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WINDFALL: HOW OKLAHOMA'S TURBINES AFFECT RURAL SCHOOL FUNDING

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Contents

List of Figures

Abstract

Oklahoma's rural schools are struggling to effectively educate their students. Because of the sparsity of students and geographic isolation, rural schools have higher transportation costs, have trouble affording capital outlay spending, and have difficulties in recruiting and retaining teachers. Oklahoma's current funding measures are insufficient to address these unique needs as the inability to pass bonds and the disparities in local property tax revenue create significant funding and learning inequities in Oklahoma schools. The state's production tax credit incentivized a boon in wind turbine installation during the past couple decades. The sudden and exogenous increase in property taxes gives us an opportunity to evaluate the effect of the policy on Oklahoma schools, providing information more broadly on the rural school funding pipeline, from commercial ventures to benefits for students. The installation of a turbine in a district dramatically increased per pupil expenditures by thousands of dollars. School districts hired more staff and teachers while also increasing their capital outlay spending.

1 Introduction

Oklahoma's rural schools need change. A majority of the state's students are rural, and these students consistently demonstrate low performance overall as well as disappointing improvement between the 4th and 8th grade when compared to other states (NAEP). They are being taught by teachers who are underpaid, even when accounting for a rural area's generally lower wages (Showalter et al., 2019). In the annual *Why Rural Matters?* report the state ranks fourth overall in its priority, its highest ranking in a decade (Showalter et al., 2019). There is clearly urgency to specifically assist the state's rural schools. Addressing this requires an understanding of what makes rurality an important distinction.

The rural/nonrural divide in K-12 schools creates differing challenges for each respective classification. The two primary, defining characteristics are the relative sparsity of the students and the geographic isolation of rural schools. Those distinctives create unique downstream effects that increase transportation costs, raise capital outlay spending, and hinder the ability of schools to recruit and retain teachers (Bowers, 2005; Hammer et al., 2005). To account for these differences, Oklahoma takes partial measures by adjusting its state funding formula and operating aid programs. Other states have more comprehensive adjustments (Kolbe et al., 2020).

The intuitive perspective on how to increase funding for rural schools would be a variation in the state funding formula to more equitably distribute revenue or perhaps a sponsored grant program (Hime and Maiden, 2017). Alternatively, I look at how wind energy development can bolster education funding for rural schools. Wind farms have grown markedly in Oklahoma since their inception around 20 years ago. They serve over 20% of the state's electrical needs and were projected to make up 6% of the nation's new wind power capacity built in 2020 (Castleberry and Greene, 2017; Brewer, 2020). This growth has been curtailed by the early sunsetting of the state's production tax credit for wind farms. Governor Fallin ended the credit in response to the state's budget deficit, but, despite the decline in growth, significant wind developments have come to the state even during the COVID-19 pandemic (Patel, 2021).

Previous research of Oklahoma wind farms struggled to link the installations to differences in class size and per student expenditures (Castleberry and Greene, 2017). The null student-to-teacher ratio finding was especially surprising given that previous research has seen improvement on that outcome variable (Kahn, 2013). However, Castleberry and Greene's methodology was not equipped to demonstrate the effects these turbines have had. Instructional funding such as paying teachers and other instructional expenses are given out 'equitably' from the state through funding the difference between a weighted measurement of enrollment and other tax measures. However, capital outlay funding is nearly fully dependent on ad valorem property tax revenues. Also, these categories of instructional and operational are not as separate as one would think. Funding is fungible, and money for instruction may have to be used for operational expenses which puts rural school districts at a distinct disadvantage.

Using NCES data, I performed an event history analysis using a regression framework to see the effect of wind turbine installation on the states' school districts. I use an intention to treat (ITT) estimate to measure the effect of a district gaining turbine installations. The installations had an immediate increase in local property tax revenues, and soon after there is a corresponding change in per pupil expenditures with increases in salaries, the hiring of teachers/staff, and outlay capital spending. This refutes previous research on the state and shows how wind installments provide meaningful revenue that affects the quality of education students receive in rural Oklahoma. It also demonstrates the relative delay that occurs between revenue increases and the utilization of that revenue.

2 Rural Education Standards

Defining Rurality

Identifying rurality is imprecise, with a variety of indicators to use. The building blocks are often the same, but the thresholds have been set inconsistently. Definitions primarily consist of proximity to a metropolitan area, population size, and population density. Even the National Center for Education Statistics (NCES) has varied their definitions over the years to now adopting one that is "urban-centric". Their locale codes establish four categories—city, suburban, town, and rural—which each have three classifications within themselves (Manly et al., 2019). City and suburb locales are large, midsize or small. Town and rural locales are fringe, distant, or remote. While these distinctions are important, Oklahoma's wind installations are rarely near the confusing thresholds. Only 33 are in fringe rural while 3992 are either distant or remote rural, split evenly between the two. Only 14 of the 70 school districts with installations even include a town (the majority of which are distant rural). This is to say that wind farms in Oklahoma are consistently in some of the most rural parts of the state, which is where the wind blows.

Education Funding Standards

The history of education funding gives some context for how it operates and how it might be studied. An important demarcation point was the 1973 United States Supreme Court case *San Antonio Independent School District v. Rodriguez.* The case had two important implications for education funding. It made it clear that education was not a right prescribed in the U.S. Constitution, and it raised new questions about provisions within individual state constitutions (Parker, 2016). Those questions were answered with around sixteen states declaring their educational funding formula unconstitutional based on equity concerns and many more being challenged in the courts (Augenblick, Myers and Anderson, 1997). Here began a divide between the standards of equitable versus adequate funding. The Kentucky Supreme Court case *Rose v. Council for Better Education*, 1989, originated the adequacy standards across seven different outcomes (Reynolds, 2019). These "essential competencies" spanned domains from vocational education to physical wellness and more, and Oklahoma was one of several states which adopted a version of them when recalculating funding formulas (OSDE, 2013). Adequacy standards are related to another seminal court case in West Virginia, *Pauley v. Bailey*, 1983, whose opinion found "disparities of expenditures were tolerable if an adequate minimum education was provided to all the state's children" (1997, p. 337).

Despite this progress, adequacy standards are imperfect because the cost to educate a student is not uniform across the state. Geographic-based price differences, enrollment size, and student-specific needs all significantly influence cost differentials and are outside the district's control (Ducombe and Yinger, 2015). These are only some of the unique challenges that rural schools face. The relative sparsity of the students and the geographic isolation of rural schools have a myriad of effects which can make rural education more difficult.

The Cost of Being Small

The size of a school district is significant in determining its efficient use of resources (Baker and Duncombe, 2004; Andrews et al., 2002). Smaller districts have fixed costs such as building maintenance, buses, and specialized personnel (e.g. superintendents) that are necessary in all schools, but the costs of these do not increase directly as a function of the number of students. Economies of scale are characterized by this exact process; costs diminish as the number of units (pupils) increases. While there are several counterbalancing forces of diseconomies which might punish overly large districts, they are relatively low in magnitude when compared to the significantly decreased costs of increasing student populations (Cotton, 1996; Duncombe and Yinger, 2007; Zimmer et al., 2009). Low density and isolated populations create smaller school districts that are unable to reach the 2000 to 6000 pupil threshold which, depending on the expenditure, is estimated to minimize costs (Andrews et al., 2002.; Zimmer et al., 2009). The debate over school district consolidation has driven much of the education research around economies of scale. In Oklahoma only 6 of the 70 districts with wind installations meet the size criteria of being an economy of scale, meaning that this problem is specifically important for the state's rural population.

The structural distinction of not being too small to efficiently disperse resources manifests itself in several ways for rural districts. Because funding is fungible, the conventional wisdom is that funds intended for instructional costs are used to pay for operational expenses. Recent research on California has called into question this assumption of fungibility and found that marginal spending between rural and nonrural schools to be broadly similar in their allocations of new funds (Dhaliwal and Bruno, 2021). However, there should be caution in generalizing this finding to a state as dissimilar as Oklahoma (Levin et al., 2011, Sipple and Yao, 2015). The study does not negate the well documented challenges that rural schools face with regards to transportation costs, the hiring and retention of personnel, and building and infrastructure costs (Bowers et al., 2010; Hammer et al., 2005; Kolbe et al., 2021). Some states have grant specific programs to help adjust for these, but they are rarely built into the funding formula (Baker and Duncombe, 2004). Below I highlight a few hurdles that are often ascribed to rural schools that this paper might help to explore. Other obstacles like transportation are important but are not thorougly discussed here.

Human Capital Costs

Rural school districts deal with teacher shortages as they find it difficult to recruit and retain teachers. Rural schools spend more per student and regularly have a greater ratio of staff—and especially teachers—to students (Levin et al., 2011). With more students per employee, potential teachers are often asked to take on a larger workload and may be asked to teach multiple subject areas. They are paid less, deal with high turnover, have fewer opportunities for professional development, and have increased transportation costs. When there is a scarcity of instructors, school districts with less disadvantages and who pay better pick off teachers from rural neighbors, an effect so apparent that it is perceived electorally (Carlson et al., 2019; Harmon, 2001; Hammer et al., 2005). In Oklahoma specifically, teachers are paid significantly less, even when accounting for the lower wages that may be common for rural areas (Showalter et al., 2019). This, of course, is not to speak of the inability to hire special education teachers or effectively serve English language learners (ELL), and a lack of professional development means districts are less able to train teachers for these specialized roles (Berry and Gravelle, 2008; Johnson and Zoellner, 2015).

Facilities and Capital Outlay Costs

Infrastructure often has minimum fixed costs. The construction and maintenance of cafeterias and gymnasiums do not increase linearly with an increase of students. Correspondingly, the move to adequacy standards has placed an increased onus on districts to convince their jurisdiction of the need for improved capital infrastructure to effectively educate students. In spite of an outsize need, these districts are less able to pass bonds. Because inter-district differences in property wealth influence facility funding, rural districts find it more difficult to pass bonds. District urbanicity has been identified to have an independent, negative effect on the ability to pass funding proposals (Bowers et al., 2010; Brunner et al., 2021). The potential result of these inequities is the deterioration of infrastructure, the delay of projects, and the use of instructional funding to cover the costs of facility needs (Davis, 2000).

3 How Wind Funds Schools

Oklahoma Funding Structure

Oklahoma's funding can be understood as divided between operational and capital outlay revenue (Reynolds 2019). Operational funding is equalized on the state level via a complex funding formula. State aid has three components: foundation aid, transportation aid, and a salary incentive. The state's foundation aid and salary incentive are made up of a formula that is primarily based on the weighted average daily membership (WADM) of a school district. The funding weights for each student are primarily based on classifications (grade, special education, gifted, bilingual, economically disadvantaged) with an additional weight for teacher quality, and then schools are able to pick the larger of either a small school weight or an isolation weight. This isolation weight is the state's best attempt at addressing rural costs, and half of turbine districts received this weight. This past year, only 22% of the state's school districts were eligible for the isolation weight, and all but 13 took it. The isolation weight on average made up 20% of those recipients' total WADM, which can equate to, on average, around 120 students per district. This marks a a substantial boon to districts to equalize operational costs. However, in totality these weights are rather small, with small school and isolation weights contributing only 1.5% of the total WADM of the state (Schlomach, 2015). Transportation aid takes into account the distance of students from the school and the density of students-per-district. Its effectiveness has come into question as it hardly resembles the actual transportation spending of districts. That, coupled with its diminutive size, has led to transportation aid being characterized as "almost irrelevant" (Scholmach, 2015).

While operational funding such as paying teachers and other instructional expenses are equalized by the state this way, capital outlay funding is dependent fully on local wealth factors like ad valorem revenues (the revenues from increased property taxes). As discussed, funds are often moved around to account for need, a phenomenon known as crossover funding which creates inequity between districts (Hime and Maiden, 2017). There has been some recent evidence that Oklahoma's decrease in education funding has caused unexpected instructional disparities such as 4-day weeks, less instructional time, or increased class sizes (Reynolds 2019), factors negatively associated with achievement (Glass et al., 1979; Thompson 2018). This does not come from a diminished general fund but rather from differentials in ad valorem revenues, meaning there are clear instructional costs when outlay funding is cut (Davis, 2000).

Given how ad valorem taxes can have important implications in instructional capabilities and the difficulties for rural districts to pass bonds, there should be an investigation as to where additional funding can come from. For Oklahoma, one of the primary drivers of changes in ad v-alorem revenues is energy companies operating oil wells, refineries, and wind farms. These disparities are far from insignificant. In 2016, the property tax revenue of school districts ranged from $25,712 to $119 per pupil. The revenue from capital improvement differs drastically across the state (Hime and Maiden 2017). The growth of energy industry operations has the potential to greatly benefit the recipient districts, making them more resilient to operational change. This is especially the case when districts fund operational costs with crossover funds.

The Advent of Wind

Wind farms have grown markedly in Oklahoma since their inception around 20 years ago. They serve over 20% of the state's electrical needs (Castleberry and Greene, 2017) and were projected to make up 6% of the nation's new wind power capacity built in 2020 (Brewer, 2020). There has been a struggle in a previous study to link wind farms to differences in class sizes and per student expenditures (Castleberry and Greene, 2017). The null student-to-teacher finding was especially surprising given that previous research has seen improvement on that outcome variable (Kahn, 2013). Castleberry and Greene provide a descriptive overview, but their method is rather crude, performing t-tests on the western half of the state between districts with and without turbines, ignoring a plethora of important inter-district differences. This strategy is statistically weak and was insufficient to parse out the effects at a granular enough level, masking over trends. However, Castleberry and

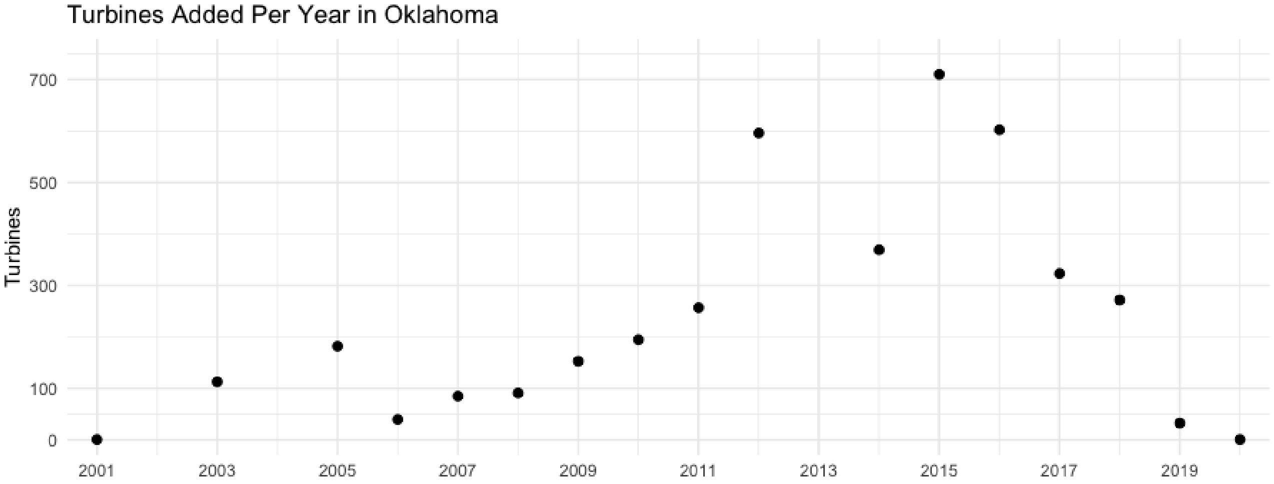


Figure 1: The Installation Counts of Turbines in the State

Greene showed the potential for promising results of other research designs. These effects may become clearer over a longer time scale as more turbines are installed, more data is collected, and the money becomes more integrated into the system.

Wind farms are relatively new (essentially all have been placed in the past 20 years) and were incentivized to be built in the state because of a 5-year production tax credit. This does not mean that schools do not get the property tax benefit. The state has filled that gap by reimbursing counties. Unfortunately, the growth of installations has been curtailed by the early sunsetting of the state's production tax credit for wind farms. In 2016 there were 602 newly operations installations, and in 2019 there were only 33. Governor Fallin ended the credit in response to the state's budget deficit, but, despite the faltering growth, some wind development has come to the state even during the COVID-19 pandemic (Patel, 2021).

From Turbines to Teachers

The process of turbine installation to the funding of schools is not a straight line. The first step is in the assessment of the property based on fair market value. These values are not uniform for every turbine because of significant variation in capacity, location, and actual electricity production (Castleberry and Greene, 2017). The blurriness of this assessment process has driven a fair amount of controversy as developers have regularly protested property-value appraisals, leading to a call for standardization (Ellis, 2019; Savage, 2019). Recent guidance by the Oklahoma Tax Commission (OTC) has attempted to ameliorate these struggles by setting values for the replacement cost per megawatt to be $1,576,835 and the replacement cost per tower to be $3,126,566. Complicating this further are depreciation schedules of 12 and 25 years for moving and static parts respectively (OTC). During the 5 exemption years, the state calculates the value of the installation project and sends the money to local authorities. They pay this from a 1% state income tax and an Ad Valorem Reimbursement Fund. After the exemption years, a county assessor calculates the taxes (Ellis and Monie, 2016).

With an understanding of how wind installations are taxed, the next step is to see how the money trickles down to schools. The state equalized funding—the foundation aid and salary incentive—is a fixed amount calculated by the WADM. School districts make up a portion of the foundation aid with local taxes, including a 15-mill levy on the aforementioned property valuation, and the rest is filled in by the state. The WADM-based salary incentive decreases by 20-mills of the assessed property valuation. These balancing forces mean that a large portion of the increased property revenue just offsets what would have been state aid. In my findings I should expect to see a reduction corresponding to increased property value assessment.

For 50% of turbine districts, their property values are so high they do not receive any foundation funding; 31% do not receive the salary incentive. Only 80 of the 548 school districts in the state have high enough revenues to not receive state foundation aid, so the fact that 35 of those are turbine districts demonstrates the significant effect turbines are having on the state's funding as a whole. Local district tax revenues are in addition to this and vary by district (see appendix for details). This is what could lead to significant revenue increases for school districts.

Wind installations, in theory, should have a downstream effect where an increase in local property tax revenues leads to an increase in per pupil expenditures. To understand this pipeline, my research looks at revenue differences before and after wind installation. Then I look at the resulting changes in expenditures, on a broad level and with more specific indicators like the hiring of teachers, instructor salaries, and capital outlay spending. This data points to whether these installations are having a significant impact on schools, and where/how those effects are manifesting.

4 Data

To locate all of the wind farms in Oklahoma I am using the United States Wind Turbine Database (USWTDB) from the United States Geological Survey (USGS) (Hoen et al., 2020). The data has an id and latitude/longitude location for each individual wind turbine, not just each wind installation project. Because wind projects of many turbines may easily span multiple school districts, isolating the independent effects on individual school districts is critical. Given the availability of outcome variables, I only look at the turbines installed through 2016. The USGS works to manually identify each turbine location using imagery, and it measures its location confidence as well. This data is well maintained and regularly updated.

Revenue and expenditure data come from the NCES and spans 1996 to 2016 to identify how school districts do in the years before and after an installation. The NCES also provides the boundary files for each school district in 2020 and the district characteristics for each year. Given availability and reliability of data, I have excluded non-traditional school districts like charter, virtual, and state-run institutions. Those districts are also not useful for comparison purposes given how relatively few of the students are enrolled there. Over that period of time, there have been a few school district consolidations outside of installation districts. They are excluded as well.

5 Methods

The purpose of this research is to measure the effect of wind farms on the allocation of education funds. To do this I perform a difference-in-difference, event study that measures an intention to treat estimate. By doing this I am able to compare districts to themselves before and after wind installation. Measuring these effects over a span of time before and after could show evidence of process on both sides of installation. Before installation there should not be a trend. Values should be consistently null and around zero. After installation we would expect to see a positive trend that eventually levels off. This is why understanding change over time is uniquely important beyond naïve summations in the pre and post treatment periods. My measurements follow this specification:

$$y_{it} = \Sigma_{j=-5}^{9} \gamma_j Treatment_{j,it} + Year_t + District_i + \epsilon_{it}$$

Each outcome is measured for each district i and year t. My statistical controls are a year fixed effect which should account for general trends of the funding formulas and enrollment over time. I also include a district fixed effect to remove in-district variation. I include an ϵ term for random error. Then there are a series of leading and lagging indicators that measure the time before and after each district's first installation. Those indicators are either 1 or 0 depending on the observation's relation to the installation of the first turbine. On the negative end, this varies from 5 or more years before installation to 2 years before installation. On the positive end, it varies from the year of the installation to over 9 years after installation, with an indicator for each year. I have grouped all observations 5 or more years previous and 9 or more years after installation. Those values would either be trivial on the negative end, or, on the positive end, they would reflect installation trends beyond the initial turbine project. I omit the year before installation as my reference category.

The γ variable is the most interesting. These terms are interacted with the treatment variable of either having a turbine or not. That coefficient should indicate to what extent the presence of a wind turbine has an effect, each year after its first installation, on the outcome variable of interest. The outcome variables I am measuring include the per pupil revenue, per pupil property tax, per pupil state revenue, per pupil total expenditures, per pupil total salaries, per pupil instructional salaries, total teachers employed, total staff employed, and total outlay capital spending. Statistical significance will be measured at the $\alpha = 0.05$ level unless otherwise specified.

6 Results

The first thing to do is analyze where the turbines are in the state, and they seem to be clustered in the western part of the state. These more rural areas likely make it easier to construct windfarms as many of the barriers to entry are removed (Firestone et al., 2018). The western part of the state is also where the wind blows, meaning the most profit can come from these locations (Dryden, 2011).

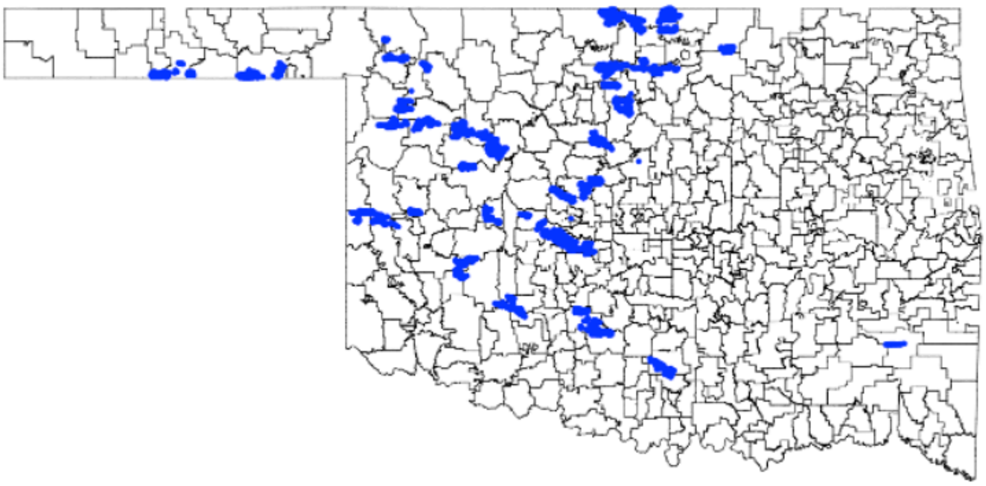


Figure 2: Turbine Locations in Oklahoma

The first model's specification should be to look at the effect on revenue. Looking at Table 1 we see total revenue per pupil decreasing with values relatively close to zero before the installation of a turbine in the area. Then we see a small increase in the year after, followed by a massive increase in all subsequent years. The school districts' per pupil total revenue decreases by the hundreds in the years previous, to expanding by an order of magnitude in the following years. Remember, this is all in reference to the year before the turbine installation. When looking at the model for property tax increases per pupil, we see immediate effects in the year following the installation of the turbine of over $1000 per pupil, with increases topping out at over $4000 per pupil 7 years after turbine installation, compared to measly variations on the scale of hundreds before the installation. The close to null values before installation is what we would expect because revenue changes should be random. The substantively large and statistically significant changes in the years following installation demonstrate clear evidence that turbine installation is driving local property tax revenue. Given the total range of per pupil property tax revenues was around $25,000, a $4000 to $5000 swing is remarkable. We would also expect a decrease in state aid for these districts as increased property value assessments trade off with distribution of state aid. In Table 2 values are null and positive before installation. After treatment, results become negative and significant in just a year. They peak at -$839 three years after treatment. This confirms that some of the turbine benefits are offset by state aid reductions.

Table 3 looks at expenditures. Per pupil expenditures follow a similar trend as revenue, but it is delayed by about a year or two. We once again see null or nearly null values for expenditures before installation. After installation, we begin to see increases in the first years, with a significant jump starting 4 years after installation. Those values peak at almost $4000 per pupil being expensed by the school district 7 years after treatment. This has measured overall expenditures. The values for instructional expenditures per pupil increase at the same pace but at a smaller scale than overall expenditures which indicates that this money is not being directly used for instructional purposes. Instructional expenditures are heavily equalized by the state, so an increase in this outcome beyond equalization is substantively significant. The coefficients mirror those of overall expenditures, which we would expect. They go from being nearly null and negative before installation to becoming positive in the years immediately following installation. They scale up to statistically significant and substantively significant standards around 4 years after installation. Instructional expenditures per pupil have increased at the scale of over $600 for the district 4 years after first installation.

Table 4 examines how this instructional spending manifests in total salaries. The trend is consistent for total and instructional salaries. Values are null and negative before installation, then become positive following installation. They become substantively and statistically significant around year 4, making huge jumps that persist through all years measured. In year 5, total salaries per pupil have increased to $841, and instructional salaries are likewise $496 higher than before installation. This increase in salaries is possibly misleading because there is the possibility that these school districts are hiring more teachers. Table 5 helps us understand that dynamic. When measuring the number of teachers employed, the variation is near 0 until 4 years after, when it appears they hire around 3 to 4 teachers. The number of staff employed is not as lagged. They see their increase in the second year following installation, hiring around 25 staffers total (note this value includes the number of teachers employed). That value peaks at a 36 employment differential in the seventh year following installation. Even if these values are less statistically significant, p-values do decrease substantially, and values are substantively large.

Finally, we can look at per pupil outlay capital spending in Table 6. The jump occurs in the fourth year following installation, and peaks at $1904 per pupil in the sixth year following installation when compared to the year before the wind farm was installed. In all of these models I have hidden the year and district fixed effects and removed the values for the grouped years of being more than 4 years before installation and being over 9 years after installation.

Evaluating Trends

In these models, values tend to increase (excluding the decreasing state revenue) and then level off in the 5-8 years following installation. The levelling off is should happen as the money gets 'settled'. Before that it takes time for the money to work through the system. It takes time for staff to be hired, salaries to be set, and budgets to be put in place with more consistent revenue expectations. This is what may explain the general increase and then flattening. The data speaks to this process as well, with revenues preceding expenditures and the other outcomes. Another possibility is that some sites gain more installations over time which grows these values even further.

The errors also increase. This should be expected as the presence of a wind turbine is not going to be as predictive of outcomes so far after installation. Also, more variation could be attributed to the fact that some districts are gaining more installations during this time. Employment outcomes specifically have large standard errors, which could speak to the differences in how districts use new funding. This is why the change in salaries can be used in conjunction with the employment data to conclude that this money is being used in some districts for the hiring of teachers. If districts do not hire teachers, the more conclusive salary model would at least point to improved teacher retention through expanded compensation. Regardless, there is likely some heterogeneity to be explored in future research.

7 Discussion

Rural school districts have unique challenges which stem from their size, isolation, student sparsity. They are too small, and the fixed costs of facilities, administration, and other specialized personnel mean that districts are forced to use funds inefficiently as they cannot utilize the diminished per pupil cost of large populations, what makes education an economy of scale (Andrew et al., 2002). Rural schools often have to ask more from their teachers, and they offer them less benefits as well (Harmon, 2001; Hammer et al., 2005). They are paid less and have to deal with high transportation costs. Even with adequacy standards, it would cost much more to educate a rural student to the same standard as a non-rural student (Duncombe and Yinger, 2008). To be able to pay for the necessary facilities and capital outlay costs, districts sometimes have to funding originally intended for instruction (Hime and Maiden, 2017). To add insult to injury, urbanicity is an independent indicator of a district's ability to pass a bond (Bowers et al., 2010). This means that when facilities need to be repaired, rural districts are unable to raise those funds independently and are dependent on local property revenues.

In the face of this dilemma to locate funding for rural schools, I measure the effect that wind farms have had on the school districts in which they are located. Districts benefit from an increase in local property taxes. The aftermath of installation in a district comes in stages. Per pupil property tax revenue increases immediately and state revenue decreases as a result of the funding formula. Soon after, per pupil total revenue increases in the first couple years following installation. Expenditures change and reach scale at around four years after installation. This growth in expenditures leads to expansions in per pupil total salaries and per pupil capital outlay spending. These increases are not just statistically significant. They are on the scale of thousands of dollars per pupil. Given total per pupil property tax revenue in the state only ranges by about $25,000, this is a substantively significant change. The growth in salaries appears to be partially determined by the hiring of 25-35 staff a couple years after installation. The employment of teachers trails this by a couple years and is on the scale of around 3-4 teachers.

When Oklahoma's production tax credit was nixed in 2017 by Governor Fallin, the number of installations per year plummeted from hundreds in years previous to only 33 in 2019. The growth of installations appears to be extremely significant for these school districts that are by and large underserved by current state funding measures. It is yet to be seen if there are notable performance gains brought about by the installation of wind farms. Wind energy in Oklahoma is relatively new, with the overwhelming majority of installations being put in in the last decade. This area of research could be extended by looking at what causes the delay from revenue to salaries. It could be from delays in tax assessment and the time it takes for districts to create and allocate budgets. This should be investigated more. It would be helpful to also better account for the scale of the installations by measuring how much energy they produce and how many turbines there are in each district.

Also finding scale value performance indicators could help us understand if the hiring of teachers and the capital outlay spending is helping students on an individual level, answering the age-old question of whether funding matters (Hanushek, 2003; Jackson, 2018). Independent of all of that is the notable conclusion that wind energy development has been helpful to Oklahoma's rural school districts in overcoming the funding obstacles of being a rural school district.

Oklahoma's state geographer Stephen Sadler sees huge potential for wind industry in the state, with production "several times what it is now", and its total capacity growing far beyond the state's total energy needs (Overall, 2015). Despite this, wind turbines will likely not be placed in every rural school district. However, the state is still incentivizing other industries to invest in the state. The tax credit was only ended for wind energy, and the exemption is still used for large manufacturing, traditional manufacturing, and data centers like the massive installation operated by Google in Mayes county. This broadens the scope of who the state could incentivize to invest in rural Oklahoma. With energy costs low and noise pollution less of a concern, there is much potential to be explored by policymakers.

8 References

M. Andrews, W. Duncombe, and J. Yinger. "Revisiting Economies of Size in American Education: Are We Any Closer to a Consensus?" Economies of Education Review 21 (2002): 245-262.

Augenblick, John G., John L. Myers, and Amy Berk Anderson. "Equity and adequacy in school funding." The Future of Children (1997): 63-78.

Baker, Bruce, and William Duncombe. "Balancing district needs and student needs: The role of economies of scale adjustments and pupil need weights in school finance formulas." Journal of Education Finance 29, no. 3 (2004): 195-221.

Berry, A. B., and Gravelle, M. (2008). The benefits and challenges of special education positions in rural settings: Listening to the teachers. The Rural Educator, 34(2). https://doi.org/10.35608/ ruraled.v34i2.400

Brewer, Gina. "Oklahoma wind power capacity" Fox 25 news. 2020
https://okcfox.com/news/local/oklahoma-wind-power-capacity

Bowers, Alex J., Scott Alan Metzger, and Matthew Militello. "Knowing the odds: Parameters that predict passing or failing school district bonds." Educational Policy 24, no. 2 (2010): 398-420.

Brunner, Eric, David Schwegman, and Jeffrey M. Vincent. "How Much Does Public School Facility Funding Depend on Property Wealth?." Education Finance and Policy (2021): 1-52.

Carlson, Deven, Byron Carlson, and Elizabeth Bell. "Interjurisdictional Competition and Policy Preferences of the Public." (2019).

Castleberry, Becca, and J. Scott Greene. "Impacts of wind power development on Oklahoma's public schools." Energy, Sustainability and Society 7, no. 1 (2017): 34.

Cotton, Kathleen. 1996. Affective and social benefits of small-scale schooling. Eric Digest No. ED401088. Available www.ericdigests.org/1997-2/small.htm.

Davis, Glen A. "Effects of Kansas' capital outlay valuation-based funding on local school districts." PhD diss., Wichita State University, Department of Educational Administration, 2000.

DeLacy, P. Barton, and MAI ASA. "Renewables, tax credits, and ad valorem taxes: are policies aligned." Real Estate Issues 39, no. 1 (2014): 50-59.

Dhaliwal, Tasminda K., and Paul Bruno. "The rural/nonrural divide? K–12 district spending and implications of equity-based school funding." AERA Open 7 (2021): 2332858420982549.

Duncombe, W., and Yinger, J. (2007). Does school district consoli- dation cut costs? Education Finance and Policy, 2(4), 341–375. https://doi.org/10.1162/edfp.2007.2.4.341

Duncombe, William, and John Yinger. "Measurement of cost differentials." Handbook of research in education finance and policy (2008): 238-256.

Duncombe, W. D., Nguyen-Hoang, P., and Yinger, J. (2015). Measurement of cost differentials. In H. F. Ladd and M. E. Goertz (Eds.), Handbook of research in education finance and policy (2nd ed., pp. 260–278). Routledge.

Dryden Jr, James Mack. "Potential climate change impacts on wind resources in Oklahoma: a focus on future energy output." PhD diss., Oklahoma State University, 2011.

Ellis, Randy "Wind industry tax protests disrupt school financing". The Oklahoman. (2019). https://www.oklahoman.com/article/5625155/wind-industry-tax-protests-disrupt-school-financing

Ellis, Randy and Monies, Paul. "Tax incentives for Oklahoma wind farms are getting scrutiny". The Oklahoman. (2016). https://www.oklahoman.com/article/5493853/tax-incentives-for-oklahoma-wind-farms-are-getting-scrutiny

Firestone, Jeremy, Ben Hoen, Joseph Rand, Debi Elliott, Gundula Hübner, and Johannes Pohl. "Reconsidering barriers to wind power projects: community engagement, developer transparency and place." Journal of environmental policy and planning 20, no. 3 (2018): 370-386.

Glass, Gene V., and Mary Lee Smith. "Meta-analysis of research on class size and achievement." Educational evaluation and policy analysis 1, no. 1 (1979): 2-16.

Greenwald, Robert, Richard Laine, and Larry Hedges. "A meta-analysis of studies of the effects of differential school inputs on student outcomes." Educational Researcher 23, no. 3 (1994): 5-14.

Hammer, P., Hughes, G., McClure, C., Reeves, C., and Salgado, D. (2005, December). Rural teacher recruitment and retention practices: A review of the research literature, national survey of rural superintendents, and case studies of programs in Virginia. Rural Teacher Recruitment and Retention. Edvantia. files.eric.ed.gov/fulltext/ED489143.pdf

Hanushek, Eric A. "The failure of input-based schooling policies." The economic journal 113, no. 485 (2003): F64-F98.

Harmon, Hobart L. "Attracting and Retaining Teachers in Rural Areas." (2001).

Hime, Shawn, and J. Maiden. "An examination of the fiscal equity of current, capital, and crossover educational expenditures in Oklahoma school districts." (2017).

Hoen, B.D., Diffendorfer, J.E., Rand, J.T., Kramer, L.A., Garrity, C.P., and Hunt, H.E., 2018, United States Wind Turbine Database (ver. 3.0, April 2020): U.S. Geological Survey, American Wind Energy Association, and Lawrence Berkeley National Laboratory data release, https://doi.org/10.5066/F7TX3DN0.

Jackson, C. Kirabo. Does school spending matter? The new literature on an old question. No. w25368. National Bureau of Economic Research, 2018.

Johnson, J. D., and Zoellner, B. P. (2015). School funding and rural districts. In S. M. Williams and A. A. Grooms (Eds.), Educational opportunity in rural contexts: The politics of place (pp. 3–20). Information Age.

Kahn, Matthew E. "Local non-market quality of life dynamics in new wind farms communities." Energy Policy 59 (2013): 800-807.

Kolbe, T., Atchinson, D., Kearns, C., and Levin, J. (2020). State funding formulas: A national review. American Institutes for Research.

Kolbe, Tammy, Bruce D. Baker, Drew Atchison, Jesse Levin, and Phoebe Harris. "The additional cost of operating rural schools: Evidence from Vermont." AERA Open 7 (2021): 2332858420988868.

Levin, J., Manship, K., Chambers, J., Johnson, J., and Blankenship, C. (2011). Do schools in rural and nonrural districts allocate resources differently ? An analysis of spending and staffing patterns in the West

Region states. IES National Center for Education Evaluation and Regional Assistance.

Manly, C. A., Wells, R. S., and Kommers, S. (2019). Who are rural students? How definitions of rurality affect research on col- lege completion. Research in Higher Education, 61, 764–779. https://doi.org/10.1007/s11162-019-09556-w ¬

Oklahoma State Department of Education (OSDE). (2013). Oklahoma school finance technical assistance document. Oklahoma City: Oklahoma State Department of Education.

Overall, Michael. “Wind farms in Oklahoma: Your tax money helps pay for it, but is it worth the price?”. Tulsa World. (2015).

Parker, Emily. ”Constitutional Obligations for Public Education. 50-State Review.” Education Commission of the States. (2016).

Patel, Sonal. “GE Snags Historic 1.48-GW Agreement for Oklahoma Wind Turbines”. Powermag. (2021).

Reynolds, Tammie. ”The Impact of Capital Outlay Inequities on School District Cost Saving Measures in a Climate of Budget Reductions.” (2019).

Savage, Tres. “Stakeholders want to standardize Oklahoma wind farm tax valuation”. Non Doc. (2019). https://nondoc.com/2019/07/12/stakeholders-want-to-standardize-oklahoma-wind-farm-tax-valuation/

Schlomach, Byron. “A Primer for Understanding Oklahoma’s School Funding System”. 1889 Institute. (2015).

Showalter, Daniel, Sara L. Hartman, Jerry Johnson, and Bob Klein. ”Why Rural Matters 2018 2019: The Time Is Now. A Report of the Rural School and Community Trust.” Rural School and Community Trust (2019).

Sipple, J. W., and Yao, Y. (2015). The unequal impact of the Great Recession on the instructional capacity of rural schools. In S. M. Williams and A. A. Grooms (Eds.), Educational opportunity in rural contexts: The politics of place (pp. 39–58). Information Age.

Thompson, Paul. ”Effects of Four-Day School Weeks on Achievement: Evidence from Oregon.” WP Department of Economics, Oregon state University (2018).

Zimmer, T., DeBoer, L., and Hirth, M. (2009). Examining econo- mies of scale in school consolidation: Assessment of Indiana school districts. Jorunal of Eduation Finance, 35(2), 103–127. https://doi.org/10.1353/jef.0.0012

9 Appendix

9.1 Tables

Table 1:

	Dependent variable:	
	Per Pupil Revenue	Per Pupil Property Tax revenue
	(1)	(2)
5+ Years Before*Treatment	—	—
4 Years Before*Treatment	−607.401	−448.802**
	(484.529)	(211.919)
3 Years Before*Treatment	−604.261	−405.842**
	(431.432)	(188.696)
2 Years Before*Treatment	−343.137	−276.241
	(419.021)	(183.268)
Year of*Treatment	−367.087	−145.802
	(421.931)	(184.541)
1 Year After*Treatment	497.643	1,184.541***
	(444.452)	(194.391)
2 Years After*Treatment	1,356.378***	1,876.636***
	(497.491)	(217.589)
3 Years After*Treatment	1,646.900***	2,429.964***
	(509.320)	(222.763)
4 Years After*Treatment	2,563.248***	3,197.912***
	(503.206)	(220.088)
5 Years After*Treatment	3,311.685***	3,536.554***
	(605.137)	(264.670)
6 Years After*Treatment	3,581.672***	4,178.555***
	(655.300)	(286.610)
7 Years After*Treatment	4,140.513***	5,049.703***
	(748.105)	(327.201)
8 Years After*Treatment	3,281.655***	4,316.139***
	(844.155)	(369.210)
9+ Years After*Treatment	—	—
Year FE and District FE and Constant	—	—
Observations	4,164	4,164
R^2	0.684	0.889
Adjusted R^2	0.635	0.872
Residual Std. Error (df = 3609)	2,017.258	882.293
F Statistic (df = 554; 3609)	14.092***	52.200***
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 2:

	Dependent variable:
	Per Pupil State Revenue
5+ Years Before*Treatment	—–
4 Years Before*Treatment	214.998 (365.272)
3 Years Before*Treatment	176.227 (325.244)
2 Years Before*Treatment	120.344 (315.888)
Year of*Treatment	−116.365 (318.081)
1 Year After*Treatment	-678.727^{**} (335.059)
2 Years After*Treatment	-683.841^{*} (375.043)
3 Years After*Treatment	-839.708^{**} (383.961)
4 Years After*Treatment	-771.515^{**} (379.352)
5 Years After*Treatment	−508.800 (456.195)
6 Years After*Treatment	−486.520 (494.011)
7 Years After*Treatment	−588.851 (563.974)
8 Years After*Treatment	−404.262 (636.383)
9+ Years After*Treatment	—–
Year FE and District FE and Constant	—–
Observations	4,164
R^2	0.495
Adjusted R^2	0.417
Residual Std. Error	1,520.751 (df = 3609)
F Statistic	6.377^{***} (df = 554; 3609)
Note:	*p<0.1; **p<0.05; ***p<0.01

Table 3:

	Dependent variable:	
	Per Pupil Total Expenditures	Per Pupil Instruction Expenditures
	(1)	(2)
5+ Years Before*Treatment	—	—
4 Years Before*Treatment	−564.068	−170.754
	(472.583)	(242.559)
3 Years Before*Treatment	−783.957*	−109.723
	(420.795)	(215.979)
2 Years Before*Treatment	−580.979	−9.406
	(408.690)	(209.766)
Year of*Treatment	−423.214	10.948
	(411.528)	(211.222)
1 Year After*Treatment	−370.880	32.625
	(433.495)	(222.497)
2 Years After*Treatment	372.119	68.655
	(485.225)	(249.048)
3 Years After*Treatment	747.115	100.692
	(496.763)	(254.970)
4 Years After*Treatment	2,444.516***	609.475**
	(490.800)	(251.910)
5 Years After*Treatment	2,673.329***	757.734**
	(590.217)	(302.937)
6 Years After*Treatment	3,690.980***	639.998*
	(639.144)	(328.049)
7 Years After*Treatment	2,829.001***	636.357*
	(729.661)	(374.508)
8 Years After*Treatment	3,789.098***	658.259
	(823.343)	(422.592)
9+ Years After*Treatment	—	—
Year FE and District FE and Constant	—	—
Observations	4,164	4,164
R^2	0.663	0.584
Adjusted R^2	0.611	0.520
Residual Std. Error (df = 3609)	1,967.523	1,009.858
F Statistic (df = 554; 3609)	12.800***	9.142***
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 4:

	Dependent variable:	
	Per Pupil Salaries	Per Pupil Instruction Salaries
	(1)	(2)
5+ Years Before*Treatment	——	——
4 Years Before*Treatment	-162.818	-90.600
	(165.569)	(117.197)
3 Years Before*Treatment	-235.351	-116.998
	(147.425)	(104.354)
2 Years Before*Treatment	-27.912	1.937
	(143.184)	(101.352)
Year of*Treatment	-5.326	14.112
	(144.178)	(102.056)
1 Year After*Treatment	2.376	24.769
	(151.874)	(107.504)
2 Years After*Treatment	56.952	0.371
	(169.998)	(120.332)
3 Years After*Treatment	85.051	40.009
	(174.040)	(123.194)
4 Years After*Treatment	468.544^{***}	323.627^{***}
	(171.951)	(121.715)
5 Years After*Treatment	841.540^{***}	496.403^{***}
	(206.782)	(146.370)
6 Years After*Treatment	737.533^{***}	422.889^{***}
	(223.923)	(158.503)
7 Years After*Treatment	788.031^{***}	416.933^{**}
	(255.636)	(180.951)
8 Years After*Treatment	786.282^{***}	414.204^{**}
	(288.457)	(204.183)
9+ Years After*Treatment	——	——
Year FE and District FE and Constant	——	——
Observations	4,164	4,164
R^2	0.773	0.722
Adjusted R^2	0.738	0.679
Residual Std. Error (df = 3609)	689.319	487.932
F Statistic (df = 554; 3609)	22.191^{***}	16.878^{***}
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 5:

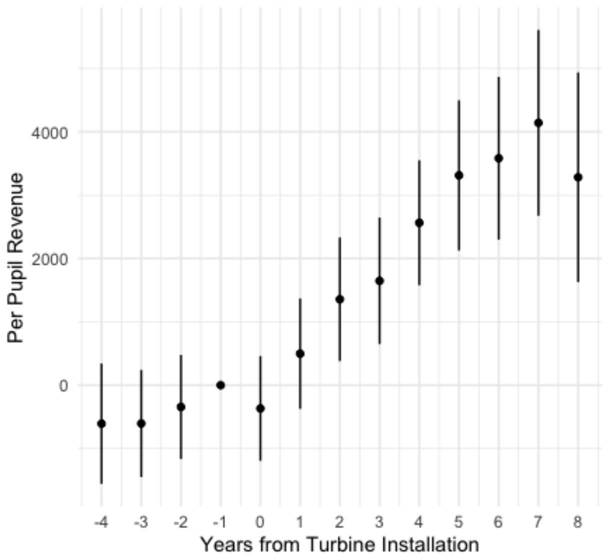
	Dependent variable:	
	Teachers Employed	Staff Employed
	(1)	(2)
5+ Years Before*Treatment	—–	—–
4 Years Before*Treatment	−1.494 (2.432)	−2.638 (10.211)
3 Years Before*Treatment	−1.263 (2.165)	−2.646 (7.403)
2 Years Before*Treatment	−0.024 (2.103)	−0.150 (5.696)
Year of*Treatment	0.139 (2.117)	2.021 (5.016)
1 Year After*Treatment	0.889 (2.230)	4.955 (6.150)
2 Years After*Treatment	0.124 (2.497)	24.833* (14.345)
3 Years After*Treatment	0.877 (2.556)	25.651 (15.636)
4 Years After*Treatment	3.063 (2.525)	29.270* (15.712)
5 Years After*Treatment	4.092 (3.037)	31.193* (16.839)
6 Years After*Treatment	3.677 (3.288)	33.815* (17.669)
7 Years After*Treatment	4.265 (3.754)	35.815* (19.201)
8 Years After*Treatment	6.298 (4.236)	35.921 (23.145)
9+ Years After*Treatment	—–	—–
Year FE and District FE and Constant	—–	—–
Observations	4,164	1,546
R^2	0.998	0.999
Adjusted R^2	0.998	0.999
Residual Std. Error	10.123 (df = 3609)	15.530 (df = 1013)
F Statistic	3,163.777*** (df = 554; 3609)	2,263.528*** (df = 532; 1013)
Note:		*p<0.1; **p<0.05; ***p<0.01

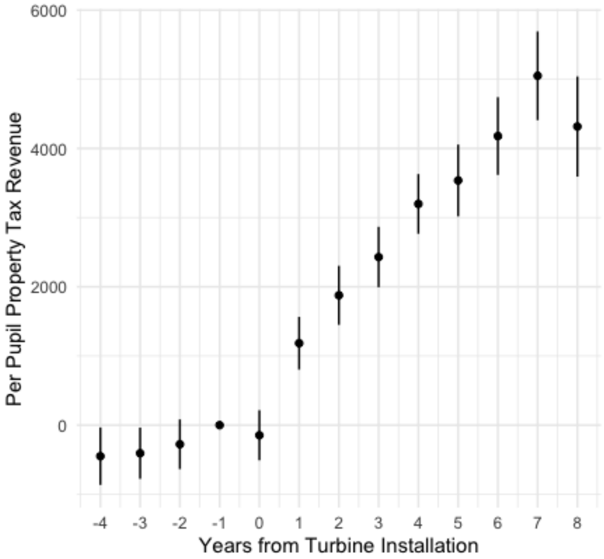
Table 6:

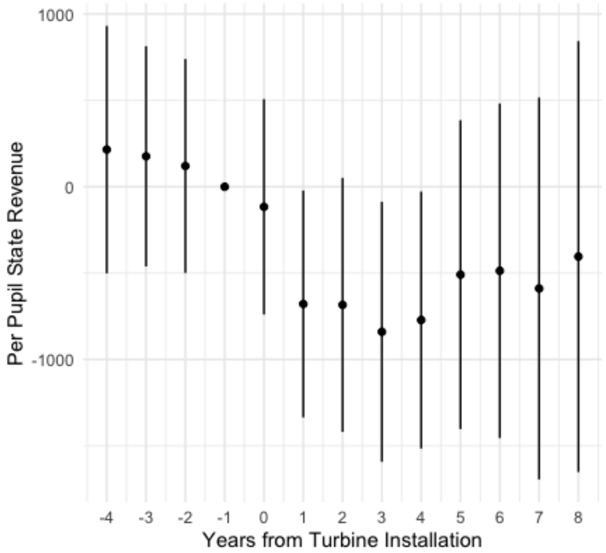
	Dependent variable:
	Per Pupil Outlay Capital Spending
5+ Years Before*Treatment	—
4 Years Before*Treatment	-223.613
	(252.951)
3 Years Before*Treatment	-460.810^{**}
	(225.232)
2 Years Before*Treatment	-468.305^{**}
	(218.753)
Year of*Treatment	-480.607^{**}
	(220.271)
1 Year After*Treatment	-490.036^{**}
	(232.029)
2 Years After*Treatment	-1.362
	(259.718)
3 Years After*Treatment	338.958
	(265.894)
4 Years After*Treatment	920.995^{***}
	(262.702)
5 Years After*Treatment	805.258^{**}
	(315.915)
6 Years After*Treatment	$1{,}904.320^{***}$
	(342.103)
7 Years After*Treatment	753.266^{*}
	(390.553)
8 Years After*Treatment	$1{,}755.359^{***}$
	(440.696)
9+ Years After*Treatment	—
Year FE and District FE and Constant	—
Observations	4,164
R^2	0.302
Adjusted R^2	0.195
Residual Std. Error	1,053.121 (df = 3609)
F Statistic	2.823^{***} (df = 554; 3609)
Note:	*p<0.1; **p<0.05; ***p<0.01

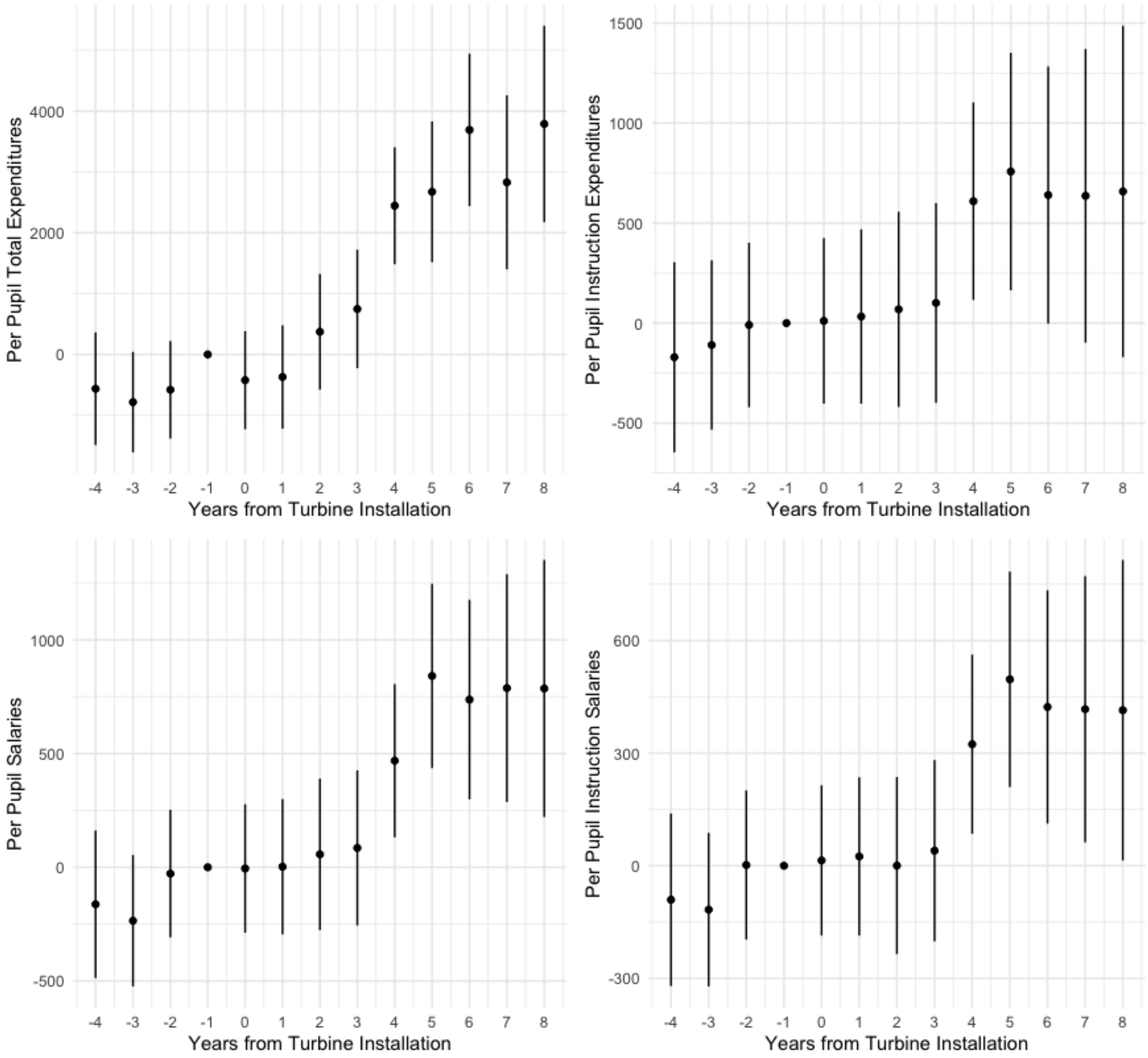
9.2 Graphs

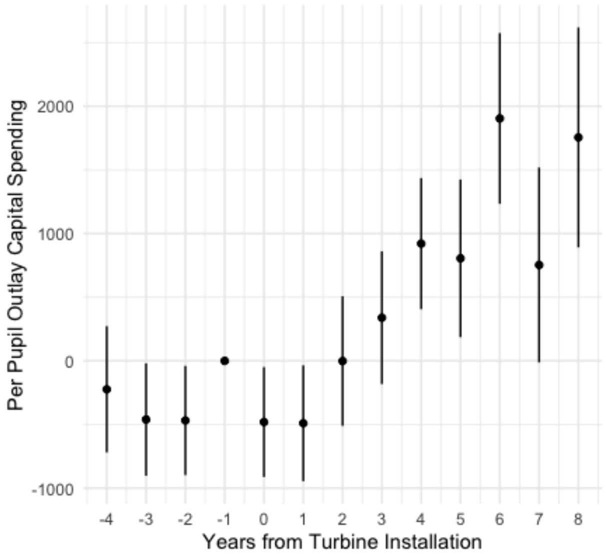
Error bars represent 95% confidence intervals

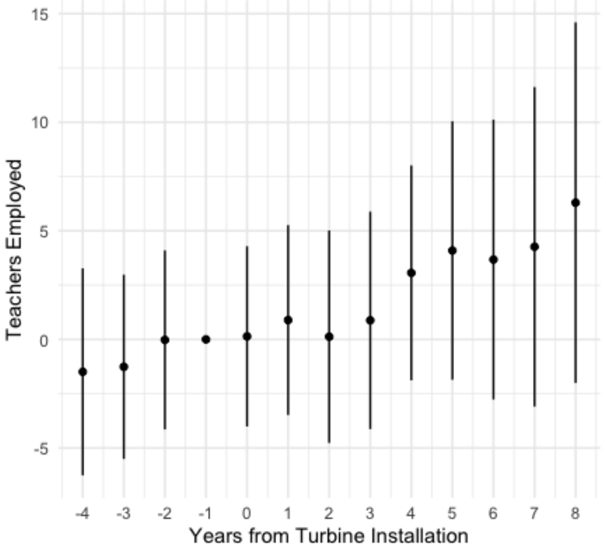


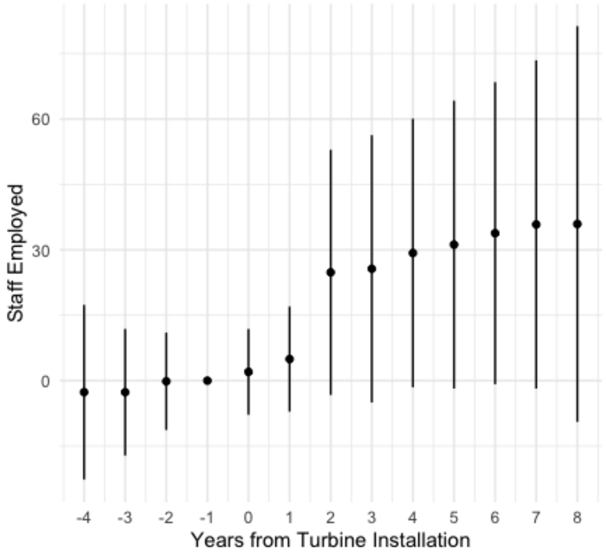





Per Pupil Total Expenditures
4000
2000
0
Per Pupil Instruction Expenditures
1500
1000
500
0
-500
Per Pupil Salaries
1000
500
0
-500
Per Pupil Instruction Salaries
600
300
0
-300
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
Years from Turbine Installation


Per Pupil Outlay Capital Spending
2000
1000
0
-1000
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
Years from Turbine Installation


Teachers Employed
15
10
5
0
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
Years from Turbine Installation


Staff Employed
60
30
0
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
Years from Turbine Installation

9.3 Ad Valorem Tax Levies in Oklahoma

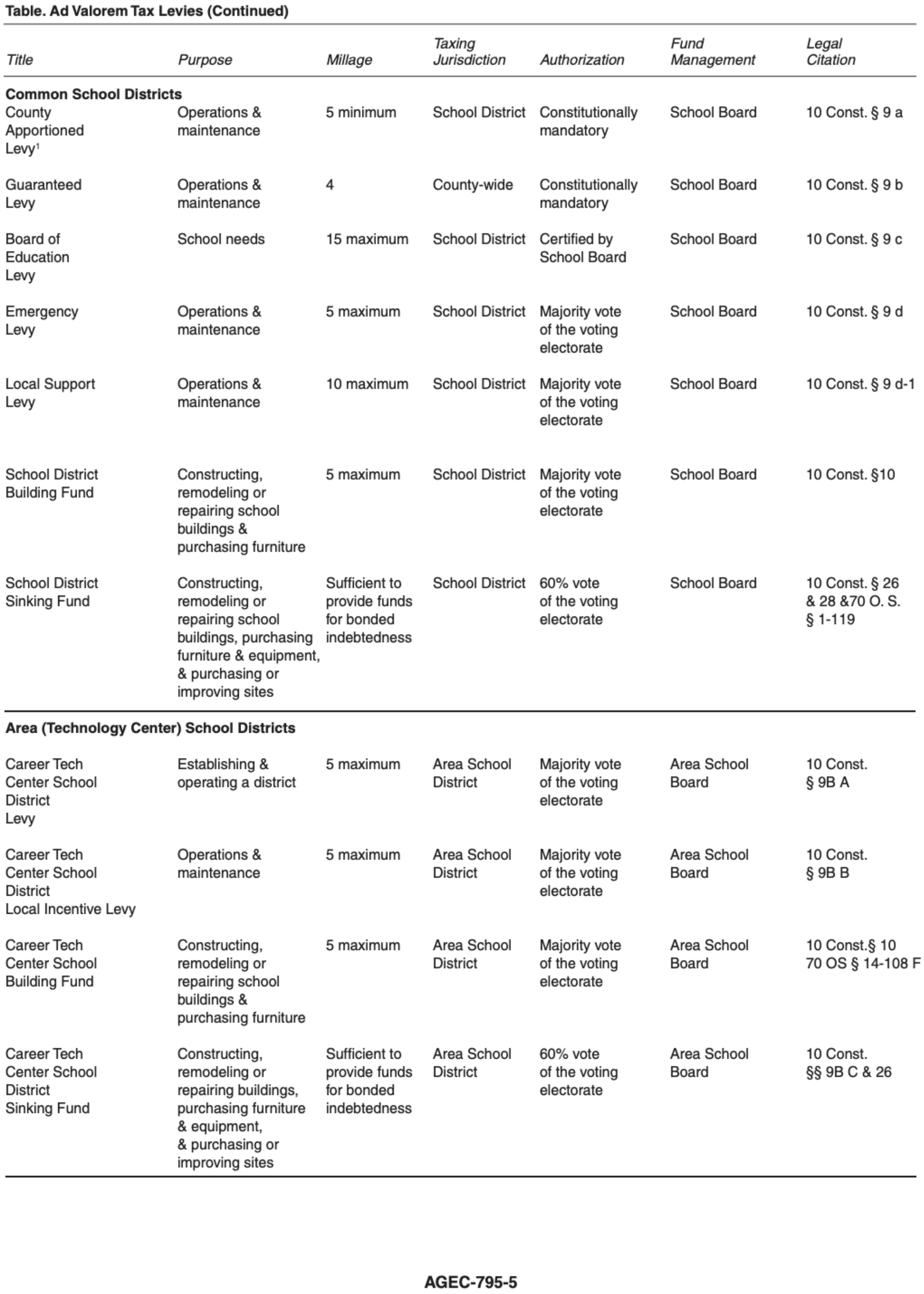


Table. Ad Valorem Tax Levies (Continued)

Title	*Purpose*	*Millage*	*Taxing Jurisdiction*	*Authorization*	*Fund Management*	*Legal Citation*
Common School Districts						
County Apportioned Levy[1]	Operations & maintenance	5 minimum	School District	Constitutionally mandatory	School Board	10 Const. § 9 a
Guaranteed Levy	Operations & maintenance	4	County-wide	Constitutionally mandatory	School Board	10 Const. § 9 b
Board of Education Levy	School needs	15 maximum	School District	Certified by School Board	School Board	10 Const. § 9 c
Emergency Levy	Operations & maintenance	5 maximum	School District	Majority vote of the voting electorate	School Board	10 Const. § 9 d
Local Support Levy	Operations & maintenance	10 maximum	School District	Majority vote of the voting electorate	School Board	10 Const. § 9 d-1
School District Building Fund	Constructing, remodeling or repairing school buildings & purchasing furniture	5 maximum	School District	Majority vote of the voting electorate	School Board	10 Const. §10
School District Sinking Fund	Constructing, remodeling or repairing school buildings, purchasing furniture & equipment, & purchasing or improving sites	Sufficient to provide funds for bonded indebtedness	School District	60% vote of the voting electorate	School Board	10 Const. § 26 & 28 &70 O. S. § 1-119
Area (Technology Center) School Districts						
Career Tech Center School District Levy	Establishing & operating a district	5 maximum	Area School District	Majority vote of the voting electorate	Area School Board	10 Const. § 9B A
Career Tech Center School District Local Incentive Levy	Operations & maintenance	5 maximum	Area School District	Majority vote of the voting electorate	Area School Board	10 Const. § 9B B
Career Tech Center School Building Fund	Constructing, remodeling or repairing school buildings & purchasing furniture	5 maximum	Area School District	Majority vote of the voting electorate	Area School Board	10 Const.§ 10 70 OS § 14-108 F
Career Tech Center School District Sinking Fund	Constructing, remodeling or repairing buildings, purchasing furniture & equipment, & purchasing or improving sites	Sufficient to provide funds for bonded indebtedness	Area School District	60% vote of the voting electorate	Area School Board	10 Const. §§ 9B C & 26

AGEC-795-5

Source: Lansford, Notie. "Ad Valorem Taxes". Oklahoma State University Extension (2017). https://extension.okstate.edu/fact-sheets/ad-valorem-taxes.html