School District Revenue Shocks, Resource Allocations, and Student Achievement: Evidence from the Universe of U.S. Wind Energy Installations

Eric Brunner, Ben Hoen, and Joshua Hyman*

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Abstract

We examine the impact of wind energy installation on school district finances and student achievement using data on the timing, location, and capacity of the universe of U.S. installations from 1995 through 2017. Wind energy installation led to large, exogenous increases in local revenues to school districts, with only minimal offsetting reductions in state aid. Expenditures increased accordingly, causing dramatic increases in capital outlays, but only modest increases in current spending, and little to no change in class sizes or teacher salaries. We find zero impact of wind energy installation on student test scores. Using administrative data from Texas, the country's top wind energy producer, we replicate our national results, and also find zero impact of wind energy installation on high school completion and other longer-run student outcomes.

* Eric J. Brunner, Department of Public Policy, University of Connecticut, 10 Prospect Street, 4th Floor, Hartford, CT 06103, eric.brunner@uconn.edu; Ben Hoen, Electricity Markets and Policy Group, Lawrence Berkeley National Laboratory, bhoen@lbl.gov; Joshua Hyman, Department of Economics, Amherst College, Amherst MA 01002, jhyman@amherst.edu.
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I. Introduction

Does increased school funding improve student outcomes? Providing a well-identified, generalizable answer to this question has proven difficult due to a lack of nationwide, plausibly exogenous variation in school funding. A growing body of work has overcome this challenge by examining the nationwide impacts of statewide school finance reforms (Hoxby, 2001; Card & Payne; 2002; Jackson, Johnson, & Persico, 2016; Lafortune, Rothstein, & Schanzenbach, 2018; Candelaria & Shores, 2019; Johnson & Jackson, 2019; Biasi, 2019; Klopfer, 2017; Brunner, Hyman, & Ju, 2020). Other more localized work has examined shocks to school funding in a single state, either due to a school finance reform (e.g., Downes, 1992; Clark, 2003; Papke, 2005; Hyman, 2017), a kink or quirk in the state aid formula (Kreisman and Steinberg, 2019; Giglioti and Sorensen, 2019), local tax elections (Baron, 2020), or local capital campaigns (Cellini, Ferreira, & Rothstein, 2010; Neilson & Zimmerman, 2014; Martorell, Stange, & McFarlin, 2016; Lafortune & Schonholzer, 2018). One very recent study exploits local tax elections in several states (Abott, Kogan, Lavertu, & Peskowitz, 2020). While state-specific studies provide important contributions, generalizability is always a concern. School finance reform is the only studied policy that has increased school funding on a national scale, and while it is an important reform, its effects on student outcomes may not generalize to other types of school revenue shocks or policies affecting school funding.[1]

In this paper, we provide evidence on the impacts of increased school funding from a novel source of variation affecting most states since the 1990s: wind energy installation. Wind energy production has grown substantially in the U.S. over the past decades, with less than 2 GW of capacity in 1995, and over 100 GW in 2019 (U.S. Energy Information Administration, 1995; AWEA, 2020). Wind projects represented 39 percent of new commercial energy installations in 2019, and generated $1.6 billion in revenues to states and local jurisdictions (AWEA, 2020). The growth in wind energy production over time, coupled with the significant variation both across and within states in the geographical location of wind energy production, provides an ideal setting to examine how wind energy installation has impacted school district finances and student outcomes.

We use data on the timing, location, and capacity of the universe of wind energy installations in the U.S. from 1995 through 2017 to examine the impacts of wind energy installation on school district revenues, expenditures, resource allocations, and student achievement. We geocode wind energy installations to school districts, and combine data on the timing and capacity of wind installations with National Center for Education Statistics (NCES) and Schools and Staffing Survey (SASS) school district

[1] Jackson, Wigger, and Xiong (Forthcoming) examine the closely related question of whether *decreases* in school funding matter by exploiting negative shocks to school spending due to the Great Recession. Their paper is national scale, however, examining the impacts of decreases in spending is substantively different from examining the impacts of spending increases.

data on revenues, expenditures, staffing, enrollments, and teacher salaries, and with student achievement data from the National Assessment for Education Progress (NAEP) and Stanford Education Data Archive (SEDA). We use event-study and difference-in-differences methodologies that exploit the plausibly exogenous timing and location of wind energy installations.

We find that wind energy installation led to large, exogenous increases in total per-pupil revenues due to increases in local revenues, with only minimal offsetting reductions in state aid. State aid formulas often penalize locally financed increases in operating expenditures and, as such, districts spent the new revenues primarily on capital outlays, causing dramatic increases in capital expenditures, but only modest increases in current expenditures, with little to no reductions in class sizes or increases in teacher salaries. Turning to student achievement, we find fairly precisely estimated zero impacts of wind energy installation on school district average test scores. To examine whether wind energy installation affected outcomes other than student test scores, we focus on Texas, which is the nation's top wind energy producer, and has administrative data on longer-run student outcomes in addition to student test scores for our entire sample period. We find the same pattern of effects in Texas as we do nationwide on district revenues, expenditures, and student test scores. We also find a precisely estimated zero impact of wind energy installation on high school graduation rates, and no evidence of improvements in other outcomes, such as Advanced Placement or college entrance exam-taking.

Finally, we explore an additional way in which school districts may benefit from wind energy installation: property tax relief. The large increases in local revenues from wind energy installation suggest that districts are not taking all of these windfalls as tax relief, but are they taking any? We use historic school district property tax rate data in Texas and Illinois to examine the impact of wind energy installation on school district property tax rates. We find that, in Illinois, districts respond to the increased revenues from wind installation by reducing their property tax rates. In Texas, where state laws incentivize districts with wind energy installations to pass new bonds to promote capital spending and to pay for these bonds by increasing property tax rates, we subsequently see tax rates slightly increase after wind energy installation.

Our study makes several contributions to the literature. First, it contributes to the environmental economics and local public finance literature examining the impacts of energy installation on local finances and welfare. Wind energy has grown significantly over the past two decades, and is now the nation's leading source of new commercial energy installation (AWEA, 2020). It is important to understand the effects of wind energy installation on local school districts revenues, resource allocations, and student outcomes. Prior work has examined impacts on school finances in a single state, such as Texas and Oklahoma (De Silva et al., 2016; Reategui & Hendrickson, 2011; Ferrel & Conaway, 2015;

Kahn, 2013; Castleberry & Greene, 2017; Loomis & Aldeman, 2011).[2] Our study adds to this literature by estimating effects nationwide and on student achievement.

Second, our paper contributes to the public economics literature on "flypaper" effects that examines whether intergovernmental grants and exogenous increases in local tax revenue "stick where they hit" rather than being crowed out by local responses, such as property tax relief. Some studies in this literature find substantial or even complete flypaper (Feiveson, 2015; Dahlberg et al., 2008), while others find little or no flypaper (Knight, 2001; Gordon, 2004; Lutz, 2010; Cascio, Gordon, & Reber, 2013). While some states, such as Illinois, reduce their local property tax rates in response to wind energy installation, the large increases in local revenue that we find imply strong flypaper effects. Further, as in other recent work, we find that local context affects the extent to which revenue shocks are taken as property tax relief instead of increasing school budgets (Brunner et al., 2020).

Finally, our study provides nationwide evidence on the effects of increased school spending on student achievement from an exogenous source of variation in spending other than school finance reform. Our finding that most of the increases in school spending are devoted to capital expenditures, and that these have no discernible impacts on student outcomes, contributes to the growing literature on the impacts of capital expenditures on student achievement. This literature finds mixed results: several studies, especially those focused on extremely large capital projects in highly impoverished urban districts with dilapidated school facilities, such as Los Angeles, California, and New Haven, Connecticut, find positive impacts on student achievement (Neilson & Zimmerman, 2014; Hong & Zimmer, 2016; Conlin & Thompson, 2017; Lafortune & Schonholzer, 2018). However, Cellini et al. (2010), Martorell et al. (2016), Goncalves (2015), and Baron (2020), focusing on California, Texas, Ohio, and Wisconsin, respectively, find zero impacts. All of the aforementioned studies focus on a single state or school district. Our study is the first to provide nationwide evidence on the impacts of capital spending, finding that capital investments do little to improve students' academic achievement.

II. Wind Energy and Tax Revenue

As noted previously, wind energy production in the United States has increased substantially over the last several decades, growing from less than 2 GW of total capacity in 1995 to over 100 GW in 2019. Furthermore, there is wide variation in the geographic location of wind energy installations both within and across states. For example, wind energy currently comprises 36%, 34%, and 32% of generated electricity in Kansas, Iowa, and Oklahoma, respectively, and 3%, 0.7%, and less than 0.01% in New York, Massachusetts, and Connecticut. Commercial wind installations or projects in the United States

[2] A small number of studies have also examined the impact of the shale energy boom in Texas on school district finances (Weber et al., 2014; Newell & Raimi, 2014; Marchand & Weber, 2015).

typically consist of several individual turbines, usually ranging in capacity from 1 to 3 megawatts (MW) each. By 2019, there were over 1,500 commercial wind installations in the United States comprised of over 61,000 individual turbines. The mean and median number of turbines in a commercial wind installation or project as of 2019 was 42 and 21 respectively, while the mean and median capacity of commercial wind projects was 76 and 44 MW, respectively.[3]

Figures Ia – Id document the geographical location and growth of wind energy production in the continental United States between 1995 and 2016. The figures illustrate installed wind turbine capacity (in megawatts) by county and year. In 1995, wind energy production was extremely rare and was concentrated almost entirely in California and to a lesser degree in Texas. There were only 16 school districts in the U.S. with wind energy installed within their boundaries at that time. By 2002, wind energy production had begun to spread across the mid- and north-west while also expanding throughout Texas counties, affecting 99 school districts. By 2009, there were 419 affected districts, and as illustrated in Figure 1d, by 2016, wind energy production had spread across 38 states, affecting 900 school districts, in the continental US, the main exception being the southeastern US.[4]

There is substantial variation across states in the property tax treatment of commercial wind energy projects. Specifically, as noted by the American Wind Energy Association (AWEA, 2017), property tax treatment typically falls into five broad categories: 1) states that offer no special property tax treatment, implying wind installations are taxed just like other real property; 2) states that adopted specific formulas for taxing wind energy installations; 3) states where local jurisdictions or the state have the authority to offer special property tax treatment; 4) states that utilize an income generation or production tax method for wind energy installations; and 5) states that offer full or partial property tax exemptions.[5] Furthermore, many states allow local jurisdictions to offer commercial wind projects special tax treatment through mechanisms such as payments in lieu of taxes (PILOTS), property tax abatements, and tax increment financing (See Appendix A for details on state-specific wind energy policies).

Because most school districts in the United States are independent jurisdictions with their own taxing authority, when a wind energy installation begins operation within the boundaries of a school district, the district will typically benefit financially from the expansion of its property tax base. However, the degree to which a school district benefits from a wind energy installation will depend on both the state and local laws and ordinances governing wind energy property taxation discussed above and the interaction of those laws with state school finance formulas. For example, during our sample timeframe,

[3] Authors calculations based on data from the United States Wind Turbine Database (USWTDB) (Hoen et al., 2020).
[4] See Appendix Figures Ia – Id for analogous maps of county-level installed wind turbine capacity per-pupil (in kilowatts), which look very similar to main Figures Ia – Id.
[5] For more details on the property tax treatment of wind energy, see "Property Tax Treatment of Commercial Wind Projects", American Wind Energy Association and Polsinelli PC, 2017.

Kansas granted a full lifetime exemption from property tax payments on wind installations and although some wind projects made PILOT payments to hosting counties, individual school districts typically received little to no revenue from the projects. Similarly, Wyoming has a centralized system of school finance and thus any revenue that is generated from wind energy projects is captured entirely by the state and redistributed through the state's school foundation program.

Texas is another example where state laws governing the taxation of wind energy installations and state school finance formulas result in a complicated system of local taxation of wind energy. School districts in Texas may approve a tax abatement agreement which allows a temporary, 10-year limit on the taxable value of a new wind project. These agreements, formally known as Chapter 313 agreements, apply only to school district taxes levied for maintenance and operations (M&O). Taxes for debt service, known as interest and sinking (I&S) fund payments are not subject to the limitation. Once a Chapter 313 agreement ends, most of the property tax revenue generated from a wind project goes back to the state due to the Chapter 41 Recapture law in Texas (commonly referred to as Robin Hood). Because revenue designated for I&S (debt service) is not subject to recapture and furthermore because the full increase in assessed value due to a wind project immediately goes on a school district's tax rolls for I&S, there is a strong incentive for school districts in Texas to pass a bond for school capital projects and use the wind project revenues to "subsidize" the capital improvement projects.

Appendix A provides more information on state and local laws and ordinances governing wind energy property taxation and how those laws interact with state school finance formulas. We present that information for the 21 states with the largest installed capacity as of 2018. These state account for approximately 95% of the total installed wind capacity in the nation.

III. Data

We construct an original panel dataset that combines information on: 1) the universe of wind energy installations in the continental United States; 2) school district revenues, expenditures, pupil-teacher ratios, and teacher salaries; 3) student achievement, as measured by standardized test scores; and 4) census data on the socio-economic characteristics of school districts.

National data on installed wind capacity comes from the United States Wind Turbine Database (USWTDB). The USWTDB contains information on the date each wind turbine became operational, the wind capacity of each turbine measured in kilowatts, and the longitude and latitude of each turbine. We use this information to geocode every turbine to a single school district using 1995 school district boundary files maintained by the National Center for Education Statistics (NCES). [6] We then create a

[6] The matched USWTDB and school district boundary data includes 1,916 "behind the meter" turbines. Because these turbines are intended for on-site use rather than being part of a larger wind energy project designed for

panel dataset containing annual data on total installed wind capacity in each school district by aggregating information on the capacity of every turbine in operation in a school district in a given year up to the school district level.

We combine the annual data on school district installed wind capacity with annual data on district revenue and expenditures from the Local Education Agency Finance Survey (F-33) maintained by the NCES. The F-33 surveys contain detailed annual revenue and expenditure data for all school districts in the United States for our sample period of 1994-95 to 2016-17. In the empirical work that follows we utilize seven revenue and expenditure outcomes: 1) local revenue, which is primarily composed of property tax revenue; 2) state revenue, which primarily consists of state aid (grants) to local school districts, revenue in lieu of taxes, and payments on behalf of school districts; and 3) total revenue, which is the sum of local, state, and federal revenues.[7] The expenditure outcomes are: 1) current expenditures, which consists of expenditures for daily operations such as teacher salaries and supplies; 2) capital outlays, which consist of expenditures for new school construction and modernization as well as the purchase of equipment and land; 3) other expenditures, which consists of community and adult education, interest on debt, and payments to other governments (such as the state) and school systems (such as charter and private schools); and 4) total expenditures, which is the sum of current expenditures, capital outlay, and other expenditures. All of these variables are divided by enrollment to obtain per-pupil measures and are adjusted to real 2017 dollars using the Consumer Price Index (CPI).

We merge our combined dataset with several other data sources. First, for the period 1994-95 to 2016-17, we merge in data from the annual common core of data (CCD) school district universe surveys that provide staff counts for every school district. We then construct district-level estimates of the pupil-teacher ratio by dividing total full-time equivalent teachers (FTE) by total district enrollment.[8] Second, we combine our dataset with data from the Special School District Tabulations of the 1990 Census on median household income, fraction of the population at or below the poverty line, fraction white, fraction rural, fraction age 65 or older, and fraction of adults 25 and older with a Bachelor's degree.[9] Third, we combine our dataset with information on teacher compensation. Teacher salaries are typically a lock-step schedule based on years of experience and whether or not a teacher has a Master's degree. While district

commercial electrical generation, we drop these turbines from the analysis. We note, however, that all of our results are robust to including these behind the meter turbines.

[7] We do not present results for federal revenues, because they are very small and have little to no response to wind energy installation.

[8] Because staff counts tend to be noisy, we follow Lafortune et al. (2018) and set values of the pupil teacher ratio that were in the top or bottom 2% of the within state-year distribution to missing.

[9] 1990 district demographic data is missing for a small number of school districts. Rather than excluding these districts, we matched school districts to counties and then replaced the missing district-level values of each variable with their county-level equivalent.

average teacher salaries are provided in the CCD, these conflate changes to the teacher salary schedule with changes in hiring of new teachers that are usually paid less than the average teacher in the district. Because information on district teacher salary schedules are not available in our primary CCD data, we use salary schedule information from the U.S. Department of Education Schools and Staffing Survey (SASS), which surveys a random cross-section of school districts every few years about staffing, salaries, and other school, district, teacher, and administrator information. We focus on district base teacher salary, which is available in every wave and particularly informative about average teacher salaries given the high rate of teacher attrition and relatively large degree of compression in teacher wages. Unfortunately, given the limited number of years and overlap of districts across waves, we lose about 94 percent of our sample size.

Finally, we use restricted-access microdata from the National Assessment of Educational Progress (NAEP) to examine student achievement. The NAEP provides representative samples of math and reading test scores in grades four and eight from over 100,000 students nationwide every other year since 1990. In each wave, representative samples of school districts from across the U.S. are required to have their students take the NAEP math and reading test in grades four and eight.[10] We restrict the data to the NAEP reporting sample and to public schools. Rather than providing a single score for each student, NAEP provides random draws from each student's estimated posterior ability distribution based on their test performance and background characteristics. We use the mean of these five draws for each student, essentially creating an Empirical Bayes "shrunken" estimate of the student's latent ability. Following Lafortune et al. (2018), we then standardize the mean score by subject and grade to the first year each subject and grade was tested. We then aggregate these individual-level scores to the district-subject-grade-year level, weighting the individual scores by the individual NAEP weight. We merge the data to our primary dataset using the NCES unique district ID that is available in the Common Core of Data (CCD) and in the NAEP data from 2000 onward.[11]

While the NAEP provides nationally representative test score data back to the 1990s, it suffers from small sample sizes relative to our baseline data because it is only every other year and a sample of districts. We attempt to partially remedy this drawback by merging the NAEP with a newer source of test score data: the Stanford Education Data Archive (SEDA). For every state and for grades three through eight, researchers at Stanford collected district test scores from 2009-2015 and standardized those test scores to the NAEP scaling (Reardon et al., 2018).[12] We start with the NAEP grade 4 and 8 data from

[10] The NAEP also tests other subjects such as writing, science, and economics, but we focus on math and reading because they were tested most consistently across years.
[11] Prior to 2000, the NAEP data did not include this unique district ID. NCES provided us with a crosswalk that they developed in collaboration with Westat to link the NAEP district ID and the NCES district ID for those earlier years.
[12] These test scores are part of state standardized exams used for accountability purposes.

1996-2015, and then fill in for 2009-2015 SEDA grade 4 and 8 scores for any district*year without a NAEP score. The result is a dataset containing test scores for a sample of districts every other year from 1996-2007, and for the universe of districts every year since 2009. We standardized all scores to mean zero and standard deviation one within year, grade, and subject.

We restrict our main sample in several ways. First, we limit the sample to traditional school districts, namely elementary, secondary and unified school systems, and thus drop charter schools, college-grade systems, vocational or special education systems, non-operating school systems and educational service agencies.[13] Second, we drop states (and thus all districts within a state) without any wind energy installations over our sample time period of 1995-2017.[14] Third, we drop districts with observed wind energy installations if the maximum wind capacity over our sample time frame was less than 2 megawatts (MW).[15] Fourth because the NCES finance data tends to be noisy, we restrict the sample to school districts with enrollment of 50 students or more in every year of our sample. Fifth, we drop Kansas from the analysis since the state provides a full lifetime exemption from property tax payments, and thus school districts do not benefit from wind energy projects. We similarly drop Wyoming from the analysis because their school finance systems prevent revenue generated from wind energy installations from flowing to local school districts (see Section II). We show in Table 3 that the results are nearly identical when we include Kansas and Wyoming.

Our final sample consists of 11,038 school districts located in 35 states over the period 1995-2017.[16] Among the 11,038 districts in our sample, 638 had a wind energy installation at some point between 1995 and 2017. Table 1 presents summary statistics for the outcome measures used in our analysis. The table presents means and standard deviations for the full sample and separately for districts with and without wind energy installations. Districts with wind energy installations have slightly lower

[13] We also drop a small number of observations associated with the following types of educational agencies: 1) Regional education services agencies, or county superintendents serving the same purpose; 2) State-operated institutions charged, at least in part, with providing elementary and/or secondary instruction or services to a special-needs population; 3) Federally operated institutions charged, at least in part, with providing elementary and/or secondary instruction or services to a special-needs population; and 4) other education agencies that are not a local school district.

[14] Those states are: Alabama, Arkansas, Connecticut, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina and Virginia.

[15] According to the Lawrence Berkeley National Laboratory, early commercial scale wind turbines had an average capacity of 1.5 MW. Turbine capacity has increased over time with the average capacity of a turbine being 2.15 MW in 2016. Thus, by limiting the sample of school districts with wind energy installations to those with 2 MW or more, we are essentially eliminating districts with a single turbine. We show in Table 3 that our results are robust to this decision.

[16] The states are: Arizona, California, Colorado, Delaware, Idaho, Illinois, Indiana, Iowa, Main, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Dakota, Tennessee, Texas, Utah, Vermont, Washington, West Virginia, and Wisconsin.

per-pupil local and total revenue and also slightly lower per-pupil total and current expenditures. Districts with wind energy installations also have lower pupil-teacher ratios and base teacher salaries.

To provide additional context about how districts with and without wind energy installations differ, Table 1 also presents summary statistics for our outcomes and control variables at baseline. For the outcome measures and enrollment, baseline corresponds to the 1994-95 year. For all the control variables other than enrollment, baseline corresponds to 1989-90. Similar to the first panels of Table 1, districts with wind energy installations have lower per-pupil local and total revenues and lower per-pupil total and current expenditures, although the differences are larger than in the first panels of Table 1. Not surprisingly, districts with wind installations tend to be smaller and significantly more rural. They also tend to contain households with lower income and lower educational attainment.

IV. Methodology

To examine the effect of wind energy installation on school district revenues, expenditures and resource allocations, we employ a difference-in-differences identification strategy. We begin with a non-parametric event-study specification of the following form:

$$y_{ist} = \sum_{j=-6}^{8} \gamma_j T_{j,ist} + X_{is}\theta_t\kappa + \delta_i + \lambda_{st} + \eta_{ist}, \tag{1}$$

where y_{ist} denotes an outcome of interest for district *i* in state *s* in year *t*; $T_{j,ist}$ represents a series of lead and lag indicator variables for when a wind energy installation became operational in district *i*, X_{is} is a vector of school district characteristics at baseline interacted with a linear time trend, θ_t; δ_i is a vector of school district fixed effects; λ_{st} is a vector of state-by-year fixed effects, and η_{ist} is a random disturbance term. We re-center the year a wind energy installation became operational so that $T_{0,ist}$ always equals one in the year the wind project became operational in district *i*. We include indicator variables for 1 to 6 or more years prior to a wind project becoming operational ($T_{-6,ist} - T_{-1,ist}$) and 1 to 8 or more years after the beginning of operation ($T_{1,ist} - T_{8,ist}$). Note that T_{-6ist} equals one in all years that are 6 or more years prior to the wind project becoming operational, and $T_{8,ist}$ equals one in all years that are 8 or more years after the beginning of operation. The omitted category is the year the wind project became operational, $T_{0,,ist}$.

The coefficients of primary interest in equation (1) are the $\gamma_j's$, which represent the difference-in-differences estimates of the impact of wind energy installation on our outcomes of interest in each year from t_{-6} to t_8. The estimated coefficients on the lead treatment indicators ($\gamma_{-6}, \ldots, \gamma_{-1}$) provide evidence on whether our outcomes were trending prior to the time a wind energy project became operational in district i. If wind energy induces exogenous increases in district revenues, expenditures etc., these lead treatment indicators should generally be small in magnitude and statistically insignificant. The lagged treatment indicators ($\gamma_{+1}, \ldots, \gamma_{+8}$) allow the effect of wind energy installations on our outcomes of interest to evolve slowly over time and in a nonparametric way. Given that treatment (wind energy installation) occurs at the district level, in all specifications we cluster the standard errors at the school district level.

The inclusion of state-by-year fixed effects in equation (1) implies that our estimates are identified off of within state variation in school district exposure to wind energy installations. Thus, our specifications control nonparametrically for differential trends in our outcomes of interest that are common to all districts within a state and across time. In our most parsimonious specification, X_{is} includes 1995 district enrollment and 1990 district median income and the fraction of adults 25 and older who have a Bachelor's degree. We then add 1990 district fraction of the population at or below the poverty line, fraction white, fraction 65 or older, and fraction rural. We exclude time-varying characteristics because they could be affected by the installation of a wind energy project within a school district (i.e., endogenous controls). Therefore, we include each characteristic interacted with a linear time trend to allow for differential trending by districts with different baseline values of these characteristics.

Given the substantial effect of statewide school finance reforms (SFRs) on district finances and student achievement during our sample period, we additionally control in all models for the impacts of SFRs. Specifically, we created an indicator variable that equals unity after the implementation of a SFR and allow the effects of SFRs to vary by district income by interacting the SFR indicator with indicators for terciles of the within-state 1990 median income distribution.[17]

We complement the event-study specification with a standard difference-in-differences model to increase our precision by pooling estimates within both the pre- and post-wind energy installation periods:

$$y_{ist} = \alpha_0 + \alpha_1 Treat_{ist} + X_{is}\theta_t + \delta_i + \lambda_{st} + \varepsilon_{ist}, \tag{2}$$

where $Treat_{ist}$ is an indicator that takes the value of one in all years after a wind project becomes operational in district i, ε_{ist} is a random disturbance term, and all other terms are as defined in equation (1). The coefficient of primary interest in equation (2) is α_1 which represents the difference-in-differences estimate of the effect of treatment (wind energy installation) on our outcomes of interest.

[17] We follow the SFR codings from Brunner et al. (2020). Note that we do not include the SFR indictor separately given it would be perfectly collinear with the state-by-year fixed effects.

Finally, to account for the fact that the capacity of wind energy projects varies across districts, in our preferred specifications we allow for continuous treatment by replacing $Treat_{ist}$ with the installed wind project capacity in a district:

$$y_{ist} = \beta_0 + \beta_1 KWPP_{ist} + X_{is}\theta_t + \delta_i + \lambda_{st} + \upsilon_{ist}, \quad (3)$$

where $KWPP_{ist}$ is installed wind project capacity in district *i* in state *s* in year *t* measured in kilowatts per-pupil, υ_{ist} is a random disturbance term, and all other terms are as defined in equation (1). $KWPP_{ist}$ is equal to zero for district-years with no installed wind energy. The coefficient of primary interest in (3) is $\beta_1$which represents the effect of a one-kilowatt per-pupil increase in wind energy capacity on our outcomes of interest.

V. Results

We begin our analysis by examining the impact of wind energy installation on school district revenues and expenditures using the event-study model described above. We estimate equation (1) for our baseline sample of school districts from 1995 to 2017, and plot estimated $\gamma_j's$ and associated 90% confidence intervals from these regressions. Figure IIa shows that within two years of when a district first installs wind energy, local revenues increase by approximately $1,000 per pupil. This increase in revenue grows to between $1,500 and $1,800 per pupil several years after installation. This effect represents a large increase given the mean local revenue in districts with installed wind energy of $6,070. Importantly, we see no evidence of a pre-trend in local revenue prior to installation.

Figure IIb shows similar, though slightly attenuated impacts of wind energy installation on school district total revenue. The magnitudes are between $1,500 and $1,600 several years out. Again, the point estimates are near zero and statistically insignificant prior to wind energy installation. Finally, given that the other large revenue source for districts aside from local revenue is state aid, Figure IIc examines impacts on district revenue from the State. We find small, marginally statistically significant declines in state aid after wind energy installation of between $100 and $250 per pupil. These decreases are consistent with the fact that many state aid formulas provide less aid to districts when local revenues are higher. Again we see no evidence of pre-trends.

We next examine whether these increases in revenues translate into increased expenditures, and toward what types of expenditures districts allocate the revenue increases due to wind energy installation. Figure IIIa shows that total expenditures per pupil increase in a similar pattern over time as total revenues after wind energy installation, though with slightly higher magnitudes. Total expenditures increase by between $1,500 and $2,000 per pupil several years after installation. Current expenditures increase only slightly, by between $200 and $300 per-pupil relative to a mean of just under $11,000 (Figure IIIb). Districts spend a significant share of the revenues toward increased capital spending, which increases by $500 and $1,000 after wind energy installation, off a mean of $1,360 per pupil (Figure IIIc). Finally, in Figure IIId we find that other expenditures, which is simply non-capital and non-current expenditures, increases substantially, also by between $500 and $1000 several years after wind energy installation.[18] None of the figures examining district expenditures show any evidence of differential pre-trends.

We next examine whether any of these expenditure increases lead to impacts on commonly studied inputs to education production, for example, class size and teacher compensation. Figure IVa shows a small, and not quite statistically significant decline in the pupil-teacher ratio, which is our measure of class size, on the order of 0.1 pupils per teacher, relative to a mean of 13.7. This is less than a 1% decline in class size, consistent with the small (1-2%) increases in current spending. As shown in Figure IVb there is no apparent impact on base teacher salaries, however, given the far smaller sample using the SASS data, the results are too imprecise to gain much inference.

One noticeable pattern in the revenue and expenditure results is that the effects of wind energy installation grow over time. It is not immediately clear why this would be the case, as another hypothetical effect could have been that the installation occurs and districts immediately and permanently reap the tax benefits, leading to a sudden increase in the level, but no change in the trend in revenues. We examine and rule out several possible explanations for this pattern. First, the effects on revenues and expenditures are per-pupil, so if installations cause enrollments to decline, then this would cause the pattern that we observe. We estimate the event-study model where the dependent variable is district enrollment and find no impact.[19]

A second possible explanation for the growing effects over time is that we are examining the impact relative to the year of the first wind energy installation in the district. However, 37.5% of districts in our sample with installed wind energy install additional wind turbines over time. To examine whether the growing effects are due to these districts with "multiple events," we drop those districts that install additional wind energy facilities in years following the initial installation. As shown in Appendix Figures III and IV, even after dropping districts with multiple installations we still observe a pattern of rising effects over time.

[18] We explore this result further in Section V(c), finding that it is driven primarily by Texas, and represents payments from districts to the state. Thus, it is not a true increase in district spending, but rather a transfer of a portion of the local revenue increases due to wind installation back to the state due the recapture design of Texas school finance laws.

[19] See Appendix Figure II. There is evidence of a small negative pre-trend in enrollment, with no noticeable impact post installation.

The final explanation is a combination of sun-setting tax abatements and other tax rules that delay the generation of tax revenue from wind energy installations. Many states and local jurisdictions enter into some type of agreement in order to encourage wind development that allows wind developers a grace period in which they do not pay (or pay significantly lower) property taxes. For example, under Iowa's wind energy conversion tax ordinance, a wind project is taxed at 0% during the first year of operation and then in the second through sixth assessment years, a wind project is taxed at an additional 5% of net acquisition costs for each year (5% in year 2, 10% in year 3, etc.) until the seventh year when taxes are capped at 30% of net acquisition cost. While we cannot confirm empirically, laws and agreements such as those in Iowa, which is one of the largest wind energy producing states, appear to be the most likely reason for the growing effect over time.

A. Difference-in-Difference Estimates

We present difference-in-differences (DD) estimates of the impact of wind energy installation in Table 2. Results based on equation (2) with binary treatment are presented in columns 1 and 2, while columns 3-5 present results based on equation (3) with continuous treatment. Row 1, column 1 shows that installation causes a $1,084 per pupil increase in local revenue. Column 1 includes the basic set of controls: baseline enrollment, 1990 median income, and 1990 fraction earning a BA or higher, all interacted with a trend; and a dummy for school finance reforms interacted with terciles of the 1990 within state median income distribution. The effect is very similar, $1,005 per pupil, or 17%, relative to the mean of $6,070, after including the expanded set of controls that adds 1990 percent poor, 1990 percent white, 1990 percent age greater than 65, and 1990 rural status, all interacted with a trend. The effect on total revenues (column 2) is $813 (6%), and the effect on state revenues is -$111 (-2%).

Focusing on our preferred specification in column 2, total expenditures increase by $1,031 (8%), over $200 per pupil more than total revenues increase. The reason that total expenditures can increase more than total revenues is that revenues in our data do not include proceeds from bond sales, while expenditures include the spending resulting from bond sales. For example, when a district passes a bond to finance a capital project, the proceeds do not count toward revenue, but the capital spending on the project is included in capital, and therefore total, expenditures. Current expenditures increase by $133 per pupil, an increase of only 1% relative to the mean current spending in wind energy districts of $10,948. On the other hand, capital expenditures increase by $433 per pupil, or 32%, relative to the mean of $1,360. The larger increases in capital than operating expenditures are perhaps unsurprising given that the school finance laws in many states require a reduction in state aid when local revenue placed in the general fund is used to finance operating expenditures, but do not require a reduction in state aid when local funds are placed in the capital fund and used to finance capital projects.[20] Finally, other expenditures increase by a similar amount, \$465 per pupil, or 45%.

Given the small effect on current expenditures, it is unlikely there would be large impacts on either teacher hiring (i.e., class size) or on increasing teacher compensation. Accordingly, we find decreases in class size of about 0.1 pupils per teacher (marginally statistically significant in column 1; insignificant in column 2). The magnitude of the -0.09 class size estimate from column 2 represents a 0.6% percent decrease. Similarly, we find no evidence of impacts on base teacher salary, with an insignificant point estimate of -\$543 (representing a 1.6% decrease).

While the estimates from the basic DD model with binary treatment are useful, there are two aspects of the model that are suboptimal. First, as in the event-study analysis, the binary treatment variable turns on when the first installation in a district occurs, and so it does not further capture the increased capacity of subsequent installations for the 37.5% of districts with multiple installations over time. Second, the binary treatment variable misses the important variation stemming from different wind energy installations having very different installed capacity, while local property tax generation from wind energy installation almost always reflects installed capacity. For example, the 10th percentile of installed capacity per pupil in our sample among districts and years with installed wind energy is 11 KW/pupil, while the 90th percentile is 642 KW/pupil. These installations clearly have very different tax implications, but the binary installation variable treats them identically.

Given the limitations of the binary treatment results, in columns 3-5 we present results based on equation (3) where we use a continuous measure of treatment, namely installed kilowatts per pupil. In district-years without installed wind energy, this variable equals zero. Once again, the results in column 3 (basic controls) and column 4 (expanded controls) are very similar, so we focus on column 4. Row 1 shows that one additional KW/pupil of installed capacity leads to \$3.78 per pupil of additional local revenue. Column 5 multiplies the point estimate by 243, which is the mean level of installed capacity per pupil among districts and years with installed wind energy. For example, a district with the mean level of installed capacity per pupil experiences an increase of \$918 in local revenue. Total revenues increase by \$3.59 with a 1 KW/pupil increase in capacity, for a \$872 increase at mean capacity. While the previous event-study and binary DD models found small, statistically significant decreases in state revenue, here we find no statistically significant impact on state revenue: a \$0.25 decrease per KW/pupil, which corresponds to a \$61 decrease at the mean.

[20] Discussions between the authors and school district superintendents in several districts with wind energy installations anecdotally confirm that these state laws are the reason districts tend to spend the money on capital expenditures.

In terms of expenditures, we find that total, current, capital, and other expenditures increase by $4.81, $0.88, $2.12, and $1.81 per one KW/pupil increase, respectively, which corresponds to a $1,168, $214, $515, and $439 increase at the mean level of installed capacity. Turning next to the pupil-teacher ratio results, to aid in interpretation for the continuous DD we multiply the pupil teacher ratio by 1,000. Thus, a 1 KW/pupil increase in capacity causes a marginally significant decrease of 0.00015 pupils per teacher, which is equivalent to 0.04 pupils per teacher at the mean. While this is marginally significant, it is essentially zero. Note that the increase in current expenditures is approximately 2% while the pupil teacher ratio decreases by substantially less than 2%. Thus, one interpretation of these findings is that districts are not spending the increases in current expenditures on hiring new teachers, although we do not have enough statistical precision to be confident in this claim. We conservatively interpret these effects as consistent with the prior results that there are small impacts on current spending, and near zero impacts on class size reduction. As in the previous models, there is no impact on teacher salary, though in the continuous DD model, the zero effect at the mean is quite precisely estimated.

In summary, districts that install wind energy see large increases in local revenues, that are only minimally offset by reductions in state aid, leading to large increases in total revenue. The districts spend these increases primarily on capital outlays, and on other, non-current and non-capital expenses, which we examine in further detail below.

B. Sensitivity Analysis

In this section, we conduct six sensitivity checks to examine the robustness of our results to decisions about the way we construct our sample and implement the difference-in-differences analysis. We proceed with our preferred specification, which is the continuous DD model with the expanded set of controls (Table 2, column 4). The first row of Table 3 replicates our baseline preferred model for comparison purposes.

In our first check, we include the eleven states, primarily in the South census region, with no installed wind energy during our sample period. In the second check, we include the two states, Kansas, and Wyoming, which we removed because their laws prevent wind energy taxes from being directed toward local school districts. In our third check, we include districts with a maximum installed wind energy capacity during our sample period of less than 2 MW. In all of these checks, the results are nearly identical to our baseline estimates.

In our fourth check, we restrict to counties with installed wind energy. In our baseline sample, we include counties with no installed wind energy if they are in a state with installed wind energy, even though these counties may be quite different from counties in that state with installed wind energy. This check is meant to create a control group of school districts without installed wind energy that looks more like the treated school districts, by drawing within state comparisons (due to the state-by-year fixed effects) between school districts with wind energy and those without, but that are in counties with wind energy. In spite of the sample size dropping from 218,851 district-years to 42,767, the point estimates are very similar.

Given that treated districts tend to be smaller than untreated districts, in our fifth check we drop large untreated districts. Specifically, we drop districts with no installed wind energy that have enrollment greater than the 90th percentile of enrollment among treated districts. The estimates are nearly identical to those using our preferred specification. In our final specification check we use propensity score weighting to weight higher those non-wind districts that are observationally similar to districts with wind energy.[21] Once again, the estimates using the propensity score weighting are very similar to our baseline results.

C. State Heterogeneity and Other Expenditures

As described in Section II, there is substantial heterogeneity not only in state laws regarding taxation of wind energy installation, but also in school finance laws. The interaction of these two quite heterogeneous sets of laws could create very different impacts of wind energy installation in different states. While the average national effect of wind energy installation we have presented is of primary interest, it is also important to understand whether our results are driven in part by any particular state. An obvious state to consider in our case is Texas, which is by far the largest producer of wind energy in the country, comprising 28% of installed capacity in our national sample.[22] In this section we explore whether and to what extent our national results are driven by Texas.

Table 4 presents effects of wind energy installation on revenues and expenditures using our preferred specification (continuous DD with expanded controls) for our national sample (baseline – column 1), Texas only (column 2), and our national sample without Texas. We find much larger impacts in Texas than in the national sample on local revenue and total revenue of $7.78 and $8.04 per pupil from a 1 KW/pupil increase in capacity. In column 3, where we drop Texas, the point estimates for local and total revenue are substantially smaller at $2.33 and $1.99 respectively. Also, in column 3, the reduction in state revenue increases slightly in magnitude and becomes marginally significant, though it is still quite small ($-0.48). Total, current, capital, and other expenditures in Texas increase by $10.03, $0.88, $4.33, and $4.82, respectively. The effect on current is identical to the baseline estimates, but the other three

[21] Specifically, we run a logit regression of a dummy for a district having wind energy on 1990 rural status, median household income, fraction BA or higher, fraction age 65 or older, fraction white, fraction poor, and baseline enrollment. We then create a propensity score from that regression, which is simply the predicted probability that a district has wind energy. Finally, we create inverse propensity score weights, equal to wind / pscore + (1-wind)/(1-pscore).

[22] The next largest, California, produces only 9% of installed wind capacity in our national sample.

outcomes have much larger point estimates (i.e., an even smaller share of the expenditure increase is devoted toward current spending). Importantly, Texas completely drives the large increases we observed on other expenditures: without Texas, the coefficient on other expenditures drops from \$1.81 to \$0.70 and becomes statistically insignificant.[23]

The large impacts in Texas on other expenditures begs the question of what specific type of expenditure is driving that effect. In the bottom rows of Table 4, we show effects on the sub-categories that comprise other expenditures. The effect in Texas comes almost completely from payments to the state government, with a small increase as well in interest payments on debt. The large increase in payments to the state government is a function of the Texas school finance laws, whereby property tax revenue from districts with high property tax bases is recaptured by the state and redistributed to districts with low property tax bases, a policy commonly referred to as Robin Hood. The large impact on other expenditures, therefore does not actually reflect school district spending on any productive education input, but rather a different form of state aid reduction. This implies that while the effects on total revenue and expenditure appear to be double the baseline effect we estimated, once you subtract off the payments to the state, the effects are only somewhat larger than our national baseline estimates. Furthermore, as discussed in Section II, the laws in Texas incentivize the wind energy money to be spent on capital and not current spending, which is why the effects are concentrated so highly in capital expenditures relative to current.

In spite of the sizable impacts on capital expenditure in Texas, the results for the national sample sans Texas, though attenuated, are still precise and present a similar pattern as before: large increases in revenues and expenditures, with larger effects on capital spending (1.32) than current (0.90), especially considering mean current spending is about ten times larger than capital spending.[24]

D. Student Achievement

In this section, we examine to what extent, if any, the increases in revenues and expenditures from wind energy installation translate into improvements in student achievement. Unlike effects on revenues and expenditures, there is no reason to expect that the effects of wind energy installation would immediately impact achievement, even if expenditures were affected immediately, given that achievement would be affected slowly over time as students are exposed to additional years of increased school funding. Consequently, we first present the event-study figures, where the outcome variable is

[23] The effect on pupil-teacher ratio without Texas is a statistically significant 0.28 reduction, which is larger than our baseline estimate, but still very small. The effect on teacher salary (0.309) is still small and statistically insignificant.
[24] We present all of our main event-study figures dropping Texas in Appendix Figures V, VI, and VII. As in Table 4, column 3, the results are somewhat attenuated, but still precise and showing the same pattern.

district test scores. We then present the DD model, but we modify it to allow the impact to evolve linearly during the post period instead of including a single post indicator as we do in equation (2):

$$NAEP_{ijgst} = \phi_0 + \phi_1 Treat_{ist} + \phi_2 YearsPost_{ist} + \phi_3 (YearsPost_{ist} * Treat_{ist}) + X_{is}\theta_t + \delta_i + \lambda_{st} + \pi_{jg} + \omega_{ijgst} \quad (4)$$

where $NAEP_{ijgst}$ is the average score in district *i*, in tested subject *j* and grade *g*, in state *s*, and year *t*, $Treat_{ist}$ is the dummy for whether a district has installed wind energy, $YearsPost_{ist}$ is a relative-year trend variable that captures the number of years since wind energy was installed (this is negative prior to installation, positive after installation, and zero during the installation year and for districts without wind energy), and $YearsPost_{ist} * Treat_{ist}$ is the interaction of the two, which gives the number of years since installation during the post period. The coefficient on $Treat_{ist}$ gives the jump in the level of test scores, while the coefficient on $YearsPost_{ist}$ shows whether there is any pre-trend, and the coefficient on the interaction term gives the additional increase in scores for every 1 year after installation. We include subject-by-grade fixed effects, π_{jg}, given that the unit of observations is now district-year-subject-grade.

Figure Va shows the event-study analysis, where the outcome is standardized district NAEP scores. Relative years are grouped into pairs to help with precision given the smaller sample size. There is no evidence of a pre-trend, and scores remain flat after installation. There is no evidence of any positive effect on scores, and if anything, there appears to be a very small, and statistically insignificant decrease. We can rule out increases of about 5% of a standard deviation. Given the starkly different results in Texas, and somewhat different results in our baseline sample after dropping Texas, we also show the effects on achievement dropping Texas. The picture looks nearly identical, with no detectable pre-trend or effect post-installation. We obtain a similar, though very noisy, null result when we restrict our sample to Texas. In section V(e), we use Texas administrative data to explore this result with greater precision.

We present the results from equation (4) in Table 5, Panel A. Effects are nearly identical with and without expanded controls: in our baseline sample and in the sample dropping Texas, as in Figure V, there is no statistically significant coefficient on the *YearsPost*, suggesting no pre-trend, or on *Treat* or *YearsPost***Treat*, suggesting no impact. The calculated impact 5 years out is a statistically insignificant negative 0.6 percent of a SD for the baseline sample, and a statistically insignificant positive 0.5 percent of a percent of a SD increase for the sample without Texas. Five years post, we can rule out positive impacts of about four percent of a SD.

Figures Vc and Vd show the impacts on test scores using the combined NAEP and SEDA achievement data, with and without Texas, respectively. Recall, that while the NAEP data are available only every other year and for a sample of districts, the SEDA data are available annually from 2009 –

2015 for the universe of school districts. Again, we see no evidence of any positive impact of wind energy installation on achievement, and can rule out increases of about 0.05 SDs. We show results from the DD model in Panel B of Table 5. As in Panel A (NAEP only), we again see no statistically significant coefficients on any of the three parameters of interest, nor on the effect 5 years post installation. The effects 5 years post are -0.037 and -0.026 with and without Texas, respectively, but again neither is statistically significant.[25] Given the standard errors of 0.026 and 0.027, we can rule out positive impacts of approximately 2–3 percent of a SD. While these estimates do suggest a negative effect, we hesitate to interpret them as such given the imprecision of the estimates, and prefer to conservatively infer a lack of positive impacts. It is worth noting, however, that a negative impact on achievement is not entirely implausible. To the extent that the large increases in capital spending are for building new schools, in the short-run switching schools has been shown to be detrimental to student achievement (Brummet, 2014; Conlin & Thompson, 2017).

What about our positive impacts on current spending? Our estimated effect on current spending of $214 per pupil (Table 2, column 5) is 35.4% (=$214/$604) of that found in Lafortune et al. (2018) for low-income school districts (see their Table 4, column 3). They find that school finance reforms increased test scores by 0.007 SDs a year for those districts, or 0.035 after five years. Scaling that 0.035 by 35.4% to account for our smaller impact on current spending yields an effect of 0.012 SDs, which we cannot rule out given our estimated effect five years out using the combined NAEP and SEDA data. Note also that Lafortune et al. (2018) find significant increases in expenditures on teacher salaries and reductions in class sizes, while we do not, which could help explain why we find zero impacts on achievement, even given the small increases in current spending.[26]

E. Effects of Wind Energy Installation in Texas

One weakness of our achievement analysis relative to the revenues and expenditures analysis, is that we do not have annual, district-level, national achievement data for the bulk of our sample period. A second weakness is that we have no longer-run student outcomes, even though it is possible that capital spending could increase a student's educational attainment, for example, without necessarily improving test scores, by improving students' experience in, and attitudes toward, school. To address these weaknesses, we turn to a case study focusing on a single state: Texas. Texas is the second most populous state (after California), is by far the top wind energy producer in the nation, and, importantly, has publicly

[25] Appendix Table 1 shows zero impacts on test scores using only the SEDA data.
[26] For example, they find a reduction in the pupil teacher ratio of 0.65 pupils, while we find a reduction of 0.04 pupils. We can rule out a reduction greater than 0.09 pupils.

available district-level administrative data on average test scores going back to the beginning of our sample period (1994-95), as well as longer-run student outcomes, such as high school graduation rates.[27]

We begin our case-study with event-study pictures showing the effects of wind energy installation on per-pupil district revenues and expenditures using the Texas administrative data (Figure VI). Local and total and revenues quickly increase by roughly $2,000 per pupil just a couple years post-installation. Total expenditures increase by more than twice that amount, which, as in the national data, can be explained by bond proceeds from capital campaigns being counted only in expenditures and not in revenues. Unsurprisingly, the impacts on total expenditures are driven by large, nearly immediate increases in capital spending approaching $4,000 per pupil, and also by slowly emerging increases in payments servicing debt, presumably to pay off capital outlay bonds. Compared to these large increases in capital spending and debt, there are only tiny positive impacts on current spending.

We next examine the impacts of these increased capital expenditures in Texas on student outcomes. Focusing first on student test scores, Figure VIIa shows a somewhat noisy, null effect post-installation.[28] If anything, there appears to be a temporary negative impact on scores. For most years, we can reject anything greater than a ten percent of a standard deviation score increase. Turning to the estimates from equation (4), neither the *Treat* or *PostYears**Treat* coefficients, nor the effect five years post-installation are statistically significant (Table 6, columns 1 and 2). For the latter, given the -0.074 point estimate and 0.056 standard error, we can reject an increase in test scores of more than 4 percent of a standard deviation, though we note that the confidence interval includes fairly large negative effects.

Given that capital spending could impact important longer-run students outcomes, such as educational attainment, in spite of its zero impact on scores, we turn to examining high school graduation. Available beginning in 1996-97, a district's graduation rate is defined as the number of graduates in year t divided by the number of 9th graders in year t-4, subtracting transfers out of the district and adding transfers into the district. We find a precisely estimated null result of wind energy installation on high school graduation. The event study (Figure VIIb) coefficients hover between -1 and 1 percentage point, and given the point estimate and standard error from the calculated effect 5-years post-installation, we can reject an effect greater than 0.9 percentage points (off a mean of 90 percent).

Finally, to examine whether capital spending affected other longer-run measures of student performance aside from graduation, we create a standardized index of longer-run student outcomes combining the high school graduation rate with five additional measures reflecting advanced course-

[27] The data come from Academic Excellence Indicator System (AEIS) reports from 1994-95 through 2011-12, and from the Texas Academic Performance Report (TAPR) from 2012-13 through 2017-18.
[28] To be consistent with the national analysis, we use the average of math and reading scores for grades 4 and 8.

taking, Advanced Placement (AP) exam-taking, and college entrance exam-taking and performance.[29] Following Kling, Liebman, and Katz (2007), we create the index by normalizing each outcome to have a mean of zero and standard deviation of one, and then take the simple average of all of the outcomes. Again, we find no evidence of any positive impact of wind energy installation on this longer-run student outcome index (Figure VIIc), although the point estimates are not particularly precise: five years post-installation we can reject an effect larger than 13 percent of a standard deviation.[30]

F. Flypaper and Local Tax Rates

Given that there appear to be no benefits to school districts of wind energy installation in the form of higher student achievement, how else might districts benefit? One possible way school districts may benefit is through taking a share of the revenue increase as property tax relief. A large literature in public economics examines the extent to which local jurisdictions reduce local tax effort in the face of a windfall of revenues that are designated for a particular purpose (e.g., education), versus the extent to which the money "sticks where it hits," a phenomenon often dubbed the flypaper effect.[31] Some studies find substantial or even complete flypaper (Feiveson, 2015; Dahlberg et al., 2008), while others find little or no flypaper (Knight, 2001; Gordon, 2004; Lutz, 2010; Cascio, Gordon, & Reber, 2013). In our context, we clearly find at least some flypaper, given the large increases in local revenue. But isolating the precise magnitude of flypaper is challenging, given the heterogeneity in state and local laws governing wind energy taxation.

In theory, one could use information on wind energy taxation laws and pre-installation local tax rates to predict the amount of revenue that should flow to local school districts from a 1 KW/pupil increase in installed capacity, and then compare this predicted amount to our estimated effect on local revenue – any difference between the two would be the estimated amount of property tax relief. Unfortunately, as described in Section II, laws governing wind energy taxation are extremely opaque, usually interact in a complicated manner with school finance formulas, and are often determined at the county or local level, preventing us from undertaking this calculation for our main sample. To our

[29] The five additional measures are: 1) Percent of 11 and 12th graders taking an AP exam, 2) percent of graduates who took the SAT or ACT, 3) the percent of graduates who took the SAT or ACT and scored above a state-determined college-readiness threshold slightly above the national median, 4) percent of 9th-12th graders who took any state-determined advanced coursework or dual-enrolled in a college course, and 5) percent of graduates who completed the state-determined recommended high school curriculum. Effects for each outcome individually are presented in Appendix Table 2.

[30] Given that these longer-run outcomes may take several years to be affected, in Appendix Figures VIII, we show event study pictures of our student outcomes results nationally and for Texas adding relative year dummies for 9, 10, 11, and 12 (or more) years post wind installation rather than combining them into the 8 or more relative years dummy. The patterns of results look the same.

[31] See Hines and Thaler (1995) and Inman (2008) for detailed discussions of and evidence on the flypaper effect.

knowledge, Illinois is the only state that during our sample period had relatively clear and straightforward state-level laws determining the flow of revenues from installed wind energy capacity to school districts. In Appendix B, we use information on Illinois state laws and districts' pre-installation tax rates to conduct a back-of-the-envelope calculation comparing our estimated effect on local revenues in Illinois to the effect of a one MW increase in installed wind energy on local district revenues as predicted from the state laws. We find that the predicted local revenue increase using tax laws and pre-installation tax rates, and therefore assuming no crowd-out, is $3,698, compared to our estimated effect restricting our sample to Illinois of $3,020. Thus, we estimate that property tax relief accounts for 18% (= ($3,698 - $3,020) / $3,698) of the total predicted revenue increase, while 82% of the revenue flows to schools. This is a non-trivial amount of local crowd-out, but is on the high end of estimated flypaper effects.

We provide additional evidence on the flypaper effect by directly estimating the impact of wind energy installation on local school district property tax rates for two states, Illinois and Texas, where we could obtain historic school district property tax rate data. These data are available for a somewhat shorter, more recent period than our baseline data: 2001-2017 for Illinois, and 2000-2018 for Texas.

Figure VIa shows that in Illinois, wind energy installation leads to a statistically significant reduction in the tax rate of about $0.50 by six years out, which is a 13% decrease relative to the mean tax rate in Illinois of $3.75 (for every $100 of assessed value). This result implies that in addition to the local revenue increases after wind energy installation in Illinois, local school district residents are benefiting from property tax relief. In Texas, we see a different story (Figure VIb). Here we see near zero, slightly positive impacts on tax rates. While seemingly counterintuitive, this result is consistent with the Texas school finance laws described above. Specifically, the laws incentivize wind energy districts to pass bonds to raise capital expenditures, and these bonds require increasing tax rates to pay the bonds. Thus, because of the particular formula and recapture aspect of the Texas laws (which focus on current expenditures), districts are incentivized to actually increase their tax rates, a form of crowding-in, after installing wind energy. While we could only obtain historic tax rate data from two states, these two states provide examples of: 1) how school districts in some cases are taking some of the benefit of wind energy as property tax relief, and 2) the significant degree to which local context matters for whether and to what extent local tax effort is crowded out (or crowded in) in the face of a windfall of tax revenue.

V. Conclusions

The only well-identified, national-scale evidence of whether increased school resources improves student outcomes comes from a single policy reform: school finance reform. In this paper, we provide evidence on the impacts of increased school funding due to wind energy installation, a novel source of funding variation affecting most states since the 1990s. We use data on the timing, location, and capacity of the universe of wind energy installations in the U.S. from 1995 through 2017 to examine the impacts of wind energy installation on school district revenues, expenditures, resource allocations, and student achievement. We geocode wind energy installations to school districts, and combine data on the timing and capacity of wind installations with National Center for Education Statistics (NCES) and Schools and Staffing Survey (SASS) school district data on revenues, expenditures, staffing, enrollments, and teacher salaries, and with student achievement data from the National Assessment for Education Progress (NAEP) and Stanford Education Data Archive (SEDA). We use event-study and difference-in-differences methodologies exploiting the plausibly exogenous timing and location of wind energy installations.

We find that wind energy installation led to large, exogenous increases in total per-pupil revenues due to increases in local revenues, with only minimal offsetting reductions in state-aid. Per-pupil expenditures increased accordingly, with the majority of the revenues spent on capital outlays, causing dramatic increases in capital expenditures, and only modest increases in current expenditures, with little to no reduction in class sizes or increase in teacher salaries. We find zero impacts of wind energy installation on school district average test scores. We replicate our main analyses using administrative data in Texas, the largest wind producing state, and further show that wind energy installation had no impact on high school completion or other longer-run achievement measures.

Finally, we examine the impacts of wind energy installation on local school district property tax rates in two states, Illinois and Texas. In Illinois, districts respond to the increased revenues from wind installation by reducing their property tax rates and taking part of the windfall as property tax relief. In Texas, where state laws incentivize districts with wind energy installations to pass new bonds to promote capital spending and to pay for these bonds by increasing property tax rates, we subsequently see tax rates slightly increase after wind energy installation.

Our study provides several contributions to the literature. First, we extend the literature examining the impact of wind energy installation on school districts by examining effects across multiple states and on student achievement, compared to prior studies that focused on a single state and only examined impacts on school finances ((De Silva et al., 2016; Reategui & Henderson, 2011; Ferrel & Conaway, 2015; Kahn, 2013; Castleberry & Greene, 2017; Loomis & Aldeman, 2011). Second, we contribute to the public economics literature on flypaper effects, finding strong evidence of flypaper, but also, as in other recent work, finding that local context affects the extent to which revenue shocks are taken as property tax relief instead of increasing school budgets (Brunner et al., 2020).

Finally, our study provides nationwide evidence on the effects of increased school spending on student achievement from an exogenous source of variation in spending other than school finance reform. Our finding that most of the increases in school spending are devoted to increased capital expenditures, and that these increases have no discernible impacts on student achievement, contributes to the growing literature on the impacts of capital expenditures on student achievement. We provide the first national evidence on the impacts of capital spending, supporting the findings in Cellini et al. (2010), Martorell et al. (2016), Goncalves (2015), and Barron (2020) that these capital investments do little to improve students' academic achievement or attainment.

This is not to say that money doesn't matter in schools. There are specific contexts, such as very low-income urban areas with decrepit facilities where extremely large capital investments have positive impacts on student achievement (Neilson & Zimmerman, 2014; Lafortune & Schonholzer, 2018). Furthermore, most recent work using school finance reforms and other natural experiments to examine the impacts of increased operating expenditures find positive impacts (see Jackson, 2020). Our study highlights that money may matter, but it matters how you spend the money; and capital investments appear to have a much smaller impact on student achievement than similarly-sized increases in current expenditures.

References

Abott, Carolyn, Vladimir Kogan, Stephane Lavertu, and Zachary Peskowitz. 2020. "School District Operational Spending and Student Outcomes: Evidence from Tax Elections in Seven States." *Journal of Public Economics* 183: 104–142.

American Wind Energy Association and Polsinelli PC. 2017. *Property Tax Treatment of Commercial Wind Energy Projects.*

American Wind Energy Association (AWEA). 2020 *Wind Powers America Annual Report 2019*. April, 2020. https://www.awea.org/resources/news/2020/wind-is-now-america%E2%80%99s-largest-renewable-energy-pro

Barron, E. Jason. 2020. "School Spending and Student Outcomes: Evidence from Revenue Limit Elections in Wisconsin." Working paper.

Biasi, Barbara. 2019. "School Finance Equalization Increases Intergenerational Mobility: Evidence from a Simulated-Instruments Approach." National Bureau of Economic Research (NBER) Working Paper 25600.

Brunner, Eric, Joshua Hyman, and Andrew Ju. 2020. "School Finance Reforms, Teachers' Unions, and the Allocation of School Resources." *Review of Economics and Statistics* 102(3): 473–489.

Candelaria, Christopher A., and Kenneth A. Shores. 2019. "Court-Ordered Finance Reforms in the Adequacy Era: Heterogeneous Causal Effects and Sensitivity." *Education Finance and Policy* 14(1), 31–60.

Castleberry, Becca., and J. Scott Greene. 2017. "Impacts of Wind Power Development on Oklahoma's Public Schools." *Energy, Sustainability and Society* 7(1), 34.

Card, David and Abigail A. Payne. 2002. "School Finance Reform, the Distribution of School Spending, and the Distribution of Student Test Scores." *Journal of Public Economics* 83, 49–82.

Cascio, Elizabeth U., Nora Gordon, and Sarah Reber. 2013. "Local Responses to Federal Grants: Evidence from the Introduction of Title I in the South." *American Economic Journal: Economic Policy* 5(3), 126–159.

Cellini, Stephanie R., Fernando Ferreira, and Jesse Rothstein. 2010. "The Value of School Facility Investments: Evidence from a Dynamic Regression Discontinuity Design." *The Quarterly Journal of Economics* 125(1), 215–261.

Clark, Melissa. (2003). "Education Reform, Redistribution, and Student Achievement: Evidence From the Kentucky Education Reform Act." Working paper.

Conlin, Michael and Paul N. Thompson. 2017. "Impacts of New School Facility Construction: An Analysis of a State-Financed Capital Subsidy Program in Ohio." *Economics of Education Review* 59, 13–28.

Dahlberg, Matz, Eva Mörk, Jørn Rattsø, and Hanna Ågren. 2008. "Using a Discontinuous Grant Rule to Identify the Effect of Grants on Local Taxes and Spending." *Journal of Public Economics* 92(12), 2320–2335.

De Silva, Dakshina G., Robert P. McComb, and Anita R. Schiller. 2016. "What Blows in with the Wind?" *Southern Economic Journal* 82(3), 826–858.

Downes, Thomas A. 1992. "Evaluating the Impact of School Finance Reform on the Provision of Public Education: The California Case." *National Tax Journal* 45(4), 405–419.

Ferrel, Shanon L. and Joshua Conaway. 2015. *Wind Energy Industry Impacts in Oklahoma*. State Chamber of Oklahoma Research Foundation.

Feiveson, Laura. 2015. "General Revenue Sharing and Public Sector Unions." *Journal of Public Economics* 125, 28–45.

Gigliotti, Philip and Lucy C. Sorensen. 2018. "Educational Resources and Student Achievement: Evidence from the Save Harmless Provision in New York State." *Economics of Education Review* 66, 167–182.

Goncalves, Felipe. 2015. "The Effects of School Construction on Student and District Outcomes: Evidence From a State-Funded Program in Ohio." Working Paper.

Gordon, Nora. 2004. "Do Federal Grants Boost School Spending? Evidence from Title I." *Journal of Public Economics* 88(9), 1771–1792.

Hines, James R. and Richard H. Thaler. 1995. "Anomalies: The Flypaper Effect." *The Journal of Economic Perspectives* 9(4), 217–226.

Hoen, B.D., Diffendorfer, J.E., Rand, J.T., Kramer, L.A., Garrity, C.P., and Hunt, H.E., 2020, United States Wind Turbine Database (ver. 3.1, July 2020): U.S. Geological Survey, American Wind Energy Association, and Lawrence Berkeley National Laboratory data release, https://doi.org/10.5066/F7TX3DN0.

Hong, Kai, and Ronald Zimmer. 2016. "Does Investing in School Capital Infrastructure Improve Student Achievement?" *Economics of Education Review* 53: 143–158.

Hoxby, Caroline. 2001. "All School Finance Equalizations Are Not Created Equal." *The Quarterly Journal of Economics* 116:4, 1189–1231.

Hyman, Joshua. 2017. "Does Money Matter in the Long Run? Effects of School Spending on Educational Attainment." *American Economic Journal: Economic Policy* 9(4), 256–80.

Inman, Robert P. 2008. "The Flypaper Effect." National Bureau of Economic Research (NBER) Working Paper 14579.

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

Jackson, C. Kirabo, Cora Wigger, and Heyu Xiong. Forthcoming. "Do School Spending Cuts Matter? Evidence from the Great Recession." *American Economic Journal: Economic Policy*.

Jackson, C. Kirabo. 2020. *Does School Spending Matter? The New Literature on an Old Question.* In L. Tach, R. Dunifon, & D. L. Miller (Eds.), *APA Bronfenbrenner series on the ecology of human development. Confronting inequality: How policies and practices shape children's opportunities* (p. 165–186). American Psychological Association.

Johnson, Rucker C. and Jackson, C. Kiarabo. 2019. "Reducing Inequality through Dynamic Complementarity: Evidence from Head Start and Public School Spending." *American Economic Journal: Economic Policy* 11(4), 310–49.

Kahn, Matthew E. 2013. "Local Non-Market Quality of Life Dynamics in New Wind Farms Communities." *Energy Policy* 59, 800–807.

Kling, Jeffrey, R., Jeffrey B. Liebman, and Lawrence F. Katz. 2007. "Experimental Analysis of Neighborhood Effects." *Econometrica* 75(1): 83–119.

Klopfer, John B. 2017. "Labor Supply, Learning Time, and the Efficiency of School Spending: Evidence from School Finance Reforms." Working Paper.

Knight, Brian. 2001. "Endogenous Federal Grants and Crowd-Out of State Government Spending: Theory and Evidence from the Federal Highway Aid Program." *American Economic Review* 92 (1), 71–92.

Kreisman, Daniel and Matthew P. Steinberg. 2019. "The Effect of Increased Funding on Student Achievement: Evidence from Texas's Small District Adjustment." *Journal of Public Economics* 176: 118–141.

Lafortune, Julien, Jesse Rothstein, and Diane W. Schanzenbach. 2018. "School Finance Reform and the Distribution of Student Achievement." *American Economic Journal: Applied Economics* 10(2), 1–26.

Lafortune, Julien and David Schönholzer. 2018. "Do School Facilities Matter? Measuring the Effects of Capital Expenditures on Student and Neighborhood outcomes." Working Paper.

Loomis, David and Matthew Aldeman. 2011. "Wind Farm Implications for School District Revenue." Illinois State University. Center for Renewable Energy.

Lutz, Byron. 2010. “Taxation with Representation: Intergovernmental Grants in a Plebiscite Democracy.” *The Review of Economics and Statistics* 92(2), 316–332.

Marchand, Joseph and Jeremy Weber. 2015. “The Labor Market and School Finance Effects of the Texas Shale Boom on Teacher Quality and Student Achievement.” University of Alberta, Working Paper, (2015-15).

Martorell, Paco, Kevin Stange, and Isaac McFarlin, Jr. 2016. “Investing in Schools: Capital Spending, Facility Conditions, and Student Achievement.” *Journal of Public Economics* 140, 13–29.

Newell, Richard G. and Daniel Raimi. 2015. “Oil and Gas Revenue Allocation to Local Governments in Eight States.” National Bureau of Economic Research (NBER) Working Paper 21615.

Neilson, Christopher A. and Seth D. Zimmerman. 2014. “The Effect of School Construction on Test Scores, School Enrollment, and Home Prices.” *Journal of Public Economics* 120, 18–31.

Papke, Leslie. E. 2005. “The Effects of Spending on Test Pass Rates: Evidence from Michigan.” *Journal of Public Economics* 89(5-6), 821–839.

Reardon, Sean F., Andrew D. Ho, Benjamin R. Shear, Erin M. Fahle, Demetra Kalogrides, and Richard DiSalvo. 2018. *Stanford Education Data Archive* (v2.1). http://purl.stanford.edu/db586ns4974.

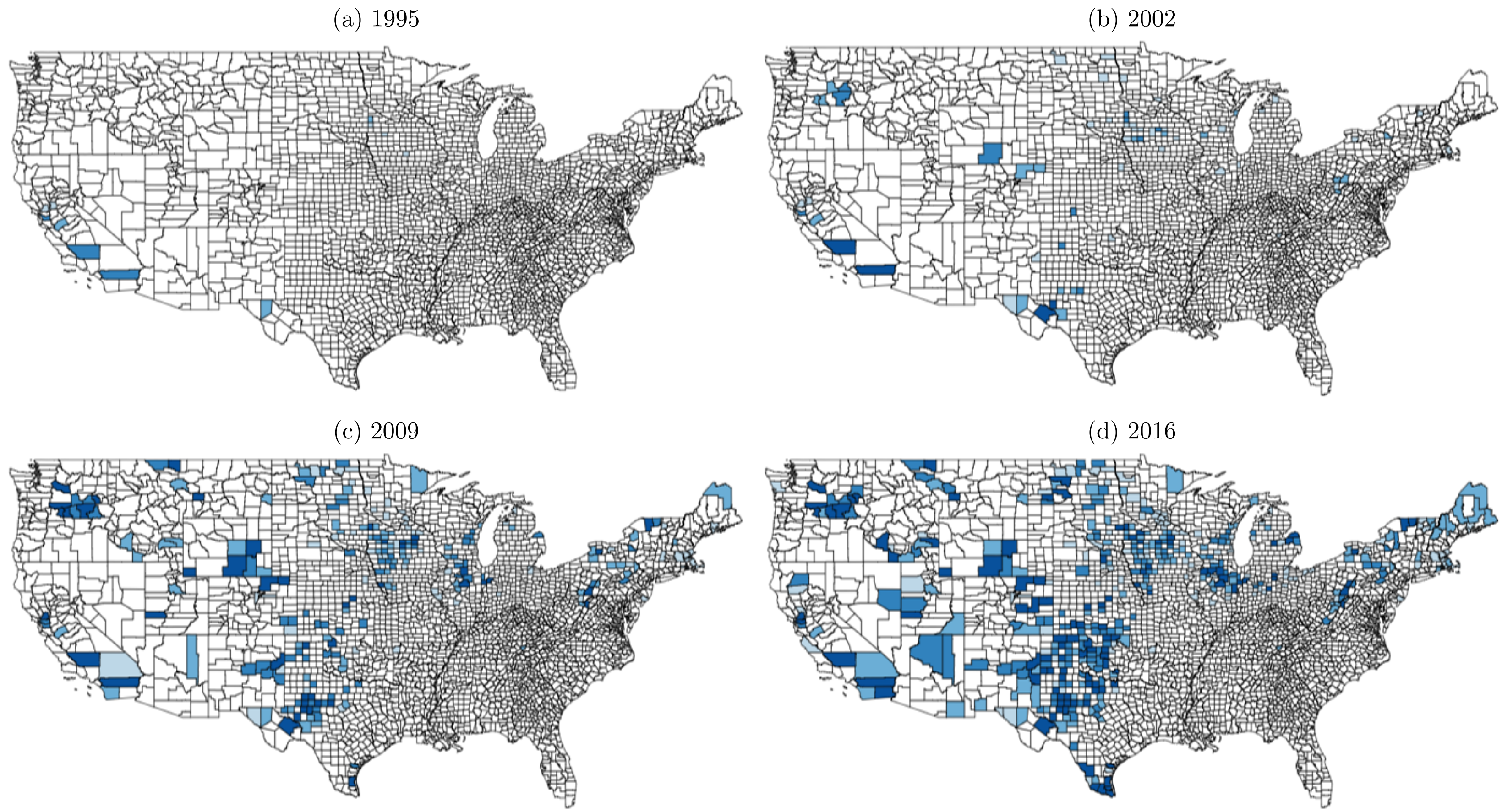
Reategui, Sandra and Stephen Hendrickson. 2011. “Economic Development Impact of 1,000 MW of Wind Energy in Texas.” NRELTechnical Report, NREL/TP-6A20-50400.

Slattery, Michael C., Eric Lantz, and Becky L. Johnson. 2011. “State and Local Economic Impacts from Wind Energy Projects: Texas Case Study.” *Energy Policy* 39(12), 7930–7940.

U.S. Energy Information Administration. 1995. *Renewable Energy Annual 1995.* Office of Coal, Nuclear, Electric and Alternate Fuels, U.S. Department of Energy, Washington, DC 20585.

Weber, Jeremy, Wesley Burnett, and Irene M. Xiarchos. 2014. “Shale Gas Development and Housing Values Over a Decade: Evidence from the Barnett Shale.” In Energy & the Economy, 37th IAEE International Conference, June 15-18, 2014. International Association for Energy Economics.

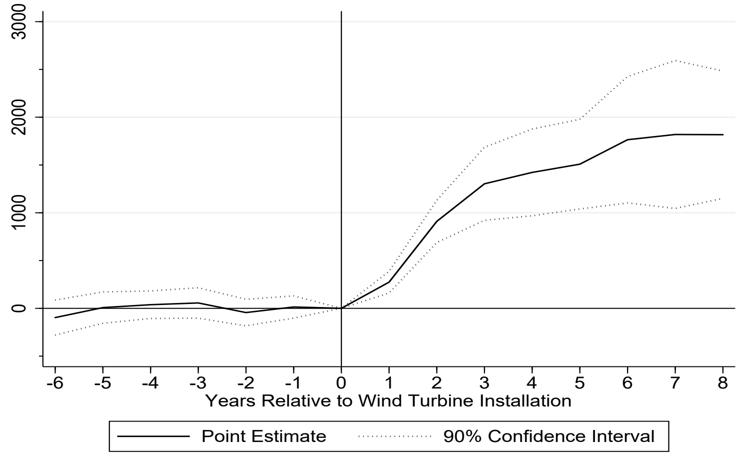
Figure I: United States County Map by Installed Wind Turbine Capacity



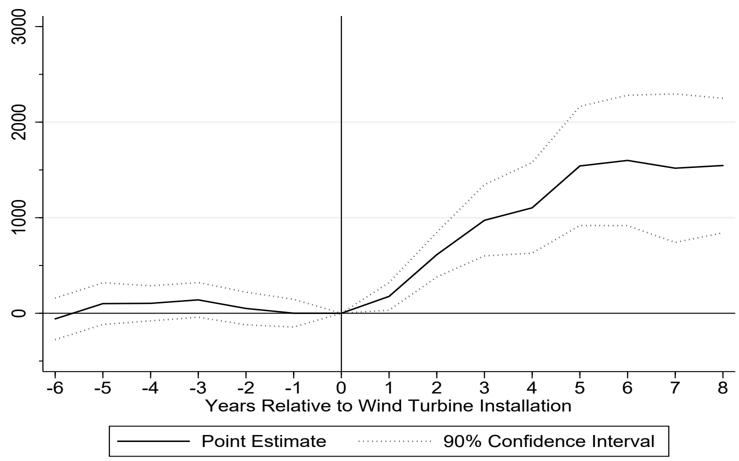
Notes: Map shows installed wind turbine capacity in megawatts (MW) by county and year. Unshaded counties have no installed capacity. The four shades ranging from lightest to darkest represent quartiles of 2016 installed capacity: <11.5 MW, 11.5-73.4 MW, 73.4-199.0 MW, and >199.0 MW, respectively.

Figure II: Effects of Wind Turbine Installation on School District Revenues

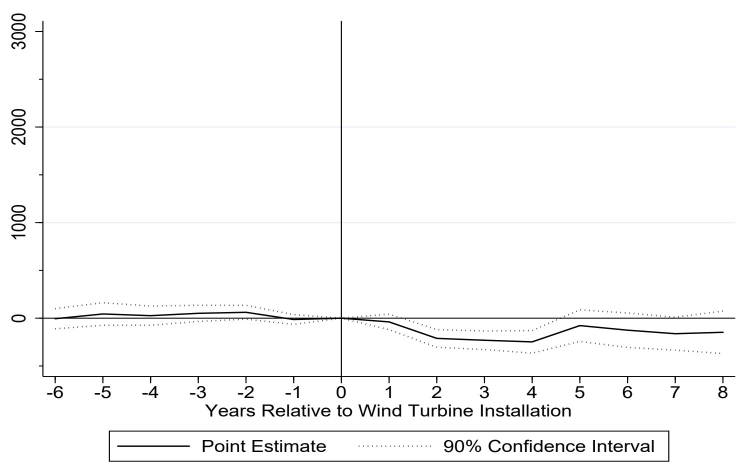
(a) Local Revenue



(b) Total Revenue

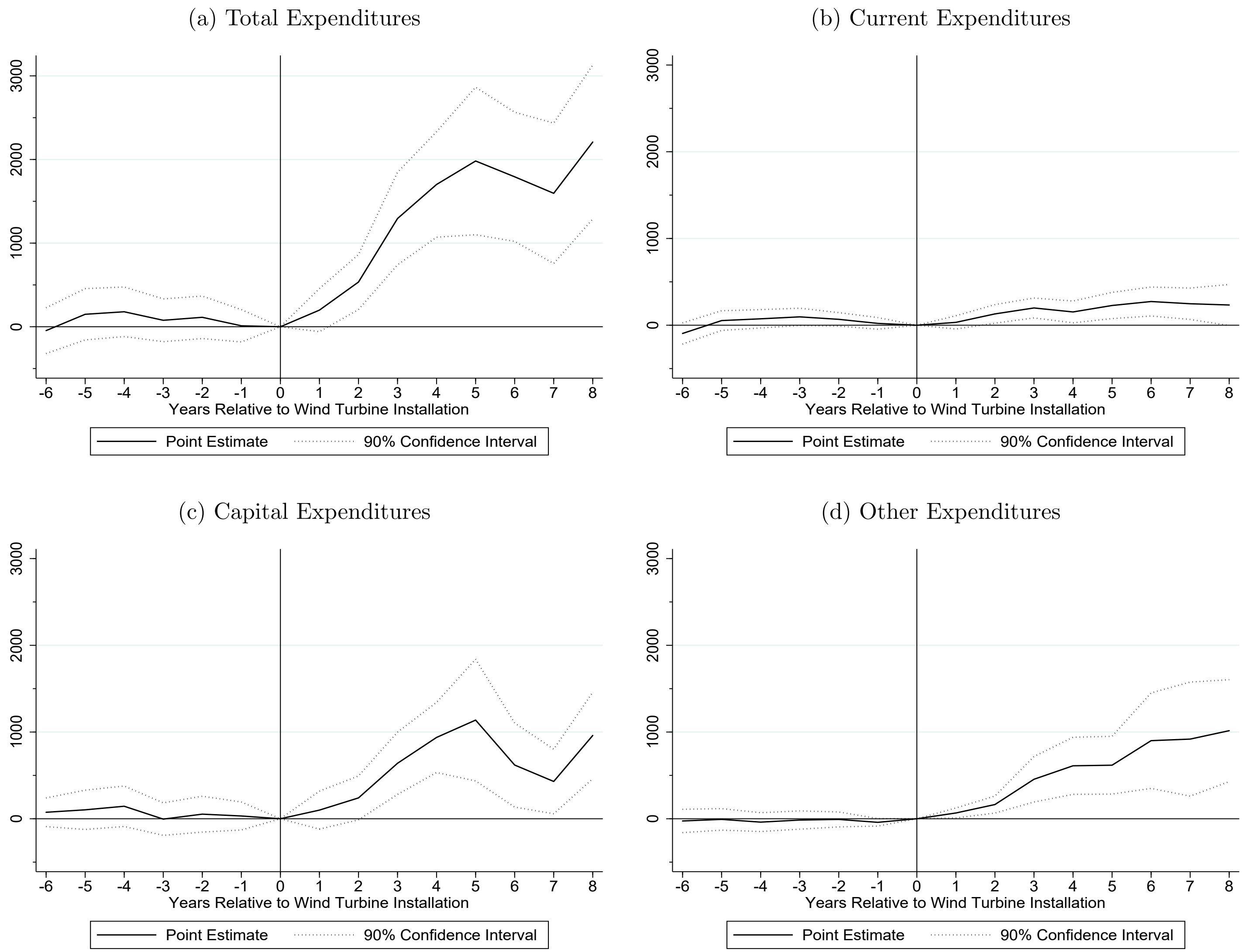


(c) State Revenue



Notes: Figures show event study estimates of the effects of wind turbine installation on per-pupil school district revenues. Solid lines are point estimates, and dashed lines are 90% confidence intervals.

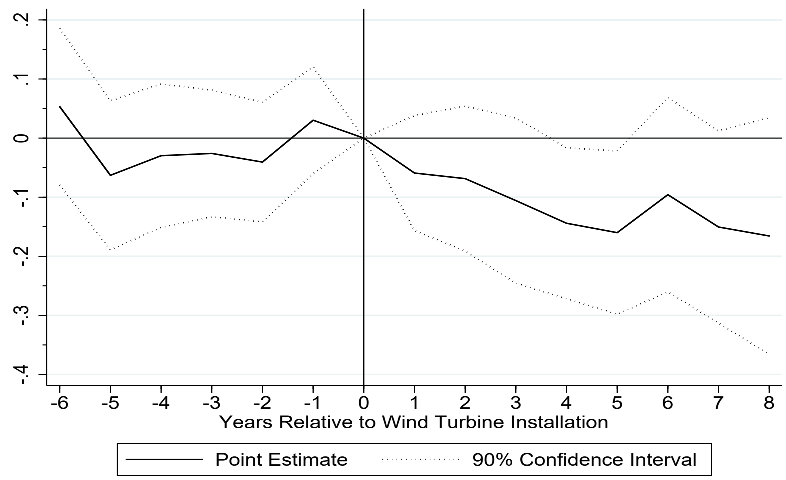
Figure III: Effects of Wind Turbine Installation on School District Expenditures



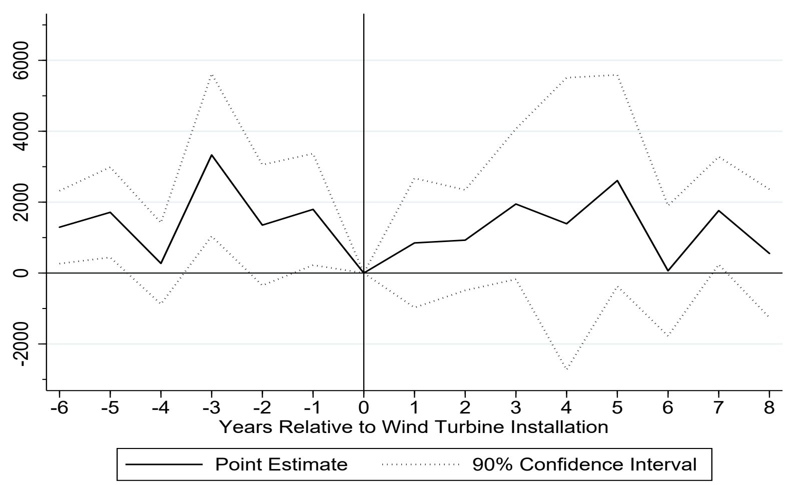
Notes: Figures show event study estimates of the effects of wind turbine installation on per-pupil school district expenditures. Solid lines are point estimates, and dashed lines are 90% confidence intervals.

Figure IV: Effects of Wind Turbine Installation on Education Production Inputs

(a) Pupil-Teacher Ratio

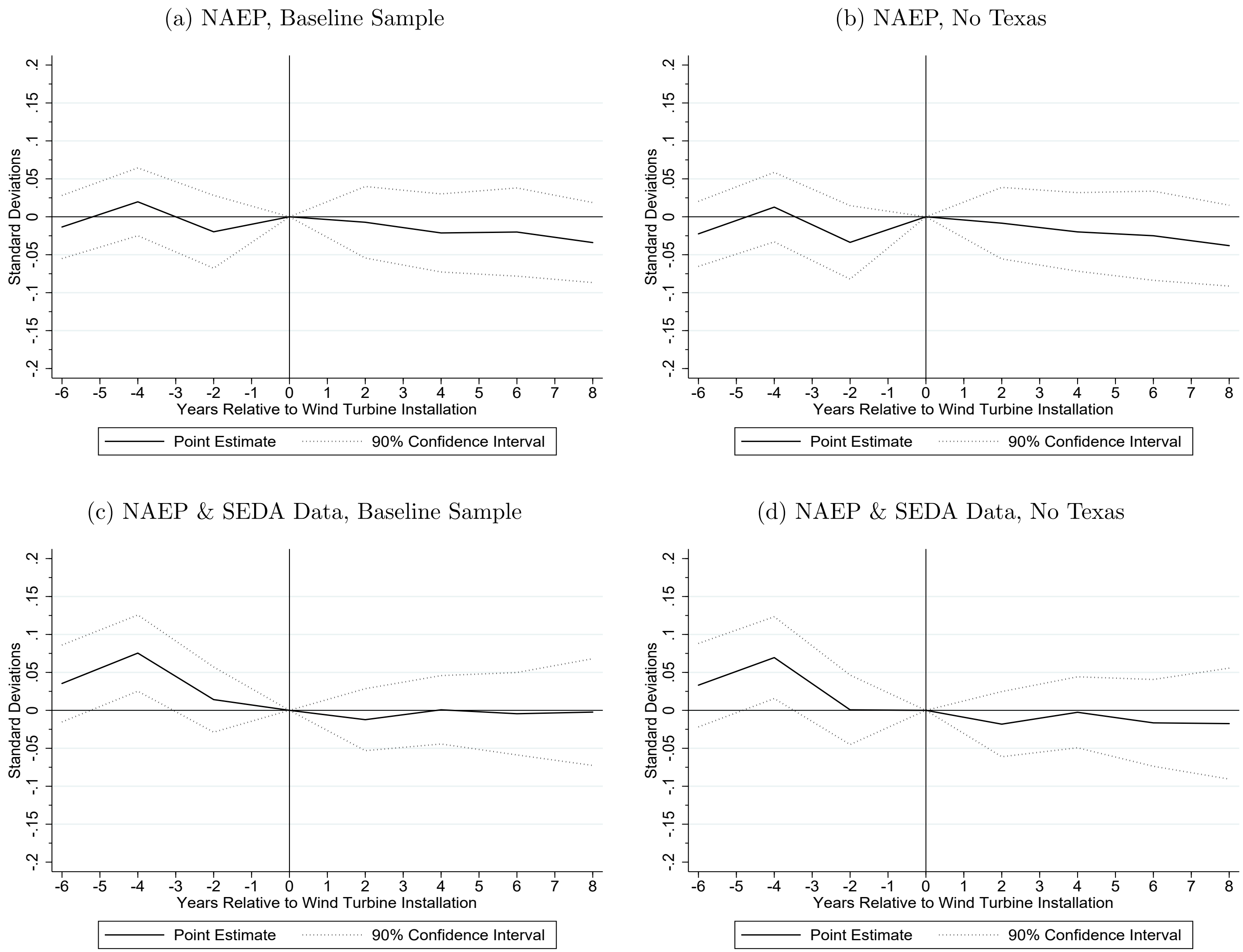


(b) Teacher Salary



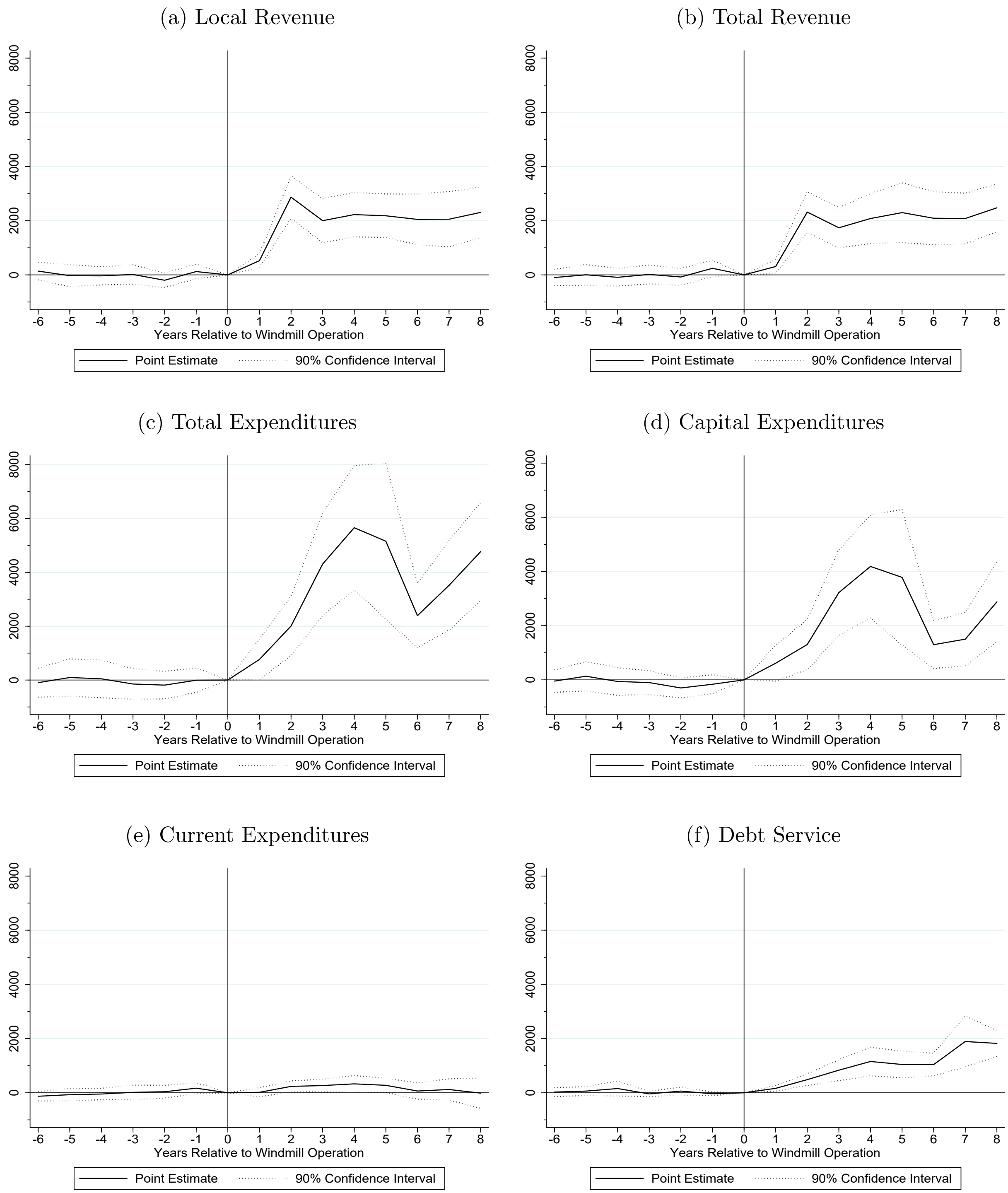
Notes: Figures show event study estimates of the effects of wind turbine installation on inputs to education production. Solid lines are point estimates, and dashed lines are 90% confidence intervals.

Figure V: Effects of Turbine Installation on Student Achievement



Notes: Figures show event study estimates of the effects of wind turbine installation on standardized district mean test scores. Subfigures (a) and (b) use NAEP scores. In subfigures (c) and (d), we supplement the NAEP scores with annual scores from the Stanford Education Data Archive for any school district with no NAEP score during 2009 to 2015. Solid lines are point estimates, and dashed lines are 90% confidence intervals.

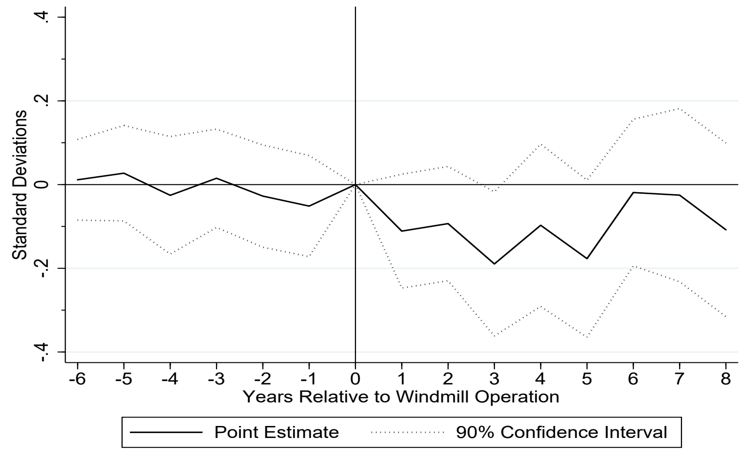
Figure VI: Effects of Turbine Installation on District Finances in Texas



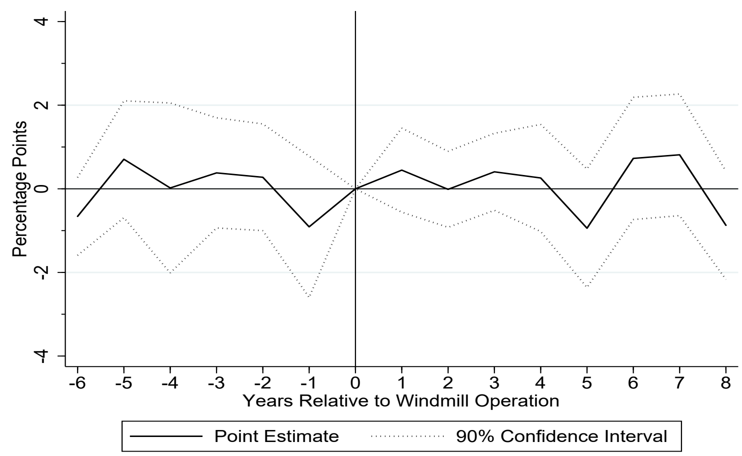
Notes: Figures show event study estimates of the effects of wind turbine installation on district revenues and expenditures using administrative data from Texas from 1995-2018. Solid lines are point estimates, and dashed lines are 90% confidence intervals.

Figure VII: Effects of Turbine Installation on Student Outcomes in Texas

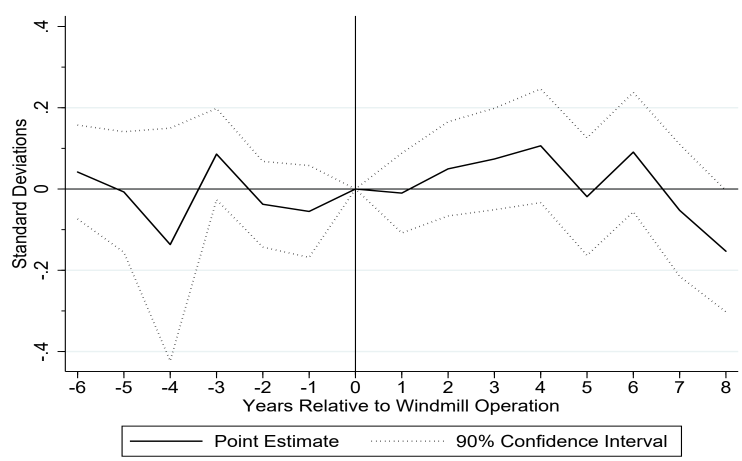
(a) Achievement



(b) High School Graduation (%)



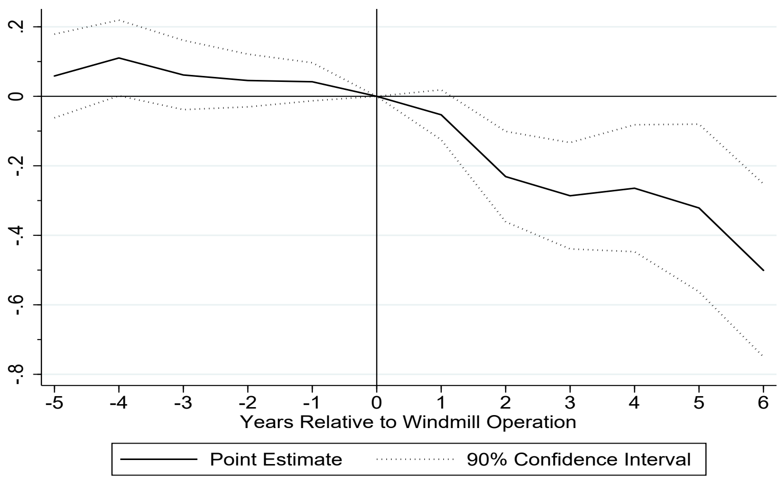
(c) Long-Run Index



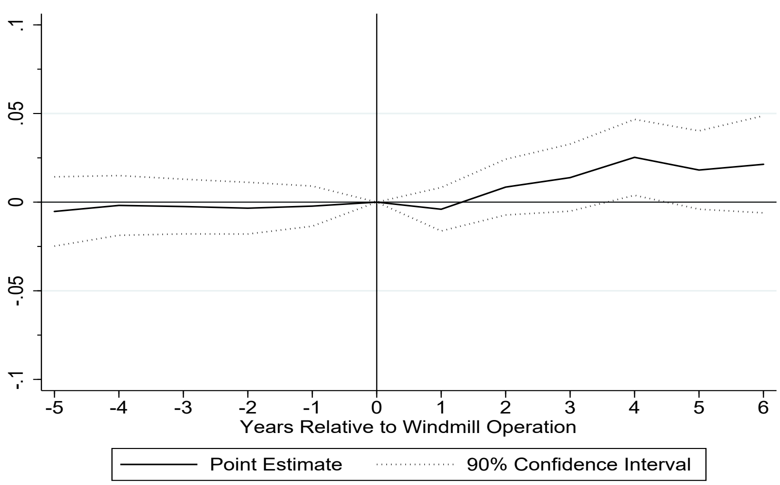
Notes: Figures show event study estimates of the effects of wind turbine installation on district average test scores, high school graduation rates, and an index of long-run student outcomes using administrative data from Texas from 1995-2018. Test scores and the long-run index are standardized to mean 0, SD 1. Graduation is a percent (0-100%). Solid lines are point estimates, and dashed lines are 90% confidence intervals.

Figure VIII: Effects of Wind Turbine Installation on District Property Tax Rates

(a) Illinois



(b) Texas



Notes: Figures show event study estimates of the effects of wind turbine installation on local school district property tax rates. Solid lines are point estimates, and dashed lines are 90% confidence intervals.

Table 1: Summary Statistics

	Full Sample		Wind Turbine District		District Without Wind Turbine	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
	(1)	(2)	(3)	(4)	(5)	(6)
Per-Pupil Outcomes						
Total Revenue	13,469	5,635	13,336	5,955	13,478	5,615
Local Revenue	6,429	5,425	6,070	5,797	6,451	5,400
State Revenue	5,971	3,226	6,187	2,938	5,958	3,243
Total Expenditures	13,502	5,984	13,336	6,754	13,512	5,933
Current Expenditures	11,237	4,142	10,948	3,265	11,255	4,189
Capital Expenditures	1,256	2,591	1,360	3,359	1,249	2,537
Other Expenditures	1,009	2,185	1,028	3,309	1,008	2,097
Other Outcomes						
Pupil-Teacher Ratio	15.0	3.6	13.7	3.4	15.1	3.6
Teacher Base Salary	37,514	6,255	35,102	5,357	37,667	6,277
Per-Pupil Outcomes in 1995						
Total Revenue	10,728	4,032	10,472	3,782	10,744	4,047
Local Revenue	5,475	4,336	4,841	3,894	5,515	4,359
State Revenue	4,620	2,168	4,955	2,026	4,600	2,175
Total Expenditures	10,615	3,887	10,154	2,842	10,644	3,941
Current Expenditures	9,047	2,929	8,748	2,143	9,065	2,970
Capital Expenditures	879	1,717	918	1,603	877	1,724
Other Expenditures	689	1,208	488	656	702	1,233
Other Outcomes in 1995						
Pupil-Teacher Ratio	16.3	3.6	15.1	3.4	16.4	3.6
Teacher Base Salary	36,201	5,393	34,329	4,643	36,316	5,415
Control Variables						
Baseline Enrollment	2,954	14,074	1,852	5,249	3,022	14,438
Median Income in 1990	29,328	11,676	24,192	5,876	29,642	11,868
Fraction BA or Higher in 1990	0.152	0.099	0.117	0.046	0.154	0.101
Fraction Rural in 1990	0.629	0.483	0.785	0.411	0.619	0.486
Fraction White in 1990	0.883	0.176	0.891	0.182	0.882	0.176
Fraction Poor in 1990	0.134	0.099	0.154	0.084	0.133	0.100
Fraction Age 65+ in 1990	0.187	0.061	0.207	0.058	0.186	0.061
Number of Districts	11,038		638		10,400	
Number of Observations	237,646		13,724		223,922	

Notes: The sample is all school districts in the 35 continental United States that had wind energy installed between 1995 and 2016. We exclude Kansas and and Wyoming, because they provide a permanent 100% exemption on property taxation of all wind energy installation.

Table 2: Effects of Turbine Installation on District Revenues, Expenditures, and Resource Allocations

	Treatment: Wind Turbine Installed (0/1)		Treatment: Installed Turbine Capacity Per-Pupil (KW)		Effect at Mean Capacity
Dependent Variable	(1)	(2)	(3)	(4)	(5)
School District Revenues					
Local	1083.74***	1004.71***	3.92***	3.78***	918.33***
	(209.57)	(209.66)	(0.71)	(0.70)	(171.21)
Total	848.21***	812.73***	3.66***	3.59***	872.32***
	(216.88)	(217.19)	(0.82)	(0.82)	(200.22)
State	-142.17**	-111.39*	-0.31	-0.25	-61.29
	(57.58)	(57.33)	(0.26)	(0.26)	(64.02)
School District Expenditures					
Total	1059.54***	1031.39***	4.86***	4.81***	1167.96***
	(251.51)	(251.71)	(0.97)	(0.97)	(236.87)
Current	168.06***	133.41**	0.95***	0.88***	214.09***
	(63.74)	(63.00)	(0.20)	(0.20)	(48.97)
Capital	430.75***	432.85***	2.11***	2.12***	514.79***
	(99.42)	(99.40)	(0.44)	(0.44)	(106.15)
Other	460.73***	465.12***	1.80***	1.81***	439.08***
	(167.81)	(168.72)	(0.59)	(0.59)	(143.08)
Education Production Inputs					
Pupil-Teacher Ratio	-0.11**	-0.09	-0.20**	-0.15*	-0.04*
	(0.06)	(0.06)	(0.09)	(0.09)	(0.02)
Teacher Salary	-552.73	-543.26	0.23	0.23	58.80
	(350.92)	(350.97)	(0.29)	(0.29)	(72.90)
Expanded Controls	No	Yes	No	Yes	Yes

Notes: The sample is as in Table 1, and includes 237,646 district-by-year observations. Column 5 multiplies the coefficient and standard error from column 4 by the mean level of installed capacity of 243 KW/pupil. The pupil-teacher ratio is multipled by 1000 for columns 3 and 4, because the impact of a 1 KW/pupil increase in installed capacity would be tiny. Subsequently, column 5 then divides by 1000, so the interpretation is in pupils per teacher.
*** = significant at 99% confidence level; ** = 95%, * = 90%.

Table 3: Effects of Installed Turbine Capacity: Sensitivity Checks

	School District Revenues			School District Expenditures				Education Production Inputs		
	Local	Total	State	Total	Current	Capital	Other	Teacher Ratio	Teacher Salary	Sample Size
Specification/Sample	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Baseline	3.78***	3.59***	-0.25	4.81***	0.88***	2.12***	1.81***	-0.16*	0.23	237,646
	(0.70)	(0.82)	(0.26)	(0.97)	(0.20)	(0.44)	(0.59)	(0.09)	(0.29)	
Include States with No Wind Turbines	3.79***	3.60***	-0.26	4.81***	0.89***	2.12***	1.81***	-0.16*	0.23	271,245
	(0.70)	(0.82)	(0.26)	(0.97)	(0.20)	(0.44)	(0.59)	(0.09)	(0.28)	
Include KS and WY	3.71***	3.53***	-0.24	4.75***	0.87***	2.10***	1.77***	-0.17*	0.23	243,974
	(0.69)	(0.81)	(0.26)	(0.96)	(0.20)	(0.43)	(0.58)	(0.09)	(0.29)	
Include Districts with < 2 MW Capacity	3.78***	3.59***	-0.25	4.81***	0.88***	2.12***	1.81***	-0.15*	0.23	239,518
	(0.70)	(0.82)	(0.26)	(0.97)	(0.20)	(0.44)	(0.59)	(0.09)	(0.29)	
Restrict to Counties with Wind Turbines	3.56***	3.39***	-0.25	4.60***	0.84***	2.10***	1.66***	-0.17	0.39	48,409
	(0.69)	(0.80)	(0.25)	(0.92)	(0.22)	(0.42)	(0.57)	(0.10)	(0.29)	
Drop High Enrollment Non-Wind Districts	3.73***	3.52***	-0.26	4.70***	0.86***	2.08***	1.77***	-0.15*	0.33	183,450
	(0.70)	(0.82)	(0.26)	(0.97)	(0.20)	(0.44)	(0.58)	(0.09)	(0.21)	
Propensity Score Weightin[g]	4.00***	3.80***	-0.28	5.13***	0.89***	2.15***	2.09***	-0.16*	0.29	237,646
	(0.89)	(0.95)	(0.26)	(1.08)	(0.21)	(0.44)	(0.75)	(0.09)	(0.28)	
Expanded Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	

Notes: Each coefficient is from a separate regression of the outcome (listed in the column header) on installed wind turbine capacity (in KW) per-pupil. High enrollment non-wind districts are districts with no installed wind capacity that have enrollment larger than the 90th percentile of enrollment among districts with installed wind capacity. The propensity score weighting weights higher those non-wind districts that are observationally similar to wind-districts.

Table 4: Effects of Installed Turbine Capacity on District Finances, Texas vs Rest of U.S.

Dependent Variable	Baseline (1)	Texas Only (2)	Baseline, No Texas (3)	Sample Mean ($/pupil) (4)
Local Revenue	3.78***	7.78***	2.33***	6,429
	(0.70)	(1.57)	(0.28)	
Total Revenue	3.59***	8.04***	1.99***	13,469
	(0.82)	(1.60)	(0.37)	
State Revenue	-0.25	0.39	-0.48*	5,971
	(0.26)	(0.37)	(0.28)	
Total Expenditures	4.81***	10.03***	2.92***	13,502
	(0.97)	(1.85)	(0.93)	
Current Expenditures	0.88***	0.88***	0.90***	11,237
	(0.20)	(0.32)	(0.25)	
Capital Expenditures	2.12***	4.33***	1.32**	1,256
	(0.44)	(0.88)	(0.54)	
Other Expenditures	1.81***	4.82***	0.70	1,009
	(0.59)	(1.41)	(0.49)	
Community Services & Adult Edu.	0.31	-0.00	0.42	86
	(0.25)	(0.01)	(0.32)	
Interest on Debt	0.30**	0.51***	0.23	286
	(0.13)	(0.10)	(0.18)	
Payments to State Government	1.14**	4.24***	0.00	91
	(0.55)	(1.36)	(0.00)	
Payments to Local Governments	-0.01	0.00	-0.01	26
	(0.01)	(0.00)	(0.01)	
Payments to Other School Systems	0.06**	0.07	0.06*	476
	(0.03)	(0.05)	(0.03)	
Payments to Private Schools	0.00	0.00	0.00	70
	(0.00)	(0.00)	(0.00)	
Payments to Charter Schools	-0.00	0.00	-0.01	23
	(0.01)	(0.00)	(0.01)	
Observations	237,646	22,099	215,547	
Expanded Controls	Yes	Yes	Yes	

Notes: Each coefficient is from a separate regression of the outcome (listed in the row header) on installed wind turbine capacity (in KW) per-pupil for the sample listed in the column header. *** = significant at 99% confidence level; ** = 95%, * = 90%.

Table 5: Effects of Turbine Installation on Student Achievement

	Baseline		No Texas	
	(1)	(2)	(3)	(4)
Panel A: NAEP Data				
Post	-0.011	-0.010	0.002	0.003
	(0.020)	(0.020)	(0.020)	(0.020)
Post*Trend	-0.000	-0.000	-0.000	-0.000
	(0.003)	(0.003)	(0.003)	(0.003)
Trend	0.001	0.001	0.000	0.001
	(0.002)	(0.002)	(0.002)	(0.002)
Effect 5 Years Post		-0.006		0.005
		(0.020)		(.019)
Observations	84,079		81,000	
Panel B: NAEP and SEDA Data				
Post	-0.032	-0.030	-0.013	-0.013
	(0.023)	(0.023)	(0.024)	(0.024)
Post*Trend	-0.001	0.000	0.000	0.000
	(0.005)	(0.005)	(0.006)	(0.006)
Trend	-0.001	-0.001	-0.003	-0.003
	(0.003)	(0.003)	(0.003)	(0.003)
Effect 5 Years Post		-0.037		-0.026
		(0.026)		(0.027)
Observations	246,361		225,303	
Expanded Controls	No	Yes	No	Yes

Notes: The level of observation is the district-year-grade-subject. The dependent variable is standardized student test scores. In Panel A, we use NAEP data, which are available for a sample of districts in every other year from 1996 to 2015 for grades 4 and 8. In Panel B, we supplement the grade 4 and 8 NAEP scores with annual scores from the Stanford Education Data Archive for any school district with no NAEP score during 2009 to 2015.
*** = significant at 99% confidence level; ** = 95%, * = 90%.

Table 6: Effects of Turbine Installation on Student Outcomes in Texas

	Avg. Test Scores		High School Grad. (%)		Long-Run Index	
	(1)	(2)	(3)	(4)	(5)	(6)
Post	-0.057	-0.049	0.143	0.126	0.069	0.079
	(0.067)	(0.067)	(0.669)	(0.667)	(0.065)	(0.064)
Post*Trend	0.001	0.001	-0.067	-0.065	-0.011	-0.010
	(0.013)	(0.013)	(0.100)	(0.099)	(0.010)	(0.009)
Trend	-0.005	-0.006	0.008	0.015	-0.003	-0.005
	(0.006)	(0.005)	(0.054)	(0.054)	(0.005)	(0.005)
Effect 5 Years Post		-0.074		-0.126		0.005
		(0.056)		(0.512)		(0.061)
Observations	22,778		20,773		22,834	
Expanded Controls	No	Yes	No	Yes	No	Yes

Notes: This table uses a separate adminstrative dataset from the Texas Department of Education. The level of observation is the district-year. The sample includes all districts in Texas from 1995-2018. Test scores are for grades 4 nd 8, standardized to mean 0, SD 1. High school graduation is a percent with a mean of 90.9. The long-run index, is mean zero, SD 1, and includes the following outcomes: 1) % take AP exam, 2) % take ACT/SAT, 3) % take ACT/SAT and score above national median, 4) % take an advanced / honors course, 5) % complete state recommended high school curriculum, and 6) % graduate high school.

*** = significant at 99% confidence level; ** = 95%, * = 90%.

Appendix A: State Wind Energy Taxation Laws and School Finance Formulas

What follows is a description of how states tax wind installations and how wind installation tax revenue affects local school districts. We present wind energy taxation information for the top 21 wind production states in the nation based on installed megawatts as of 2018. These 21 states account for approximately 95% of the total installed wind energy capacity in the nation.

California: Due to Proposition 13, property tax rates are capped at 1% of assessed value. As a result, wind projects are also taxed at 1% of assessed value. Due to school finance reform in California, school districts are subject to a revenue limit which limits the total amount of revenue a district can collect from local property taxes and state aid. Each district's revenue limit is set by the state. When local property tax revenue increases, state aid is decreased proportionally so that a district remains within its revenue limit. As a result, increases in a school district's tax base that results from a wind energy installation have little effect on school district operating revenues. If a school districts tax base is large enough that even without state aid it would exceed its revenue limit the state allows the district to keep the revenue. Such districts are known as basic aid districts.

Colorado: As of 2006, Colorado assesses the value of wind projects based on the income generated by the project. The state sets a tax factor that is applied to the sale price of wind energy to determine the projects assessed value. Funding to school districts is based on a per-pupil formula that calculates the district's spending limit known as the Total Program. A district can exceed its spending limit if it gets approval from local voters during an override election which allows for additional property tax revenues. Starting in 2009-10, a district's override revenues were limited to 25% (30% for small rural districts) of its Total Program. When a district passes an override, its state share of funding is not reduced.

Idaho: In 2007, Idaho authorized a property tax exemption for wind energy producers. In lieu of paying property taxes, producers pay a tax of 3% of annual energy earnings to the county. Wind developers that are regulated by the Idaho Public Utilities Commission are excluded from this exemption. Since 2006, Idaho uses a system of voter-approved levies for funding local school operations.

Illinois: Illinois wind energy tax is considered a model for property taxation of wind projects. In 2007, the Illinois legislature set the real property cost basis of a wind energy devices at $360,000 per megawatt of nameplate capacity. The wind energy tax formula used in Illinois is also adjusted annually for inflation using the CPI and for depreciation via a transparent and uniform formula that applies to all wind projects. The tax revenue from wind projects that a school district receives is based on a percentage of the assessed value of the property within the boundaries of the school district. When a district's tax base increases due to a new wind installation, the amount of state aid the school district receives is reduced. However, state aid is not generally reduced dollar-for-dollar with increases in local revenue. As a result, school districts generally benefit from increases in local property tax payments resulting from a wind project. The usage of any additional revenues is up to the discretion of local school districts and therefore can be used to increase current or capital expenditures or reduce local tax rates.

Indiana: Most commercial wind projects in Indiana have negotiated property tax abatements with their host counties, typically for 10 years. Property tax abatements reduce the property tax liability associated with a wind project by a negotiated amount. Beginning in calendar year 2009, the state began funding 100% of costs for the school general fund. Property tax dollars are no longer used to support operating purposes of Indiana's school districts. Local property tax revenue can only be deposited into either the transportation fund, capital projects fund or rainy-day fund.

Iowa: Counties in Iowa may enact a wind energy conversion tax ordinance that allows a county to assess wind projects at their net acquisition cost. If a county does not enact a wind energy conversion tax ordinance, state statutes provide that the taxable value of a wind project shall not increase for five years. Under a wind energy conversion tax ordinance, a wind project is taxed a 0% for the first year and then for the second through sixth assessment years, a wind project is taxed at an additional 5% of net acquisition costs for each year (5% in year 2, 10% in year 3, etc.) until the seventh year when taxes are capped at 30% of net acquisition cost. After the energy conversion ordinance expires, wind projects are valued at the market value. In addition, most counties create tax-increment financing (TIF) districts around wind farms which effectively divert any additional tax revenue from a wind farm to the TIF rather than the local taxing authority including school districts. Counties can then use the TIF revenue for projects related to economic development. School districts affected by a TIF are held harmless by the state, which replaces the lost property tax revenue through the school finance formula. Thus, counties have strong incentives to create TIFs to attract new wind projects since all the revenue from the TIF flows to the county and other local taxing jurisdictions within the TIF are held harmless in terms of tax revenue via increased state aid. In the absence of a TIF, school districts receive their portion (along with counties and other local taxing authorities) of the revenue from wind projects, Iowa's school finance law limits spending on maintenance and operations (daily operations funded through the general fund) via a state specified spending authority, which is the maximum amount a school district can spend. The limit is determined by multiplying a district's previous year's enrollment by a cost factor per-pupil which is set by the state legislature. As a result, revenue from wind projects has little effect on spending on daily operations.

Kansas: Until 2015, wind projects in Kansas were granted a full life time exemption from property tax payments. Starting in 2015, however, new projects will receive a property tax exemption for the first 10 years after which the project is taxed based on its full value. Prior to 2015, wind projects often made Payments in Lieu of Taxes (PILOT) to hosting counties. These PILOTs generally provided relatively small payments to the counties and the use of PILOT funds was at the discretion of the county. As a result, school districts in Kansas benefitted very little from wind installations.

Maine: Maine does not offer direct property tax exemptions for commercial scale wind facilities, but many of Maine's wind energy projects were developed and financed through Tax Increment Financing (TIFs). TIFs are a flexible economic development tool used by municipalities, towns, or defined geographic districts to leverage new property taxes generated by a specific project. Municipalities can define districts and choose how much of the new taxes will go to what public or private economic development projects over a defined timeframe. TIF packages in Maine require local approval. As of 2018, there are 17 wind energy projects included in the Maine TIF program.

Michigan: Prior to 2008, wind turbines in Michigan were taxed as real property. Starting in 2008, wind turbines were taxed as industrial personal property with the assessed value of the turbines determined by their megawatts. Local school districts receive wind project tax revenue for debt millage. Only debt millage goes directly to local districts. If a district has no debt, it gets no direct tax revenue. Per Proposal A (1994), local school district general funds are redistributed on a per-pupil basis. Local districts keep sinking/debt fund revenues.

Minnesota: In 2002, Minnesota implemented a wind energy production tax. Tax rates range from 0.012 to 0.12 cents per kilowatt hour depending on the size of a project. Systems that have a total capacity of 250 kilowatts or less or are owned by a municipality and have a total capacity of 2000 kilowatts or less are exempt from the production tax. Wind projects are exempt from property taxes, except for the land on which the system is situated. Under the law, 80% of wind project tax revenue goes to the county, 14% to cities and townships and 6% to school districts. In 2007, however, the state legislature changed the education finance formula and deducted all revenues stemming from wind projects from state aid payments, implying school districts no longer received the 6% of tax revenue from wind energy installations. Then in 2010, the state legislature changed the distribution of wind energy tax revenues again such that 80% of tax revenues went to the county and 20% to cities and townships with none going to local school districts. This had the effect of eliminating the state's ability to recapture the 6% of revenue that went to school districts. School districts may still benefit from wind energy projects through the establishment of educational foundations by wind energy producers or charitable contributions from wind energy producers. As an alternative to the production tax, wind farm owners may negotiate with the county in which the farm is located for payments in lieu of the wind energy production tax. The amount of these payments is based on production capacity, historical production, or other factors agreed upon by the parties. The PILOT payments must be used to maintain public infrastructure and services within the city or town and the county in which the facility is located.

Nebraska: In 2010, the Nebraska Legislature passed a bill which exempted wind energy generation systems from property taxes, although the law allows a county assessor to evaluate real property and land used by wind generation facilities. The property tax is replaced by a nameplate capacity tax of $3,518 per megawatt. In 2017, this tax generated $3,056,623 for Nebraska counties, with $1,862,959 going to local schools.

New Mexico: Since 1985, New Mexico has issued Industrial Revenue Bonds (IRBs) totaling billions of dollars to many projects, including wind farms. In an IRB transaction, the property used for the wind farm is deeded from the benefitting company to the municipality or county, which then leases the property back to the company. This makes the property tax-exempt for the duration of the bond term, which can be up to thirty years. Taxes are instead negotiated between the government entity and company that is asking for the IRBs. In recent years it has been common for issuers to require PILOTs for the benefit of the issuer and other local governmental units. PILOTs are only required for IRBs issued to electrical generating facilities, such as wind farms. The issuer and local school district must agree upon an annual PILOT to be paid to the district in these cases, although there is nothing in state law specifying how much this amount must be.

New York: As of 2019, no commercial wind project in New York has been built without a PILOT (payment in lieu of taxes) agreement that provides significant property tax relief. Under the state's tax cap law, taxing districts, including school districts, must "add any PILOTs that were receivable in the base year. The total amount of PILOTs receivable is to be included in the calculation of the tax levy limit. No adjustment is permitted." The tax cap limits the total levy set by school districts, not assessed value or tax rates. School districts generally may not adopt a budget that requires a tax levy that exceeds the prior year's levy by more than 2% or the rate of inflation, unless they officially override the tax levy limitation.

North Dakota: Prior to 2015, wind turbines were valued at 3% of assessed value and subject to local property tax rates. Beginning in 2015, wind projects with a nameplate capacity of 100 kilowatts or more are centrally assessed for tax purposes. Wind projects completed after December 31, 2014, or are 20 years or more from the date of first assessment, are subject to payment in lieu of taxes which consist of $2.50 per kilowatt multiplied by rated capacity and a 0.5 mill per kilowatt-hour of electricity generated during the tax period. All taxes are paid to the local governments where the wind projects are located. Taxes are distributed to local governments, including school districts, based on the mill rates of each tax jurisdiction. The state limits the amount of property tax revenue school districts can levy. Specifically, schools must not exceed the dollar amount levied the prior year plus 12%. Districts may also levy 12 mills on the taxable valuation for miscellaneous purposes. Districts may also ask voters to approve a specified levy above the levy limits specified by the state.

Oklahoma: Oklahoma exempts from ad valorem taxation for a five-year period, new, expanded, or acquired manufacturing facilities owned by a "qualifying manufacturing concern." Okla. Constitution Art. X § 6B(A); OKLA. STAT. tit. 68, § 2902(A). As of January 1, 2017, commercial wind installations "are no longer defined as a qualifying manufacturing concern for purposes of the exemption." The state reimburses school districts and counties for the lost tax revenue during the five-year property tax exemption. This includes lost tax revenue from wind projects built before 2017, which were exempted from ad valorem taxation for a five-year period. Oklahoma's system of school finance is designed to equalize resources across school districts. Specifically, Oklahoma's school finance law specifies that if "per pupil revenue exceeds one hundred fifty percent (150%) of the projected state average per pupil revenue then the district's state aid shall be reduced by an amount that will restrict the district's projected per pupil revenue to one hundred fifty percent (150%) of the projected state average per pupil revenue." As a result, districts with significant revenue from wind projects may see declines in state aid.

Oregon: Oregon does not offer property tax incentives for commercial scale wind facilities. However, counties can establish Rural Renewable Energy Development Zones (RREDZ). Commercial wind projects within the zone are eligible for a 3 to 5-year local property tax exemption. RREDZ's must set a cap on the amount of a projects assessed value that can be abated with the maximum abatement set at $250 million. The state also has a Strategic Investment Program (SIP) that provides a partial property tax exemption for 15 years. In exchange, wind developers pay a community service fee to the county. For both the RREDZ and SIP programs, negotiations for payments made by wind developers occur at the county level. School districts may benefit from RREDZ and SIP programs based on the county-determined use of wind project tax revenues.

Pennsylvania: Since 2006, wind turbines and related equipment (including towers and foundations) in Pennsylvania cannot be included as part of the real property in determining the fair market value and assessment of the property used for wind generation. Wind generation property is instead valued under Section 8842 of Pennsylvania law: the county assessor utilizes the income capitalization approach to value, taking into account the capitalized value of land lease agreements to determine the real property value. As of 2016, 57% of school district funding comes from local taxes, mainly property taxes that each district enacts and collects. Since 2016, the state uses a "fair funding" formula to determine state funding for school districts. The formula takes student attendance, student poverty, and school district wealth into account. Poor districts receive more state funding while wealthy districts rely on their own local taxes. This means that any increase in the property tax base of a district that comes from a wind energy installation results in a decrease in state funding.

South Dakota: South Dakota provides a local property tax exemption for wind energy systems less than 5 megawatts in size. The continuous exemption applies to the first $50,000 or 70% of the assessed value of the renewable energy property, whichever is greater. Local tax revenue from wind farms is collected through nameplate and production taxes which are deposited into the renewable facility tax fund. The taxes are distributed to the treasurer of the county where projects are located. 20% of the taxes from the production tax go to the counties that host the project. Remaining revenue in the fund is deposited into the state's general fund. 50% of the money goes to school districts, 35% to the county, and 15% to organized townships where the project is located. Over a period of 10 years, local schools receive a decreasing share of the tax revenue from the renewable facility tax fund.

Texas: School districts may approve a tax abatement agreement, known officially as a Chapter 313 agreement, which allows a temporary, 10-year limit on the taxable value of a new wind project. Chapter 313 agreements apply only to school district taxes levied for maintenance and operations (M&O). Taxes for debt service, known as interest and sinking (I&S) fund payments are not subject to the limitation. Furthermore, Chapter 313 requires some portion of the increased assessed value due to a wind project to go on a school districts tax rolls for M&O while the full increase in assessed value goes on a school districts tax rolls for I&S. Because Chapter 313 agreements increase a school districts tax base, and state aid in Texas is tied to a districts tax base, state aid generally declines when a Chapter 313 agreement goes into effect. However, because only part of the assessed value of wind project is added to the tax rolls for the abatement period, Chapter 313 agreements typically result in a small decline in state aid during the period when the abatement agreement is in effect. Once the tax abatement period ends, a wind project is taxed at full value resulting in a large decline in state aid. Specifically, once a Chapter 313 agreement ends, most of the property tax revenue generated from a wind project goes back to the state due to the Chapter 41 Recapture law in Texas (commonly referred to as Robin Hood). Because revenue designated for I&S (debt service) is not subject to recapture and furthermore because the full increase in assessed value due to a wind project immediately goes on a school districts tax rolls for I&S, there is a strong incentive for school districts in Texas to pass a bond for school capital projects and use the wind project revenues to "subsidize" capital improvement projects. Since school bonds are backed by property tax increases which remain in effect until the bonds are fully repaid, this also implies that school district I&S tax rates will rise if voters approve a bond to protect wind project tax revenues from recapture or to take advantage of the fact that the district's tax base expands by the full amount of the assessed value of the wind project for I&S purposes.

Washington: Wind projects are assessed at 100% of fair market value for property tax purposes. School districts can collect property tax levies for maintenance and operations (M&O), capital projects, debt service and transportation. State law limits school district M&O levies to 24% of the school district's state and federal funding for the previous school year. Wind developments within the boundaries of a school district that increase the tax base add to the property tax revenue of districts. Districts have used such revenues for maintenance and operations, to build new schools, and lower property tax rates.

Wyoming: Wind projects are centrally assessed by the state and are considered industrial property assessed at 11.5% of market value. Property tax revenue for wind projects is distributed 22% to the state general fund, 38% to the state School Foundation fund and 40% to local jurisdictions. Starting in 2012, wind projects are also subject to a $1 per megawatt hour production tax that is distributed 40% to the state general fund and 60% to the wind project's host county. School finance in Wyoming is highly centralized and school districts have little control over revenue or expenditures. If a local school district has revenue in excess of its state guarantee, it is recaptured by the state. All recaptured revenue is deposited in the state Foundation Program.

Appendix B: Using Local Wind Energy Tax Rules to Estimate Crowd-Out

In this appendix, we estimate the magnitude of local crowd-out of wind energy installation tax revenues by conducting a back-of-the-envelope calculation using wind energy tax laws and district pre-installation tax rates to determine the expected impact on local revenue from a one MW increased in installed wind energy and comparing this amount to the observed effect we estimate. As described in Appendix A, in nearly every state with substantial wind energy during our sample period, the tax laws determining the flow of tax revenues to local jurisdictions were either opaque, determined at the county or municipality level, or interact with school finance laws in a manner that is too complicated to allow for a straightforward calculation. To our knowledge, Illinois is the only state that during our sample period had relatively clear and simple state-level laws determining the flow of revenues from installed wind energy capacity.

Using our preferred specification, we find that a one KW per-pupil increase in installed capacity in Illinois leads to a $3.02 increase in local revenue per pupil (or a one MW per-pupil increase in wind leads to a $3,020 increase in local revenue per pupil). Now assuming enrollments are relatively stable from year to year we can express this as follows:

$$\frac{Rev_t - Rev_{t-1}}{Enrl} = 3{,}020 * (\frac{MW_t - MW_{t-1}}{Enrl})$$

Since the change in MW is simply one, this simplifies to:

$$\frac{Rev_t - Rev_{t-1}}{Enrl} = 3{,}020 * (\frac{1}{Enrl})$$

Which further simplifies to:

$$\Delta Rev = 3{,}020$$

So our results suggest that a one MW increase in installed wind capacity leads to a $3,020 increase in local revenues. As a reminder, this estimated effect is net of any revenue taken by districts as property tax relief.

We now turn to examining how this estimate compares to what we would expect given Illinois tax formulas for wind turbines and using pre-installation tax rates, i.e., predicting what effect should be expected if there were no local crowd-out.

Illinois taxes wind using the formula: ($360,000 x trending factor) – depreciation = fair cash value. Where Depreciation = (age of turbine in years / 25) x trended RP cost basis. The local Mill rate is then applied to 33% of fair cash value.

First assuming no inflation (i.e. no trending factor) and no depreciation, a one MW increase in wind capacity should increase revenues by: (360,000/3) * Tax Rate.

The average tax rate in Illinois districts with installed wind capacity during the year prior to installation is $4.28 per $100. This implies:

Change in revenues of (360,000/3) * 0.0428=$5,136.

Incorporating estimated depreciation, the mean installation year in Illinois districts is 2010, suggesting that the average turbine has been installed for 7 years in our sample. This implies that the fair cash value of a one MW project is (once again assuming no inflation):

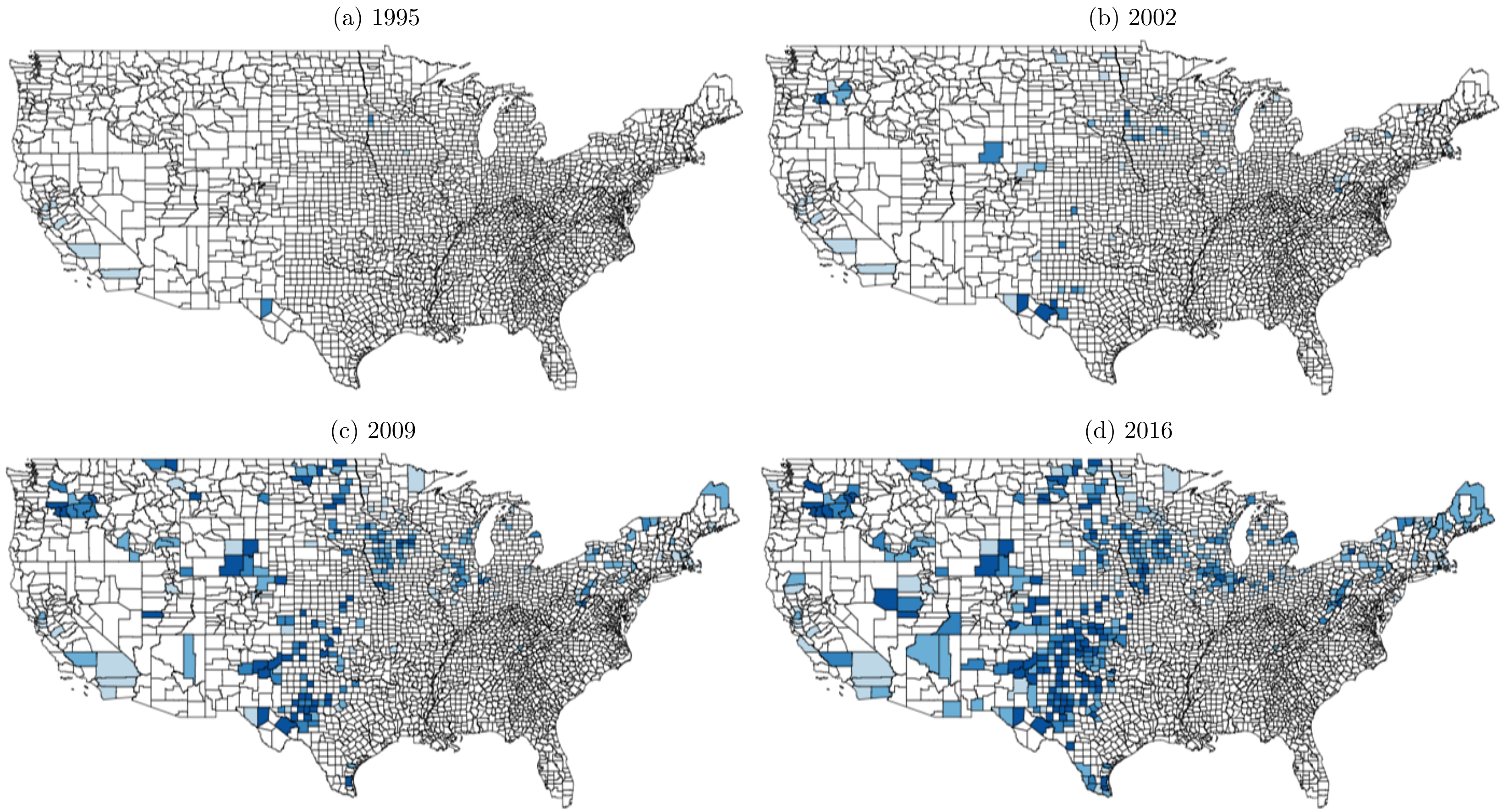
FCV=$360,000 - (360000 * (7/25)) = $259,200

Implying the change in tax revenue would be:

($259,200/3) * 0.0428 = $3,698.

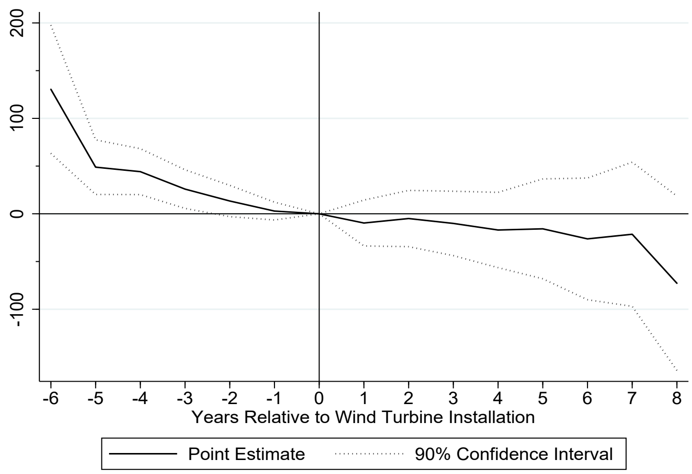
Thus, the predicted increase in local revenues from a 1 MW increase in installed capacity is $3,698, while our estimated effect including any reductions due to property tax relief, is $3,020, for a difference of $678, or 18% of the total revenue gain going toward property tax relief rather than local schools.

Appendix Figure I: United States County Map by Installed Wind Turbine Capacity Per-Pupil



Notes: Map shows installed wind turbine capacity per-pupil in kilowatts (KW) by county and year. Unshaded counties have no installed capacity. The four shades ranging from lightest to darkest represent quartiles of 2016 installed capacity per-pupil: <1.8 KW/pupil, 1.8-16.0 KW/pupil, 16.0-87.8 KW/pupil, and >87.8 KW/pupil, respectively.

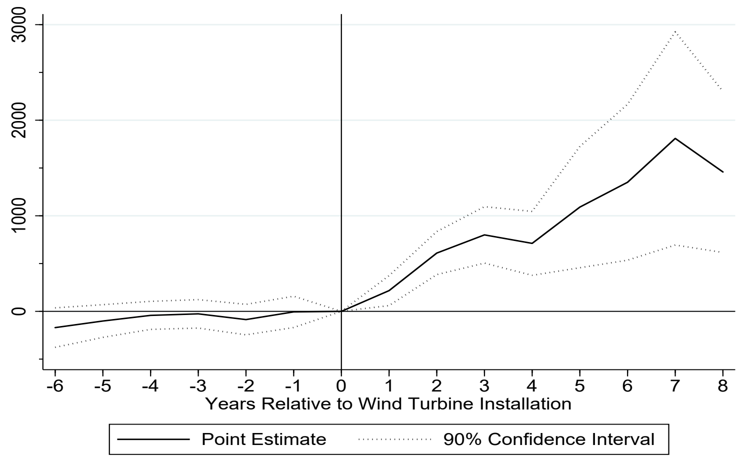
Appendix Figure II: Effects of Wind Turbine Installation on District Enrollment



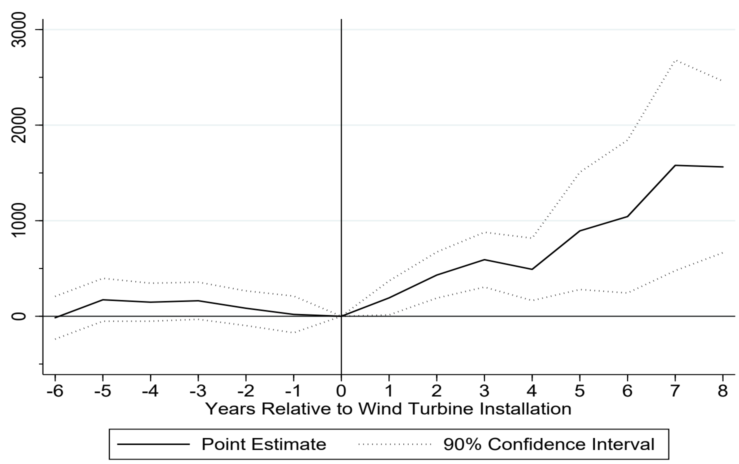
Notes: Figures show event study estimates of the effects of wind turbine installation on school district student enrollment. Solid lines are point estimates, and dashed lines are 90% confidence intervals.

Appendix Figure III: Effects on District Revenues Dropping Multiple Installation Districts

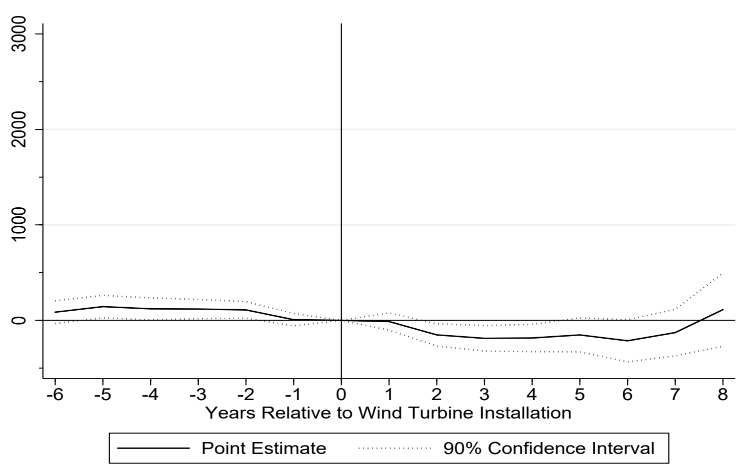
(a) Local Revenue



(b) Total Revenue

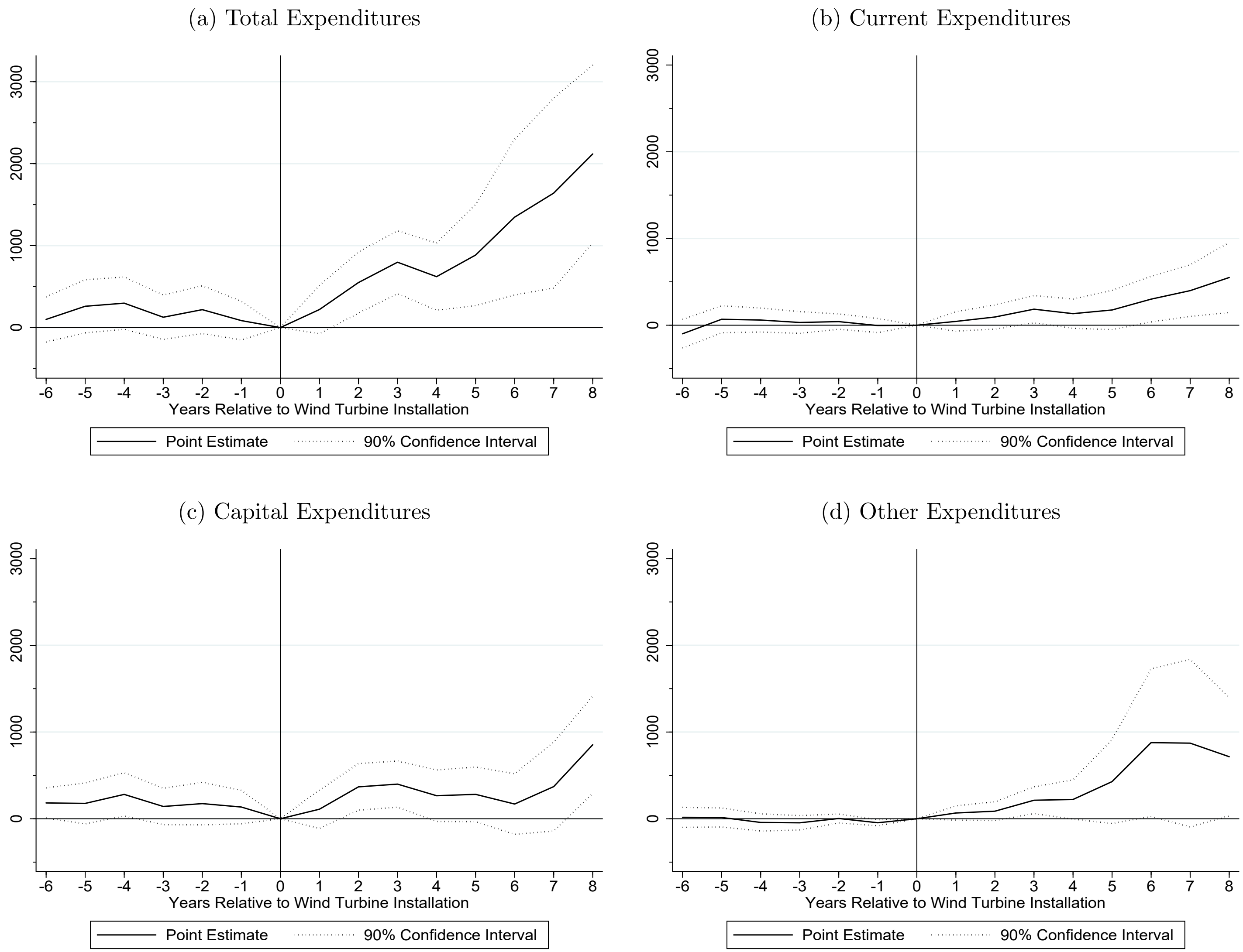


(c) State Revenue



Notes: Figures show event study estimates of the effects of wind turbine installation on per-pupil school district revenues after dropping districts that install multiple wind energy facilities over time. Solid lines are point estimates, and dashed lines are 90% confidence intervals.

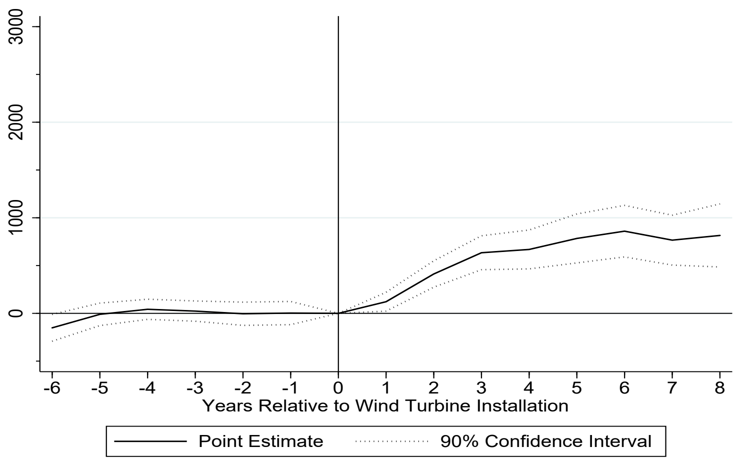
Appendix Figure IV: Effects on District Expenditures Dropping Multiple Installation Districts



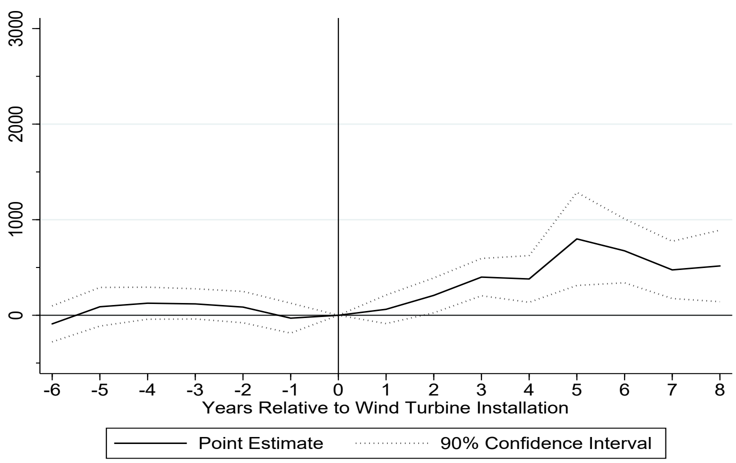
Notes: Figures show event study estimates of the effects of wind turbine installation on per-pupil school district expenditures after dropping districts that install multiple wind energy facilities over time. Solid lines are point estimates, and dashed lines are 90% confidence intervals.

Appendix Figure V: Effects on District Revenue, No Texas

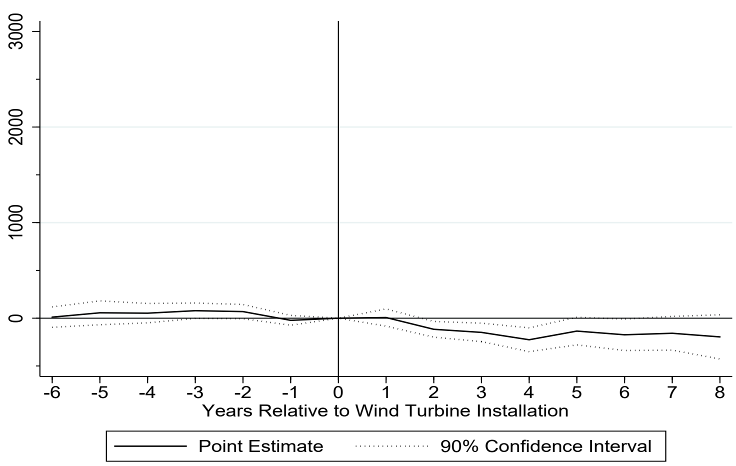
(a) Local Revenue



(b) Total Revenue

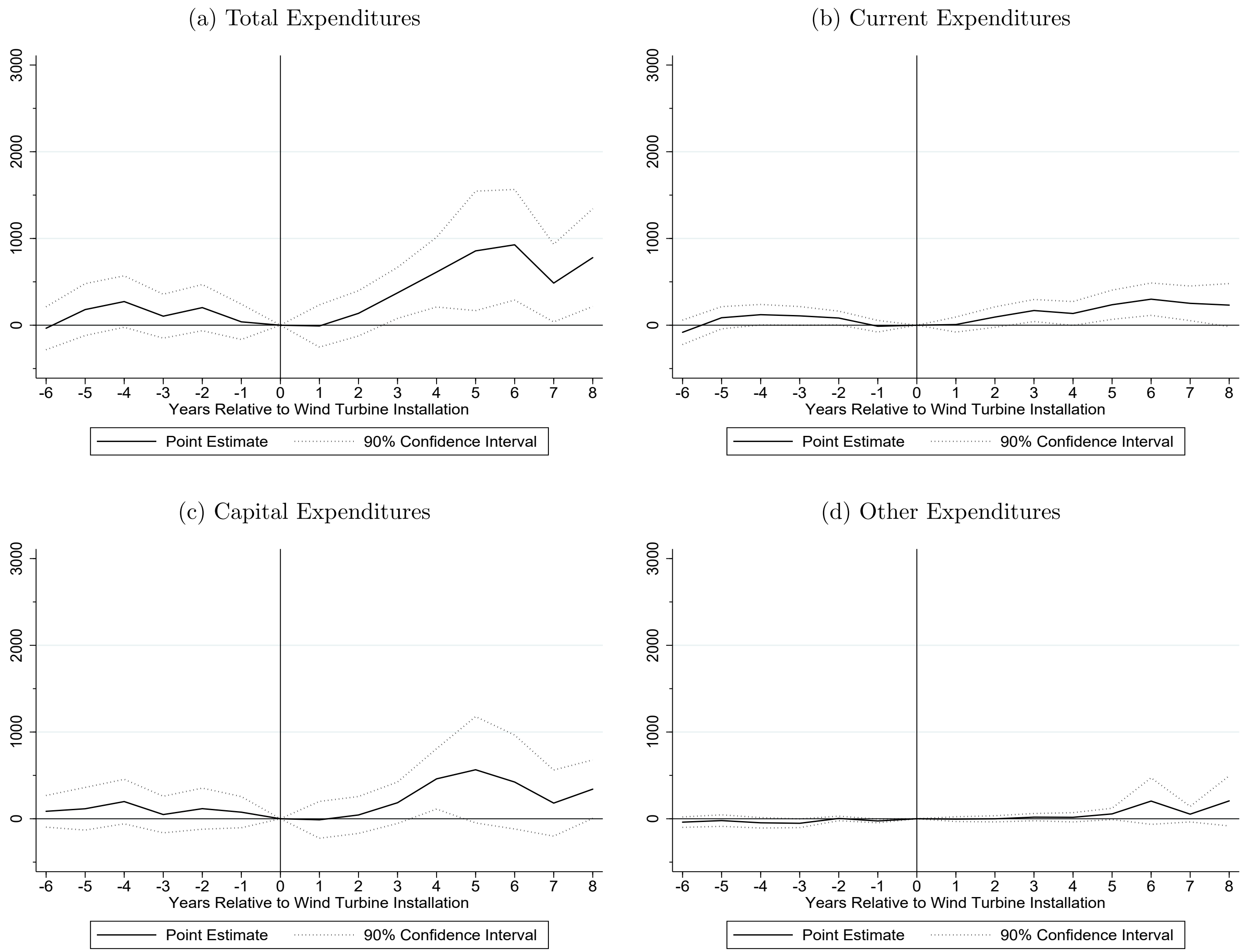


(c) State Revenue



Notes: Figures show event study estimates of the effects of wind turbine installation on per-pupil school district revenues after removing Texas from the baseline sample. Solid lines are point estimates, and dashed lines are 90% confidence intervals.

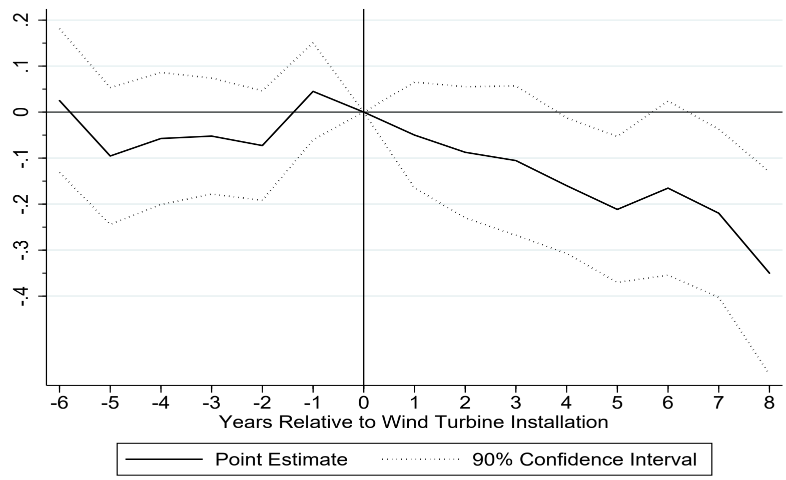
Appendix Figure VI: Effects on District Expenditures, No Texas



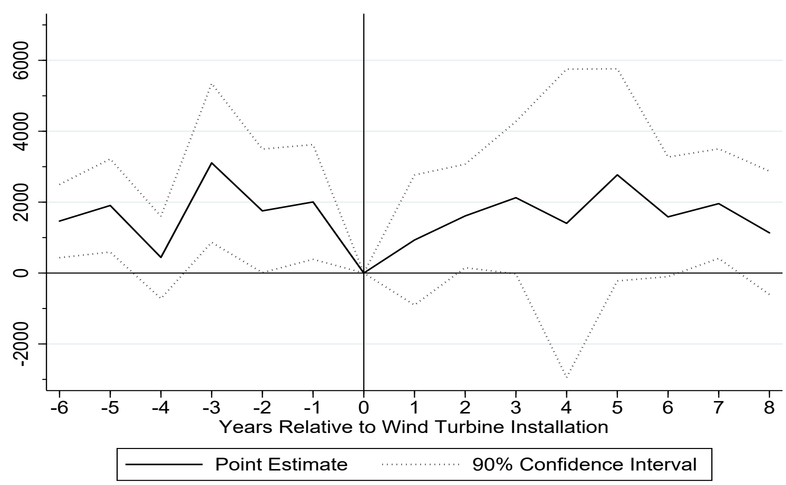
Notes: Figures show event study estimates of the effects of wind turbine installation on per-pupil school district expenditures after removing Texas from the baseline sample. Solid lines are point estimates, and dashed lines are 90% confidence intervals.

Appendix Figure VII: Effects on Education Production Inputs, No Texas

(a) Pupil-Teacher Ratio



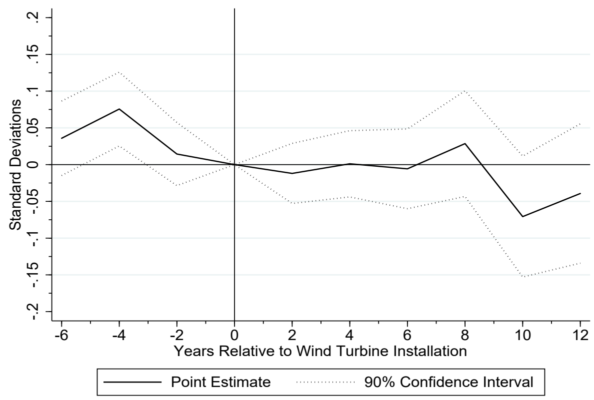
(b) Teacher Salary



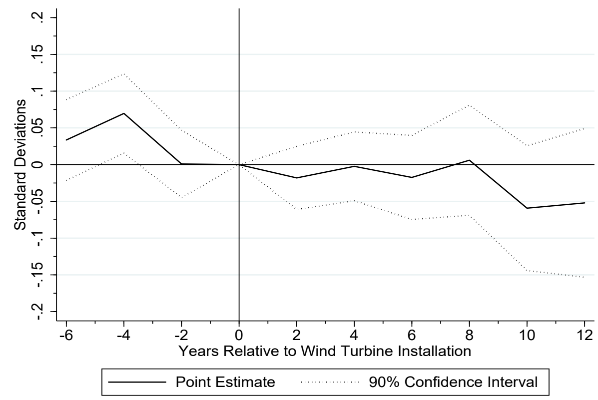
Notes: Figures show event study estimates of the effects of wind turbine installation on inputs to education production after removing Texas from the baseline sample. Solid lines are point estimates, and dashed lines are 90% confidence intervals.

Appendix Figure VIII: Effects of Turbine Installation on Student Outcomes, 12 Years Out

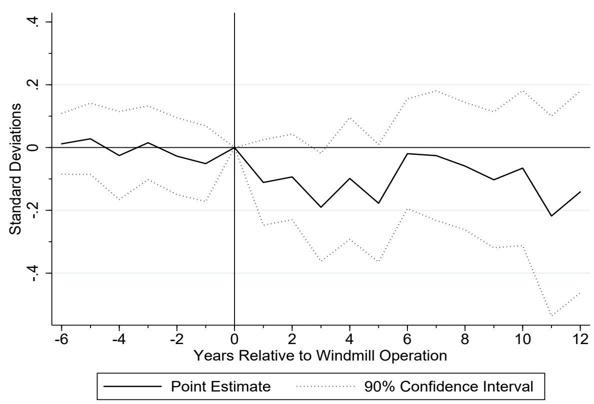
(a) NAEP & SEDA Data, Baseline Sample



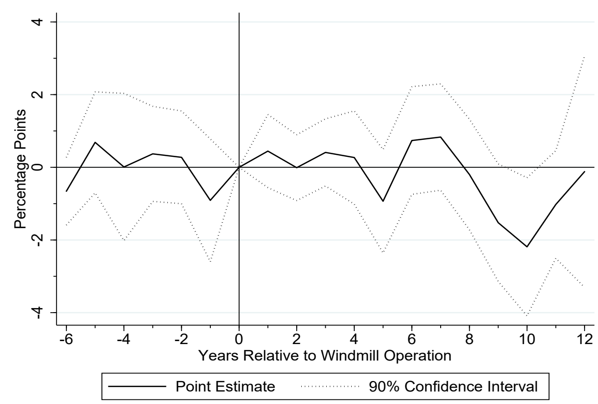
(b) NAEP & SEDA Data, No Texas



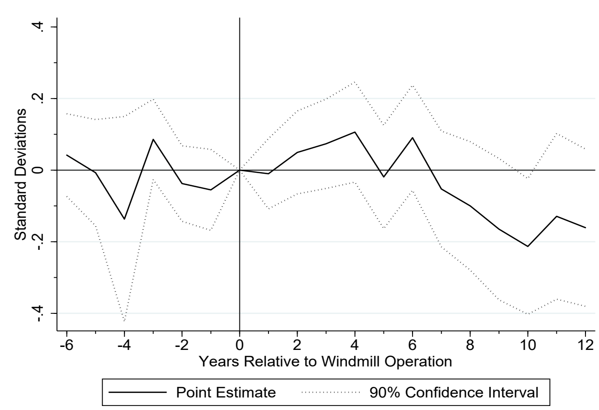
(c) Texas Only, Achievement



(d) Texas Only, High School Grad. (%)



(e) Texas Only, Long-Run Index



Notes: Figures show event study estimates of the effects of wind turbine installation on student outcomes out to 12 years post-event. Subfigures (a) and (b) show effects on standardized district mean test scores for the main sample with and without Texas, respectively, using the combined NAEP and SEDA data. Subfigures (c), (d), and (e) show effects on test scores, high school graduation rates, and an index of long-run student outcomes using administrative data from Texas from 1995-2018. Test scores and the long-run index are standardized to mean 0, SD 1. Graduation is a percent (0-100%). Solid lines are point estimates, and dashed lines are 90% confidence intervals.

Appendix Table 1: Achievement Effects Using SEDA Data Only

	Baseline		No Texas	
	(1)	(2)	(3)	(4)
Stanford Data				
Post	0.002	0.003	0.013	0.013
	(0.022)	(0.022)	(0.024)	(0.024)
Post*Trend	-0.005	-0.005	-0.003	-0.003
	(0.010)	(0.010)	(0.012)	(0.012)
Trend	-0.003	-0.004	-0.006	-0.007
	(0.009)	(0.009)	(0.011)	(0.011)
Effect 5 Years Post		-0.040		-0.037
		(0.028)		(0.030)
Observations	633,857		571,417	
Expanded Controls	No	Yes	No	Yes

Notes: The level of observation is the district-year-grade-subject. The dependent variable is standardized student test scores. In this table, we use annual scores from the Stanford Education Data Archive for the universe of districts from 2009-2015 for grades 3-8.
*** = significant at 99% confidence level; ** = 95%, * = 90%.

Appendix Table 2: Effects of Turbine Installation on Long-Run Student Outcomes in Texas

	% Take AP Exam	% Take ACT/SAT	% Take ACT/SAT & Score High	% Take Advanced Course	% Complete Recommended Curriculum	% Graduate High School
	(1)	(2)	(3)	(4)	(5)	(6)
Post	-0.114	0.066	0.520	1.573	-1.361	0.126
	(0.824)	(1.093)	(0.784)	(1.103)	(1.327)	(0.667)
Post*Trend	-0.173	0.177	-0.124	-0.190	0.130	-0.065
	(0.113)	(0.221)	(0.123)	(0.172)	(0.248)	(0.099)
Trend	-0.031	-0.108	-0.054	-0.068	0.016	0.015
	(0.072)	(0.097)	(0.066)	(0.081)	(0.089)	(0.054)
Effect 5 Years Post	-1.131	0.412	-0.370	0.288	-0.630	-0.126
	(0.794)	(1.098)	(0.844)	(1.138)	(1.256)	(0.512)
Dep. Var. Mean	9.4	62.7	21.5	21.2	56.9	90.9
Observations	22,427	22,084	21,983	22,758	21,656	20,773
Expanded Controls	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table uses a separate adminstrative dataset from the Texas Department of Education. The level of observation is the district-year. The sample includes all districts in Texas from 1995-2018. See text for definitions of the dependent variables.

*** = significant at 99% confidence level; ** = 95%, * = 90%.