estimates based on shale thickness are qualitatively the same as those using depth. The key difference is that the boom was smaller for the district with average thickness than for the district with average depth. This is most clearly seen by looking at the change in the oil and gas tax base. For the oil district with average thickness, the tax base increased by about $425,000 per student from 2001 to 2014. The district with the average depth, in contrast, had an increase of more than a million dollars per student. In turn, the rest of the effects based on thickness are smaller than those based on depth and further suggest that the observed changes stem from oil and gas development. For example, private wages increased by 10 percent based on thickness but by 19 percent based on depth. Other key results are also more modest, such as an increase in the percentage of inexperienced teachers by 1.9 percentage points instead of 3.2 percentage points when using depth, and the overall decline in pass rates was 1.4 percentage points,

[20] The robustness of the results is also tested using a sample of oil and non-shale districts trimmed to excluded oil districts that look unlike any non-shale districts and vice-versa. This is done by using year 2000 characteristics (e.g. tax base, spending per student, student composition, etc.) to estimate a Probit model that predicts the propensity of a given district to be an oil district. The propensity score serves as an index that summarizes district-level characteristics in a uni-dimensional way. Following Imbens (2015), the optimal upper and lower thresholds for the score are identified, which are then used to exclude the least comparable districts. In our case, this leads to dropping 47 non-shale districts. The LD estimates based on the trimmed sample are very similar to those based on the full sample, the within-shale sample, or the oil-gas sample. The only notable difference is that the trimmed sample shows no change in the size of the student population in oil districts relative to non-shale districts, which all of the other samples show.

as compared to 2.3 in the depth-based results.

Lastly, the robustness of our qualitative findings are tested with a different empirical approach and functional form. Specifically, a district fixed effects model is estimated that interacts shale depth with the price of oil and uses all years of data. The interaction between depth and the price of oil proxies for the value of the shale endowment and captures changing market conditions that matter for labor markets and school finances. Put differently, the effects of higher oil prices depend on whether a district is shale rich, and the model permits estimating how a given increase in price, conditional on having average shale depth, affects the outcomes of interest. In this model, price is normalized, so that for shale districts, the interaction equals zero for the period average price at any shale depth and equals one when the price is double the period average price at average shale depth.

A very similar pattern of results emerges when using this alternative approach (results not shown). For the average oil district, doubling the price of oil leads to a nearly $600,000 increase in the tax base and higher spending on non-payroll items, but not on payroll. As private and public sector wages increased and teacher wages remained flat, teacher turnover and the percentage of inexperienced teachers increased. Finally, pass rates fell by 1.7 percentage points, and attendance rates were lower.

# 7 Conclusion

Economic booms can generate additional revenues for schools, but also create incentives for students and teachers to leave the classroom. Using school districts across Texas, a state where oil and gas wells enter the property tax base once production begins, this study explores how the recent shale boom affected student achievement through the competing channels of school finances and labor markets. From 2001 to 2014, a period with large increases in oil prices and drilling in shale formations, the tax base of shale districts roughly tripled while private sector wages increased by nearly 20 percent.

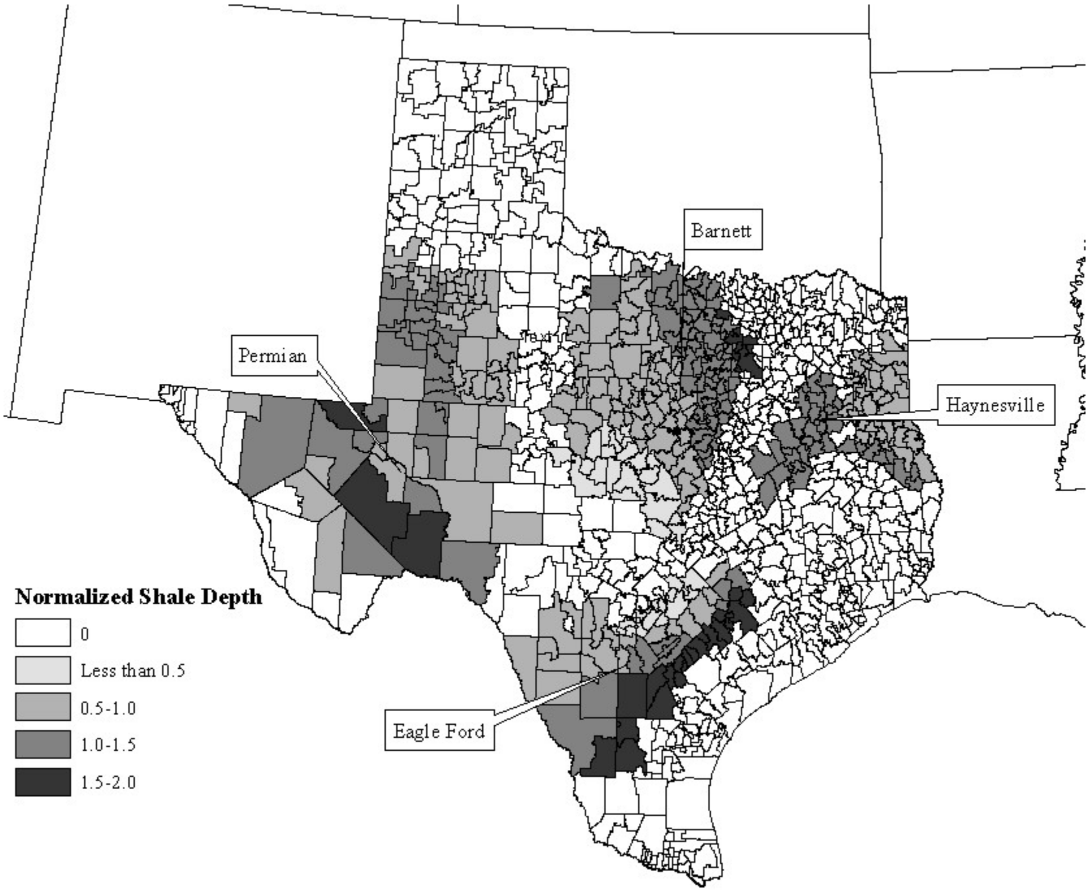
The findings add to the literature on school resources and student achievement by illustrating that schools can use additional funds in a variety of ways, not all of which may improve achievement. Despite shale districts benefiting from a revenue windfall caused by an expanded tax base, student achievement in shale districts declined. Overall spending per student did increase, but only in non-payroll categories, most notably in capital spending and debt servicing. Spending on teachers and other staff remained unchanged.

The decline in student achievement is not readily explained by changes in student composition. Although some changes in composition occurred, namely a decline in the percentage of of economically-disadvantaged students, controlling for these changes results in a larger decline in achievement. Instead, increased teacher turnover and more inexperienced teachers in the classroom most likely explain at least some of the decline in achievement. One plausible cause of the changes among teachers is the expanding wage gap between the private and education sectors, which could have drawn teachers out of schools. The effects of turnover and teacher composition on achievement have to be large enough to counter any positive effects of increased spending and changes in student composition, highlighting the importance of teacher quality for students. The findings also suggest that the education sector may act as the lagging sector in the booming-sector model of Corden and Neary (1982), with the output of the lagging sector declining as more labor is demanded by the booming sector.

The evidence also highlights the importance of policies regarding the taxation of oil and gas activities, which vary enormously across states. Fifteen states tax oil and gas wells as property, and at least ten other producing states do not. Because of greater property tax revenues, Texas school districts had the money to mitigate the labor market pull on teachers, but they spent it elsewhere. In states such as Louisiana and North Dakota, production generates some revenues for state-wide school spending but not necessarily for resource-rich districts. In other states, such as Pennsylvania, production-related revenues bypass the education sector entirely.

The lack of a link between greater spending and student achievement does not mean that districts in Texas mismanaged their revenue windfall. Buildings and classrooms may have needed renovation, and school administrators may have been hesitant to raise salaries in the boom, knowing it would be difficult to lower them in a bust. Still, using some additional revenue to fund temporary bonuses may have mitigated teacher turnover in boom times. In any case, making renovations or funding temporary bonuses requires more resources for districts in shale areas, something that would not happen under the current policy in states like Louisiana or Pennsylvania. In such states, it is especially unlikely that oil and gas development contributes to human capital improvements in resource-rich districts.

Figure 1: Normalized Shale Depth across Texas School Districts




*Notes*: Authors' calculations of normalized shale depth data from Los Alamos National Laboratories. The Eagle Ford and Permian shale formations primarily produce crude oil, while the Barnett and Haynesville shale formations primarily produce natural gas. Each district's depth is normalized by the average depth of its formation. The normalized depth for the average shale district is therefore about one and is set to zero for all non-shale districts.

Figure 2: Comparisons between Oil and Gas Formations, 2000-2014


*Notes*: Authors' calculations of well data from DrillingInfo, price data from the Energy Information Administration, oil & gas tax base data from the Public Education Information Management System of Texas Education Agency, and wage data from the Bureau of Economic Analysis. Panel (1) shows the total number of wells drilled by formation and the energy price, with the oil price being the national first-purchase price for crude oil and the natural gas price being the national wellhead price, both in constant 2010 dollars. Panel (2) shows the district mean oil & gas tax base, which is the assessed value (for property tax purposes) of all producing oil and gas wells in the district. Panel (3) shows the difference in the mean of the log of the private sector wage (compensation per job) between shale and non-shale districts.

Table 1: Baseline Differences in Local Finances, School Spending, and Wages, 2000

| | | Shale Oil and Non-Shale Districts (n=751) | | | |
|---|---|---|---|---|---|
| | | Shale Oil | Non-Shale | Norm Diff | P-Value |
| (1) Local Finances | Total Tax Base ($100,000 per student) | 5.31 | 4.33 | 0.14 | 0.04 |
| | Oil & Gas Tax Base | 2.21 | 0.69 | 0.30 | 0.00 |
| | Non Oil & Gas Tax Base | 3.10 | 3.64 | -0.14 | 0.02 |
| | Property Tax Rate (%) | 1.45 | 1.45 | 0.00 | 0.99 |
| | Total Debt ($1,000/student) | 3.21 | 7.80 | -0.38 | 0.00 |
| | Total Revenues (ln($/student)) | 9.29 | 9.23 | 0.18 | 0.01 |
| (2) School Spending | Total Spending (ln($/student)) | 9.32 | 9.29 | 0.09 | 0.15 |
| | Payroll Spending | 8.93 | 8.83 | 0.32 | 0.00 |
| | Non-Payroll Spending | 8.16 | 8.22 | -0.10 | 0.10 |
| | Capital Spending | 6.43 | 6.63 | -0.12 | 0.05 |
| | Debt Spending | 5.50 | 6.12 | -0.37 | 0.00 |
| | Other Spending | 7.72 | 7.61 | 0.21 | 0.00 |
| (3) Wages | Private Sector Wage (ln($/job)) | 10.09 | 10.25 | -0.41 | 0.00 |
| | Public Sector Wage | 10.65 | 10.66 | -0.06 | 0.36 |
| | Teacher Wage | 10.76 | 10.73 | 0.30 | 0.00 |
| | Private - Teacher Wage Gap | -0.67 | -0.49 | -0.49 | 0.00 |
| | Public - Teacher Wage Gap | -0.12 | -0.08 | -0.23 | 0.00 |

*Notes*: Authors' calculations of local finances and school spending data from the Public Education Information Management System of the Texas Education Agency and the Texas Bond Review Board (for property tax rates and debt) and wage data from the Bureau of Economic Analysis (non-teacher wages) and the Snapshot School District Profiles of the Texas Education Agency (teacher wage) in the base year of 2000. Data on capital spending and debt are not available for every district. Shale oil districts are over one of the two shale formations with primarily crude oil (Eagle Ford and Permian). Non-shale districts are not over any shale formation. The first two columns show the average values for shale oil and non-shale districts, the third column shows the difference in means normalized by the average standard deviation of the two groups, and the fourth column provides the p-value associated with the null hypothesis of equivalent means across the groups. (%) denotes a variable in percentage terms.

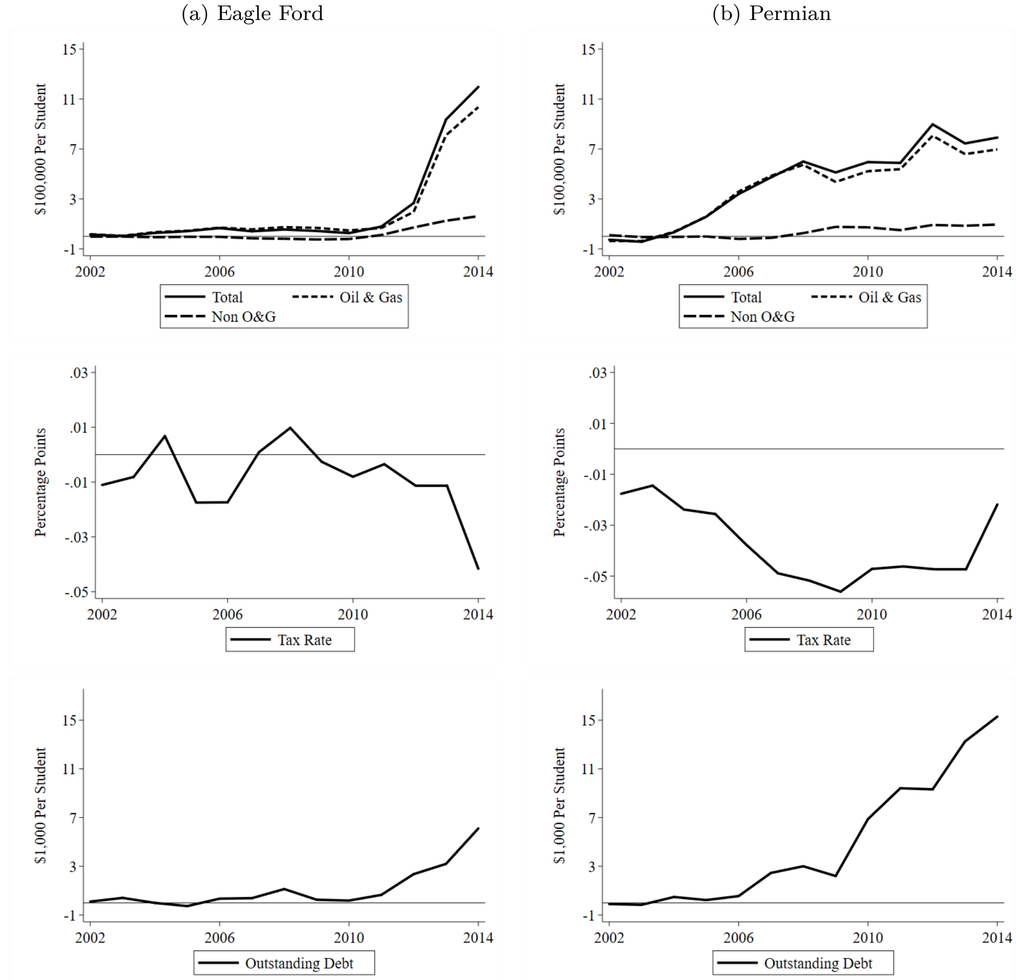
Figure 3: Shale Oil and Non-Shale Differences in Local Finances, 2002-2014

(a) Eagle Ford (b) Permian

(1) Tax Base

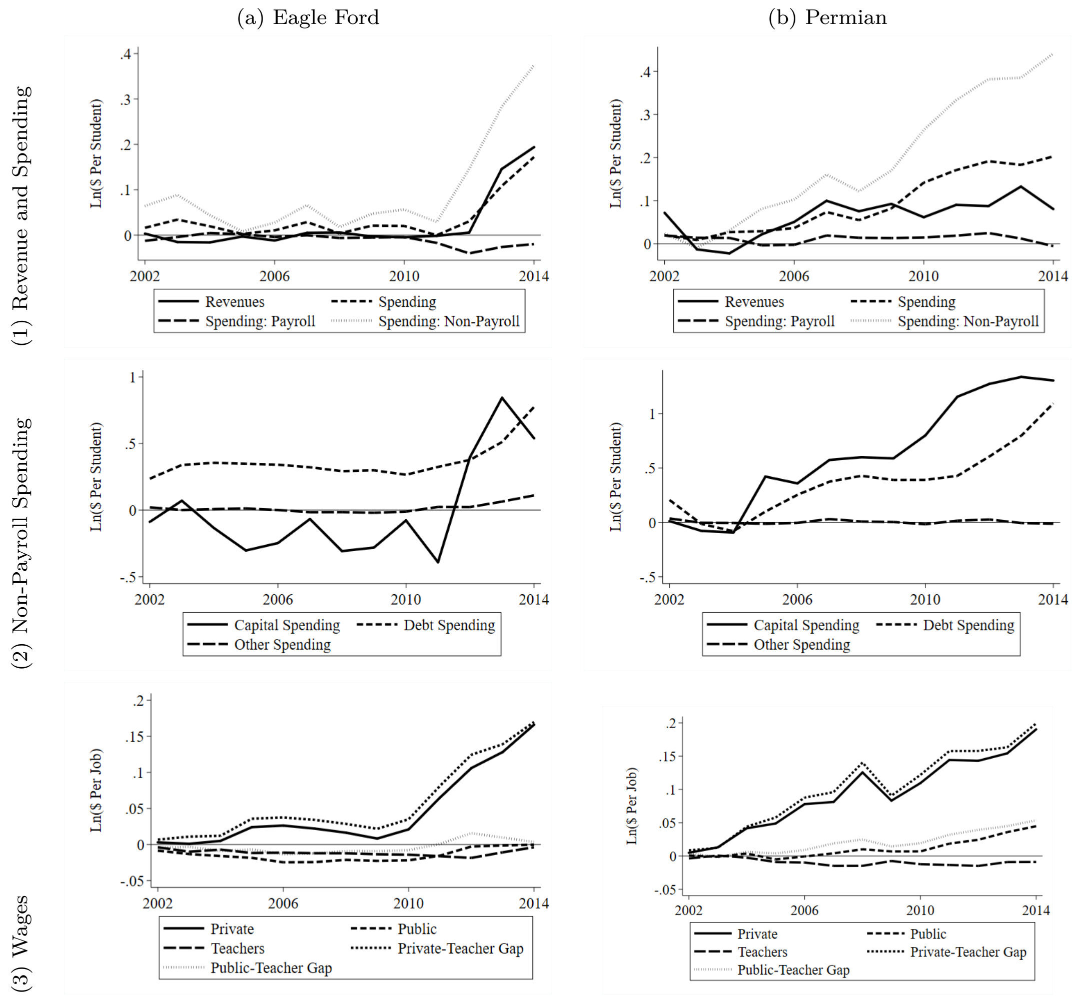
(2) Tax Rate

(3) Total Debt




*Notes*: Authors' calculations of multiple data sources, as described in the text and the notes of baseline Table 1. The graphs display the $\beta_y$ coefficients from Equation (1). The coefficients capture the evolution of differences in the outcome across shale oil districts with average depth relative to non-shale districts, controlling for district fixed effects and year dummy variables. The reference year is 2001.

Figure 4: Shale Oil and Non-Shale Differences in Revenue, Spending, and Wages, 2002-2014




*Notes*: Authors' calculations of multiple data sources, as described in the text and the notes of baseline Table 1. The graphs display the $\beta_y$ coefficients from Equation (1). The coefficients capture the evolution of differences in the outcome across shale oil districts with average depth relative to non-shale districts, controlling for district fixed effects and year dummy variables. The reference year is 2001.

Table 2: Long Difference Estimates for Local Finance, School Spending, and Wages, 2001-2014

| | | | Tax Base | | | Property | Total | Total |
|---|---|---|---|---|---|---|---|---|
| | | | Total | Oil and Gas | Non O&G | Tax Rate (%) | Debt | Revenues (ln) |
| (1) Local Finance | (a) Long Difference | Shale Depth | 10.20*** | 8.87*** | 1.33*** | -0.03*** | 10.38*** | 0.14*** |
| | - Full Sample | (Std. Error) | (2.45) | (2.20) | (0.38) | (0.01) | (2.14) | (0.03) |
| | | Observations | 751 | 751 | 751 | 751 | 751 | 751 |
| | (b) Long Difference | Shale Depth | 11.46*** | 9.56*** | 1.89*** | -0.05*** | 9.77*** | 0.19*** |
| | - Within-Shale | (Std. Error) | (2.72) | (2.45) | (0.39) | (0.02) | (2.36) | (0.04) |
| | | Observations | 299 | 299 | 299 | 299 | 299 | 299 |
| | | | Spending (ln) | | | Non-Payroll Spending (ln) | | |
| | | | Total | Payroll | Non-Payroll | Capital | Debt | Other |
| (2) School Spending | (a) Long Difference | Shale Depth | 0.19*** | -0.01 | 0.41*** | 0.97*** | 0.86*** | 0.05 |
| | - Full Sample | (Std. Error) | (0.03) | (0.01) | (0.06) | (0.17) | (0.14) | (0.04) |
| | | Observations | 751 | 751 | 751 | 724 | 584 | 751 |
| | (b) Long Difference | Shale Depth | 0.23*** | -0.01 | 0.50*** | 1.14*** | 0.98*** | 0.11** |
| | - Within-Shale | (Std. Error) | (0.04) | (0.02) | (0.07) | (0.21) | (0.15) | (0.05) |
| | | Observations | 299 | 299 | 299 | 287 | 221 | 299 |
| | | | Average Wage (ln) | | | | Wage Gap (ln) | |
| | | | Private | Public | Teacher | | Private - Teacher | Public - Teacher |
| (3) Wages | (a) Long Difference | Shale Depth | 0.18*** | 0.02*** | -0.01 | | 0.18*** | 0.03*** |
| | - Full Sample | (Std. Error) | (0.02) | (0.01) | (0.01) | | (0.02) | (0.01) |
| | | Observations | 751 | 751 | 751 | | 751 | 751 |
| | (b) Long Difference | Shale Depth | 0.19*** | 0.02** | -0.01 | | 0.20*** | 0.02** |
| | - Within-Shale | (Std. Error) | (0.02) | (0.01) | (0.01) | | (0.02) | (0.01) |
| | | Observations | 299 | 299 | 299 | | 299 | 299 |

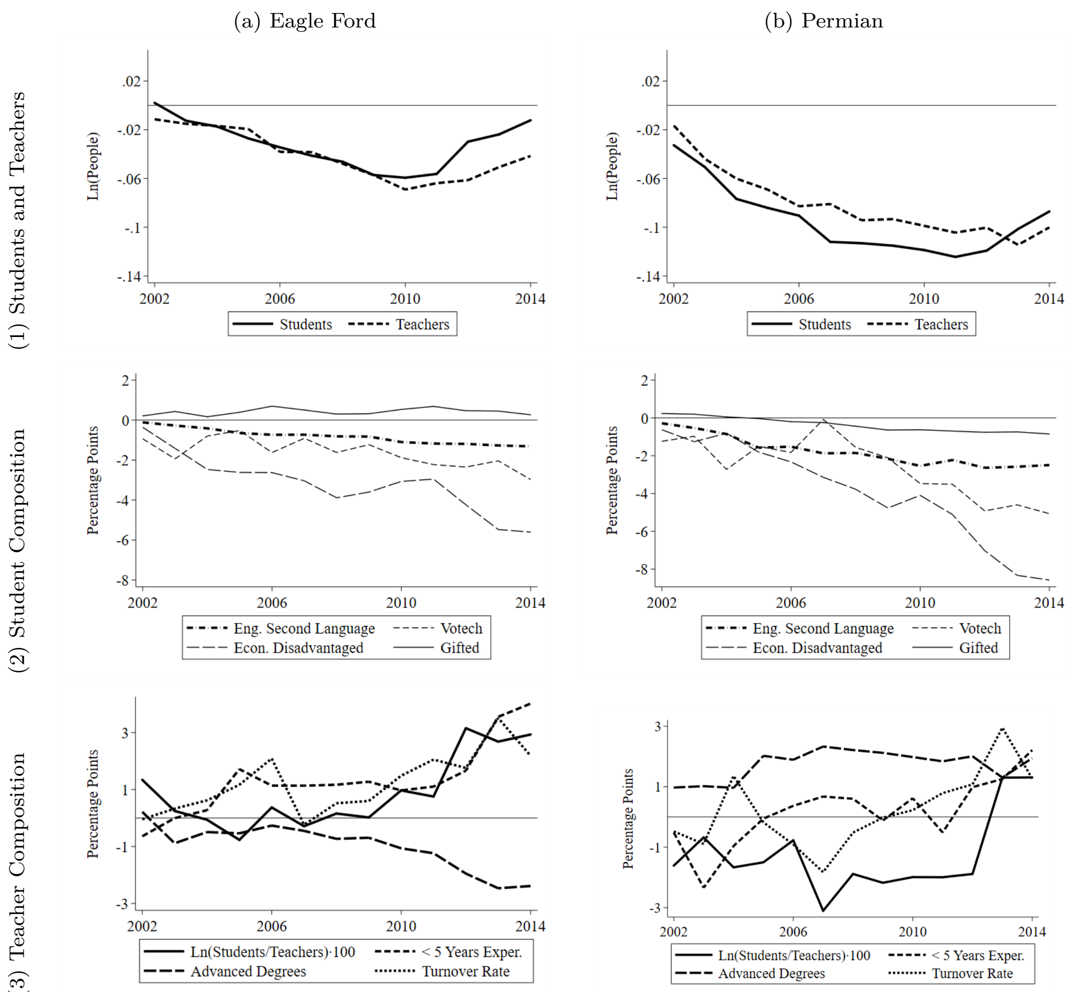
*Notes:* Authors' calculations of multiple data sources, as described in the text and the notes of baseline Table 1. The displayed estimates are the $\beta_{LD}$ coefficients from Equation (2). The coefficients capture the average change in the outcome over the study period form 2001 to 2014 for shale oil districts with average depth relative to non-shale districts. Tax base variables are in $100,000 per student, while debt is $1,000 per student. (%) denotes a variable in percentage terms. (ln) denotes the natural logarithm of a variable. Robust standard errors are in parentheses.

Table 3: Baseline Differences in Students, Teachers, and Achievement, 2000

| | | Shale Oil and Non-Shale Districts (n=751) | | | |
|---|---|---|---|---|---|
| | | Shale Oil | Non-Shale | Norm Diff | P-Value |
| (1) Students | Economically Disadvantaged (%) | 55.27 | 47.07 | 0.32 | 0.00 |
| | Vocational / Technical (%) | 26.74 | 21.36 | 0.39 | 0.00 |
| | English as a Second Language (%) | 6.78 | 6.80 | -0.00 | 0.97 |
| | Academically Gifted (%) | 8.03 | 7.86 | 0.03 | 0.59 |
| | Number of Students | 6.80 | 7.04 | -0.12 | 0.06 |
| (2) Teachers | Teachers with < 5 Years Experience (%) | 28.93 | 32.26 | -0.21 | 0.00 |
| | Teachers with Advanced Degree (%) | 18.06 | 19.42 | -0.11 | 0.08 |
| | Teacher Turnover Rate (%) | 15.67 | 16.49 | -0.07 | 0.26 |
| | Student-Teacher Ratio | 2.47 | 2.53 | -0.20 | 0.00 |
| | Number of Teachers | 4.33 | 4.50 | -0.10 | 0.12 |
| (3) Achievement | Passing State Tests Overall (%) | 81.06 | 82.35 | -0.10 | 0.12 |
| | Passing State Tests Reading (%) | 88.10 | 89.20 | -0.12 | 0.07 |
| | Passing State Tests Math (%) | 89.17 | 89.63 | -0.05 | 0.45 |
| | Attendance Rate (%) | 95.90 | 95.99 | -0.07 | 0.29 |
| | Completion Rate (%) | 93.22 | 93.79 | -0.06 | 0.44 |
| | Taking SAT/ACT Exams (%) | 59.11 | 60.65 | -0.07 | 0.29 |
| | Meeting SAT/ACT Criterion (%) | 17.27 | 18.39 | -0.06 | 0.32 |

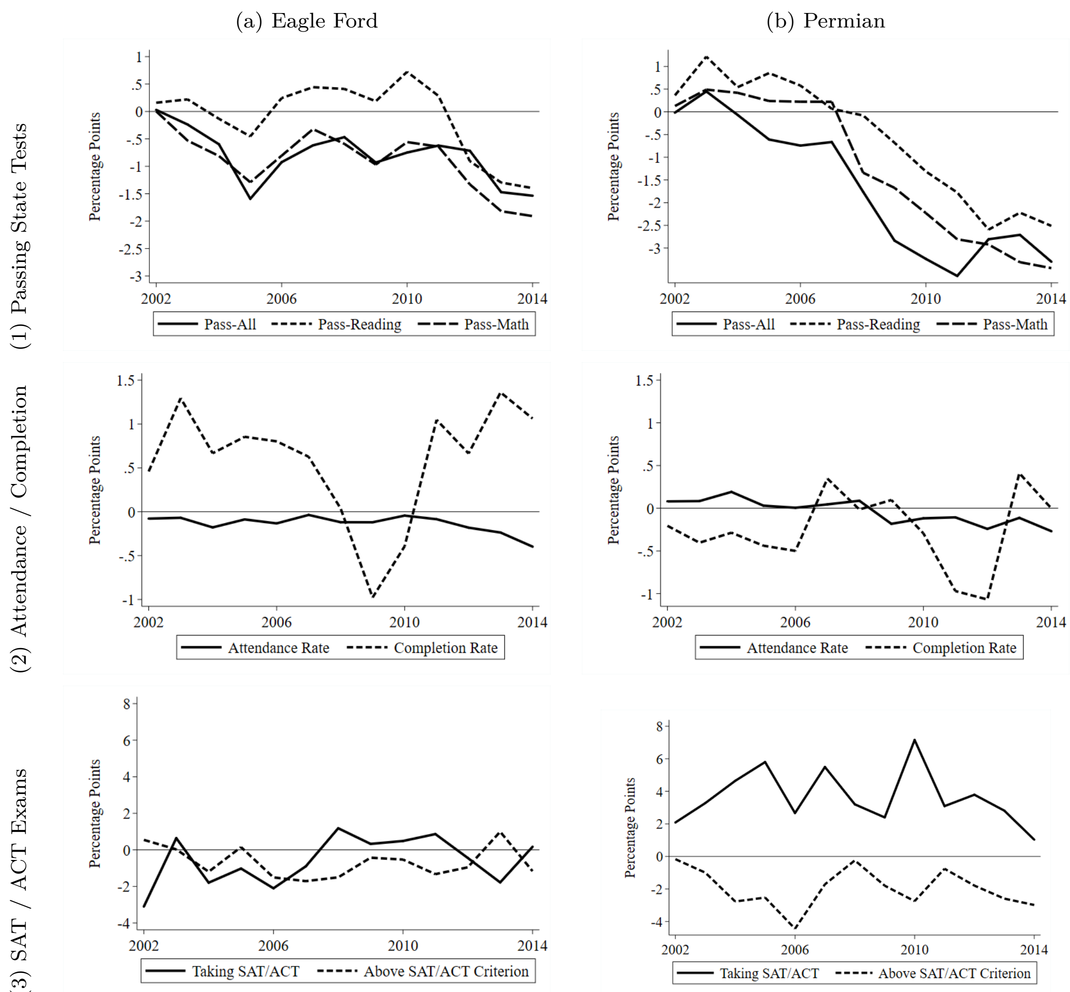
*Notes*: Authors' calculations of student and teacher data from the Snapshot School District Profiles of the Texas Education Agency in the base year of 2000. Shale oil districts are over one of the two shale formations with primarily crude oil (Eagle Ford and Permian). Non-shale districts are not over any shale formation. The first two columns show average values for shale oil and non-shale districts, the third column shows the difference in means normalized by the average standard deviation of the two groups, and the fourth column provides the p-value associated with the null hypothesis of equivalent means across groups. (%) denotes a variable in percentage terms.

Figure 5: Shale Oil and Non-Shale Differences in Students and Teachers, 2002-2014




*Notes*: Authors' calculations of multiple data sources, as described in the text and the notes of baseline Table 3. The graphs display the $\beta_y$ coefficients from Equation (1). The coefficients capture the evolution of differences in the outcome across shale oil districts with average depth relative to non-shale districts, controlling for district fixed effects and year dummy variables. The reference year is 2001.

Figure 6: Shale Oil and Non-Shale Differences in Student Achievement, 2002-2014




*Notes*: Authors' calculations of multiple data sources, as described in the text and the notes of baseline Table 3. The graphs display the $\beta_y$ coefficients from Equation (1). The coefficients capture the evolution of differences in the outcome across shale oil districts with average depth relative to non-shale districts, controlling for district fixed effects and year dummy variables. The reference year is 2001.

Table 4: Long Difference Estimates for Students, Teachers, and Achievement, 2001-2014

| | | | Economically Disadvantaged (%) | Vocational - Technical (%) | English as Second Language (%) | Academically Gifted (%) | Number of Students (ln) |
|---|---|---|---|---|---|---|---|
| (1) Students | (a) Long Difference | Shale Depth | -6.94*** | -3.95*** | -1.84*** | -0.25 | -0.05** |
| | - Full Sample | (Std. Error) | (0.95) | (0.65) | (0.43) | (0.35) | (0.02) |
| | | Observations | 751 | 751 | 751 | 751 | 751 |
| | (b) Long Difference | Shale Depth | -8.43*** | -4.11*** | -1.80*** | -0.65 | -0.11*** |
| | - Within-Shale | (Std. Error) | (1.19) | (0.81) | (0.54) | (0.41) | (0.03) |
| | | Observations | 299 | 299 | 299 | 299 | 299 |
| | | | Less Than 5 Years Experience (%) | With Advanced Degree (%) | Turnover Rate (%) | Student-Teacher Ratio (ln) | Number of Teachers (ln) |
| (2) Teachers | (a) Long Difference | Shale Depth | 3.21** | -0.51 | 1.72* | 0.02* | -0.07*** |
| | - Full Sample | (Std. Error) | (1.28) | (0.86) | (0.95) | (0.01) | (0.02) |
| | | Observations | 751 | 751 | 751 | 751 | 751 |
| | (b) Long Difference | Shale Depth | 5.33*** | -1.63 | 2.92** | 0.02 | -0.13*** |
| | - Within-Shale | (Std. Error) | (1.54) | (1.01) | (1.18) | (0.02) | (0.03) |
| | | Observations | 299 | 299 | 299 | 299 | 299 |
| | | | Passing State Tests (%) | | | Rates (%) | |
| | | | Overall | Reading | Math | Attend | Complete |
| (3) Achievement | (a) Long Difference | Shale Depth | -2.33*** | -1.53** | -2.55*** | -0.34*** | 0.47 |
| | - Full Sample | (Std. Error) | (0.71) | (0.71) | (0.87) | (0.07) | (0.60) |
| | (no controls) | Observations | 751 | 751 | 751 | 751 | 686 |
| | (a+) Long Difference | Shale Depth | -2.43*** | -1.93*** | -2.44*** | -0.25*** | 0.48 |
| | - Full Sample | (Std. Error) | (0.71) | (0.69) | (0.84) | (0.07) | (0.65) |
| | (with controls) | Observations | 751 | 751 | 751 | 751 | 686 |
| | (b) Long Difference | Shale Depth | -3.09*** | -2.58*** | -2.47** | -0.39*** | -0.10 |
| | - Within-Shale | (Std. Error) | (0.85) | (0.83) | (1.07) | (0.08) | (0.64) |
| | (no controls) | Observations | 299 | 299 | 299 | 299 | 272 |
| | (b+) Long Difference | Shale Depth | -3.42*** | -2.89*** | -2.71** | -0.32*** | -0.14 |
| | - Within-Shale | (Std. Error) | (0.95) | (0.85) | (1.11) | (0.10) | (0.74) |
| | (with controls) | Observations | 299 | 299 | 299 | 299 | 272 |

*Notes:* Authors' calculations of multiple data sources, as described in the text and the notes of baseline Table 3. The displayed estimates are the $\beta_{LD}$ coefficients from Equation (2). The coefficients capture the average change in the outcome over the study period form 2001 to 2014 for shale oil districts with average depth relative to non-shale districts. The controls are the 2000 levels of the student composition variables and the 2001-2014 changes for those same variables. (%) denotes a variable in percentage terms. (ln) denotes the natural logarithm of a variable. Robust standard errors are in parentheses.

# References

Allcott, H., and D. Keniston. 2018. "Dutch Disease or Agglomeration? The Local Economic Effects of Natural Resource Booms in Modern America." *Review of Economic Studies*, 85(2): 695-731.

Bacolod, M. 2007. "Do Alternative Opportunities Matter? The Role of Female Labor Markets in the Decline of Teacher Quality." *Review of Economics and Statistics* 89(4): 737-751.

Black, D., T. McKinnish, and S. Sanders. 2005a. "The Economic Impact of the Coal Boom and Bust." *Economic Journal* 115(502): 444-471.

Black, D., T. McKinnish, and S. Sanders. 2005b. "Tight Labor Markets and the Demand for Education: Evidence from the Coal Boom and Bust." *Industrial and Labor Relations Review* 59(1): 3-16.

Boyd, D., H. Lankford, S. Loeb, and J. Wyckoff. 2005. "The Draw of Home: How Teachers' Preferences for Proximity Disadvantage Urban Schools." *Journal of Policy Analysis and Management* 24(1): 113-132.

Brown, J. 2014. "Production of Natural Gas from Shale in Local Economies: A Resource Blessing or Curse?" *Economic Review* 99(1). Federal Reserve Bank of Kansas City.

Brown, J., T. Fitzgerald, and J. Weber. 2016. "Capturing Rents from Natural Resource Abundance: Private Royalties from U.S. Onshore Oil and Gas Production." *Resource and Energy Economics* 46: 23-38.

Brown, J., T. Fitzgerald, and J. Weber. 2017. "Asset Ownership, Windfalls, and Income: Evidence from Oil and Gas Royalties." Federal Reserve Bank of Kansas City RWP 16-12.

Buddin, R., and G. Zamarro. 2009. "Teacher Qualifications and Student Achievement in Urban Elementary Schools." *Journal of Urban Economics* 66: 103–115.

Cascio, E., and A. Narayan. 2017. "Who Needs a Fracking Education? The Educational Response to Low-skill Biased Technological Change." NBER Working Paper 21359, December.

Corcoran, S., W. Evans, and R. Schwab. 2004. "Women, the Labor Market, and the Declining Relative Quality of Teachers." *Journal of Policy Analysis and Management* 3(3): 449–470.

Corden, W., and J. Neary. 1982. "Booming Sector and De-Industrialisation in a Small Open Economy." *Economic Journal* 92: 825-848.

Davis, M., and F. Ferreira. 2017. "Housing Disease and Public School Finances." NBER Working Paper No. 24140.

Ebenstein, A., V. Lavy, and S. Roth. 2016. "The Long-Run Economic Consequences of High-Stakes Examinations: Evidence from Transitory Variation in Pollution." *American Economic Journal: Applied Economics* 8(4): 36-65.

Eide, E., D. Goldhaber, and D. Brewer. 2004. "The Teacher Labour Market and Teacher Quality." *Oxford Review of Economic Policy* 20(2): 230-244.

Emery, H., A. Ferrer, and D. Green. 2012. "Long-Term Consequences of Natural Resource Booms for Human Capital Accumulation." *Industrial and Labor Relations Review* 65(3): 708-734.

Energy Information Administration/Advanced Resources International (EIA/ARI). 2013. "EIA/ARI World Shale Gas and Shale Oil Resource Assessment." Report prepared for the U.S. Department of Energy, Energy Information Administration.

Fetzer, T. 2014. "Fracking Growth." CEP Discussion Paper No. 1278.

Feyrer, J., E. Mansur, and B. Sacerdote. 2017. "Geographic Dispersion of Economic Shocks: Evidence from the Fracking Revolution." *American Economic Review* 107(4): 1313-1334.

Gibbons, S., and S. McNally. 2013. "The Effects of Resources across School Phases: A Summary of Recent Evidence." CEP Discussion Paper No. 1226.

Goodman, J., Hurwitz, M., Park, J., and J. Smith. 2018. "Heat and Learning." NBER Working Paper 24639, May.

Haegeland, T., O. Raaum, and K. Salvanes. 2012. "Pennies from Heaven? Using Exogenous Tax Variation to Identify Effects of School Resources on Pupil Achievement." *Economics of Education Review* 31: 601-614.

Hanushek, E. 2006. "School Resources." In Hanushek, E. and Welch, F. (eds.), *Handbook of the Economics of Education, Volume 2*, Elsevier: 865-908.

Hanushek, E., M. Piopiunik, and S. Wiederhold. 2019. "The Value of Smarter Teachers: International Evidence on Teacher Cognitive Skills and Student Performance." *Journal of Human Resources*, forthcoming.

Harris, D., and T. Sass. 2011. "Teacher Training, Teacher Quality and Student Achievement." *Journal of Public Economics* 95: 798-812.

Hyman, J. 2017. "Does Money Matter in the Long Run? Effects of School Spending on Educational Attainment." *American Economic Journal: Economic Policy* 9(4): 256-280.

Imbens, G. 2015. "Matching Methods in Practice: Three Examples." *Journal of Human Resources*, 50(2): 373-419.

Jacobsen, G., and D. Parker. 2016. "The Economic Aftermath of Resource Booms: Evidence from Boomtowns in the American West." *Economic Journal* 126(593): 1092-1128.

Jackson, K., R. Johnson, and C. Persico. 2016. "The Effects of School Spending on Educational and Economic Outcomes: Evidence from School Finance Reforms." *Quarterly Journal of Economics* 131(1): 157-218.

Krueger, A. 2003. "Economic Considerations and Class Size." *Economic Journal* 113: F34-F63.

Kumar, A. 2017. "Impact of Oil Booms and Busts on Human Capital Investment in the USA." *Empirical Economics* 52(3): 1089-1114.

Lafortune, J., J. Rothstein, and D. Schanzenbach. 2018. "School Finance Reform and the Distribution of Student Achievement." *American Economic Journal: Applied Economics* 10(2): 1-26.

Marchand, J. 2012. "Local Labor Market Impacts of Energy Boom-Bust-Boom in Western Canada." *Journal of Urban Economics* 71(1): 165-174.

Marchand, J., and J. Weber. 2015. "The Labor Market and School Finance Effects of the Texas Shale Boom on Teacher Quality and Student Achievement." University of Alberta, Department of Economics, Working Paper 2015-15.

Marchand, J., and J. Weber. 2018. "Local Labor Markets and Natural Resources: A Synthesis of the Literature." *Journal of Economic Surveys* 32(2): 469-490.

Martorell, P., Stange, K. and I. McFarlin. 2016. "Investing in Schools: Capital Spending, Facility Conditions, and Student Achievement. *Journal of Public Economics* 140: 13-29.

Muehlenbachs, L., E. Spiller, and C. Timmins. 2015. "The Housing Market Impacts of Shale Gas Development." *American Economic Review* 105(12): 3633-3659.

Nagler, M., M. Piopiunik, and M. West. 2015. "Weak Markets, Strong Teachers: Recession at Career Start and Teacher Effectiveness." NBER Working Paper 21393, July.

Neilson, C., and S. Zimmerman. 2014. "The Effect of School Construction on Test Scores, School Enrollment, and Home Prices." *Journal of Public Economics* 120: 18-31.

Raimi, D., and R. Newell. 2015. "Oil and Gas Revenue Allocation to Local Governments in Eight States." NBER Working Paper 21615, October.

Rickman, D., H. Wang, and J. Winters. 2017. "Is Shale Development Drilling Holes in the Human Capital Pipeline?" *Energy Economics* 62: 283-290.

Rivkin, S., Hanushek, E., and J. Kain. 2005. "Teachers, Schools, and Academic Achievement." Econometrica 73(2): 417-458.

Ronfeldt, M., S. Loeb, and J. Wyckoff. 2013. "How Teacher Turnover Harms Student Achievement." *American Educational Research Journal* 50(1): 4-36.

Scafidi, B., D. Sjoquisty, and T. Stinebrickner. 2006. "Do Teachers Really Leave for Higher Paying Jobs in Alternative Occupations?" *Advances in Economic Analysis & Policy* 6(1): 1-44.

Staiger, D. and J. Rockoff. 2010. "Searching for Effective Teachers with Imperfect Information." *Journal of Economic Perspectives* 24(3): 97-118.

Stoddard, C. 2003. "Why Has the Number of Teachers per Student Risen while Teacher Quality Has Declined? The Role of Changes in the Labor Market for Women." *Journal of Urban Economics* 53(3): 458-481.

Unnever, J., A. Kerckhoff, and T. Robinson. 2000. "District Variations in Educational Resources and Student Outcomes." *Economics of Education Review* 19: 245-259.

Weber, J. 2012. "The Effects of a Natural Gas Boom on Employment and Income in Colorado, Texas, and Wyoming." *Energy Economics* 34(5): 1580-1588.

Weber, J. 2014. "A Decade of Natural Gas Development: The Makings of a Resource Curse?" *Resource and Energy Economics* 37: 168-183.

Weber, J., W. Burnett, and I. Xiarchos. 2016. "Broadening Benefits from Natural Resource Extraction: Housing Values and Taxation of Natural Gas Wells as Property." *Journal of Policy Analysis and Management* 35(3): 587-614.

Zuo, N., J. Schieffer, and S. Buck. 2019. "The Effect of the Oil and Gas Boom on Schooling Decisions in the U.S." *Resource and Energy Economics* 55, 1-23.

Table A1: Robustness Estimates for Local Finance, School Spending, and Wages, 2001-2014

| | | | Tax Base | | | Property | Total | Total |
|---|---|---|---|---|---|---|---|---|
| | | | Total | Oil and Gas | Non O&G | Tax Rate (%) | Debt | Revenues (ln) |
| (1) Local Finance | (c) Long Difference | Shale Depth | 10.68*** | 9.20*** | 1.48*** | -0.04*** | 10.31*** | 0.16*** |
| | - Gas as Placebo | (Std. Error) | (2.57) | (2.31) | (0.38) | (0.01) | (2.21) | (0.03) |
| | | Observations | 408 | 408 | 408 | 409 | 409 | 409 |
| | (d) Long Difference | Shale Thick | 5.06*** | 4.25*** | 0.81*** | -0.02** | 5.11*** | 0.07*** |
| | - With Thickness | (Std. Error) | (1.42) | (1.26) | (0.25) | (0.01) | (1.48) | (0.02) |
| | | Observations | 751 | 751 | 751 | 751 | 751 | 751 |
| | | | Spending (ln) | | | Non-Payroll Spending (ln) | | |
| | | | Total | Payroll | Non-Payroll | Capital | Debt | Other |
| (2) School Spending | (c) Long Difference | Shale Depth | 0.19*** | -0.02 | 0.42*** | 0.90*** | 0.77*** | 0.08* |
| | - Gas as Placebo | (Std. Error) | (0.03) | (0.01) | (0.07) | (0.19) | (0.15) | (0.04) |
| | | Observations | 409 | 409 | 409 | 397 | 308 | 409 |
| | (d) Long Difference | Shale Thick | 0.10*** | -0.00 | 0.21*** | 0.59*** | 0.43*** | 0.05* |
| | - With Thickness | (Std. Error) | (0.03) | (0.01) | (0.05) | (0.15) | (0.09) | (0.03) |
| | | Observations | 751 | 751 | 751 | 724 | 584 | 751 |
| | | | Average Wage (ln) | | | | Wage Gap (ln) | |
| | | | Private | Public | Teacher | | Private - Teacher | Public - Teacher |
| (3) Wages | (c) Long Difference | Shale Depth | 0.15*** | 0.02*** | -0.00 | | 0.16*** | 0.03*** |
| | - Gas as Placebo | (Std. Error) | (0.02) | (0.01) | (0.01) | | (0.02) | (0.01) |
| | | Observations | 409 | 409 | 409 | | 409 | 409 |
| | (d) Long Difference | Shale Thick | 0.10*** | 0.02*** | 0.00 | | 0.09*** | 0.01** |
| | - With Thickness | (Std. Error) | (0.02) | (0.01) | (0.00) | | (0.02) | (0.01) |
| | | Observations | 751 | 751 | 751 | | 751 | 751 |

*Notes:* Authors' calculations of multiple data sources, as described in the text and the notes of baseline Table 1. The displayed estimates are the $\beta_{LD}$ coefficients from Equation (2). The coefficients capture the average change in the outcome over the study period form 2001 to 2014 for shale oil districts with average depth relative to non-shale districts. Tax base variables are in \$100,000 per student, while debt is \$1,000 per student. (%) denotes a variable in percentage terms. (ln) denotes the natural logarithm of a variable. Robust standard errors are in parentheses.

Table A2: Robustness Estimates for Students, Teachers, and Achievement, 2001-2014

| | | | Economically Disadvantaged (%) | Vocational - Technical (%) | English as Second Language (%) | Academically Gifted (%) | Number of Students (ln) |
|---|---|---|---|---|---|---|---|
| (1) Students | (c) Long Difference | Shale Depth | -7.99*** | -3.58*** | -2.19*** | -0.51 | -0.05* |
| | - Gas as Placebo | (Std. Error) | (1.04) | (0.73) | (0.44) | (0.37) | (0.02) |
| | | Observations | 409 | 409 | 409 | 409 | 409 |
| | (d) Long Difference | Shale Thick | -3.93*** | -2.18*** | -1.06** | -0.12 | -0.04*** |
| | - With Thickness | (Std. Error) | (0.91) | (0.48) | (0.45) | (0.23) | (0.02) |
| | | Observations | 751 | 751 | 751 | 751 | 751 |
| | | | Less Than 5 Years Experience (%) | With Advanced Degree (%) | Turnover Rate (%) | Student-Teacher Ratio (ln) | Number of Teachers (ln) |
| (2) Teachers | (c) Long Difference | Shale Depth | 5.15*** | -0.64 | 1.56 | 0.03** | -0.08*** |
| | - Gas as Placebo | (Std. Error) | (1.44) | (0.96) | (1.02) | (0.01) | (0.02) |
| | | Observations | 409 | 409 | 409 | 409 | 409 |
| | (d) Long Difference | Shale Thick | 1.95* | -0.15 | 0.97 | 0.02* | -0.06*** |
| | - With Thickness | (Std. Error) | (1.03) | (0.75) | (0.60) | (0.01) | (0.01) |
| | | Observations | 751 | 751 | 751 | 751 | 751 |
| | | | Passing State Tests (%) | | | Rates (%) | |
| | | | Overall | Reading | Math | Attend | Complete |
| (3) Achievement | (c) Long Difference | Shale Depth | -2.88*** | -2.68*** | -3.50*** | -0.37*** | -0.27 |
| | - Gas as Placebo | (Std. Error) | (0.78) | (0.77) | (0.93) | (0.07) | (0.63) |
| | | Observations | 409 | 409 | 409 | 409 | 387 |
| | (d) Long Difference | Shale Thick | -1.40** | -1.45*** | -1.80*** | -0.27*** | -0.16 |
| | - With Thickness | (Std. Error) | (0.64) | (0.53) | (0.66) | (0.05) | (0.42) |
| | | Observations | 751 | 751 | 751 | 751 | 686 |

*Notes:* Authors' calculations of multiple data sources, as described in the text and the notes of baseline Table 3. The displayed estimates are the $\beta_{LD}$ coefficients from Equation (2). The coefficients capture the average change in the outcome over the study period form 2001 to 2014 for shale oil districts with average depth relative to non-shale districts. (%) denotes a variable in percentage terms. (ln) denotes the natural logarithm of a variable. Robust standard errors are in parentheses.

## Department of Economics, University of Alberta
## Working Paper Series

| |
|---|
| **2017-11:** Self-Sabotage in the Procurement of Distributed Energy Resources – **Brown, D.,** Sappington, D. |
| **2017-10:** Public Private Competition – **Klumpp, T., Su, X.** |
| **2017-09:** Testing for State-Dependent Predictive Ability – **Fossati, S.** |
| **2017-08:** Default Risk, Productivity, and the Environment: Theory and Evidence from U.S. Manufacturing – **Andersen, D.** |
| **2017-07:** Does Maternal Employment Affect Child Nutrition Status? New Evidence from Egypt – Rashad, A., **Sharaf, M.** |
| **2017-06:** The Effect of Default Rates on Retail Competition and Pricing Decisions of Competitive Retailers: The Case of Alberta – **Brown, D., Eckert, A.** |
| **2017-05:** Optimal Procurement of Distributed Energy Resources – **Brown, D.,** Sappington, D. |
| **2017-04:** The Impact of Schooling Intensity on Student Learning: Evidence from a Quasi-Experiment – Andrietti, V., **Su, X.** |
| **2017-03:** The Voting Rights of Ex-Felons and Election Outcomes in the United States – **Klumpp, T.,** Mialon, H., Williams, M. |
| **2017-02:** Does the Design of a Fiscal Rule Matter for Welfare? – **Landon, S., Smith, C.** |
| **2017-01:** Carbon Pricing with an Output Subsidy under Imperfect Competition: The Case of Alberta's Restructured Electricity Market – **Brown, D., Eckert, A., Eckert, H.** |
| **2016-18:** Monetary Policy Tradeoffs Between Financial Stability and Price Stability – **Shukayev, M.,** Ueberfeldt, A. |
| **2016-17:** Managing Risk Taking with Interest Rate Policy and Macroprudential Regulations – Cociuba, S., **Shukayev, M.,** Ueberfeldt, A. |
| **2016-16:** On the Role of Maximum Demand Charges in the Presence of Distributed Generation Resources – **Brown, D.,** Sappington, D. |
| **2016-15:** Implementing Cross-Border Interbank Lending in BoC-GEM-FIN – **Shukayev, M.,** Toktamyssov, A. |
| **2016-14:** The Effects of Early Pregnancy on Education, Physical Health and Mental Distress: Evidence from Mexico – **Gunes, P.,** Tsaneva, M. |
| **2016-13:** An Equilibrium Selection Theory of Monopolization – **Eckert, A., Klumpp, T., Su, X.** |
| **2016-12:** Education Curriculum and Student Achievement: Theory and Evidence – Andrietti, V., **Su, X.** |
| **2016-11:** Poverty and Aging – **Marchand, J.,** Smeeding, T. |
| **2016-10:** Local Labor Markets and Natural Resources: A Synthesis of the Literature – **Marchand, J.,** Weber, J. |
| **2016-09:** Accounting for Firm Exit and Loss of Variety in the Welfare Cost of Regulations – **Andersen, D.** |
| **2016-08:** Analyzing the Impact of Electricity Market Structure Changes and Mergers: The Importance of Forward Commitments – **Brown, D., Eckert, A.** |
| **2016-07:** Credibility of History-Dependent Monetary Policies and Macroeconomic Instability – Cateau, G., **Shukayev, M.** |
| **2016-06:** Electricity Market Mergers with Endogenous Forward Contracting – **Brown, D., Eckert, A.** |
| **2016-05:** Thinking about Minimum Wage Increases in Alberta: Theoretically, Empirically, and Regionally – **Marchand, J.** |