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

Joseph Marchand *
University of Alberta

Jeremy G. Weber
University of Pittsburgh

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Abstract

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

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

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

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*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. The authors thank the participants of the following conferences and seminars for their feedback: Canadian Economic Association, Eastern Economic Association, Ryerson University, Society of Labor Economists, Syracuse University, University of Pittsburgh, University of Toronto, and West Virginia University. We also appreciate comments by Jeanette Winn, superintendent of Karnes City school district in Karnes County, Texas. 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".

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 both large and localized, tripling the tax base of the average shale school district and increasing private sector wages by a quarter.

How do schools, students, and teachers respond to a localized economic shock that provided resources to schools, but also increased 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 in 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 drop out of school. Teachers may also leave for higher paying jobs, especially if no commensurate increase in teacher salaries occurs. The labor market effects on school-wide student achievement will therefore depend on 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. Specifically, shale depth serves as a proxy for a district's energy resources, which is interacted with energy prices or time period indicators to capture the timing of extraction. Home to four major shale formations, Texas has been the epicenter of the U.S. shale boom. The state is also one of fifteen U.S. states with a policy that subjects oil and gas wells to property taxes.[1] Because of the policy, the drilling boom increased

[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.

the property tax base and revenues to schools in at least some areas of the state (Raimi and Newell, 2014; Weber et al., 2016).

For the 2000-2014 period, standardized test scores in shale oil districts declined relative to non-shale districts. 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, but none of it went to teachers. Despite the shale boom increasing the private market wage by 24 percent, completion rates among high school students did not decline. However, a growing gap between private and education sector wages contributed to greater teacher turnover and put more inexperienced teachers in the classroom. The overall negative effect of shale development on student achievement, therefore, likely stems from the resulting decline in teacher quality.

2 School Finances, Labor Markets, & Education

2.1 School Finances & Student Achievement

Cascio and Narayan (2015) find no effect of shale reserves on local, state, or federal revenues to schools at the commuting zone level. The result, however, is hard to interpret because of the differences in tax policy across states. Raimi and Newell (2014) 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).

A drilling boom should improve school finances in states where oil and gas wells are taxed as real property, because property taxes are a major revenue source for schools. In Texas, a well enters the property tax base when it begins producing. Independent appraisers assign a value to the well based on the discounted flow of profits that it is expected to generate. Wells are reassessed annually as they mature and prices change. Unsurprisingly, Weber et al. (2016) show that the development of the Barnett Shale in Texas caused a large increase in the property tax base, which subsequently increased school revenues.

It is not a forgone conclusion that an expanded tax base will increase school revenues and spending. If voters are well-informed and the tax rate reflects the optimal demand for public services, a tax base expansion could cause policy makers to decrease the tax rate, leaving the government with just enough funds to maintain (but not expand) services. As such, additional revenue from one source may crowd out revenue from another source (Gordon, 2004; Dahlberg et al., 2008; Litschig and Morrison, 2013). Carnicelli and Postali (2014) find that oil windfalls led Brazilian municipalities to reduce their effort in the collection of revenue through taxes. Similarly, Caselli and Michaels (2013) find that revenues from oil production had inconsistent effects on spending on education for Brazilian municipalities.

Even if school spending increases, it may not improve student achievement. Reviews of research on the effect of spending on achievement have showed diverse findings (Krueger, 2003; Hanushek, 2006). Briefly summarizing the literature, Gibbons and McNally (2013) argue that the majority of early studies lacked proper identification, which led to the conclusion that greater school spending had no effect, but more recent studies, employing better research designs, generally show that resources matter. For example, Haegeland et al. (2012) use the location of waterfalls in Norway to estimate how higher revenue from hydro-power plants affected the achievement of 16 year olds, finding a positive effect.

Of course, how schools spend the additional money also matters. Cobb-Clark and Jha (2013) show that spending on ancillary teaching staff and school leadership improved test scores more than per pupil spending in general. Given that revenues from the oil and gas property tax base can come quickly and without conditions during boom times, school districts may find themselves unprepared to use the money effectively, with few people qualified to evaluate the merits of spending options. Schools may spend much of the additional revenues in ways that have little to do with student achievement, such as on gyms or football stadiums, rather than on hiring more and better teachers.

2.2 Labor Markets & Student Achievement

Numerous studies of resource booms document their extensive effects on labor markets (for a review, see Marchand and Weber, 2017). Growth in resource extraction can create jobs and raise incomes, drawing workers from near and far. The local employment and earnings effects can be large and spill over into other sectors, as found by Black et al. (2005a), for coal counties in the Appalachian region of the United States, and by Marchand (2012), for the oil and gas rich areas of Western Canada. The expansion of oil and gas drilling into U.S. shale formations in the 2000s also had substantial labor market effects. Weber (2012) found that the average county experiencing a boom in natural gas production, across the states of Colorado, Texas, and Wyoming, had a $69 million increase in wage and salary earnings. Other studies have documented spillover effects and increases in earnings per worker and wages (Brown, 2014; Fetzer, 2014; Weber, 2014; Jacobsen and Parker, 2016).

For students, a higher local wage could encourage them to work (or work more hours), leading them to miss class or dropout altogether. If higher wages attract lower performing students, the average achievement of the remaining students may increase through changes in composition alone. This might occur if many of the jobs associated with shale drilling require little formal education. Black et al. (2005b) showed that the 1970s boom in coal mining in the eastern U.S. increased the returns to unskilled labor, causing youth to leave school for the mines. The finding is consistent with Kumar (2014), who shows that the 1970s oil boom slowed growth in the relative demand for skills in the U.S. Looking at a similar period in Alberta, Canada, Emery et al. (2012) find that the 1970's oil boom caused males to delay their education, but not decrease their eventual attainment. Recently, Cascio and Narayan (2015) look across U.S. commuting zones and find that the shale boom increased dropout rates among males. Similarly, Rickman et al. (2016) find that the shale boom reduced high school and college attainment among local residents in Montana, North Dakota, and West Virginia.

For teachers, rising local wages imply a greater opportunity cost of staying in the classroom, if schools do not increase salaries to stay competitive with outside opportunities. In practice, formula-based teacher salaries are unlikely to keep pace with private sector wage growth during boom times. And, even if teachers find the new non-teaching jobs unattractive, more expensive housing rents and local services mean that, without pay increases, real teacher wages will decline, encouraging them to live and work elsewhere. As with students, the pull of the labor market may be strongest for certain types of teachers, thereby altering their composition. If teachers who leave for outside opportunities are replaced by those with less experience, average teacher experience would decline and potentially reduce student achievement within a district.

Ample evidence shows that labor market conditions can affect teacher quality. Several studies link the declining quality of teachers in the U.S. from the 1960s to the 1990s to improved labor market opportunities for talented women (Stoddard, 2003; Corcoran et al., 2004; Eide et al., 2004; Bacolod, 2007). Other research links teacher quality to student achievement. Goldhaber and Brewer (1997) found that teacher qualifications (certifications, degrees, and experience) matter for student outcomes, as measured by tenth grade math scores. More recent research highlights the role of teacher experience, in particular. Buddin and Zamarro (2009) find that student achievement weakly increases with teacher experience, mainly because of poor student outcomes in the first two years of teaching. Similarly, Harris and Sass (2011) show that elementary and middle school teacher productivity increases with experience, with the largest gains coming within the first few years. Increased teacher turnover caused by teachers leaving the classroom for jobs elsewhere can itself harm students (Hanushek and Rivkin, 2010), and Staiger and Rockoff (2010) argue that turnover reduces student achievement by the most when experienced teachers are replaced with inexperienced teachers.

3 Empirical Strategy

3.1 Descriptive Details

Across the education literature, the unit of observation ranges from the student to the state, with classrooms, schools, school districts, and counties lying in between those extremes.[2] 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 (5,000,470), in more than one thousand schooling districts (1,031). The full sample includes 1,012 independent school districts for which shale depth data were available (98.1 percent

[2]Hanushek et al. (1996) established a link between this level of aggregation and the magnitude and statistical significance of the estimates.

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

of the available 1,031 districts).[4]

Figure 1 shows the delineation of Texas school districts and their shale depth. As later explained in the regression specifications, each district's average shale depth is normalized by the formation-specific average depth. Fifty-two percent of all districts in the sample are located over one of the four major shale formations in Texas: the Barnett, the Haynesville, the Eagle Ford, and the Permian. The Barnett and Haynesville formations produce natural gas and are in the north and east of the state. The Eagle Ford and Permian formations primarily produce crude oil and are in the south and west of the state.

Texas school districts are followed for 15 years, from 2000 to 2014, a period with much variation in drilling that coincides with variation in oil and gas prices. The descriptive figures that follow show various trends for each of the major oil formations (Eagle Ford and Permian) and each of the major gas formations (Barnett and Haynesville). The breakout reveals heterogeneity between formations, which will be used to motivate and justify details of the empirical approach and aid in the interpretation of the estimates.

Figures 2a shows that the real price of crude oil grew steadily from 2003 to 2008, and then sharply declined from 2008 to 2009, before returning to higher levels from 2009 to 2014. The number of wells drilled in the Permian 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. The onset of shale technology can be seen more 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, when the widespread application of horizontal drilling and hydraulic fracturing occurred.[5]

Natural gas prices and well drilling follow more of a boom and bust over the period, with prices increasing from 2002 to 2005, remaining high until 2008, and

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

[5]The role of horizontal wells, as opposed to vertical wells, is one indicator of conventional versus unconventional development. The shift towards shale development in the Permian can be seen by the drop in the ratio of vertical to horizontal wells. The lack of conventional oil production in the Eagle Ford can be seen by a ratio close to zero. For more information, please see the EIA Today In Energy report from March 17, 2015: http://www.eia.gov/todayinenergy/detail.php?id=20392.

then plummeting in 2009 and remaining low afterward (Figure 2b). Drilling followed prices in both gas formations, with the number of wells drilled peaking in 2008 and declining thereafter.

Similar to wells drilled, the oil and gas tax base in Figures 3a and 3b is also a measure of the shale boom, because it depends on the number of producing wells and their profitability. Districts in the Permian saw large increases in the oil and gas tax base, going from below $400,000 per student in 2000 to over $1,200,000 per student in 2012. Districts in the Eagle Ford also saw a large increase, but almost all of it occurred from 2011 to 2014, when the oil and gas tax base expanded from under $200,000 to nearly $1,000,000 per student.

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 increase the value of existing wells and encourage the drilling of new ones, which enter the tax base upon commencement of production. Districts in the natural gas formations experienced smaller expansions in the oil and gas tax base, which followed the price of natural gas. The average district in the Barnett shale had an increase of less than $50,000 per student over the study period, while the average district in the Haynesville had a roughly $150,000 increase from 2000 to 2008, but the base returned to its 2000 level by 2014. 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.

As the tax base expanded in oil districts, so did spending per student in shale districts relative to non-shale districts. Figures 4a and 4b show the difference in average school spending between district type. In the Permian, the difference rose from under $1,000 in 2000 to roughly $6,000 in 2011 and remained high. In the Eagle Ford, shale and non-shale districts had similar spending over the 2000 to 2011 period, but by 2014, a difference of $4,000 had emerged. The differences are large considering that the average district only spent about $10,000 per student in 2000. For gas districts, the modest expansion in the tax base had a small and delayed effect on spending in the Haynesville and no clear effect in the Barnett.

Turning to wages, measured as compensation per job, 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 (Figure 5a). By 2014, the difference had switched, with oil districts now having an average wage roughly 10 percent higher than non-shale districts. Shale districts in the Eagle Ford began with a 13 percent lower wage relative to non-shale districts, but by 2014, the difference had disappeared. For both of the gas plays, the difference in wages between shale and non-shale districts remained roughly constant, at just below zero 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 analysis that follows focuses on districts in the oil formations and those outside of any formation. The focus on the oil formations is due to the economically-ignorable changes in spending and wages observed in the natural gas formations. Without these school finance or labor market effects, there is no reason to expect shale development to have important effects on student achievement.

3.2 Regression Specifications

This study uses three complementary regression approaches to provide a robust description of the effects of shale development on schools, students, and teachers. Each approach estimates the effect of shale depth on outcomes related to student achievement, school finances and spending, labor market wages, and the composition of teachers and students.

Shale depth is defined as the average distance from the surface to the formation and proxies for the district's resource endowment, because oil in deeper shale tends to be under greater pressure, which leads to more prolific and profitable wells and greater resource recovery (EIA/ARI, 2013).[6] For example, across the major shale formations in the U.S., Brown et al. (2016) find that a ten percent increase in average depth is associated with a seven percent increase in the ultimate recovery of a typical county well. To improve the interpretation of the coefficients, each district's depth is normalized by the average depth across all districts in the formation (for either the Eagle Ford or the Permian). Normalized shale depth has an average of about one for shale districts and always equals zero for non-shale districts.

The first approach, the long difference (LD) approach, uses changes between the first and last years of the study period, 2000 and 2014, with normalized shale

[6]Allcott and Keniston (2017) instead use 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.

depth as the lone explanatory variable:

$$\Delta_{2014-2000}Outcome_d = \alpha + \beta_{LD} \cdot Depth_d + \Delta_y \epsilon_d \tag{1}$$

Differencing over the first and last year eliminates the district (d) fixed effect. 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 because technologies for shale development were in an experimental stage and oil prices were low in 2000, both of which were not true in 2014. The long difference coefficient on depth (β_{LD}) is easily interpretable: it gives the average change in the outcome over the study period for shale districts relative to non-shale districts. A weakness, however, is that it does not exploit annual variation in oil prices and drilling that happened between 2000 and 2014.

The second approach, the fixed effects (FE) approach, exploits annual data by interacting shale depth with the normalized oil price, while controlling for school district and year fixed effects (with the year 2000 excluded to set up the comparison):

$$Outcome_{d,year} = \beta_{FE} \cdot (Depth_d \cdot Price_y) + District_d + Year_y + \varepsilon_{d,y} \tag{2}$$

The district fixed effect controls for additive differences across districts, but not multiplicative effects such as a temporal shock that affects districts differently based on their shale depth. The interaction between depth and the price of oil can be seen as a proxy for the value of the shale endowment. It captures changing market conditions that matter for labor markets and school finances. Rising prices motivate the drilling of new wells and increase the value of existing wells, magnifying the importance of differences in shale geology. This follows the approach of other resource-related studies, such as Black et al. (2005a) for coal dependence and coal price, Angrist and Kugler (2008) for coca cultivation and coca price, and Michaels (2010) for oil endowments and time effects.

The national energy price for crude oil is normalized by the average annual price observed over the study period. Including a district fixed effect is equivalent to transforming each variable by subtracting out each district's time-average value of the variable. For the depth and price interaction term, this results in:

$$Depth_d \cdot \left(\frac{p_y}{\bar{p}} - \frac{1}{Y} \sum_{y}^{Y} \frac{p_y}{\bar{p}} \right) = Depth_d \cdot \left(\frac{p_y}{\bar{p}} - 1 \right) \quad (3)$$

For non-shale districts, the interaction always equals zero because of zero depth. For shale districts, the interaction equals zero when the oil price equals the period average price at any shale depth, and it equals one when the price is double the period average price at average shale depth. The interaction term therefore differs across districts in each year, with the difference changing from year to year based on changes in oil prices.

The third approach, the annual difference (AD) approach, permits testing for differences in prior trends for shale and non-shale districts, at least for the Eagle Ford, which had negligible development over the 2000-2008 period. Neither the long difference or fixed effect approaches do this. The AD approach uses annual differences and estimates effects by time period (2000-2008, 2008-2009, 2009-2014) and by formation (Eagle Ford and Permian):

$$\Delta_{y-(y-1)} Outcome_d = \sum_{t=1}^{3} \beta \cdot (Depth_d \cdot Period_t) + Year_y + \Delta_y \varepsilon_d \quad (4)$$

Similar to the LD approach, normalized shale depth is used and district fixed effects are eliminated through differencing. Similar to the FE approach, year fixed effects are included, but now refer to consecutive year pairings (with the 2000-2001 pair excluded). And, instead of an interaction with the oil price, the AD approach interacts shale depth with period (t) indicators, which are similar to the binary indicators used for the boom, stagnation, and bust periods in Black et al. (2005a).

Estimating formation-specific effects captures differences in the evolution of development across the two regions. The Permian basin had been a large oil producer for decades, so when oil prices more than doubled from 2000 to 2008, conventional drilling expanded. The Eagle Ford formation, which did not have historic production, had little development because shale technologies had not yet been proven to work in oil formations. The lack of development in the Eagle Ford in the 2000-2008 period permits documenting a common prior trend across shale and non-shale districts. The 2008-2009 period brought the Great Recession, lower oil prices, and less drilling. From 2009 to 2014, oil prices rebounded and the introduction of new drilling technologies led to the shale boom, with widespread shale development in both the Permian and Eagle Ford. Again, there were differences across the two formations: new shale wells seemingly offset declining production from conventional wells for the Permian, while the Eagle Ford experienced rapid production growth.

One advantage of estimating the long difference, fixed effect, and annual difference approaches is that a confounding shock correlated with shale development and depth will bias the estimates in different ways. The LD approach will not be affected by confounding shocks that occur in the middle of the study period but do not have persistent effects on the outcomes. Similarly, a confounding shock correlated with oil prices will affect the FE approach more than the AD approach, which interacts period indicator variables with depth instead of the price of oil.

At the same time, the interpretation of the coefficients differs across the LD, FE, and AD approaches, limiting their comparability. The LD approach gives the 15-year change in the outcome for a shale district with average depth relative to a non-shale district. The FE approach gives the effect of being in an average shale district when oil prices are double the period-average price. The AD approach gives the difference in annual growth across shale and non-shale districts in particular periods. To compare the LD and AD coefficients, the long difference would have to be divided by 15 years to roughly represent the average annual effect over all years.

4 Regression Evidence

4.1 Student Achievement

The local effects of the shale boom on student achievement appear in Table 1, which is horizontally divided into four panels. The first panel displays the long difference (LD) estimates, the second panel shows the fixed effect (FE) estimates, and the third and fourth panels present the annual difference (AD) estimates by period for each of the two formations. The estimates represent the combined, or net effect, of the shale boom through the possible school finance and labor market channels and are based on comparing oil and non-shale districts over the 2000-2014 period. Appendix Table A1 shows the baseline values for all outcomes and district groups.

Overall, the estimates show weaker student achievement in oil districts compared to non-shale districts. Performance on state standardized tests, which are given to students in grades 3 through 12, declined as measured by the percentage of students passing the tests. The LD approach shows that, over the study period, districts with average depth experienced a decline in pass rates of 1.9 percentage points. Similarly, the FE approach shows a 1.8 percentage point decline for a doubling of the oil price in the average oil district. The largest decline occurred for the math test, with a decline of 2.6 percentage points compared to a 1.3 percentage point decline for reading. The Eagle Ford and Permian displayed similar results for achievement, with the Permian having slightly larger and more precisely estimated declines. 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.

The decline in pass rates is not negligible. The 2.6 percentage point decline in the pass rate for math represents a 3 percent decline for the average shale district. To put the decline in perspective, several studies previously estimated the effect of increased per student spending on the percentage of fourth graders passing the standardized math test in the state of Michigan. Considering a 10 percent increase in spending, one study finds an increase in the pass rate of 0.8 percentage points (Papke, 2005) and another finds a 2.7 percentage point increase (Chaudhary, 2009). The estimates suggest that increasing the pass rate by 2.6 percentage points – the decline observed for shale districts – would require a per student spending increase of roughly 10 to 30 percent.

The attendance rate for students in grades 1 through 12 also declined, but by small percentages, for example, 0.3 percentage points from 2000 to 2014 in oil districts relative to districts outside of any shale formation (a less than 0.3 percent decrease from the baseline level). The decline occurred during the shale boom (2009-2014) for the Eagle Ford, but only during the recession (2008-2009) for the Permian (AD results). There were no clear declines in completion rates, which are based on students who originally formed part of the grade 12 cohort, including those who dropped out before reaching grade 12. This is consistent with Texas policy, which has compulsory schooling until age 18. There were also no consistent changes in the percentages of students taking and meeting the passing criteria for the college entrance exams of the SAT and ACT across the three approaches.

4.2 Local Finances

The estimated effects on achievement represent the combined effect of changes in labor markets and school finances. Table 2 shows the relationship between shale depth and various financial outcomes, which include three different tax base variables (total, oil and gas, and non oil and gas), the tax rate, total debt, and total revenues. All of the variables except the tax rate are per student. The baseline values in 2000 for the finance variables appear at the top of Appendix Table A2.

Oil districts had large increases in their tax base over the study period, so the decline in student achievement in oil districts is not because of a lack of resources. From 2000 to 2014, the total tax base of an oil district at average shale depth grew by over one million dollars more per student relative to non-shale districts. 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 (LD results). The remaining 13 percent reflects growth in the non-oil-and-gas tax base, which consists of residential property, commercial property, and land. The FE results are similar, with the oil and gas tax base accounting for 90 percent.

Looking by shale formation and period (AD results), Eagle Ford districts had tax base trends similar to non-shale districts from 2000 through 2009. But when shale development boomed in the Eagle Ford from 2009 to 2014, the total tax base expanded by $230,000 per student per year, also primarily because of growth in the oil and gas tax base. For Permian districts, the tax base expansion occurred in the 2000-2008 and 2009-2014 periods, albeit by less than the boom in the Eagle Ford.

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 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, as oil prices fell precipitously because of the recession.

Oil districts responded to the expanded tax base by lowering property tax rates, similar to what Weber et al. (2016) found for the Barnett Shale, with tax rates declining by 0.058 percentage points in oil districts relative to non-shale districts (LD). The effect represents a 4 percent decline over the baseline tax rate. As the tax base expanded and tax rates decreased, oil districts borrowed about $10,000 more per student according to the LD results, which is three times higher than the initial level of debt. Revenues also increased by 18 percent. The FD approach displays similar results and the AD results are largely consistent with the booms in the Eagle Ford and Permian formations. For the Eagle Ford, no economically important differences in these financial variables emerged before the shale boom.

4.3 School Spending

Table 3 provides the estimates for school spending, which is broken into payroll and non-payroll, with non-payroll further broken into capital, debt, and other spending (e.g. non-payroll operating expenses). The middle of Appendix Table A2 shows the values of these variables at baseline. For the average school district in 2000, slightly less than two-thirds of their total spending went to payroll, with other spending being the next largest category, followed by spending on capital, and then on debt.

The greater revenues in oil districts, shown in the previous sub-section, translated into similar percentage increases in spending. From 2000 to 2014, the LD approach shows that spending per student increased by 24 percent more in oil districts than in non-shale districts ($e^{0.215}-1$). Strikingly, none of the spending growth occurred in the payroll category. Non-payroll spending, in contrast, increased by 58 percent. Breaking out non-payroll expenditures reveals that capital accounted for the largest proportional non-payroll increase, with oil districts roughly tripling capital spending relative to non-shale districts. Consistent with the finding that outstanding debt increased, spending to service debt also grew, but the increase is less economically important, as debt is the smallest of the non-payroll categories. The FE approach provides similar results.

The formation and period-specific results show that, prior to the shale boom, Eagle Ford districts and non-shale districts had similar spending growth. This changed in the 2009-2014 period, when spending grew 3.0 percent faster per year. As with the LD results, all of the growth occurred in non-payroll spending, a 6.6 percent increase per year during that period, with the largest increase occurring in capital spending. Spending also increased in Permian districts, with growth during both boom periods, as expected given the continued expansion of drilling in the Permian from 2000 to 2014. Again, non-payroll spending, and capital spending in particular, increased by the most. The only statistically significant increase in payroll spending occurred in the Permian during the conventional boom period (2000-2008), but this was less than one fifth of the growth in non-payroll spending.

To summarize the local finance and school spending results, 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. Districts spent additional revenues on capital and debt expenses, as well as on reducing property tax rates. Surprisingly, none of the additional spending went to teachers. In turn, the financial windfalls from the shale boom did not translate into greater student achievement.

It is possible that some types of spending might hinder student achievement. Building better gyms and football fields could distract students from academics and the construction of new classrooms could disrupt instruction. A more plausible explanation is that other changes related to the shale boom, namely changes in labor markets, worked against the effects of improved school finances that would have otherwise had a neutral or positive effect on student achievement. The subsections that follow explore this channel and its possible composition effects.

4.4 Labor Market Wages

Greater labor demand and higher wages from a shale boom may be large enough to alter the composition of students and teachers. Table 4 shows the estimated effects on several measures of wages, including the wage across all sectors, private and public sector wages, teacher wages, and the gap between teacher and private sector wages, with all wages reflecting the average compensation per job. While the overall wage represents the general labor market effects of the boom, the private sector wage is most relevant for the opportunity costs faced by students, as it is a rough measure of what they could earn by dropping out. The average teacher wage, or more specifically, its wage difference with the private sector, best represents what a teacher could gain by leaving her teaching job.[7]

Baseline values of the wage variables appear at the bottom of Appendix Table A2. Across all districts in 2000, the overall wage was just over $40,000 and the private sector wage was $28,490, about $14,000 less than the public sector wage. The average teacher earned about $46,000 annually. The higher public and teacher wages could be due to public sector and teacher jobs primarily being full-time, whereas many private jobs may be part-time.

From 2000 to 2014, the average shale district experienced a 14 percent increase in the overall wage relative to non-shale districts. Almost all of the increase came from growth in the private sector wage, which increased by 24 percent, as compared with a 2 percent increase in the public wage. The teacher wage, in contrast, 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 more than a quarter. The FE results document a similar pattern.

Looking by period and formation, the 2009-2014 boom provided the largest and most consistent growth across overall, private, and public wages in the Eagle Ford (AD), reflecting the widespread growth in drilling. There, private sector wages grew 3.2 percent faster per year than in non-shale districts. Similar to the overall results, the teacher wage was stagnant over the boom period, and the private-teacher wage gap widened. The estimates for the pre-boom period (2000-2008) show slightly higher wage growth for Eagle Ford districts, suggesting a pre-trend, but the differential growth rates are orders of magnitude smaller than in the boom period. For example, wages grew 0.2 percent faster in shale districts prior to the boom and 1.7 percent faster during the boom. Turning to Permian districts, the differential growth in wages appears during the conventional boom (2000-2008) and the shale boom (2009-2014), which have similar annual increases in private sector wages of 2.4 and 2.1 percent. In both periods, teacher wages were stagnant or declining, and the wage gap widened.

[7]This differs slightly from Hanushek et al. (2014), which used "the wage position of public sector employees (excluding all teachers) in the distribution of all employees" for this purpose.

4.5 Teacher Composition

The lack of wage growth for teachers, combined with increasing private sector wages, could have encouraged at least some teachers to leave the classroom. This could then alter the composition of teachers and their quality, if those leaving have more experience or qualifications than those being hired. A decline in teacher quality could help explain the decline in student achievement in oil districts relative to non-shale districts. Several variables capture changes among teachers: the teacher turnover rate, the total number of teachers, average teacher experience, the percentage of teachers with less than five years experience, and the percentage of teachers with advanced degrees. The middle of Appendix Table A1 provides baseline values.

Changes in composition are only possible if the turnover rate and/or the number of teachers are changing. The regression results of Table 5 suggest that the teacher turnover rate increased by 1.9 percentage points more in oil districts from 2000 to 2014 (LD) and by 1.3 percentage points more when the oil price was double the period average (FE). Relative to baseline values, the changes represent an 8 and a 12 percent increase. The largest increase in the turnover rate occurred during the shale boom period (2009-2014) in both the Eagle Ford and Permian, though the formation-specific differences with non-shale districts were less precisely estimated.

The LD and FE approaches both show a decline in the number of teachers over the study period, with the LD giving a decline of about 8 percent. The decline was only in relative terms: the number of teachers in shale districts did not change over the 2000-2014 period, while it increased for non-shale districts. Additional results show that the relative decline in shale districts occurred in both the Eagle Ford and Permian in the 2000-2008 period. This is not surprising for the Permian, which had conventional drilling growth over the period, but it is unexpected for the Eagle Ford, which had little drilling at the time. Therefore, the decline in the Eagle Ford may largely be spurious. It is also telling that there was no decline in the number of teachers in shale districts during the shale boom period (2009-2014) in either the Eagle Ford or the Permian.

As the turnover rate increased, teacher experience fell. From 2000 to 2014, average teacher experience in oil districts decreased by 4.3 percent relative to non-shale districts. Similarly, the percentage of teachers with less than five years of experience increased by 3.9 percentage points, a 13 percent increase for the average oil district, and the FE and AD approaches show similar results. Looking by formation and period, both the Eagle Ford and the Permian had a half a percentage point annual increase in the percentage of teachers with less than five years of experience during the shale boom (2009-2014). Both also saw decreases in average teacher experience, although the decline was only statistically significant for the Eagle Ford. For Eagle Ford districts, there is some evidence of a weak pre-boom trend of growth in the percentage of teachers with less than five years of experience, but the magnitude nearly doubled during the boom period.

In the shale boom period, when most of the composition changes occurred, the number of teachers was roughly constant in both shale and non-shale districts. The lack of a change in the overall number of teachers in this period, combined with a higher turnover rate in shale districts, suggests that the change in composition stems from more experienced teachers leaving and districts replacing them with less experienced teachers. According to the previously-reviewed literature, more inexperienced teachers in the classroom, coupled with the disruption of greater teacher turnover, would be expected to decrease student achievement.

A larger wage gap between the education and private sectors, along with increased teacher turnover, does not necessarily imply that teachers took 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, and possibly to spend more time at home with their families (see Scafidi et al., 2006). Similarly, royalty payments to teacher households could encourage them to retire earlier. Such royalty payments can be large and widespread. For example, Brown et al. (2017) show that most of the increase in local income from shale oil and gas development comes from royalty payments. Alternatively, disamenities associated with drilling, including dust, noise, truck traffic, or a decline in real wages brought about by greater living costs, would also lower the quality of life and encourage teachers to move elsewhere for jobs, even for similar nominal wages.

4.6 Student Composition

As with teachers, the compositional effects for students might help explain the differential decline in achievement in shale districts. The results for student achievement showed no changes in high school completion rates, suggesting that student composition would not have changed because of certain types of students dropping out of school to work. Still, the composition may have changed for other reasons.

The bottom of Appendix Table A1 shows baseline values for the percentage of students in several categories: economically-disadvantaged students (those eligible for free or reduced-price lunch programs), vocational-technical students (those participating in votech programs), English-as-a-second-language (those participating in ESL programs), and gifted students (those participating in gifted and talented programs). In 2000, economically-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.

A first-order question is whether the shale boom affected the total number of students. The FD and FE regression results, found in Table 6, show a decline in the number of students in shale districts relative to non-shale districts, similar to what was found for teachers. Estimating effects by period and formation, however, reveals that the relative decline in the number of students in shale districts only occurred in the 2000-2008 period. Moreover, during the shale boom period of 2009 to 2014, the number of students actually increased in Eagle Ford and Permian districts relative to non-shale districts. It also increased in absolute terms for the 2009-2014 period and for the full study period. This is consistent with the empirical literature on natural resource booms, which generally shows population increases during boom times (e.g. Marchand and Weber, 2017).

Turning to the results for the composition of students, the percentage of gifted students did not change relative to non-shale districts, but the percentages of students in the other categories tended to decrease. Whatever the reasons for the decreases, they do not help to explain the previously-documented decline in achievement. One would not expect economically-disadvantaged students or votech students to have above-average performances on standardized tests. The opposite is more likely to be true, meaning that lower percentages of such students should increase the performance of the average student within a district.

The lack of decline in completion rates in shale districts (shown in the initial sub-section on student achievement), coupled with the growth of the student population during the shale boom, suggests that higher wages did not systematically cause students to dropout. Any changes in student composition cannot then be explained by certain types of students being more likely to dropout of school for work.

Other explanations are plausible. Higher wages would have increased incomes for some households above 185 percent of the poverty line, causing students to lose eligibility for free and reduced-price lunch programs, and thereby lifting them 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.

A complementary explanation is that growth in the student population in shale districts during the boom may have disproportionately come from students who were not economically-disadvantaged or interested in votech. This would be consistent with a scenario where people moving to shale districts were either young men without kids or engineers and company managers with children who were neither disadvantaged nor interested in such programs. Another explanation for the changing composition, particularly for the Eagle Ford, is a pre-existing trend unrelated to shale development. Although Eagle Ford districts saw a decline in the percentage of economically-disadvantaged during the boom, the trend was even stronger in the pre-boom period (a decline of 0.6 percentage points instead of 0.4). The percentage of ESL students also declined slightly in the pre-boom period (by 0.1 percentage point), and this continued into the boom period, albeit with a larger standard error.

Whatever the explanations for the change in composition in shale districts, the change would likely have improved the achievement of the average student. The decline in standardized test scores in shale districts relative to non-shale districts, therefore, might have been larger without this shift in student composition.

5 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 2000 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 a quarter.

The study's 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.

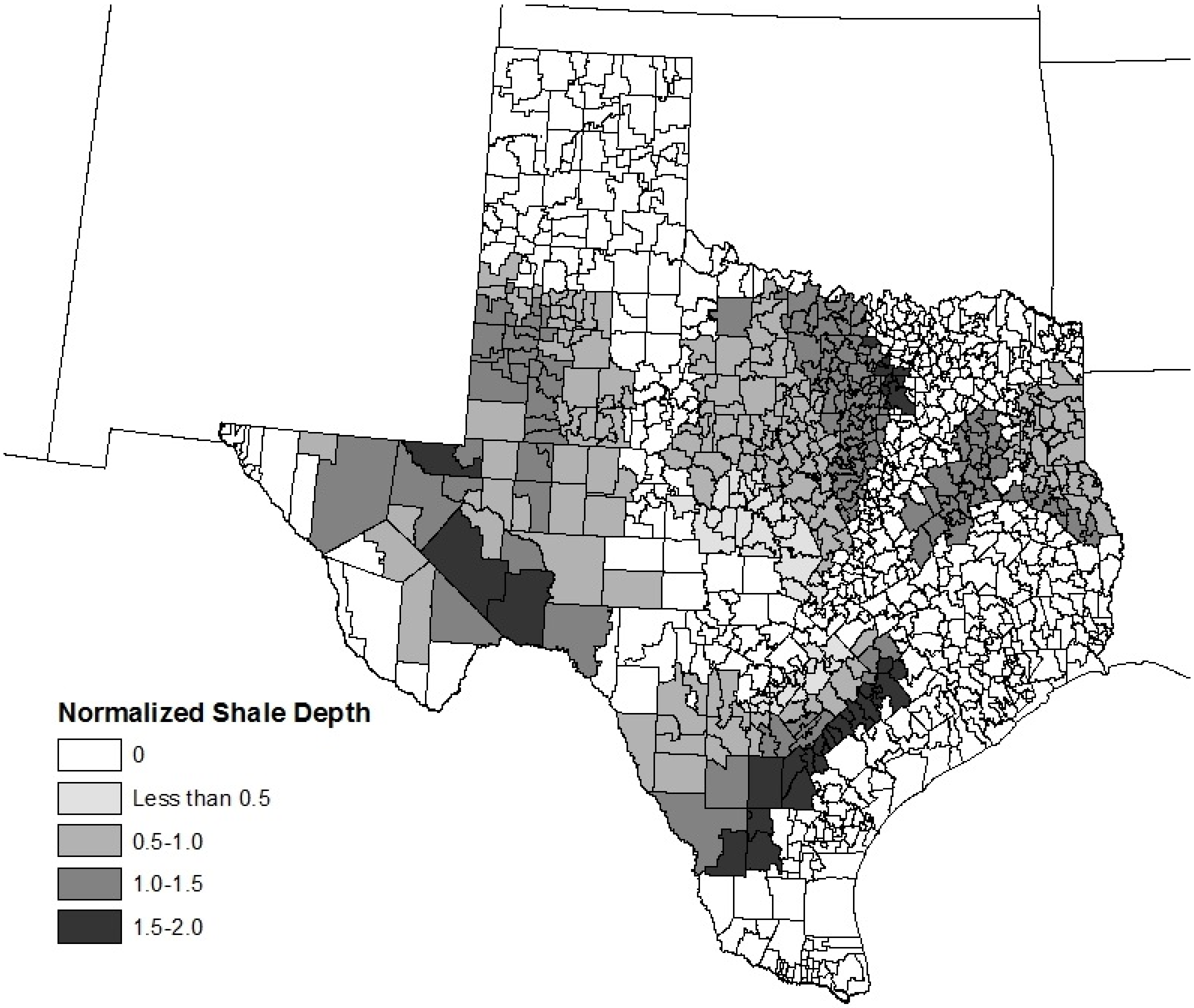
The decline in student achievement does not appear to be explained by changes in student composition. The percentage of students in three separate categories – economically-disadvantaged, vocationally-oriented, and non-native English speakers – all declined. If such students have below-average achievement on standardized tests, a decline in their share of the student population would not reduce the achievement of the average enrolled student and might instead increase it.

Increased teacher turnover and more inexperienced teachers in the classroom provide a more plausible explanation for the decline in achievement. These changes were likely driven, in part, by an expanding wage gap between the private and education sectors, which drew teachers out of schools. The effects of turnover and teacher composition on achievement would 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 findings also highlight 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. Their buildings and classrooms may have needed renovation, and school administrators may have been hesitant to raise salaries in the boom, knowing that it would be difficult to lower them in a bust. Still, it is plausible that using some of the additional revenue to fund temporary bonuses could have mitigated teacher turnover in boom times. But addressing needed renovations or funding temporary bonuses requires more resources for districts in shale areas, something that will not happen under the current policy in states like Louisiana or Pennsylvania. In those states, it is unlikely that oil and gas development contributes to human capital improvements in resource-rich districts.

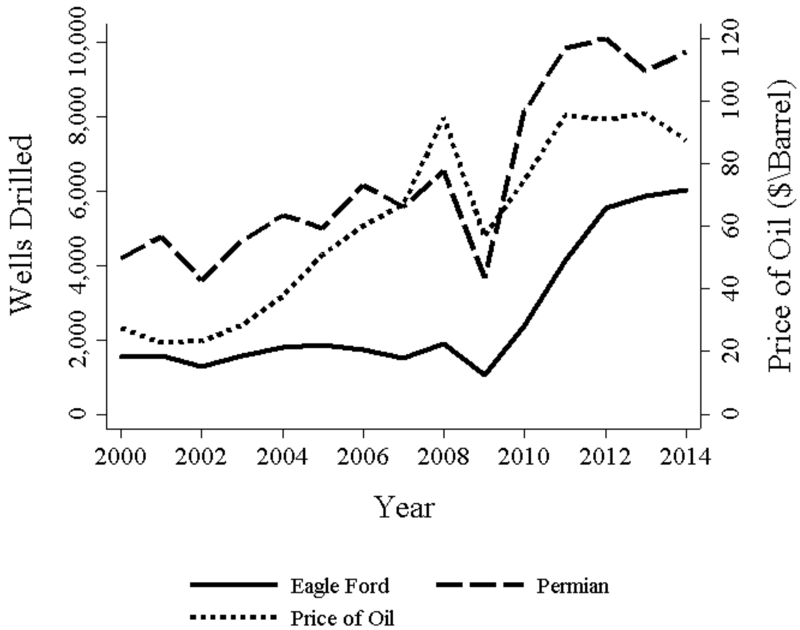
Figure 1: Texas School Districts & Normalized Shale Depth



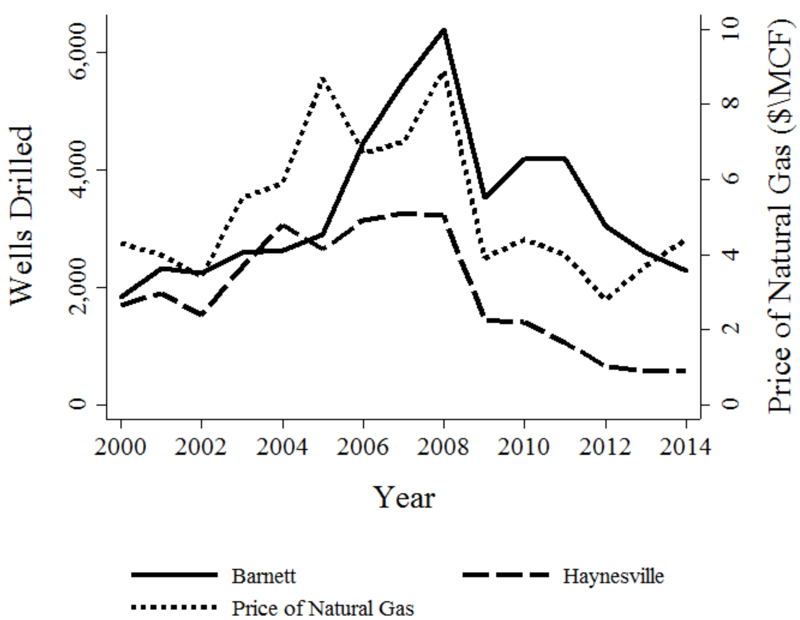
Notes: Authors' calculations of shale depth data from Los Alamos National Laboratories. The Eagle Ford and Permian formations primarily produce crude oil and are located in the south and west of the state, while the Barnett and Haynesville formations produce almost entirely natural gas and are located in the north and east.

Figure 2: Number of Wells Drilled & Price by Oil & Gas Play

a. Crude Oil



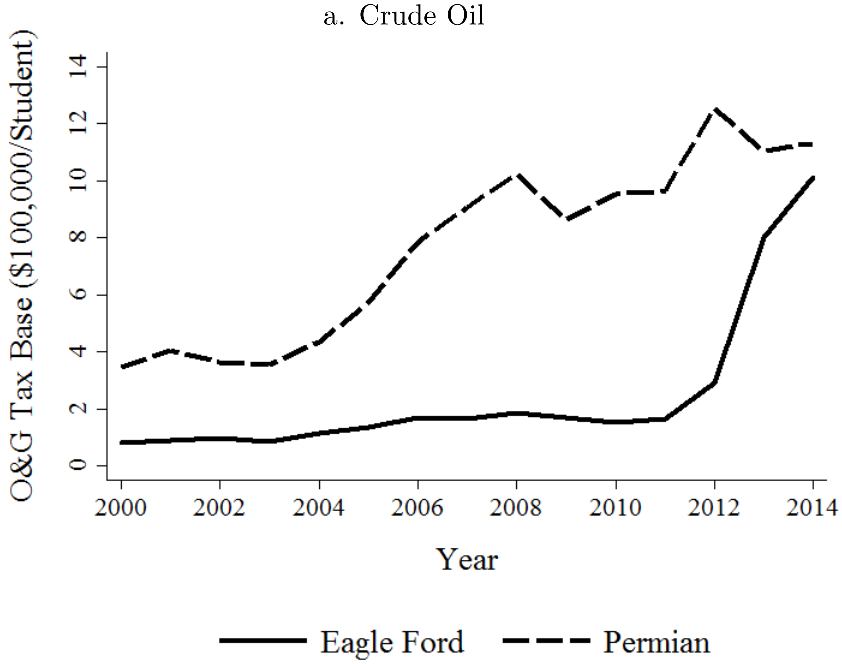
b. Natural Gas



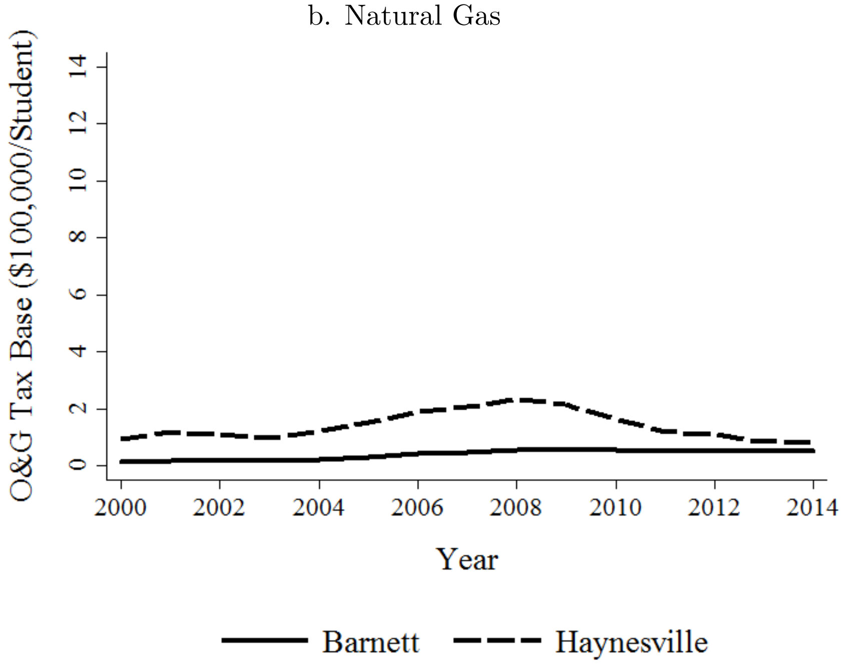
Notes: Authors' calculations of well data from DrillingInfo and price data from the Energy Information Administration. Wells drilled is the total number of wells drilled by formation. The oil price is the national first-purchase price for crude oil, and the natural gas price is the national wellhead price, both in constant 2010 dollars.

Figure 3: Oil & Gas Tax Base by Oil & Gas Play

a. Crude Oil



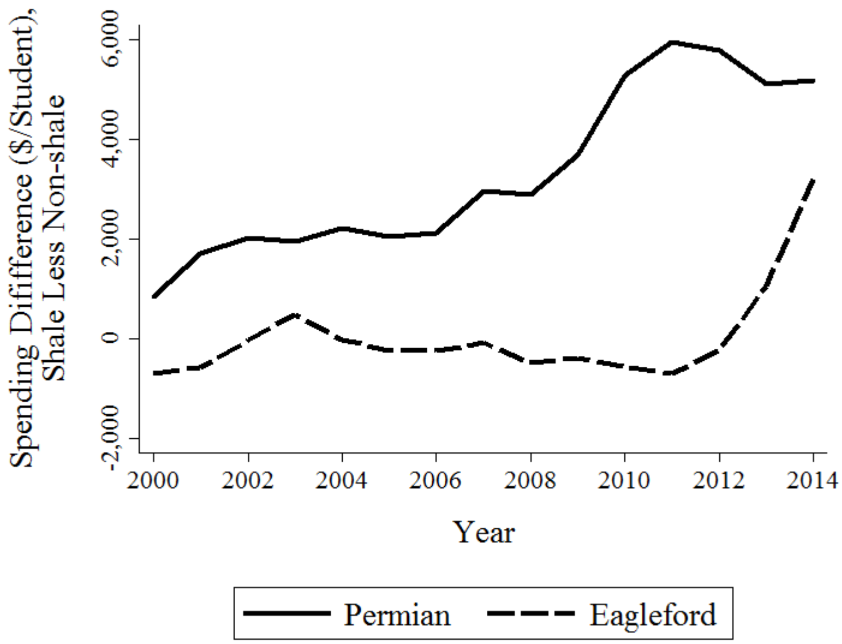
b. Natural Gas



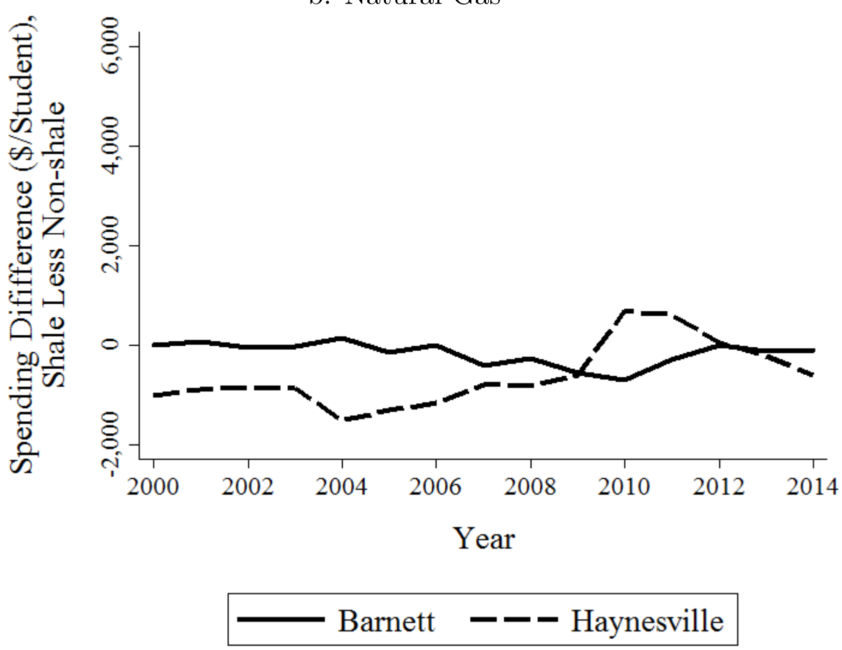
Notes: Authors' calculations of oil and gas tax base data from the Public Education Information Management System of Texas Education Agency. The oil and gas tax base per student is the assessed value (for property tax purposes) of all producing oil and gas wells in the district.

Figure 4: Spending Differences in Shale & Non-Shale Districts by Oil & Gas Play

a. Crude Oil



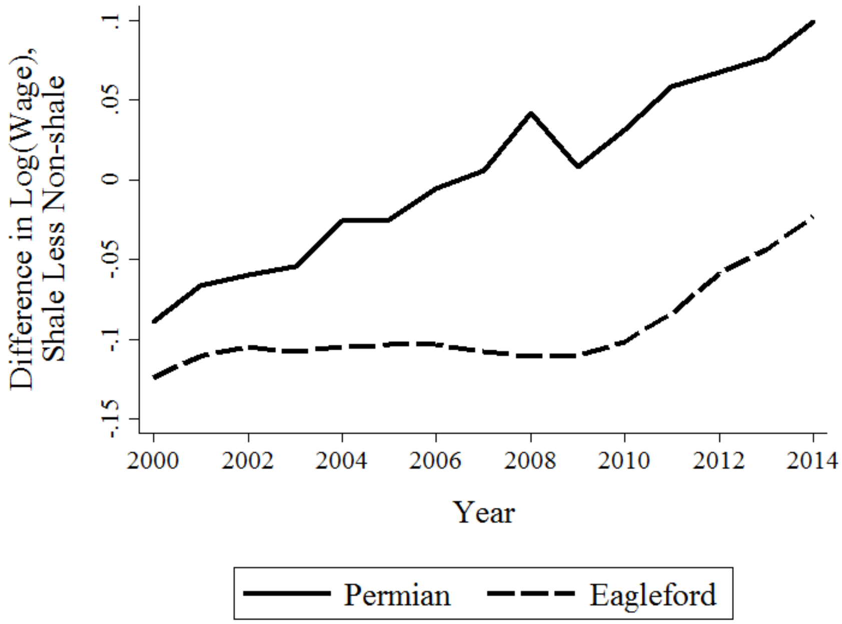
b. Natural Gas



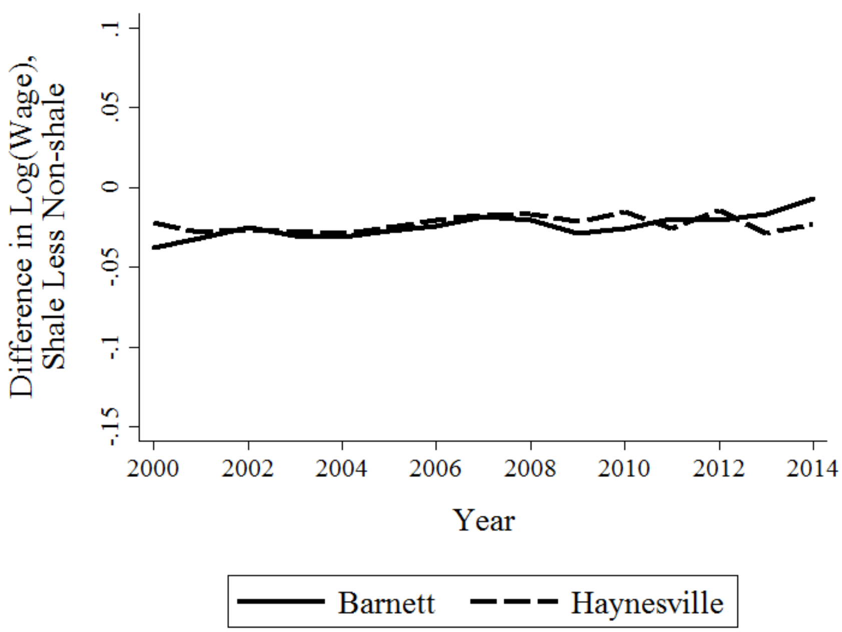
Notes: Authors' calculations of spending data from the Public Education Information Management System of Texas Education Agency. Spending is in terms of dollars per student.

Figure 5: Wage Differences in Shale & Non-Shale Districts by Oil & Gas Play

a. Crude Oil



b. Natural Gas



Notes: Authors' calculations of wage data from the Bureau of Economic Analysis. Wages reflect the average wage in a district's county in constant 2010 dollars.

Table 1: Student Achievement Estimates using LD, FE, & AD Approaches

a. Oil & Non-Shale Districts:	Rates (%)		Passing State Tests (%)			SAT/ACT Exams (%)	
Long Difference (LD):	Attend	Complete	Overall	Reading	Math	Take	Meet
Shale Depth	-0.003	0.006	-0.019	-0.013	-0.026	0.011	-0.011
(2000 & 2014)	(0.001)	(0.005)	(0.007)	(0.007)	(0.009)	(0.016)	(0.010)
Observations	751	686	750	750	750	661	751
b. Oil & Non-Shale Districts:	**Rates (%)**		**Passing State Tests (%)**			**SAT/ACT Exams (%)**	
Fixed Effects (FE):	Attend	Complete	Overall	Reading	Math	Take	Meet
Shale Depth X Price	-0.002	-0.002	-0.018	-0.012	-0.020	0.021	-0.010
(2000 to 2014)	(0.000)	(0.003)	(0.006)	(0.004)	(0.006)	(0.010)	(0.006)
Observations	15,176	14,192	15,164	15,096	15,147	13,765	15,177
c. Eagle Ford & Non-Shale:	**Rates (%)**		**Passing State Tests (%)**			**SAT/ACT Exams (%)**	
Annual Difference (AD):	Attend	Complete	Overall	Reading	Math	Take	Meet
Shale Depth X Period 1	-0.000	0.000	-0.000	0.001	-0.001	0.005	-0.000
(2000 to 2008)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.001)
Shale Depth X Period 2	-0.000	-0.002	-0.005	-0.002	-0.004	-0.004	0.011
(2008 to 2009)	(0.001)	(0.012)	(0.004)	(0.004)	(0.004)	(0.023)	(0.011)
Shale Depth X Period 3	-0.001	0.003	-0.001	-0.002	-0.002	-0.003	-0.001
(2009 to 2014)	(0.000)	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.002)
Observations	9,403	8,620	9,390	9,289	9,364	8,194	9,405
d. Permian & Non-Shale:	**Rates (%)**		**Passing State Tests (%)**			**SAT/ACT Exams (%)**	
Annual Difference (AD):	Attend	Complete	Overall	Reading	Math	Take	Meet
Shale Depth X Period 1	0.000	-0.001	-0.002	0.000	-0.002	0.001	0.000
(2000 to 2008)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.004)	(0.002)
Shale Depth X Period 2	-0.003	0.001	-0.011	-0.006	-0.004	0.013	-0.016
(2008 to 2009)	(0.001)	(0.005)	(0.005)	(0.003)	(0.004)	(0.019)	(0.014)
Shale Depth X Period 3	-0.000	-0.001	-0.001	-0.003	-0.004	-0.001	-0.002
(2009 to 2014)	(0.000)	(0.002)	(0.002)	(0.002)	(0.002)	(0.005)	(0.003)
Observations	9,543	8,801	9,530	9,430	9,504	8,303	9,545

Notes: Authors' calculations of multiple data sources (see Descriptive Details and Data Appendix). (%) denotes a variable in percentage terms. Robust standard errors, clustered by district, are provided in parentheses.

Table 2: Local Finance Estimates using LD, FE, & AD Approaches

a. Oil & Non-Shale Districts:	Tax Base			Property	Total	Total
Long Difference (LD):	Total	Oil and Gas	Non O&G	Tax Rate (%)	Debt	Revenues (log)
Shale Depth	1,053,217	916,935	136,282	-0.058	9,944	0.178
(2000 & 2014)	(244,834)	(220,361)	(38,129)	(0.013)	(2,141)	(0.032)
Observations	751	751	751	751	751	751
b. Oil & Non-Shale Districts:	Tax Base			Property	Total	Total
Fixed Effects (FE):	Total	Oil and Gas	Non O&G	Tax Rate (%)	Debt	Revenues (log)
Shale Depth X Price	609,912	547,081	62,831	-0.025	5,771	0.082
(2000 to 2014)	(123,698)	(110,150)	(27,129)	(0.011)	(1,699)	(0.015)
Observations	15,176	15,176	15,176	15,177	15,177	15,177
c. Eagle Ford & Non-Shale:	Tax Base			Property	Total	Total
Annual Difference (AD):	Total	Oil and Gas	Non O&G	Tax Rate (%)	Debt	Revenues (log)
Shale Depth X Period 1	8,825	10,867	-2,042	-0.002	165	0.004
(2000 to 2008)	(8,022)	(7,085)	(1,799)	(0.002)	(267)	(0.002)
Shale Depth X Period 2	-12,103	-6,027	-6,076	-0.012	-884	-0.009
(2008 to 2009)	(15,393)	(13,774)	(9,793)	(0.007)	(292)	(0.010)
Shale Depth X Period 3	230,746	193,458	37,288	-0.008	1,170	0.039
(2009 to 2014)	(80,217)	(73,572)	(9,327)	(0.002)	(508)	(0.011)
Observations	9,405	9,405	9,405	9,405	9,405	9,405
d. Permian & Non-Shale:	Tax Base			Property	Total	Total
Annual Difference (AD):	Total	Oil and Gas	Non O&G	Tax Rate (%)	Debt	Revenues (log)
Shale Depth X Period 1	81,896	77,986	3,910	-0.010	234	0.015
(2000 to 2008)	(18,142)	(15,839)	(5,553)	(0.002)	(263)	(0.003)
Shale Depth X Period 2	-87,584	-137,498	49,914	-0.004	-811	0.017
(2008 to 2009)	(42,006)	(40,690)	(26,893)	(0.008)	(939)	(0.019)
Shale Depth X Period 3	55,864	52,133	3,731	0.007	2,617	-0.002
(2009 to 2014)	(30,223)	(27,564)	(7,123)	(0.003)	(789)	(0.004)
Observations	9,545	9,545	9,545	9,545	9,545	9,545

Notes: Authors' calculations of multiple data sources (see Descriptive Details and Data Appendix). (%) denotes a variable in percentage terms. (log) denotes the natural logarithm of a variable. Robust standard errors, clustered by district, are provided in parentheses.

Table 3: School Spending Estimates using LD, FE, & AD Approaches

a. Oil & Non-Shale Districts:	Spending (log)			Non-Payroll Spending (log)		
Long Difference (LD):	Total	Payroll	Non-Payroll	Capital	Debt	Other
Shale Depth	0.215	0.001	0.459	1.037	0.952	0.088
(2000 & 2014)	(0.034)	(0.013)	(0.063)	(0.159)	(0.152)	(0.042)
Observations	751	751	751	724	576	751
b. Oil & Non-Shale Districts:	Spending (log)			Non-Payroll Spending (log)		
Fixed Effects (FE):	Total	Payroll	Non-Payroll	Capital	Debt	Other
Shale Depth X Price	0.096	-0.005	0.219	0.565	0.473	0.026
(2000 to 2014)	(0.019)	(0.009)	(0.040)	(0.107)	(0.120)	(0.020)
Observations	15,177	15,177	15,177	14,712	13,313	15,177
c. Eagle Ford & Non-Shale:	Spending (log)			Non-Payroll Spending (log)		
Annual Difference (AD):	Total	Payroll	Non-Payroll	Capital	Debt	Other
Shale Depth X Period 1	0.002	0.000	0.004	-0.003	0.017	0.000
(2000 to 2008)	(0.004)	(0.002)	(0.008)	(0.030)	(0.021)	(0.004)
Shale Depth X Period 2	0.017	0.001	0.029	0.041	0.075	-0.005
(2008 to 2009)	(0.033)	(0.007)	(0.059)	(0.189)	(0.064)	(0.016)
Shale Depth X Period 3	0.030	-0.003	0.066	0.107	0.052	0.026
(2009 to 2014)	(0.011)	(0.003)	(0.020)	(0.057)	(0.026)	(0.013)
Observations	9,405	9,405	9,405	8,888	8,159	9,405
d. Permian & Non-Shale:	Spending (log)			Non-Payroll Spending (log)		
Annual Difference (AD):	Total	Payroll	Non-Payroll	Capital	Debt	Other
Shale Depth X Period 1	0.013	0.005	0.028	0.099	0.050	0.008
(2000 to 2008)	(0.004)	(0.002)	(0.008)	(0.025)	(0.037)	(0.003)
Shale Depth X Period 2	0.027	-0.001	0.048	0.005	0.039	-0.005
(2008 to 2009)	(0.023)	(0.007)	(0.047)	(0.186)	(0.098)	(0.020)
Shale Depth X Period 3	0.024	-0.004	0.054	0.126	0.126	-0.003
(2009 to 2014)	(0.009)	(0.003)	(0.017)	(0.053)	(0.043)	(0.006)
Observations	9,545	9,545	9,545	9,025	8,124	9,545

Notes: Authors' calculations of multiple data sources (see Descriptive Details and Data Appendix). (%) denotes a variable in percentage terms. (log) denotes the natural logarithm of a variable. Robust standard errors, clustered by district, are provided in parentheses.

Table 4: Labor Market Wage Estimates using LD, FE, & AD Approaches

a. Oil & Non-Shale Districts:	Average Wage (log)				Private - Teacher
Long Difference (LD):	Overall	Private	Public	Teacher	Wage Gap (log)
Shale Depth	0.137	0.218	0.021	-0.009	0.228
(2000 & 2014)	(0.011)	(0.021)	(0.005)	(0.007)	(0.022)
Observations	751	751	751	751	751
b. Oil & Non-Shale Districts:	Average Wage (log)				Private - Teacher
Fixed Effects (FE):	Overall	Private	Public	Teacher	Wage Gap (log)
Shale Depth X Price	0.084	0.119	0.010	-0.012	0.131
(2000 to 2014)	(0.009)	(0.015)	(0.004)	(0.005)	(0.016)
Observations	15,177	15,177	15,177	15,174	15,174
c. Eagle Ford & Non-Shale:	Average Wage (log)				Private - Teacher
Annual Difference (AD):	Overall	Private	Public	Teacher	Wage Gap (log)
Shale Depth X Period 1	0.002	0.004	-0.002	-0.002	0.006
(2000 to 2008)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)
Shale Depth X Period 2	-0.001	-0.008	-0.001	-0.001	-0.007
(2008 to 2009)	(0.002)	(0.003)	(0.002)	(0.003)	(0.004)
Shale Depth X Period 3	0.017	0.032	0.004	0.002	0.030
(2009 to 2014)	(0.002)	(0.004)	(0.001)	(0.001)	(0.004)
Observations	9,405	9,405	9,405	9,403	9,403
d. Permian & Non-Shale:	Average Wage (log)				Private - Teacher
Annual Difference (AD):	Overall	Private	Public	Teacher	Wage Gap (log)
Shale Depth X Period 1	0.016	0.024	0.001	-0.003	0.027
(2000 to 2008)	(0.002)	(0.003)	(0.001)	(0.001)	(0.003)
Shale Depth X Period 2	-0.032	-0.042	-0.003	0.007	-0.050
(2008 to 2009)	(0.006)	(0.008)	(0.003)	(0.003)	(0.009)
Shale Depth X Period 3	0.018	0.021	0.008	-0.000	0.022
(2009 to 2014)	(0.002)	(0.003)	(0.001)	(0.001)	(0.003)
Observations	9,545	9,545	9,545	9,543	9,543

Notes: Authors' calculations of multiple data sources (see Descriptive Details and Data Appendix). (%) denotes a variable in percentage terms. (log) denotes the natural logarithm of a variable. Robust standard errors, clustered by district, are provided in parentheses.

Table 5: Teacher Composition Estimates using LD, FE, & AD Approaches

a. Oil & Non-Shale Districts:	Turnover	Number of	Experience	Less Than 5 Years	With Advanced
Long Difference (LD):	Rate (%)	Teachers	(years) (log)	Experience (%)	Degree (%)
Shale Depth	0.019	-0.084	-0.043	0.039	-0.007
(2000 & 2014)	(0.010)	(0.021)	(0.021)	(0.013)	(0.009)
Observations	751	751	751	751	751
b. Oil & Non-Shale Districts:	Turnover	Number of	Experience	Less Than 5 Years	With Advanced
Fixed Effects (FE):	Rate (%)	Teachers	(years) (log)	Experience (%)	Degree (%)
Shale Depth X Price	0.013	-0.076	-0.031	0.026	-0.001
(2000 to 2014)	(0.006)	(0.016)	(0.016)	(0.009)	(0.007)
Observations	15,176	15,176	15,175	15,177	15,177
c. Eagle Ford & Non-Shale:	Turnover	Number of	Experience	Less Than 5 Years	With Advanced
Annual Difference (AD):	Rate (%)	Teachers	(years) (log)	Experience (%)	Degree (%)
Shale Depth X Period 1	0.001	-0.007	-0.002	0.003	-0.001
(2000 to 2008)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)
Shale Depth X Period 2	0.001	-0.010	-0.004	0.001	0.000
(2008 to 2009)	(0.011)	(0.007)	(0.009)	(0.007)	(0.005)
Shale Depth X Period 3	0.003	0.003	-0.010	0.005	-0.003
(2009 to 2014)	(0.002)	(0.003)	(0.004)	(0.003)	(0.001)
Observations	9,403	9,403	9,403	9,405	9,405
d. Permian & Non-Shale:	Turnover	Number of	Experience	Less Than 5 Years	With Advanced
Annual Difference (AD):	Rate (%)	Teachers	(years) (log)	Experience (%)	Degree (%)
Shale Depth X Period 1	-0.000	-0.015	-0.000	0.001	0.003
(2000 to 2008)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Shale Depth X Period 2	0.005	0.001	0.026	-0.007	-0.001
(2008 to 2009)	(0.011)	(0.006)	(0.013)	(0.008)	(0.003)
Shale Depth X Period 3	0.003	-0.001	-0.007	0.005	-0.000
(2009 to 2014)	(0.002)	(0.003)	(0.004)	(0.003)	(0.002)
Observations	9,543	9,543	9,543	9,545	9,545

Notes: Authors' calculations of multiple data sources (see Descriptive Details and Data Appendix). (%) denotes a variable in percentage terms. (log) denotes the natural logarithm of a variable. Robust standard errors, clustered by district, are provided in parentheses.

Table 6: Student Composition Estimates using LD, FE, & AD Approaches

a. Oil & Non-Shale Districts:	Number of	Economically	Vocational -	English as Second	Academically
Long Difference (LD):	Students	Disadvantaged (%)	Technical (%)	Language (%)	Gifted (%)
Shale Depth	-0.077	-0.078	-0.037	-0.022	-0.002
(2000 & 2014)	(0.024)	(0.009)	(0.007)	(0.005)	(0.004)
Observations	751	751	751	751	751
b. Oil & Non-Shale Districts:	Number of	Economically	Vocational -	English as Second	Academically
Fixed Effects (FE):	Students	Disadvantaged (%)	Technical (%)	Language (%)	Gifted (%)
Shale Depth X Price	-0.071	-0.055	-0.020	-0.019	-0.002
(2000 to 2014)	(0.017)	(0.007)	(0.005)	(0.003)	(0.003)
Observations	15,177	15,177	15,177	15,177	15,177
c. Eagle Ford & Non-Shale:	Number of	Economically	Vocational -	English as Second	Academically
Annual Difference (AD):	Students	Disadvantaged (%)	Technical (%)	Language (%)	Gifted (%)
Shale Depth X Period 1	-0.008	-0.006	-0.001	-0.001	0.001
(2000 to 2008)	(0.002)	(0.001)	(0.001)	(0.001)	(0.000)
Shale Depth X Period 2	-0.011	0.003	0.004	-0.000	0.000
(2008 to 2009)	(0.006)	(0.007)	(0.006)	(0.002)	(0.001)
Shale Depth X Period 3	0.009	-0.004	-0.003	-0.001	-0.000
(2009 to 2014)	(0.004)	(0.002)	(0.002)	(0.001)	(0.001)
Observations	9,405	9,405	9,405	9,405	9,405
d. Permian & Non-Shale:	Number of	Economically	Vocational -	English as Second	Academically
Annual Difference (AD):	Students	Disadvantaged (%)	Technical (%)	Language (%)	Gifted (%)
Shale Depth X Period 1	-0.019	-0.005	-0.003	-0.003	-0.001
(2000 to 2008)	(0.003)	(0.001)	(0.001)	(0.001)	(0.001)
Shale Depth X Period 2	-0.002	-0.010	-0.006	-0.003	-0.002
(2008 to 2009)	(0.007)	(0.007)	(0.007)	(0.002)	(0.001)
Shale Depth X Period 3	0.006	-0.008	-0.006	-0.001	-0.000
(2009 to 2014)	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)
Observations	9,545	9,545	9,545	9,545	9,545

Notes: Authors' calculations of multiple data sources (see Descriptive Details and Data Appendix). (%) denotes a variable in percentage terms. (log) denotes the natural logarithm of a variable. Robust standard errors, clustered by district, are provided in parentheses.

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Data Appendix

Spatially disaggregated data on shale depth come from Los Alamos National Laboratories, which were used to calculate the average depth in each school district. Depth provides a continuous measure of shale richness, because deeper shale is generally associated with more productive wells, as described in the text. Data on wells drilled, which is only used for descriptive purposes, come from the proprietary data provider, Drillinginfo. Energy prices are from the Energy Information Administration, using the national first-purchase price for crude oil and the national wellhead price for natural gas. Prices and all other monetary variables are in 2010 dollars.

Appendix Table A1 displays the summary statistics for variables related to student achievement, as well as variables related to the composition of teachers and students, all in the base year of 2000. The district-level characteristics of students and teachers come from the Snapshot School District Profiles of the Texas Education Agency, which is based on school administrative records; not surveys.

Student attendance and completion rates are included as measures of student achievement. 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; the denominator is the number of graduates, continuers, GED recipients, and dropouts. The other achievement measures are the percentage of students passing all state standardized tests (also shown separately for the reading and math tests), taking college entrance exams (SAT or ACT), and meeting the college entrance exam criteria (1110 on SAT or 24 on ACT). The students taking standardized tests may include students enrolled in grades 3-12, though not all grades take all tests in every year.

Teacher variables include the teacher turnover rate (the percentage of teachers from the prior year that did not return in the current year), the number of teachers, the average years of teaching experience, the percentage of teachers with less than five years of experience, and the percentage with an advanced degree.

Student characteristics include the number of students, the percentage that are economically-disadvantaged, the percentage of students enrolled in vocational or technical (votech) programs, the percentage enrolled in English as a Second Language (ESL) programs, and the percentage that are gifted. 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. 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.[8] Gifted students are those participating in state-approved gifted and talented programs.

Appendix Table A2 shows the summary statistics for the local finance, school spending, and labor market variables in the base year of 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 comes 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 local finance and school spending variables are the total tax base (also shown separately for oil-and-gas and non-oil-and-gas), the property tax rate, total debt, total revenues, total spending, payroll spending, and non-payroll spending (also shown separately for capital, debt, and other). The other spending category includes all non-payroll operating expenditures, such as supplies and materials, professional or contracted services, and other operating costs. All finance and spending variables, except for the tax rate, are reported in dollars per student.

The labor market variables include the average compensation per job (average wage), per private sector job (private wage), per public sector job based on all state and local government jobs (public wage), which are all reported at the county level. The average teacher wage is instead reported at the district level. The wage gap is then calculated as the difference between the private sector and the teacher wage.

[8] See https://www.gpo.gov/fdsys/pkg/FR-2013-03-29/pdf/C1-2013-06544.pdf.

Table A1: Descriptive Statistics for Student Achievement, Teacher Composition, & Student Composition

	All Districts (909-1,012 districts) (248 counties maximum)			Oil Districts (138-148 districts) (61 counties maximum)			Gas Districts (238-261 districts) (64 counties maximum)			Non-Shale Districts (533-603 districts) (123 counties maximum)		
	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median
Attendance Rate (%)	96.0	0.9	96.0	95.9	1.0	95.9	96.1	0.8	96.1	96.0	0.8	96.0
Completion Rate (%)	93.8	5.8	94.5	93.2	8.5	94.7	94.1	5.7	94.7	93.8	4.9	94.5
Passing State Tests (%)	82.6	8.7	83.8	81.1	9.0	83.1	84.0	8.1	85.3	82.4	8.9	83.5
Passing State Reading Tests (%)	89.4	6.5	90.4	88.1	6.5	89.5	90.5	5.7	91.5	89.2	6.7	90.4
Passing State Math Tests (%)	89.8	6.3	90.8	89.2	6.7	90.8	90.5	6.0	91.7	89.6	6.4	90.5
Taking SAT/ACT Exams (%)	60.2	15.9	60.0	59.1	15.2	57.0	59.9	17.0	60.0	60.6	15.6	60.3
Meeting SAT/ACT Criterion (%)	18.9	13.1	18.8	17.3	12.1	17.2	20.9	13.1	22.1	18.4	13.3	17.6
Teacher Turnover Rate (%)	16.0	7.6	15.0	15.7	7.9	14.5	15.0	7.6	14.3	16.5	7.5	15.6
Number of Teachers	261	714	74	186	414	67	264	799	68	278	733	78
Teacher Experience (years)	12.1	2.3	12.2	12.6	2.2	12.9	12.0	2.4	12.2	12.0	2.3	12.1
Teachers with < 5 Years Experience (%)	31.7	11.5	30.9	28.9	10.8	28.5	31.9	11.7	31.1	32.3	11.4	31.4
Teachers with Advanced Degree (%)	19.4	9.6	18.7	18.1	8.2	17.5	19.9	10.2	19.3	19.4	9.7	18.7
Number of Students	3,886	11,688	926	2,689	6,548	808	3,893	12,708	850	4,177	12,198	988
Economically Disadvantaged (%)	46.9	19.1	46.7	55.3	16.4	54.9	41.9	16.3	41.8	47.1	20.1	47.1
Vocational / Technical (%)	22.7	10.0	23.0	26.7	9.7	27.0	23.6	9.5	23.0	21.4	9.9	22.0
English as a Second Language (%)	6.0	8.9	3.0	6.8	6.9	5.0	3.8	5.0	2.0	6.8	10.4	3.0
Academically Gifted (%)	7.9	3.9	7.0	8.0	3.5	7.0	8.0	3.7	7.0	7.9	4.0	7.0

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. All districts, oil districts, gas districts, and non-shale districts are the observation sets. Oil districts are over one of the two shale formations with primarily crude oil (Eagle Ford and Permian), while gas districts are over one of the two shale formations with primarily natural gas (Barnett and Haynesville). The district numbers with complete data vary across variables, with the district ranges presented for each observation set. SD is the standard deviation. (%) denotes a variable in percentage terms.

Table A2: Descriptive Statistics for Local Finances, School Spending, & Labor Market Wages

	All Districts (1,010-1,012 districts) (248 counties total)			Oil Districts (148 districts) (61 counties total)			Gas Districts (259-261 districts) (64 counties total)			Non-Shale Districts (603 districts) (123 counties total)		
	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median
Total Tax Base	437,884	479,851	305,669	531,403	508,657	318,162	396,786	392,024	307,232	432,718	504,214	304,591
Oil & Gas Tax Base	83,259	309,682	2,536	221,444	398,168	25,053	38,909	183,648	2,524	68,539	319,399	917
Non Oil & Gas Tax Base	354,624	308,939	272,659	309,959	223,562	250,361	357,877	307,683	272,194	364,179	326,512	277,736
Property Tax Rate (%)	1.453	0.145	1.469	1.452	0.117	1.480	1.458	0.150	1.470	1.452	0.148	1.460
Total Debt	7,459	10,721	4,157	3,209	5,125	0	9,074	12,141	4,836	7,803	10,829	4,999
Total Revenues	10,584	5,284	9,687	11,172	3,426	9,980	10,112	2,147	9,633	10,644	6,469	9,635
Total Spending	11,360	5,288	10,298	11,549	3,209	10,854	11,112	3,424	10,207	11,421	6,272	10,216
Payroll Spending	7,105	2,680	6,701	7,727	1,772	7,361	6,791	1,192	6,576	7,089	3,247	6,659
Non-Payroll Spending	4,255	3,585	3,393	3,822	1,878	3,385	4,321	2,946	3,375	4,332	4,113	3,397
Capital Spending	1,516	2,683	702	1,089	1,315	552	1,669	2,532	687	1,554	2,973	752
Debt Spending	509	596	421	321	444	180	532	487	478	544	660	451
Other Spending	2,230	1,505	1,949	2,412	913	2,155	2,120	757	2,005	2,234	1,827	1,886
Average Wage	40,575	8,623	38,299	36,937	4,519	36,090	40,255	8,740	38,024	41,606	9,085	39,062
Private Sector Wage	28,490	9,761	26,272	24,572	5,169	23,656	27,805	10,336	25,669	29,749	10,089	27,941
Public Sector Wage	42,601	4,502	41,866	42,257	4,301	41,548	42,687	4,413	41,830	42,648	4,591	42,027
Average Teacher Wage	46,018	2,939	45,863	47,307	3,411	46,850	45,416	2,676	45,544	45,960	2,829	45,917
Private - Teacher Wage Gap	-17,537	9,565	-19,117	-22,735	5,552	-23,045	-17,652	9,692	-19,196	-16,211	9,856	-17,611

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 labor market 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. All districts, oil districts, gas districts, and non-shale districts are the observation sets. Oil districts are over one of the two shale formations with primarily crude oil (Eagle Ford and Permian), while gas districts are over one of the two shale formations with primarily natural gas (Barnett and Haynesville). The district numbers with complete data vary across variables, with the district ranges presented for each observation set. All school finance and spending variables are in terms of dollars per student, except for the property tax rate, which is a percentage. All wage variables are in dollars per year and refer to the wage in the district's county, except for the teacher wage, which is district-specific. SD is the standard deviation. (%) denotes a variable in percentage terms.