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What Blows in with the Wind?

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Abstract

The shift toward renewable forms of energy for electricity generation in the electricity generation industry has clear implications for the spatial distribution of generating plant. Traditional forms of generation are typically located close to the load or population centers, while wind and solar-powered generation must be located where the energy source is found. In the case of wind, this has meant significant new investment in wind plant in primarily rural areas that have been in secular economic decline. This paper investigates the localized economic impacts of the rapid increase in wind power capacity at the county level in Texas. Unlike Input-Output impact analysis that relies primarily on levels of inputs to estimate gross impacts, we use traditional econometric methods to estimate net localized impacts in terms of employment, personal income, property tax base, and key public school expenditure levels. While we find evidence that both direct and indirect employment impacts are modest, significant increases in per capita income accompany wind power development. County and school property tax rolls also realize important benefits from the local siting of utility scale wind power although peculiarities in Texas school funding shift localized property tax benefits to the state.

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1 Introduction

Global growth of wind powered electricity generation in the last decade has been substantial. In the United States alone, according to the National Renewable Energy Laboratory, installed wind power capacity has increased from 2,539 MW in year 2000 to 61,108 MW by year-end 2013. Although most wind generation is concentrated across the Great Plains, Midwest, and Far West regions of

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the U.S., nearly 39 states now have utility-scale wind powered electricity generation. As turbine technology continues to improve, with concomitant reductions in generating costs, the geographic range of economically feasible generation will expand. Mounting economic and political pressure to increase the share of clean, renewable energies in the nation's electrical power generation portfolio will likely pave the way for build-out of high voltage power transmission from high quality wind resources to populous regions.

While the main appeal of wind generation is its environmental benefit, it also offers a different industrial trajectory that is seen as having the potential to bestow benefits on new constituencies. Indeed, the spatial distribution of utility-scale electricity generation among the different types of electrical generation is quite different and thus implies a corresponding change in the spatial distribution of employment (at the point of generation) and, possibly, income. Thermal generation, the dominant form of electricity generation, is typically located close to load centers, i.e., more populous areas; whereas wind generation must necessarily be located where the wind resource is found. A casual glance at a wind resource map suggests that these wind resource-rich regions tend to be more rural, exhibiting relatively low population densities. This has meant, among other things, a sharp uptick in fixed plant in some windy rural areas that have been in secular decline and increased investment in transmission capacity to exploit the wind resources and deliver the energy to urban consumers.

It is therefore not too surprising that rural development interests have been allied with environmental groups at the forefront of political advocacy for policies to promote growth of wind generation. There are, of course, both short and long-term benefits and costs associated with this development that need to be considered before net localized benefits can be identified. However, the extent of net localized economic impacts has not been widely studied.

In this paper, we investigate the localized economic effects of wind power development. We use the State of Texas as the region for analysis. We are able to exploit the controlled comparison enabled by the fact that Texas has large regions with high quality wind resources and (otherwise similar) large regions with uneconomic wind regimes to identify wind power-related changes in the variables of interest. Rather than relying on an input-output modeling methodology to extrapolate gross outcomes, we consider the net localized spillover effects on other industrial employment, per capita personal income, county property tax bases, and key variables related to localized public school finance using standard regression analysis. Unlike previous research in this area, we conduct an analysis that seeks to observe the nature of employment growth in terms of its industrial composition and the likely inter-industry spillovers. Although we are unable to observe directly whether or not the increases in tax capacity result in higher levels of local public goods provision, we consider the question of changes in levels of per-student public education expenditures as an indirect measure of changes in levels in local public goods.[1] This paper is the first to examine the net effects of wind energy development on school tax rates, revenues and expenditures.

Restricting the analysis to Texas still captures a significant share of the wind power industry. Over 20 percent of the total installed wind generation capacity in the United States at the end of 2013 was located in Texas. With 12,355 megawatts (MW) of installed wind generation capacity at year-end 2013, Texas produces more wind generated electricity than any other state in the United States. The rapid growth of this industry in Texas has mirrored that of the U.S. In year 2001, Texas had only 898 MW of installed wind capacity.[2]

By limiting the analysis to a single state, we have a consistent means by which to consider changes in property tax bases, rates, and public school finance. We seek to determine what, if any, persistent local benefits accrue to the residents of the counties in which the wind power generation is located. We find that, at best, direct and indirect employment effects are modest while increases in per capita county personal income can be important. This result implies that gains in personal income come from sources other than wage income such as net lease income for farmers and ranchers. As expected, we find that the value of county property tax bases increases with increases in installed wind capacity. This appears to enable county governments to reduce tax rates while the benefits to school districts are mitigated due, probably, to the state and local school funding formula in Texas.

It should also be noted that, since the utility-scale wind developments are non-locally owned, the lion's share of benefits will accrue outside the locality while many of the costs are borne locally. The effects on (non-migratory) avian populations, noise pollution, degradation of the landscape, and

[1] Beginning with Oates (1968), public education expenditures have been widely used as a proxy for the level of provision of local public goods. More recently, Weber, Burnett, and Xiarchos (2014) find that the larger property tax base that resulted from shale oil development in Central Texas led to increased school expenditures.

[2] To scale the size of the wind industry in the U.S., it is noted that wind generated electricity accounted for 3.5 percent of all electricity consumed nationwide in 2012. Shares of state generation depend on capacity as well as market size. Thus, while Texas generates more wind power than any other state, wind generated electricity represented only 7.4 percent of electricity delivered in the state in 2012 (9.2 percent on the Electrical Reliability Council of Texas, ERCOT, grid), ranking Texas at number 11 among all states by this measure.

reductions in agricultural and tourism activities that accompany utility-scale wind development are detrimental to the welfare of the local residents. The long-term consequences for land-use and the landscape will depend on the disposition of the turbines and their foundations when their economic life is over. We do not correct our impact analysis to take these costs into consideration.

While production technologies and supply chains are clearly quite different between the different means of generating electricity, it is not obvious how the substitution of wind-powered generation for generation by other energy sources will influence overall employment and income in the electricity generation sector. For example, employment in thermal generation of electricity includes activities in fuel extraction, processing and transportation while no fuel *per se* is required for wind generation. Comparing macro-level employment and income effects from the shift to renewable forms of electricity generation is complex and beyond the scope of this paper.

Of course the substitution of renewable energy sources for fossil fuels provides environmental benefits in terms of reduced emissions of carbon dioxide, sulfur dioxide, and mercury. These are for the most part global benefits.[3] Moreover, wind power does not require water to generate electricity, a big advantage in Texas and the Southwest. No effort is made to quantify the broader environmental value of substituting wind power for gas or coal-powered generation nor is any attempt made to establish the effect on market prices of electricity of mandated changes in the electrical generation portfolio.

The paper is organized as follows. Section 2 provides a discussion of the economic and institutional context with a brief literature review. Section 3 describes the data and empirical models that are used to estimate the localized economic impacts. Section 4 provides a brief discussion and conclusions.

2 The Economic and Institutional Context

The growth of wind power in Texas, as in the United States, appears to have resulted primarily from the presence of the high quality wind resource, improvements in turbine performance, and the assured, *ex ante* availability of the federal Production Tax Credit (PTC) that was enacted in 2006.[4] Since installed capacity in Texas has already exceeded the requirements of the state's 2025 Renewable

[3] A referee suggested to us that substitution toward wind energy may represent a relatively expensive means by which to reduce carbon emissions. For more on this point, see Cullen (2013). In such a case, policy makers may reduce subsidies for new wind development, and future localized impacts may be affected.

[4] Gulen, et al. (2009), Wiser et al. (2007).

Portfolio Standard (RPS), the RPS does not help to explain the rapid increase in capacity.[5] Nor does the creation of tradable Renewable Energy Certificates (RECs) in 1999 provide much help. The acceleration in wind development occurred after the price of RECs collapsed in early 2006 from over $10 to around $3 per MWh.

Although the Texas Legislature does not explicitly refer to the economic development impact of installing wind capacity in West Texas in the bills that enacted and expanded the state's RPS, it has nevertheless been widely recognized as a significant benefit mostly as a consequence of growth in school and property tax base. Employment considerations are important in rural counties that have been losing jobs and population for decades.[6] Activities that bring new vitality to these communities are of course particularly welcome in these rural areas. Moreover, Texas has a tradition of protection of property rights in resource exploitation without significant regard to external effects. For example, oil and gas development (even the more recent hydraulic fracturing methods) has gone largely unchallenged since its beginnings and protection of the "right of capture" in groundwater withdrawals has been easily maintained. In the pro-business, pro-extraction culture of Texas, wind developers have met little local resistance to siting the turbine fields.

The State of Texas has also encouraged the development of wind power in the state by extending and deepening the transmission infrastructure and ensuring a receptive regulatory environment with a competitive electricity market. Indeed, continued growth of wind power has rather been constrained by the lack of high voltage transmission from the areas with the highest quality wind resources to the load centers in the eastern half of Texas within the grid operated by the Electrical Reliability Council of Texas, or ERCOT. The potential for expansion of productive capacity encouraged the Texas Public Utility Commission (PUC) in collaboration with ERCOT to move forward with the construction of high voltage transmission lines to connect the wind resources in five designated Competitive Renewable Energy Zones (CREZs) in West Texas (Panhandle, Permian Basin, Edwards Plateau and Trans-Pecos regions) to load centers in East Texas and to relieve east-west congestion. With an aggregate capacity

[5] The original RPS passed in 1999 mandated 2000 MW by 2009. In 2005, the RPS was amended to mandate 5,880 MW by 2015 and a target of 10,000 MW in 2025. Texas has already easily surpassed the 2025 goal.

[6] The State of Texas had substantial population growth over the period 1980-2000, increasing some 6.6 million persons or about 46%. However, as an indication of how unevenly this population growth was distributed, 77 Texas counties, or just under one-third, experienced population declines over these two decades. Of the 6.6 million person increase, about 6.4 million appear in counties that had populations in excess of 20,000 in 1980, with the other 200,000 persons being located across 157 counties whose 1980 populations were less than 20,000. As to employment growth, 63 of the 254 counties saw absolute declines in employment between 2000 and 2011 while the State of Texas had employment growth on the order of 16%. All but two of these 63 counties are clearly rural.

of 18,500 MW (about twice current installed wind capacity), it should greatly reduce curtailments and bring a substantial amount of additional wind power onto the ERCOT grid. The CREZ transmission line build-out was not completed until December, 2013, well after the period under consideration in this study.

The electricity system in Texas is unique in the United States insofar as the main Texas interconnection, operated by ERCOT, has no synchronous ties to either the Eastern or Western Interconnections.[7] Since the ERCOT grid is wholly contained within the state, and has no AC ties to grids outside the state, ERCOT is exempt from most federal regulatory authority – primarily that vested in the Federal Electricity Regulatory Commission (FERC). But not all of Texas falls within the ERCOT domain. Most of the Panhandle and much of the South Plains is within the Southwest Power Pool (SPP) while the corner of the state that contains El Paso is in the grid operated by the Western Electricity Coordinating Council (WECC).

Looking at a map of wind development in the state, the effects of this anomaly are clear. That is, much of the wind energy development has taken place along the edges of the ERCOT boundary closest to the wind resources in the South Plains and Panhandle regions, and has been slow to develop in the regions (most notably the Panhandle) with higher quality wind resources due to the lack of market and interconnection.[8] Transmission from the Panhandle of Texas to the principal SPP load centers in Oklahoma City and Kansas City has been limited.[9] An interesting facet of this has been that none of the wind power generated in utility-scale facilities located in the non-ERCOT regions that have transmission connections to ERCOT can be delivered locally or to entities in the SPP. This is because a wind generator that delivers power into both ERCOT and another interconnection would imply a de facto ERCOT synchronous tie to a non-ERCOT grid and thus bring ERCOT under FERC authority.

To underscore the effect of the ERCOT boundary and the rural nature of the location of the wind generation, seven counties along the northwestern edge of the ERCOT region, Borden, Coke, Fisher,

[7]ERCOT has 5 DC ties of which 2 interconnect with the Eastern Interconnection through the SPP and 3 are located along the Texas-Mexican border. ERCOT also maintains a diesel generator in Austin in the event a "dark start" is ever necessary.

[8] It should be borne in mind, however, that wind class estimates at the county level can be misleading given the effects that highly localized topography can have on average wind speeds. For example, in the Fluvanna wind power development near Post, TX, as across the Edwards Plateau, turbine placements take advantage of wind acceleration over mesas or along ridgetops that sit along and below the Caprock escarpment. Thus, the localized wind resource is substantially better than the average wind class for the county.

[9]Xcel Energy has recently purchased wind power for delivery in the SPP from Texas generators in the Panhandle region: the Wildorado Wind Ranch (161 MW) located in Potter/Randall/Oldham Counties, Spinning Spur (161 MW) located in Oldham County, and White Deer (80 MW) in Carson County.

Nolan, Runnels, Scurry, and Taylor, combined in 2012 to host 3,836 MW of wind generation capacity, or nearly one-third of the total state capacity. Excluding Taylor County, in which Abilene is located, the combined total employment in 2012 in the other six counties was 23,828 according to the Texas Workforce Commission.

Further to this point, most of the areas where wind power development has occurred are rural with predominantly (pre-wind power) agricultural economies. Even for counties within the ERCOT grid, local demand for electricity is typically a fraction of the locally generated wind power. Wind power development has occurred with the purpose of export of the electricity from the regional economy and has not measurably displaced regional generation capacity for local consumption. Employment effects from the substitution of wind generated electricity for thermally generated electricity, if they occur, would be mostly observed in the eastern portion of the state.[10]

Based on the authors' experience in West Texas, there is a popular view that development of wind power brings significant local economic benefits. A piece published by WorldWatch Institute in 2009 describes the economic impact of wind power in Sweetwater, TX, a city in Nolan County where extensive wind development has occurred. It states, "The wind industry boom has stimulated job growth across the entire local economy. Some 1,500 construction workers are engaged in Nolan County's five major wind energy projects. Building permit values shot up 192 percent in 2007 over 2001 values. Sales tax revenues increased 40 percent between 2002 and 2007. The county's total property tax base expanded from $500 million in 1999 to $2.4 billion this year." More recently, as a part of its reporting on the approval by the Hockley County Commissioners' Court of an 80 MW wind project, KLTV News reported that the project will be a "significant economic boost" for Hockley County, stating that it "is expected to bring $27 Million to landowners in lease payments and will add approximately 130 Million Dollars to the tax rolls once the project and special county agreement is complete in year 11." [11]

This notion that large scale wind development in relatively rural counties will have a significant

[10] These employment effects would mostly occur in the more densely populated counties along the I-35 corridor from Dallas-Fort Worth to Houston. These highly urban counties have been excluded from the analysis and so substitution effects on employment should not affect the comparative results in this paper.

[11] This article can be found at http://hprnnews.wordpress.com/2014/07/28/hockley-county-approves-agreement-with-red-raider-wind-llc/. The report also states that, "There is also an estimated 418 Million Dollars in Regional Economic Impact expected with the project as part of the Texas Tech Wind Research Facility as they will expand as part of this project." It is worth noting that the Commisioners' Court approved an agreement to limit county receipts to $1500 per MW for the first 10 years.

localized economic impact is indeed persuasive. Brown et al. (2012) suggest several avenues by which wind power development can affect its local economy. Five of the eight ways they suggest seem relevant to the Texas context. 1) Wind generation provides a direct source of employment. This employment may be associated with the construction phase of the project and, thus, be temporary; or it may be permanent jobs associated with ongoing O&M once the turbines are fully commissioned.[12] 2) Both construction and operations activities may generate demand for locally produced/distributed inputs. 3) Landowners who lease land to situate the turbines enjoy lease income.[13] It is perhaps worth noting that this land typically has alternative agricultural uses and thus the lease income needs to be viewed as the net income benefit, presumed positive, after correcting lease revenues for the foregone agriculturally-derived income. Denholm et al. (2009) report that wind turbines displace on average 0.74 acres of land per MW of installed capacity; Reategui and Hendrickson (2011) reference a 2008 DOE report that found that wind power uses between 2-5% of the total land area.[14] 4) The turbines contribute to the local property tax base and yield increased tax revenues *ceteris paribus* to local tax jurisdictions. 5) The localized consumption spending from the increases in personal income that accrue to workers and landowners can provide a boost to local retail and service providers.

Most of the recent economic impact studies of wind energy in the literature have utilized input-output modeling methodologies to estimate gross impacts and have been based on the state-level as impact study area (Tegen (2006), Lantz and Tegen (2011), Keyser and Lantz (2013)). These studies, by and large, have used the JEDI (Jobs and Economic Development Impact) model, a spread-sheet based input-output model developed by a private contractor for the National Renewable Energy Laboratory (NREL). JEDI utilizes the Minnesota IMPLAN database and enables the user to conduct impact

[12] According to a source at the Sweetwater, TX Economic Development Corporation, 2013 wage rates for wind technicians in Nolan County, TX were approximately $15 per hour with no experience, $18 per hour with some experience, and $22 and higher per hour depending on the type of turbines the technician is qualified to maintain.

[13] A conversation with a Texas-based wind power developer provided an overview of a typical agreement on landowner revenue. The agreement recognizes three different periods –development, construction, and operations. In the development phase, during which the project developer undertakes both wind and environmental testing to determine project viability, there is usually an up-front payment ($/acre) at the time the lease is signed and may include an annual rental payment ($/acre). In the construction phase, the landowner is reimbursed for damages due to roads, electric lines, substations, staging areas, etc., and a royalty payment (percentage of revenue) for any electricity sold prior to full commercial operation of the project (as turbines come on line a couple at a time). During the operations phase, typically 25-30 years, there is a royalty payment (percentage of gross revenue) from any electricy sold, including revenue from RECs. There is also a minimum annual royalty payment specified, usually about half of what the expected annual revenue would be, in the event the project is curtailed, electricity prices drop, or there is some type of serial defect in the turbines.

[14] The actual density of turbines depends on the quality of the wind resource. An average density used by NREL/AWS Truewind is 5 MW/km^2, although this number could be as high as 20 MW/km^2. Higher density arrays would be found along ridgetops which have lower valued opportunity uses in agriculture.

analyses for a given scale of wind power development.[15]

The limitations of input-output modeling are well known and become more problematic as the study area decreases in size and industrial diversity. State-level impact analyses reflect the greater industrial diversity and potential for in-area sourcing of inputs than would be the case in a county-level analysis. Aside from the assumptions of constant returns to scale, fixed-input proportions technologies in all industries and perfectly elastic factor responses, a significant amount of project-specific knowledge and familiarity with the local industrial base and sourcing patterns is necessary to calibrate the models' parameters for credible results to emerge from the exercise. The "off-the-shelf" JEDI model is based on state-level multipliers. Use of the "off-the-shelf" model, i.e., no adjustments for the actual local production and sourcing of requisite specialized inputs, labor market conditions, sales margins, etc., can readily lead to over-stated impacts.

Slattery *et al* (2011) estimate economic impacts for two large utility-scale wind projects in Texas at both the state-level and the smaller area (contained in Texas) of the region within 100 miles of each of the two wind developments. At the state level in Texas, as they note, growth in wind power equipment manufacturing and specialized construction firms has increased the potential for more Texas-based value-added in the wind development supply chain. They use JEDI –but adjust the model parameters to reflect specific information they obtained for each project– to consider two wind plants, Horse Hollow (735.5 MW), in Nolan/Taylor Counties, and Capricorn Ridge (662.5 MW), in Coke/Sterling Counties. Nolan/Taylor Counties are both more populous and industrially diversified than the very rural Coke/Sterling Counties. State-level estimates of the impacts normalized to the MW unit do not of course differ much between the two projects. Their estimates of the smaller region gross impacts differ somewhat in terms of induced impacts as a result of the different industrial profiles of the two counties. During each of the projected 20 years of the operations phase, they estimate 128 (.174/MW) FTE's for Horse Hollow and 97 (.146/MW) FTE's for Capricorn Ridge.

Reategui and Henderson (2011) conduct an economic impact analysis that looks at five specific wind projects in Texas using JEDI, with results scaled to 1000 MW of installed capacity over the statewide study area. Their estimates of local shares of construction and input costs thus refer to Texas rather than the smaller locality of the project. Even with this broader impact area, the authors

[15] http://www.nrel.gov/analysis/jedi/about_jedi.html The JEDI model has been expanded to include economic impact analysis of other forms of renewable energy production of electricity.

estimate that 80 percent of the project construction cost is sourced from out-of-state. Of total O&M costs, they estimate that 14.1 percent goes toward labor/personnel costs. Their results suggest that between 140 and 240 localized jobs are associated with 1000 MW of wind power during the operation phase of a project. This estimate of the county-level employment impact would depend on how their estimate of 100 local jobs in equipment and supply chain sectors is allocated between the state-level (non-local county) and the county level. Consistent with other estimates, they found that annual land lease payments average approximately $5,000 per MW such that 1000 MW of wind generates about $5 million per year in lease income for farmers and ranchers and the present value (for project life of 20 years) of property tax payments is around $7 million per 1000 MW of wind development.[16]

The impression that emerges from looking at economic impact analyses for wind projects is that there are important localized effects on employment and income.[17] For the many reasons enumerated above, however, one should view these results in the proper context. First and foremost, these projects do not attempt to measure net localized effects, i.e., correct for declines in employment and income in other sectors as wind development attracts workers and (potentially) increases wages. Studies conducted by industry advocates, in particular, must be approached with caution since they emphasize gross effects. For example, the WorldWatch Institute, in the article quoted above, notes a study released by the West Texas Wind Energy Consortium that found that an estimated 1,124 of Nolan County's 14,878 residents, or nearly 8 percent, have jobs directly related to wind energy. This figure includes employment in all wind-related industries, i.e., it includes construction, manufacturing, service sectors, etc. Nevertheless, this translates to about 15.6 percent of the establishment-based 2012 employment in Nolan County.

A casual look at Nolan County employment totals, however, suggests there may have indeed been crowding out of other activities. Total employment in Nolan County, as reported by the Texas Workforce Commission, increased from 6,972 in 2000 to 7,217 in 2012, or 245 employed persons.[18] This represents employment growth of a little more than 3 percent, compared to growth in total employment

[16] 2009 dollars.

[17] Brown *et al.* (2013) provide a tabular summary of input-output estimates of wind power development in several states. I-O employment impact estimates ranged from .14 to .62 jobs per MW and, for income, from $5400 to $17800 per MW (2010 dollars).

[18] This seems reasonable for new direct employment in wind power production if all else were unchanged. Nolan County has something on the order of 2000 MW of installed capacity which, according to Reategui and Hendrickson's conclusion, should result in 240-480 jobs during the operations phase of the wind turbines.

in Texas (including Nolan County) of 18.6 percent. This is of course an unconditional comparison, but nevertheless provides *prima facie* evidence of a modest net positive effect of the wind power industry on overall county employment. A back of the envelope calculation (that ignores income and welfare considerations) leads to a simple conclusion that some 1200 jobs in pre-wind power employment must have been lost between 2000 and 2012 to accommodate this increase in wind power-related employment.[19]

Recent experience with large wind projects in Texas does not seem consistent with these I-O estimates. For example, following commissioning of the initial 202 MW phase of the Penascal Project in Kenedy County (an onshore development near Corpus Christi) in 2009, Iberdrola Renewables, the project owner/operator, reports 10 ongoing O&M jobs, or only .05 jobs/MW.[20] According to Red Raider Wind LLC, their 80 MW project in Hockley County, referenced above, will employ 6-8 persons, or about .075-.1 jobs/MW. Perhaps as turbine technology and reliability have improved and capacity has increased, since these earlier studies, more recent wind developments have realized significant labor economies as measured by changes in jobs/MW.[21] The Penascal Project uses 2.4 MW turbines compared to 1.5 MW turbines at the Red Raider development. In the earlier wind developments in the first half of the decade of the 2000s, turbines with nameplate capacity of 1 MW or less were fairly standard.

At least one previous study has attempted to estimate total net effects from wind power development on employment and income. In lieu of the input-output modeling methodology, Brown *et a*l. (2012) conduct an econometric analysis as a means of measuring the *net* county-level economic impact of wind power in the central United States. They regress changes in county per capita income and employment on changes in MW per capita of installed wind capacity between 2000 and 2008 in 1009 counties located across the Great Plains. Their results lead them to conclude that for every MW of installed wind power capacity, total county personal income increased by $11,150 and county employment increased by 0.482 jobs over the eight year period. From this, they inferred a median increase of 0.22% in total county

[19]Using the consistent longer-term establishment-based employment series from the County Business Patterns, rather than TWC total employment data, suggests a somewhat different picture. Employment increased from 4150 to 4237, or 2.1%, between 1992-2002, but decreased from 4237 to 4233 between 2002-2012. Changes in population are not positive in any of the last three decades up to 2010. U.S. Census data indicate that population changes in Nolan County were -4.4% over the 1980s, -4.8% over the 1990s, and -3.7% over the first decade of the 2000s.

[20]See http://iberdrolarenewables.us.files.s3.amazonaws.com/pdf/Penascal-Fact-Sheet-Final-english.pdf

[21]O&M labor is more closely correlated to the number of turbines rather than total MW installed. So fewer, but larger, turbines should yield labor savings per MW.

personal income and 0.4% in employment in counties with installed wind power. These conclusions are based on coefficient estimates that were only weakly statistically significant. They note that their results are in line with input-output derived estimates.

Other studies that have looked at the long-run effects of natural resource development, more generally, suggest that some skepticism toward a substantial net positive long-run impact from development of the wind resource may nevertheless be warranted. Working at the state level in the U.S., Papyrakis and Gerlagh (2007) find that natural resource abundance leads indirectly to slower economic growth as it tends to depress the values of other variables, such as investment and education, that are important to long-term growth. James and Aadland (2011) find that natural resource-dependent counties in the U.S. exhibit slower growth than counties with less such dependence. On the other hand, Weber (2012, 2013) finds that natural gas development in the western and south-central U.S. is associated with increases in local employment, population, and income per job.

There is no doubt that utility-scale wind development represents significant new fixed plant and, thus, increases in the county property tax rolls. This should translate into increased property tax revenues, at constant tax rates, in the tax jurisdictions where the wind plant is located. However, much of the literature that looks at levels of local public goods following fiscal windfalls at the local or municipal level finds that the fiscal benefits fail to reach the local population. Caselli and Michaels (2013) report that oil revenues accruing to Brazilian municipalities appear to increase local spending levels but actual changes in real social expenditures and household income are much more modest and, in fact, may not even occur.

There is also the question of the "flypaper effect" if one thinks of these natural resource-based fiscal windfalls as having some equivalence to a permanent increase in transfers from either the state or federal government.[22] In the absence of a flypaper effect, or some partial effect, the new revenue streams to county governments and school districts should result in tax reductions. However, Olmsted, Denzau, and Roberts (1993) find that Missouri school districts tended to increase operating budgets so as to offset the reductions in debt payments that occurred as debt issues were retired. As a result,

[22] Hines and Thaler (1995) attribute the term "flypaper effect" to Arthur Okun, and it describes the tendency for fiscal transfers, grants-in-aid, from the federal government to state or local governments to often result in greater increases in local spending than would a commensurate increase in local income, i.e., the transfer tends "to stick." For an overview of the phenomenon, see Robert P. Inman (2008), "The Flypaper Effect," NBER Working Paper 14579, available at http://www.nber.org/papers/w14579

even though debt service declined, total revenue needs did not and tax rates were left unchanged. An informal survey in the newly developed wind resource counties of West Texas would probably lead most people to conclude that school districts have recently undertaken a large amount of construction and renovation of school and related facilities that would not have otherwise occurred (at this scale). By the same token, it seems quite likely that investments in rural school infrastructure have been lagging behind their urban counterparts in Texas and allocating new resources in these districts is quite justified.

We now turn as well to the econometric modeling of the economic impacts of wind power in Texas. We consider, in turn, industry employment spillovers, personal income, and impacts on the total assessed value of the county and school property tax base, tax rates, and school expenditures.

3 Data and Estimations

The matter of direct localized employment impacts seems reasonably well established in the input-output literature. That is, direct local employment during the operations phase of a wind plant is on the order of 0.13 - 0.14 jobs per MW, or 130-140 jobs per 1000 MW. This is in fact a verifiable outcome if private employment records were made available. Total net localized effects are another matter. Predicted outcomes from input-output modeling are gross effects and determined by the model's parameters and input levels. County-level net effects are observable *ex post* through empirical means. This point is made by Brown et al (2012) who empirically estimate the effect on total county employment, finding that the sum of the direct, indirect, and induced effects is about three times the direct employment impact.[23] This in turn suggests measurable spillover effects in other industries in the counties in which large scale wind plant is located.

Data

Our primary data for the number of establishments and average payrolls by industry are compiled from the Quarterly Census of Employment and Wages (QCEW) for Texas. Prior to 2007, the QCEW data were not publicly available. The authors were provided the QCEW data for Texas for the years 1998-2006 by the Texas Workforce Commission. There were changes to the QCEW industry

[23] In the language of impact analysis, direct localized employment would be the O&M jobs directly tied to the wind farm field site or management offices; indirect employment would be the workers engaged in wind power supply chain jobs; and induced employment is the localized effect of the spending of wages, salaries, lease revenue, etc., in the county.

configuration in 2007. We are assuming that industry definitions remain consistent at the two-digit level. Wind energy capacity by county and year of commissioning were available from ERCOT in the Capacity, Demand and Reserves Report for 2012 and from the Xcel Energy corporate website.[24]

Texas general fund county property tax rates were taken from the County Information Program, Texas Association of Counties, from data supplied by the Texas Comptroller of Public Accounts. Our property and school district level taxable values (assessed property value or total tax base) and tax rates are gathered from the Texas Education Agency, and school district revenue and expenditure data are taken from the Texas Education Agency's Public Education Information Management System (PEIMS).

We only observe total installed wind capacity at the county level. School districts, however, do not correspond to county divisions. Since we are unable to observe exact locations of the turbines, we cannot apportion them across the school districts within any given county. However, all school districts are contained within a single county and all area of all the counties are within a school district. Therefore, using property tax base values at the school district-level, we aggregate all districts in a county to report school district variables at the county-level. Thus, school tax rates are averaged to the county level by the weighted average of the individual ISD tax rates using school district shares of total county-level tax receipts as weights. This aggregation will result in an under-estimation of property tax base impacts at the level of the school districts in which the turbines are actually sited and an over-estimation for those districts without wind power that are located in a wind county. A concomitant to this issue is that the effect of using the average tax rate for the districts in a county will also tend to over or under-estimate actual rates for the specific school districts in wind counties. School expenditures are averaged to the county level using the districts' average daily attendance as weights. County level annual personal income, unemployment rates, and populations are compiled from the U.S. Department of Commerce Bureau of Economic Analysis and the Bureau of Labor Statistics.

We identify two non-overlapping subsets of Texas counties, i.e., wind and non-wind (control) counties. Wind counties are all counties that contain utility-scale wind development in 2011. These two subsets do not include all counties in Texas. The acuity of the analysis is enhanced if we narrow the comparison between wind and non-wind counties to those counties that had some degree of similarity

[24] Available at xcelenergy.com/Environment/Renewable_Energy/Wind/New_Mexico_and_Texas_Wind_Power.

Table 1: Number of establishments and employees by industry

Industry		Wind counties				Other counties			
		Estab.		Emp.		Estab.		Emp.	
NAICS -2	Title	Average	$\Delta_{2011-2001}$	Average	$\Delta_{2011-2001}$	Average	$\Delta_{2011-2001}$	Average	$\Delta_{2011-2001}$
11	Agriculture	27.850	12.452	171.798	-46.387	26.867	11.665	184.364	22.560
		(24.177)	(10.627)	(229.237)	(237.222)	(30.520)	(13.858)	(250.161)	(136.802)
21	Mining	28.205	16.903	517.543	441.903	13.014	9.319	255.575	208.539
		(38.838)	(26.493)	(978.023)	(1,099.307)	(22.483)	(15.039)	(533.129)	(479.343)
22	Utilities	5.346	1.774	105.114	15.839	5.879	1.304	98.275	14.047
		(6.001)	(3.030)	(175.237)	(59.689)	(5.313)	(3.285)	(188.180)	(80.445)
23	Construction	41.314	59.484	569.663	691.194	33.465	47.560	341.400	421.707
		(75.348)	(83.793)	(1,083.969)	(1,128.292)	(59.843)	(63.593)	(643.683)	(696.463)
31-33	Manufacturing	33.642	8.677	1,116.003	101.097	25.261	6.560	1,172.477	-297.120
		(54.128)	(15.947)	(1,975.000)	(988.451)	(37.537)	(11.989)	(2,086.129)	(1,314.219)
42	Wholesale	49.372	16.065	641.487	120.613	27.712	13.073	290.219	87.414
		(82.049)	(35.438)	(1,162.018)	(450.715)	(37.930)	(22.059)	(495.429)	(337.806)
44-45	Retail	120.490	32.387	1,904.446	387.161	81.727	24.099	1,173.685	177.042
		(180.823)	(60.934)	(3,277.421)	(877.851)	(104.269)	(39.917)	(1,860.794)	(721.554)
48-49	Transportation	49.903	26.935	681.809	174.419	19.982	11.743	264.203	148.257
		(151.233)	(80.029)	(2,055.559)	(543.949)	(20.837)	(14.145)	(468.387)	(340.203)
51	Information	11.798	5.000	246.918	-63.323	8.458	3.728	107.253	9.911
		(16.975)	(8.641)	(501.785)	(302.789)	(11.252)	(6.148)	(264.789)	(88.151)
52	Finance	48.446	22.452	586.560	60.710	31.176	14.728	282.320	1.801
		(74.008)	(37.667)	(1,172.668)	(350.544)	(43.738)	(24.453)	(454.387)	(179.738)
53	Real Est.	32.059	12.355	178.261	50.097	18.346	8.424	89.689	28.733
		(52.147)	(20.591)	(337.328)	(120.251)	(30.365)	(17.075)	(180.764)	(99.364)
54	Scientific	56.985	32.645	359.569	160.774	38.290	23.382	204.077	102.236
		(88.837)	(52.466)	(618.122)	(321.370)	(62.704)	(42.065)	(423.682)	(236.816)
55	Managment	2.226	1.290	43.587	29.484	0.965	0.743	19.663	11.796
		(4.511)	(3.476)	(125.260)	(138.739)	(2.356)	(2.751)	(68.904)	(78.504)
56	Waste Mang	29.801	16.774	526.328	220.484	18.458	13.665	275.706	68.817
		(48.841)	(26.365)	(1,018.779)	(530.304)	(33.183)	(23.112)	(692.185)	(484.341)
61	Education	6.742	6.065	1,092.900	1,191.194	5.161	5.539	738.984	810.476
		(10.106)	(7.598)	(2,188.487)	(2,466.532)	(8.056)	(7.225)	(1,732.052)	(2,069.117)
62	Health	75.572	35.613	2,309.856	328.194	49.672	24.623	1,248.842	339.461
		(122.650)	(61.714)	(4,260.885)	(1,414.401)	(74.311)	(36.533)	(2,347.066)	(778.776)
71	Arts Ent.	8.994	5.194	157.015	17.290	6.400	3.110	79.896	21.848
		(12.877)	(8.236)	(277.924)	(107.522)	(9.405)	(6.604)	(181.581)	(86.397)
72	Accommodation	59.487	6.839	1,352.924	-21.226	38.010	6.037	705.920	0.492
		(88.869)	(66.813)	(2,417.272)	(1,430.503)	(52.495)	(37.139)	(1,273.824)	(594.131)
81	Other Service	66.818	33.935	413.903	125.032	43.289	26.414	224.172	77.419
		(99.672)	(49.481)	(713.685)	(199.865)	(60.608)	(44.475)	(385.534)	(185.912)
92	Public Admin.	18.604	22.323	677.455	337.226	17.562	21.225	382.251	245.969
		(18.752)	(13.984)	(1,223.089)	(532.001)	(15.348)	(10.446)	(642.553)	(465.765)
	All	773.654	322.903	13,653.138	3,539.00	514.688	241.1728	8,225.615	2,012.712
		(1,119.221)	(484.330)	(22,582.831)	(6,823.811)	(650.291)	(332.226)	(12,721.523)	(4,161.802)

Standard deviations are in parentheses.

Table 2: Regression variables

Variables	All	Wind counties	Other counties
Number of Counties	222	31	191
Construction phase	0.010	0.073	0.000
	(0.098)	(0.261)	(0.000)
Wind energy capacity	19.680	135.417	0.000
	(107.604)	(249.594)	(0.000)
area (2012-2002)	(20,955.390)	(27,331.760)	(19,738.330)
Taxable value	501.322	914.219	434.308
(in millions of $)	(796.628)	(1,462.753)	(598.521)
Property tax rate	0.536	0.510	0.540
	(0.160)	(0.141)	(0.163)
School revenue	20.561	24.539	19.908
(in millions of $)	(25.360)	(28.977)	(24.655)
School tax rate	1.305	1.305	1.305
	(0.186)	(0.173)	(0.188)
Total per student	10,027.146	12,036.961	9,700.946
expenditure	(4,280.924)	(7,902.033)	(3,225.862)
Per student expenditure	4,955.632	6,672.885	4,676.915
from local tax revenues	(3,448.396)	(5,729.208)	(2,817.588)
Per student expenditure	4,779.493	4,514.902	4,822.437
from state revenues	(1,835.779)	(1,933.160)	(1,815.887)
Average daily attendance	5,360.226	7,507.205	5,011.763
	(7,488.689)	(12,218.867)	(6,331.293)
Unemployment rate	5.783	5.600	5.823
	(2.044)	(1.743)	(2.091)
Population	27,099.448	37,243.261	25,943.962
	(36,472.121)	(54,286.283)	(32,953.749)
Average wage ($)	23,395.954	23,206.943	23,426.631
	(16,142.080)	(15,854.779)	(16,188.206)
Average income ($)	23,968.644	24,854.357	23,824.889
	(4574.246)	(5,738.567)	(4339.081)
Median income ($)	31,007.441	31,188.049	30,978.128
	(5,942.070)	(6,844.074)	(5,783.734)
MSA central county	0.279	0.387	0.262
	(0.449)	(0.487)	(0.440)
MSA outlying county	0.185	0.194	0.183
	(0.388)	(0.395)	(0.387)
ERCOT border county	0.108		0.126
(outside)	(0.311)		(0.331)
ERCOT border county	0.126	0.161	0.120
(inside)	(0.32)	(0.368)	(0.325)

Standard deviations are in parentheses.

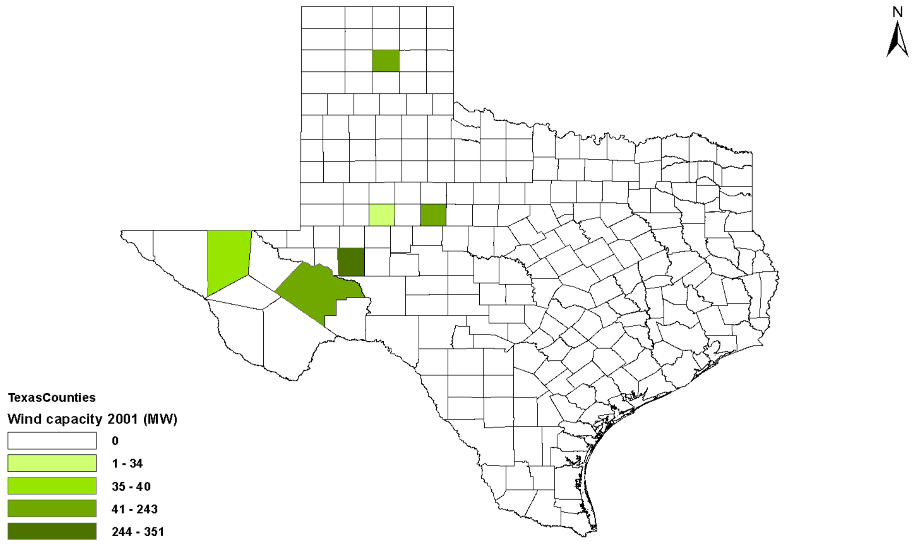
at the the beginning of the study period. Since wind development has taken place in the relatively rural counties, it would be innappropriate to compare outcomes between the relatively static rural counties and the urban counties that have enjoyed substantial population and employment growth over the period from factors unrelated to wind power. Specifically, we exclude counties with populations less than 421 or greater than 200,347 in 2001 (the largest wind county by population) or per capita personal income less than $13,865 or greater than $30,804 in 2001 (the highest value among the wind counties). This restriction reduces the number of counties used in the anlaysis from 254 to 222. The excluded counties are the more populous counties found along the I-35 corridor (the Dallas-Fort Worth, Austin/San Antonio, and Houston metropolitan areas), the (Rio Grande) Valley region of Texas, El Paso, Lubbock, and Midland. Only one county, Loving County, with a 2001 population of 72, failed to meet the minimum values.[25]

Table 1 presents two-digit NAICS industry-level data on numbers of estalishments and employment levels for the wind and non-wind counties in Texas. For each subset, the table includes both average values over the eleven years of observations and the average changes in total values between the two sample years of 2001 and 2011.

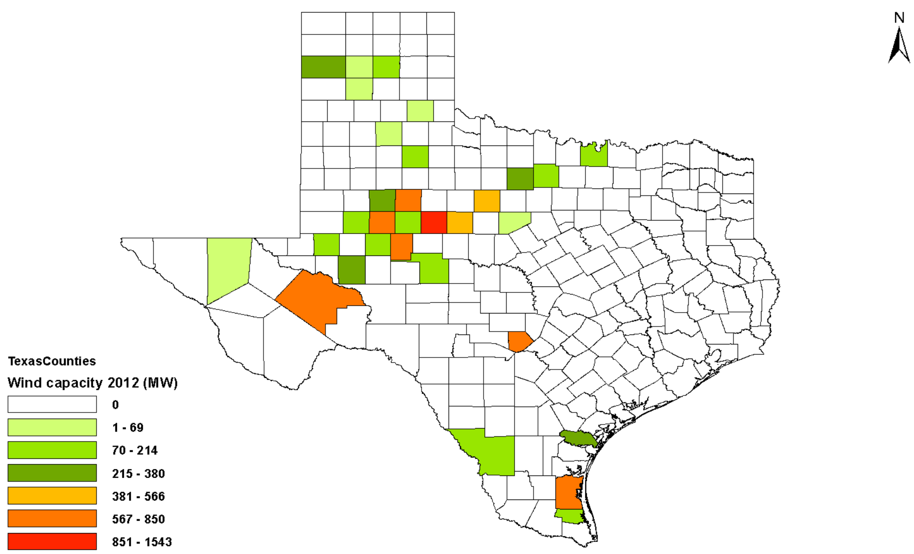
Comparisons between wind counties and non-wind counties at the beginning of the study period are clearer when looking at Table 2. One observes that wind counties, on average, are more populous than control counties. Wind counties have only a slightly higher number of establishments and employees than the average control county. The largest disparities are in the wholesale, retail, scientific, transportation, and health sectors. Average income and wages are the same in both, for practical purposes. However, there are contrasting differences in the values of the property tax bases and school revenues, as would be expected from the differences in average county populations. Average taxable value and school revenues are higher by about $500 million and $5 million respectively in the wind counties compared to non-wind counties. Not surprisingly, wind counties' average daily school attendance is higher by about 2,500 pupils compared to the other counties in the analysis. Finally, average wind generation capacity in wind counties is about 135 MW.

[25] Excluded counties are Bell, Bexar, Brazoria, Cameron, Collin, Dallam, Dallas, Denton, El Paso, Fort Bend, Galveston, Hansford, Harris, Hemphill, Hidalgo, Jefferson, King, Loving, Lubbock, Maverick, McLennan, Midland, Montgomery, Nueces, Rockwall, Sherman, Starr, Tarrant, Travis, Williamson, Zapata, and Zavala.

Figure 1: Wind energy generation counties in Texas

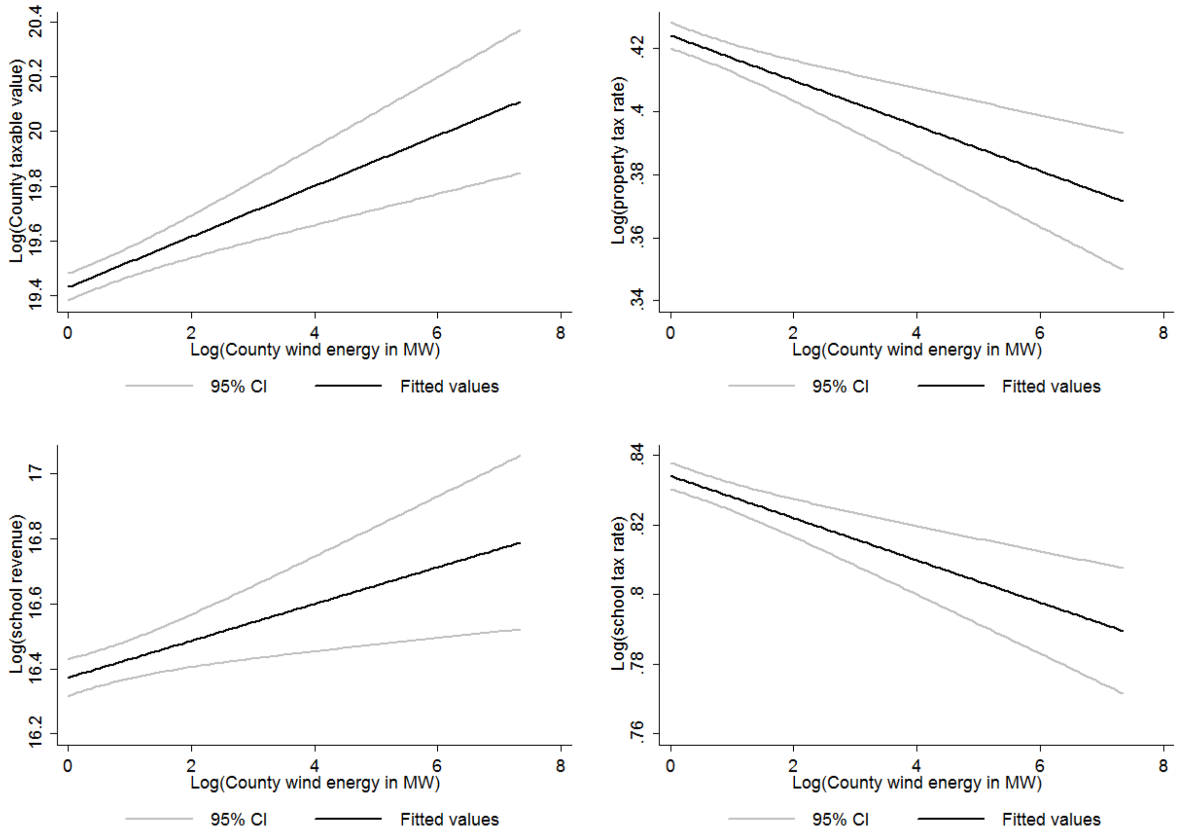


Panel A: Wind energy capacity in 2001



Panel B: Wind energy capacity in 2012

Figure 2: Taxable value, property tax rate, school tax rate, and wind energy capacity



Summary plots

Panel A in Figure 1 represents the distribution of wind generation capacity in 2001. In total, there were only 6 counties with about 900 MW in total capacity. In Panel B we show wind generation capacity by county in 2012. As can be seen, it has increased to 32 counties with total capacity in excess of 12,000 MW. In Figure 2, we show some summary plots depicting the relationship between taxable property value, wind capacity, and property tax rates in the top two panels and school revenues, school tax rates, and wind capacity in the bottom two panels. We see that total taxable property value is increasing in wind generation capacity while property tax rates (and school tax rates) are decreasing in wind energy generation capacity. However, one should be cautious in interpreting these observations as they are summary plots.[26]

Empirical Analysis

Industry Effects

We first investigate the impact of wind development on levels of establishments and employment in each county. We look at the 10-year change in both the numbers of establishments and employed persons between 2001 and 2011 in the subset of all wind and non-wind energy generation counties in Texas, as described above. We regress these changes on, *inter alia*, the changes in installed wind power capacity between 2001 and 2011. The model to be estimated is as follows:

$$\Delta y_{c,T-t_1} = \alpha_0 + \beta_1 \Delta w_{c,T-t_1} + x'_{c,t_1}\gamma + z'_{c,j,t_1}\lambda + m'_c\psi + \varepsilon_c \quad (1)$$

Our dependent variable (y) is either the difference in number of establishments or employees between 2001 and 2011 per county. Our independent variables can be categorized into four groups: county-level wind capacity in 100 MW units (w), county characteristics that vary with time such as unemployment rate and population, (x) industry characteristics such as industry specific county-level wages (z), and county characteristics that do not vary with time such as MSA central or peripheral county (m). The term $\varepsilon_{c,j}$ is the error.

Table 3 contains the OLS estimation results from three specifications for both of the outcome variables. As can be seen, the estimated coefficient for the change in total county wind capacity is positive but statistically insignificant for both establishments and employment in all specifications. While a

[26] These summary plots are done by lfit command in Stata. lfit calculates the prediction for y from a linear regression of y on x and plots the resulting curve.

Table 3: Regression results for 10 year change in number of establishments and employees

Variables	Δ Number of firms$_{c,T_{10}-t_1}$			Δ Number of employees$_{c,T_{10}-t_1}$		
	(1)	(2)	(3)	(4)	(5)	(6)
Δ Wind energy	1.861	1.619	3.031	115.519	112.102	118.219
capacity$_{c,T_{10}-t_1}$ (in 100 MW)	(11.087)	(5.485)	(5.309)	(127.312)	(77.989)	(73.078)
Unemployment rate$_{c,t_1}$		-6.290	-5.780		34.937	38.372
		(4.990)	(4.842)		(107.455)	(112.598)
Population$_{c,t_1}$		0.010***	0.010***		0.103***	0.110***
		(0.001)	(0.001)		(0.018)	(0.021)
Wages$_{c,t_1}$ (in $10,000)		0.000	0.001		-0.012	0.004
		(0.001)	(0.001)		(0.032)	(0.029)
MSA central county$_c$			-63.600**			-1,066.514
			(25.802)			(672.342)
MSA outlying county$_c$			-12.287			215.300
			(20.363)			(408.231)
ERCOT border county			-36.026			-1,107.415
(outside)$_c$			(29.076)			(796.311)
ERCOT border county			3.680			-727.409
(inside)$_c$			(24.346)			(608.696)
Observations	222	222	222	222	222	222
R^2	0.000	0.868	0.872	0.002	0.562	0.576

Robust standard errors in parentheses. ***Denotes statistical significance at the 1% level, **denotes statistical significance at the 5% level, and * denotes statistical significance at the 10% level.

finding of no statistical evidence of an employment impact is contrary to our initial expectations, given the results from the other studies surveyed, it should perhaps not be too surprising in Texas. For the average total wind plant of 135 MW, in the wind counties, a sizeable employment impact of .482 jobs/MW implies an average employment increase of 65 jobs, or only about 0.05% of the average wind county employment of 13,653. Such a small proportional change is difficult to discern statistically.

In order to consider the possibility of effects within and across industries, that may tend to offset one another, we disaggregate county employment in Texas using both establishment and employment data by industry for the 10 year change within the 20 industrial categories of the NAICS-2 in the QCEW as reported by the Texas Workforce Commission. Analysis at the NAICS-2 industry-level should provide greater statistical precision in estimating changes in establishments or employment than the estimate of changes in total (all industries) outcomes if any changes are concentrated in a subset of industries and/or opposite in sign. As noted, we are aware of the changes to the NAICS industrial categories that occurred during the course of the decade but proceed under the view that substantive changes at the NAICS-2 level of aggregation are insignificant.

By considering the 10-year change, our goal is to observe persistent effects and to avoid transient construction impacts at the industry level. At least for direct employment measures, this should not pose an issue, even for 2011. Since the QCEW data are establishment-based, and given that the bulk of the construction activity relies on specialized construction firms, and few of these firms are local establishments, the recorded construction employment effects would largely be associated with the external locality in which the employing establishments are located.

We again specify two models for each outcome variable. Similar to total employment, the observed differences in the industry-level outcome variables between 2001 and 2011 are regressed, *inter alia*, on the total change in wind power capacity in each county during the period 2001-2011. We consider the following empirical model:

$$\Delta y_{c,j,T-t_1} = \delta_0 + \theta_1 \Delta w_{c,T-t_1} + x'_{c,t_1}\varphi + z'_{c,j,t_1}\upsilon + m'_c\vartheta + \eta_{c,j} \tag{2}$$

Our dependent variable (y) is either the difference in number of establishments or employees in industry j between 2001 and 2011 by NAICS-2 per county. Independent variables are similar to the ones described in equation 1. The term $\eta_{c,j}$ is the error.

Table 4: Regression results for 10 year change in number of establishments

Panel A										
Variables	Δ Number of firms$_{c,j,T_{10}-t_1}$									
	Agriculture	Mining	Utilities	Construct.	Manufact.	Wholesale	Retail	Transport	Information	Finance
Δ Wind energy	-0.365*	0.903**	0.143*	0.308	0.035	-0.081	0.263	0.594	0.155	0.457
capacity$_{c,T_{10}-t_1}$ (in 100 MW)	(0.216)	(0.415)	(0.076)	(1.134)	(0.190)	(0.664)	(0.605)	(0.756)	(0.140)	(0.432)
Unemployment rate$_{c,t_1}$	-0.064	-0.626*	-0.185**	-1.478*	-0.131	-0.266	-0.220	-0.087	-0.015	-0.232
	(0.470)	(0.330)	(0.074)	(0.819)	(0.204)	(0.335)	(0.662)	(0.490)	(0.091)	(0.302)
Population$_{c,t_1}$	-0.000	0.000***	0.000***	0.002***	0.000***	0.001***	0.001***	0.001**	0.000***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Wages$_{c,t_1}$(in $10,000)	0.000	0.000	0.000	0.001*	0.000***	0.000	-0.000	-0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
MSA central county$_c$	4.781	-1.376	1.216**	-5.087	-1.429	-6.069**	-9.254**	-11.680	-0.643	-2.559
	(3.501)	(2.800)	(0.563)	(7.533)	(1.865)	(2.634)	(3.772)	(9.541)	(0.765)	(2.039)
MSA outlying county$_c$	-0.819	-1.467	-0.419	4.981	1.954	-0.473	-0.723	-3.754	-0.353	-3.599**
	(2.156)	(2.280)	(0.556)	(4.581)	(1.699)	(2.387)	(2.658)	(4.424)	(0.590)	(1.669)
ERCOT border county	3.953	-0.498	0.386	-13.012***	-2.051	-2.283	-6.071**	-4.780	0.506	-0.111
(outside)$_c$	(4.460)	(3.831)	(0.666)	(4.752)	(2.662)	(2.796)	(2.717)	(3.398)	(0.713)	(2.891)
ERCOT border county	-0.062	0.659	-0.473	-5.750	-1.500	0.931	-1.003	-1.414	0.499	-1.184
(inside)$_c$	(3.171)	(2.830)	(0.379)	(3.578)	(1.420)	(1.972)	(2.610)	(3.106)	(0.763)	(2.073)
Observations	222	222	222	222	222	222	222	222	222	222
R^2	0.037	0.325	0.324	0.833	0.505	0.714	0.821	0.453	0.735	0.845

Panel B										
	Real Estate	Scientific	Manag.	Waste Mng.	Education	Health Care	Arts Ent	Accommod.	Other	Public adm.
Δ Wind energy	0.183	0.701	-0.001	0.142	-0.017	0.302	0.196	-0.248	0.220	-0.329
capacity$_{c,T_{10}-t_1}$ (in 100 MW)	(0.271)	(1.030)	(0.065)	(0.399)	(0.116)	(0.812)	(0.120)	(1.046)	(0.714)	(0.241)
Unemployment rate$_{c,t_1}$	-0.030	-0.484	-0.077	-0.098	0.054	-0.782	-0.165	-0.242	-1.136	-0.346
	(0.367)	(0.801)	(0.054)	(0.286)	(0.139)	(0.559)	(0.143)	(1.251)	(0.749)	(0.218)
Population$_{c,t_1}$	0.000***	0.001***	0.000***	0.001***	0.000***	0.001***	0.000***	0.001**	0.001***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Wages$_{c,t_1}$(in $10,000)	0.000	0.000	-0.000	0.000*	0.000	-0.000	0.000	-0.001	0.000	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
MSA central county$_c$	-1.190	-9.251**	0.060	-2.817	0.706	-6.370*	0.754	-4.199	-10.268*	-1.079
	(1.800)	(3.611)	(0.494)	(2.195)	(1.009)	(3.319)	(0.820)	(7.830)	(5.626)	(1.763)
MSA outlying county$_c$	-1.730	-0.418	-0.559*	1.150	0.576	-1.348	0.278	-6.017	-5.693*	0.097
	(1.245)	(3.449)	(0.289)	(1.753)	(0.724)	(2.301)	(0.606)	(5.993)	(3.320)	(1.223)
ERCOT border county	-1.869	-4.125	0.060	-0.512	0.585	-5.120	-1.348*	6.797	-7.028*	-1.930
(outside)$_c$	(1.551)	(3.315)	(0.453)	(2.399)	(0.617)	(3.240)	(0.739)	(6.827)	(3.800)	(2.203)
ERCOT border county	-1.034	0.917	0.392	-0.394	-0.223	0.577	-1.084**	10.921**	3.135	-2.148*
(inside)$_c$	(1.202)	(3.785)	(0.469)	(1.777)	(0.588)	(2.815)	(0.455)	(4.925)	(8.689)	(1.258)
Observations	222	222	222	222	222	222	222	222	222	222
R^2	0.753	0.751	0.500	0.812	0.640	0.872	0.621	0.140	0.781	0.548

Robust standard errors in parentheses. ***Denotes statistical significance at the 1% level, **denotes statistical significance at the 5% level, and * denotes statistical significance at the 10% level.

Table 5: Regression results for 10 year change in number of employees

Panel A										
Variables	Δ Number of employees$_{c,j,T_{10}-t_1}$									
	Agriculture	Mining	Utilities	Construct.	Manufact.	Wholesale	Retail	Transport	Information	Finance
Δ Wind energy	-11.991	10.745	0.393	22.235	24.455	-2.492	19.845*	-10.191	-2.517	9.228
capacity$_{c,T_{10}-t_1}$ (in 100 MW)	(8.993)	(17.920)	(1.879)	(17.125)	(16.294)	(6.476)	(11.589)	(11.480)	(4.095)	(8.583)
Unemployment rate$_{c,t_1}$	4.653	-15.038	0.209	-10.545	-6.563	-3.366	-9.828	2.130	-1.034	2.523
	(5.003)	(10.779)	(1.868)	(8.373)	(31.938)	(6.654)	(22.942)	(8.607)	(2.122)	(5.600)
Population$_{c,t_1}$	-0.001	0.008***	0.001**	0.016***	-0.009	0.004***	0.010***	0.008***	0.000	0.000
	(0.001)	(0.002)	(0.000)	(0.003)	(0.007)	(0.001)	(0.003)	(0.002)	(0.001)	(0.001)
Wages$_{c,t_1}$(in $10,000)	-0.001	0.003	0.001	0.009*	0.019*	-0.001	-0.001	-0.005	-0.001	0.002
	(0.001)	(0.004)	(0.001)	(0.006)	(0.011)	(0.003)	(0.005)	(0.003)	(0.001)	(0.002)
MSA central county$_c$	21.383	7.154	23.646	63.834	-22.482	53.002	-131.107	-40.604	-27.832	41.920
	(32.671)	(103.892)	(15.442)	(99.436)	(245.618)	(64.165)	(134.827)	(74.383)	(18.264)	(40.974)
MSA outlying county$_c$	0.999	-40.809	-4.998	-106.422	398.620**	40.415	51.022	1.957	11.164	17.214
	(23.822)	(88.297)	(17.455)	(69.596)	(185.665)	(48.827)	(65.718)	(43.960)	(14.856)	(31.635)
ERCOT border county	-13.362	-21.620	-0.825	115.432	-409.883	-120.393	-189.059***	-20.064	-15.532	-94.410
(outside)$_c$	(45.383)	(117.407)	(11.671)	(216.163)	(473.481)	(118.231)	(70.808)	(67.891)	(35.142)	(78.729)
ERCOT border county	-28.747	-39.357	28.258*	-70.105	-379.512	-13.032	-445.404*	1.036	20.374	-24.914
(inside)$_c$	(30.375)	(74.532)	(15.043)	(48.123)	(352.441)	(27.948)	(246.790)	(42.778)	(24.993)	(18.464)
Observations	222	222	222	222	222	222	222	222	222	222
R^2	0.041	0.197	0.152	0.569	0.081	0.178	0.224	0.410	0.013	0.048
Panel B										
	Real Estate	Scientific	Manag.	Waste Mng.	Education	Health Care	Arts Ent	Accommod.	Other	Public adm.
Δ Wind energy	1.813	4.345	-0.837	20.996*	11.430	1.691	-2.284	8.172	2.123	8.900
capacity$_{c,T_{10}-t_1}$ (in 100 MW)	(1.455)	(8.290)	(1.488)	(10.955)	(38.952)	(15.957)	(2.191)	(19.678)	(5.204)	(15.605)
Unemployment rate$_{c,t_1}$	-0.194	-5.401	-2.009	6.826	98.589	-6.978	0.747	3.503	-3.404	-5.254
	(2.861)	(4.682)	(2.153)	(12.946)	(70.491)	(15.348)	(2.318)	(22.744)	(4.322)	(10.535)
Population$_{c,t_1}$	0.002***	0.006***	0.001***	0.005	0.049***	0.015***	0.001***	0.004	0.004***	0.006***
	(0.001)	(0.001)	(0.000)	(0.004)	(0.013)	(0.005)	(0.000)	(0.004)	(0.001)	(0.002)
Wages$_{c,t_1}$(in $10,000)	0.001	-0.001	0.000	0.004	0.000	-0.008	-0.001	-0.014	0.002	0.001
	(0.001)	(0.002)	(0.001)	(0.007)	(0.010)	(0.008)	(0.001)	(0.011)	(0.001)	(0.006)
MSA central county$_c$	-9.713	-47.945	-0.571	-34.347	-547.015	-163.997	12.148	-85.887	-5.713	-61.577
	(19.995)	(29.455)	(15.192)	(69.059)	(357.832)	(179.504)	(15.197)	(137.390)	(30.207)	(107.259)
MSA outlying county$_c$	-16.231	-19.317	-23.667**	-23.781	-163.173	139.894	-3.334	-75.994	-13.273	-26.263
	(11.022)	(21.991)	(9.758)	(51.684)	(194.221)	(103.437)	(8.950)	(99.902)	(17.882)	(47.950)
ERCOT border county	-1.775	7.820	11.959	34.769	-84.912	-381.140	-17.856*	120.638	-10.049	134.082
(outside)$_c$	(19.224)	(44.535)	(19.540)	(56.626)	(174.068)	(292.482)	(9.543)	(114.166)	(22.098)	(168.416)
ERCOT border county	-6.190	7.788	24.260	65.242	-72.292	99.695	-3.005	199.776**	-0.697	-49.852
(inside)$_c$	(12.040)	(31.593)	(19.795)	(55.554)	(171.673)	(102.199)	(8.686)	(98.784)	(30.044)	(54.857)
Observations	222	222	222	222	222	222	222	222	222	222
R^2	0.303	0.624	0.248	0.129	0.516	0.263	0.268	0.035	0.465	0.196

Robust standard errors in parentheses. ***Denotes statistical significance at the 1% level, **denotes statistical significance at the 5% level, and * denotes statistical significance at the 10% level.

Table 4 contains regression results for differences in the number of establishments across the 20 industries at the NAICS-2 between the beginning and end of the study period. In terms of numbers of establishments, mining and, of course, utilities appear to be positively affected by the wind development that occurred over the decade. Consistent with the substitution in land-use that wind power implies, the effect on the number of agricultural establishments is negative.[27]

Table 5 considers the decade change in growth of total employment by industry, a more interesting comparison than establishments. Only employment in retail and waste management appears to have been positively affected by wind development. Although statistical significance is low, these estimates suggest a total indirect/induced effect in these two industries of about 40 jobs per 100 MW. Increases in local retail activity would be expected through higher levels of spending associated with higher levels of personal income from wind power production, a so-called induced effect. Waste management employment would be affected by the need for services in the recycling and disposal of turbine lubricating oil, hydraulic and cleaning fluids. Although the number of agricultural establishments declines with wind power development, there is no evidence of such a change in employment in agricultural industry activities. It is worth noting at this point that employment in education shows no effect, suggesting that any localized property and school tax benefits from the increase in fixed wind plant did not result in measurable increases in school employment. Nor is there any statistically significant change in employment in the utilities sector.

While this latter result is surprising, a look at unconditional comparisons helps to provide credibility. There were positive changes of about 14.0 jobs in utilities employment in the control counties, and 15.8 in the wind counties. Based on this unconditional, and relatively simple, comparison, the difference of fewer than two jobs (less than 2 percent of total industry employment) between the changes in average utilities employment between the control and the wind counties is not great enough to infer a clear statistical difference.

One caveat may be in order. Since the QCEW employment data are establishment-based, if on-site turbine O&M personnel are employed and reported by an establishment, either the plant operator or a relevant sub-contractor, that is located in another county (or state), then those jobs will not appear

[27] We estimated the effect of changes in wind power on changes in total harvested cropland in acres using data from the USDA NASS Agricultural Census for years 2002 and 2012. The estimated coefficient of the wind power variable was negative but statistically insignificant.

in our employment data for the given wind county. Remote monitoring and operation of turbines can take place from anywhere on the globe. If, for example, oil temperatures increased slightly, the turbine can be remotely shut down and a technician dispatched from a regional office to look into the situation. Moreover, this technician may be employed by a sub-contractor in an establishment which does not report under NAICS 22. Indeed, when looking at fully disclosed establishment-based QCEW data for Texas up to 2006, we cannot locate the great majority of wind plants in the counties where those wind plants are known to be sited. However, we do find establishment-based employment for wind generation firms (searching at the NAICS-6 level) in Austin and Houston, areas with no installed utility-scale wind plant. This suggests that direct employment effects may rather be found in establishments that report employment in regional population hubs or remote cities where wind plant operators base their administrative operations.

While we find positive effects from wind development on employment levels at the industry level, these effects have to be interpreted in the context of the result that there was no significant wind-related change in total county employment levels. These conclusions are not inconsistent if there have been small, offsetting changes in other industrial employment that were below the level of statistical detection. Thus, we believe that employment gains related to wind development have tended to crowd out employment in other activities, indicating that labor has been inelastically supplied in these rural counties.

County Personal Income

We next turn our attention to the relationship between income and wind energy development. However, we must first investigate the question of endogeneity between wind development and county income. It may be that an endogenous relationship exists because, for example, higher income in a county reflects a higher level of financial or business acumen. Such a county may be better positioned to establish relationships with wind energy developers and increase the likelihood that wind development will occur. On the other hand, given the environmental issues surrounding the siting of wind plant, lower income counties may be more receptive or more likely to seek out wind development. If the initial income level is significant in explaining growth in income up to 2011, i.e., regression toward the mean suggests that counties with lower initial income would grow faster than counties with higher initial income, then income changes could be erroneously attributed to wind development if a significant correlation between wind development and initial income exists. We empirically examine this question by estimating whether or not initial or year 2001 county characteristics (x) that are unrelated to wind resources (income, in particular) can help to explain installed wind capacity at the end of the sample period. Note that in year 2001, there were only 6 counties producing wind energy with total capacity of less than 900 MW.

Our empirical model is presented in equation 3. Here, the dependent variable is the level of wind capacity in year 2011. Initial conditions (2001) such as per capita income, unemployment rates, and population are represented in the matrix (x) and county characteristics that do not change over time are represented in matrix (m). The variables that do not change over time are modeled by dummy variables. There is a dummy that captures whether the county is in the ERCOT area (1) or not (0), two dummies to identify if the county is a central or peripheral MSA county, and another dummy for the 178 counties with an average wind resource categorized as Class 2 or higher.[28]

$$w_{c,T} = \alpha_0 + x'_{c,t=1}\varsigma + m'_c\varphi + \eta_c \tag{3}$$

Our results in Table 6 indicate that initial per capita income is not an explanatory factor in the choice of a specific county for wind farm location. Not surprisingly, the coefficient of the "wind resources" dummy appears to provide all the explanatory power. The presence of the wind resource is exogenous to county location and unchanged over the period of this analysis.

Given this result, OLS will provide an unbiased means to estimate the effect of installed wind generation capacity on county-level per capita income. To examine this effect, we estimate county-level per capita income as function of installed wind capacity controlling for observable and unobservable county and time effects. Note that the empirical approach will capture *net* changes to county per capita income due to wind development, i.e., wind power-related changes net of displaced agricultural and other industrial activity-related changes.

[28] Wind resource classes are determined by both wind density and speed at a particular location and are used to describe the quality of the location for wind powered electricity generation. The classes range from 1 to 7, with 1 being the least powerful resource. Generally speaking, current turbine technology is best suited for location in a Class 4 regime, or higher, although Class 2 is at the margin for economic viability of large scale turbines. See Combs, (2013) "Chapter 11, Wind Energy." Window on State Government, Texas Comptroller of Public Accounts, http://www.window.state.tx.us/specialrpt/energy/renewable/wind.php. More recently, NREL has moved to characterizing localized wind resources by average wind speeds at hub heights and associated capacity factors. We employ wind class since this average measure exists at county-level.

Table 6: Regression results for wind installation capacity

Variables	Wind energy capacity$_{c,T}$		
	(1)	(2)	(3)
Initial income$_{c,t_1}$	0.003	0.002	0.001
	(0.005)	(0.005)	(0.005)
Initial county unemployment rate$_{c,t_1}$		-1.357	-2.053
		(4.510)	(4.453)
Initial population$_{c,t_1}$		-0.000	-0.000
		(0.001)	(0.001)
MSA central county$_c$		68.472	66.227
		(54.158)	(54.140)
MSA outlying county$_c$		32.023	31.140
		(26.955)	(26.968)
ERCOT border county			-35.555**
(outside)$_c$			(14.141)
ERCOT border county			-26.032
(inside)$_c$			(17.787)
Counties with wind resources (wind class $\geq$ 2)		42.088**	34.680*
		(19.413)	(19.804)
Observations	222	222	222
R^2	0.003	0.037	0.042

Robust standard errors in parentheses. ***Denotes statistical significance at the 1% level, **denotes statistical significance at the 5% level, and * denotes statistical significance at the 10% level.

Table 7: Regression results for income

Variables	Δ Per capita income$_{c,T_{10}-t_1}$			Δ Median household income$_{c,T_{10}-t_1}$		
	(1)	(2)	(3)	(4)	(5)	(6)
ΔWind energy capacity	2,657.710**	2,697.469**	2,432.020*	2,893.344	2,435.498	2,245.764
per person$_{c,T_{10}-t_1}$	(1,031.351)	(1,074.829)	(1,279.309)	(2,149.089)	(2,143.770)	(2,149.054)
Unemployment rate$_{c,t_1}$		33.875	-12.351		-163.720**	-172.457**
		(105.406)	(107.760)		(65.507)	(69.303)
MSA central county$_c$		-869.514	-1,041.729*		-614.215*	-688.633**
		(557.735)	(565.259)		(329.483)	(330.176)
MSA outlying county$_c$		-581.014	-651.410		313.751	361.147
		(726.445)	(727.929)		(460.824)	(465.256)
ERCOT border county			-1,920.835***			-1,272.680***
(outside)$_c$			(662.480)			(408.798)
ERCOT border county			-2,223.605***			-416.904
(inside)$_c$			(733.505)			(561.675)
Observations	222	222	222	222	222	222
R^2	0.006	0.016	0.064	0.022	0.060	0.089

Robust standard errors clusterd by counties in parentheses. ***Denotes statistical significance at the 1% level, **denotes statistical significance at the 5% level, and * denotes statistical significance at the 10% level.

Consider the following empirical model:

$$\Delta I_{c,T-t_1} = \alpha_c + \psi \Delta(w/pop)_{c,T-t_1} + \varphi unemp_{c,t_1} + x'_{c,t-1}\eta + \epsilon_{c,t} \quad (4)$$

Depending on the specification, the dependent variable is either the change in level of county per capita income or county median income between 2000 and 2011. Thus, the regression captures a one-time change in per capita personal income or median income between 2001 and 2011 as a function of the total of all increments in county wind capacity between 2001 and 2011. The wind capacity variable is measured as MW per person. Results are presented in Table 7.

Considering the effects of changes in installed wind capacity on per capita county income, the value of the estimated coefficient, while large, is quite reasonable within the estimation context. Given the estimate for the change in per capita income per MW per person of 2657.71, and using the average population for wind counties of 37,243 persons, a 100 MW increase in wind capacity would imply an increase in county per capita income of about \$7.14 in base year dollars or .03 percent.[29] For a small population county, such as Sterling County, population 1,158 in 2011, a 100 MW plant would generate

[29] That is, a 100 MW wind plant in a county with a population of 37,243 implies .0026851 MW per person. Our estimate of the increase in per capita income of 2,657.71 per MW per person then results in a total increase of 7.14 in per capita income in the county.

an increase in per capita personal income of $230 in year 2000 dollars. Considering the example of the 662.5 MW Capricorn Ridge installation in Coke and Sterling Counties, combined population of 4,463 in 2011, our results suggest an increase of $395 in per capita income across the two counties, which represents an increase on the order of 2 percent (based on a population-weighted average per capita income in 2001 of $19,537).

Columns 4-6 contain the coefficient estimates for the model with the change in *median* county income on the left-hand side. As can be seen, there is no statistically significant effect of wind power development on median county income. This is consistent with the very modest employment impacts that were estimated above. That is, the results suggest that the principal local beneficiaries of wind power are the landowners who enjoy lease and royalty income and whose personal incomes are most likely above the county median income.

These results on income are somewhat less than the I-O model estimates of Reategui and Henderson (2011) and significantly less than the estimates of Brown *et al.* (2012). It is of interest to note, in regard to the I-O results, that it has been widely observed that realized wind project production has consistently fallen short of projections, given nameplate capacities and the quality of the wind resource. The problem is thought to be a product of a limited understanding of inter-turbine interactions that results in sub-optimal design of the turbine array over a given terrain. That is, production projections for wind developments have failed to properly take turbine drag and other wake effects across the turbine field into account (Adams and Keith (2013)). Thus, I-O estimations that incorporate nameplate capacities and wind resource quality measures (capacity factors) may also tend to overestimate landowner royalty income that is largely based on the value of electricity produced and sold. Moreover, the collapse in natural gas prices that occurred in the latter half of 2008, after the study period of Brown *et al.* (2012), had a negative effect on wind-generated electricity margins. The innauguration of ERCOT's nodal market pricing model in December, 2010, may also have played a role in CY2011 income from wind power. The nodal market structure includes a binding day-ahead market in which wind producers that benefit from the Production Tax Credit have been willing to offer electricity at negative prices.

Property Taxes and School Expenditures

We conclude our analysis by examining the impact of wind energy generation capacity on county and school property taxes, i.e., total assessed value of property or property tax base, county general fund property tax rates and school tax rates, and school expenditures. Our intention is to estimate total assessed value as a function of installed wind capacity and property tax rates as functions of county total assessed value.

Texas has no specific mandated tax treatment for wind power producers. In each county, a central appraisal district is responsible for assessing the taxable value of all real property (including minerals in place). The State of Texas allows special tax treatment to be offered at the local level. However, school districts are somewhat more limited in their abatement options. The school district can offer a value limitation in an area designated as a reinvestment zone. In exchange for the value limitation, the property owner must enter into an agreement to create jobs and meet the minimum amount of qualified investment. Value limitations that can range from $1 million to $100 million are only applicable to the districts' maintenance and operations (M&O) tax rate. Qualified property includes renewable energy electric generation equipment, land and associated improvements. In some cases, the limitation agreement can include payments to the school district that depend on the number of students in the district. For example, in 2009, a commercial wind farm developer entered into a value limitation agreement that capped the value of the property at $10 million for 10 years. The estimated market value of the improved property was $29 million. In return, the developer agreed to pay an annual fee of $142,000 to the school district. A taxing unit other than a school district may enter into a tax abatement agreement exempting all or part of the increase in value of real property and/or tangible personal property from taxation for a period not-to exceed 10 years.[30]

Counties and school boards should set tax rates with an eye to their budgetary requirements, given the assessed value of the relevant non-exempt property tax base determined by the appraisal district. County and school revenue realizations are then the product of tax rates and total non-exempt assessed value. School district revenues can also include payments from, say, the wind farm operators, as noted above. While such payments would not influence total school tax revenues, they would affect total district revenue and, indirectly, tax rates.

[30] See AWEA, Property Tax Treatment of Commercial Wind Energy Projects, 2011.

However, the system of school finance in Texas has offsetting elements between state and local funding sources that have important implications for local taxing incentives. At the local level, virtually all revenues are generated by means of property taxation. The local share of the basic school funding is the base pre-determined school tax rate multiplied by the district's total property tax base. If those revenues are insufficient to meet the basic district funding level (as determined by the State), the State covers the difference. Thus, increases/decreases in the district's property tax base that generate higher/lower local school tax revenues are offset by reductions/increases in the State's share of basic funding. However, local districts have the option of increasing the local tax rate by up to 17 cents/$100 valuation over their base rate for funding for educational "enhancement" above the basic level.

There is also a statutory provision intended to ensure "equalized wealth levels" across school districts. Districts are deemed to be property-wealthy districts if their property tax base per student exceeds a given threshold. Property-wealthy districts' local tax revenues are then subject to recapture by the State in the amount generated by the district's pre-determined tax rate applied to the excessive property tax base for that year.[31]

We consider the following empirical models:

$$\ln(v)_{c,t} = \alpha_c + \tau_t + \delta \ln(w+1)_{c,t} + x'_{c,t-1}\zeta + \omega_{c,t} \tag{5}$$

$$\ln(tax\ rate^{i=p,s}_{c,t}) = \alpha_c + \tau_t + \psi \ln(\widehat{v}^*_{c,t-1}) + \xi \ln(w+1)_{c,t} + \mu_{c,t} \tag{6}$$

$$\ln(r_{school})_{c,t} = \alpha_c + \tau_t + \vartheta \ln(\widehat{v}^*_{c,t-1}) + \kappa \ln(w+1)_{c,t} + \varrho \ln(a)_{c,t} + e_{c,t} \tag{7}$$

$$\text{where } \widehat{v}^*_{c,t-1} = \widehat{v}_{c,t-1} - \delta \ln(w+1)_{c,t-1}.$$

There is an empirical problem in the question relating to the effects of wind capacity on tax rates. Assessed values of real property are to reflect market values and market values depend, at least partially, on tax rates. Thus, tax rates and property tax assessed values will be endogenously determined and the modeling methodology must allow for influences on these intertwined variables to be separately

[31] This is the so-called Robin Hood provision. The pre-determined tax rate is 2/3 of the district's 2005 tax rate. This provision can result in a significant transfer from the district to the State. For example, in the 2011-12 school year, with only 141 students, the Kenedy County Wide Consolidated School District (home to the Penascal Wind Development) had a school property tax base of $7,234,228 per student against an allowable $476,500. $9,772,671 was recaptured by the State from this district. Property-wealthy districts are not necessarily wealthy districts in terms of median or per capita income.

identified. In this circumstance, without identification, OLS will produce a lower bound of the parameter estimates.[32]

To avoid this endogeneity problem and to identify the separate effects of growth in wind capacity on county and school tax bases and rates, we conduct the empirical analysis in three steps. In Step 1, we estimate a model of the assessed value of the county and school property tax bases as a function of wind capacity and county characteristics (equation 5). Then, in Step 2, we strip out the wind capacity effects by computing values for county property tax bases as the predicted value from the estimated Step 1 model with the wind capacity variable omitted. We consider this to be the estimated value of the assessed tax base that would have been observed in the absence of wind development, a sort of counter-factual value ($\widehat{v}^{*}_{c,t-1}$). Finally, in Step 3, we estimate county and school tax rates and school revenues in equations 6 and 7 using wind capacity on the right-hand side and the stripped-out or counter-factual taxable values. In the school revenue calculation (equation 7), we have included average daily public school attendance (a) as a control group for county size as well.[33]

As would be expected, the results displayed in columns 1, 2, 3 and 5 (taxable school property tax base) in Table 8 indicate that wind capacity, in all specifications, has a significant and positive effect on the total value of the tax base. Results from column 3, from the specification that includes county fixed effects, suggest an elasticity of the value of the county property tax base with respect to wind capacity on the order of .044. The elasticity estimate for the county school districts in column 5, which is based on the change in school property tax bases between 2005 and 2011, is somewhat lower at .036. This may reflect the incentives school districts have to provide ten-year property tax exemptions to wind projects in exchange for annual non-tax payments.

[32] In addition to the three step method reported in the paper, we estimated the tax-related models using an instrumental variable (IV) technique. We used log levels of wind capacity for the IV instead of changes in installed capacity since a given increment to installed capacity only appears in the year in which the new wind plant is commissioned. In future periods, the change is zero even though the effect on the value of the total tax base persists through the end of the analysis. We do not report these results because the level of wind capacity as instrument does not pass the Hausman test in all of the specifications.

[33] Although some researchers have used county wind potential as an instrument for installed capacity, our specification does not allow such an approach. Since wind potential (or ERCOT/non-ERCOT location) is time invariant, and our models, based on annual observations on the variables of interest, already control for fixed, unobservable county heterogeneities, it would be infeasible to use a time invariant instrument. Therefore we prefer our three-step method to an instrumental variable regression approach. Regardless, county-level wind class values can significantly under-represent the presence of highly economic wind resources at the sub-county level. This can be seen, for example, in the extensive wind development that has occurred in the western border ERCOT counties. The Texas counties with the highest average wind resources are in the Panhandle region, an area in which, until recently, limited transmission infrastructure had stunted wind power development.

Table 8: Regression results for property and school tax rates

Variables	Log(taxable value)$_{c,t}$			Log(property tax rate)$_{c,t}$	Log(taxable value)$_{c,t}$	Log(school tax rate)$_{c,t}$	Log(per student local revenues)$_{c,t}$	Log(per student expenditure)$_{c,t}$	
								From all sources	From local tax
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log(wind energy	0.044***	0.044***	0.044***	-0.020**	0.036***	-0.001	0.014*	0.014	0.028**
capacity + 1)$_{c,t-1}$ (δ_1)	(0.012)	(0.012)	(0.012)	(0.009)	(0.010)	(0.002)	(0.008)	(0.016)	(0.012)
Log(population)$_{c,t-1}$		0.366*	0.388*		0.435*				
		(0.215)	(0.214)		(0.222)				
Log(income)$_{c,t-1}$		0.148	0.154		0.012				
		(0.119)	(0.115)		(0.116)				
Log(total number of			-0.026		-0.106				
establishments)$_{t-1}$			(0.097)		(0.094)				
$\widehat{v}^*_{c,t-1}$				0.053		0.049	0.034	0.040	0.099
				(0.131)		(0.064)	(0.104)	(0.220)	(0.193)
Log(average daily							-0.045	-0.025	-0.194
attendance)$_{c,t}$							(0.058)	(0.135)	(0.128)
Log(per student expenditure									-0.158***
from state)$_{c,t}$									(0.031)
County effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,220	2,220	2,220	1,998	1,776	1,554	1,554	1,554	1,554
R^2	0.984	0.984	0.984	0.884	0.985	0.927	0.953	0.782	0.971

Robust standard errors clusterd by counties in parentheses. ***Denotes statistical significance at the 1% level, **denotes statistical significance at the 5% level, and * denotes statistical significance at the 10% level.

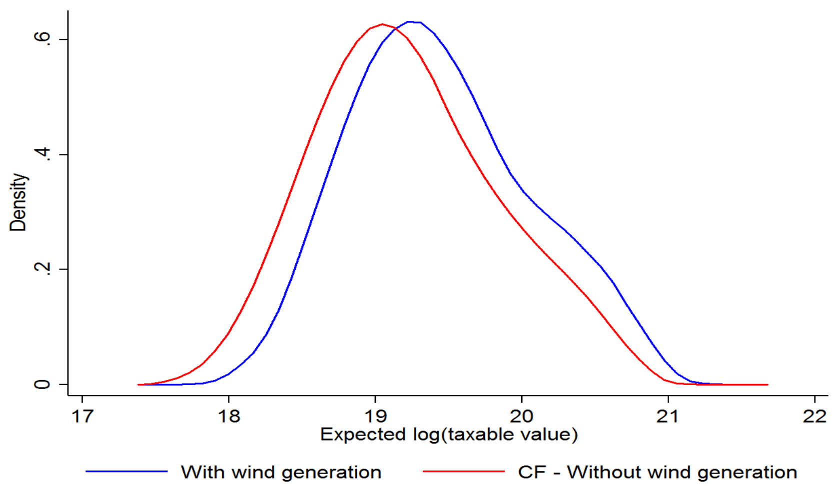
By the same token, the results of this exercise suggest that the presence of wind development has a negative effect on property tax rates for the wind counties' county governments but no effect on the school districts' tax rates. In the case of the wind county governments, the magnitude of the effect of wind power on the value of the county property tax base is greater than the magnitude of its effect on county property tax rates, suggesting a net gain in county revenues. In the case of school district taxes, absence of a change in tax rates implies that local school tax revenues at the county level increase hand-in-hand with increases in the county property tax base. There is also a weakly significant increase observed in per student revenues from local taxes, most likely as a consequence of the increase in the value of the taxable base.

In terms of per student expenditures, we observe a statistically significant elasticity of expenditures from local revenues with respect to installed wind capacity of .028. However, given the structure of Texas school funding, the increase in local tax revenues is offset by a reduction in state support for the base-level district funding. Thus, as expected, there is no net effect of the increased local revenues on per student expenditures from all sources, both state and local. Consistent with the state-local trade-off in the school finance method, the elasticity of locally-funded per student expenditures with respect to state funding, per student, is a highly significant -.158. It is useful to recall here that the method of aggregating school districts yields results that correspond to the lower bound in magnitudes of effects at the sub-county district levels.

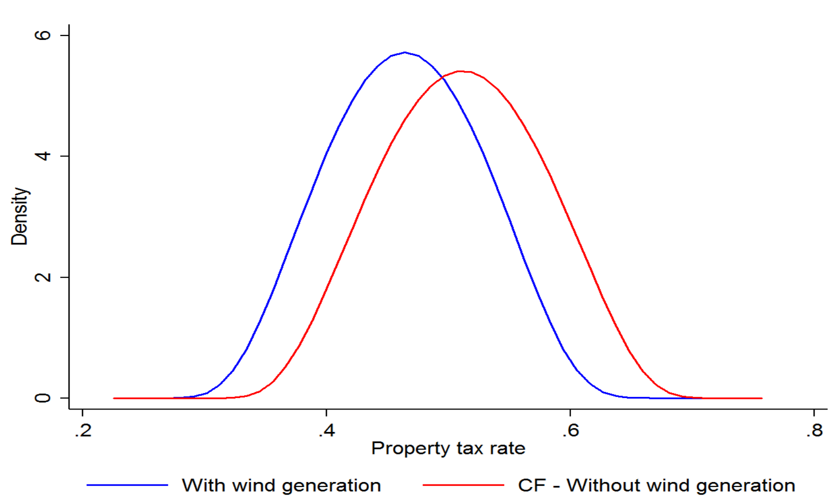
Overall, these results support the view that wind development makes a positive contribution to O&M school finance, although not necessarily at the local level in Texas. The nature of the Texas system of school finance alters the distribution of these benefits. Wind energy appears clearly to increase local property tax bases that, in turn, increase local resources for school funding. However, in Texas, these local gains are offset by the attendant reduction in state support for local school districts. While districts still enjoy a net increase in potential enhancement funding from the application of the allowable 17 cents in additional property tax rate to the wind-related increases in their property tax base, we find no evidence that those changes in the tax base have inspired either increases or decreases in tax rates or even influenced per student expenditures.[34] School districts already subject to recapture, or newly subjected to recapture due to the increase in the property tax base, derive

[34] It is worth noting that there is no recapture on the first 6 cents of these enhancement funds.

Figure 3: Taxable value, property tax rate, and wind energy capacity



Panel A: County taxable value



Panel B: County property tax rate

no school tax revenue benefit from the increases in the property tax base above the threshold level. Increases in recaptured local tax revenues are, regardless, recycled to support education across the state. In such cases, increases in local school taxing capacities disproportionately benefit state-level school finance.

We graph the results from this counter-factual exercise in Fig 3. As can be seen in Panel A, the counterfactual property tax line is shifted to the left of the actual line, or the level of counterfactual property tax base is lower over most of the density range. The inverse is true for county property tax rates, or the counterfactual line is shifted to the right of the actual line corresponding to actual county property tax rates.

4 Conclusions

We summarize our findings as follow. First, we find that wind power development does not have a statistically significant effect on net overall employment at the county level, although there are effects at the industry level. Second, localized personal income gains can be substantial for landowners. Third, increases in the property tax base provide localized benefits in the form of reductions in county general tax rates, while counties enjoy additional tax revenues, and school finance, particularly at the state-level, gains.

There is without question direct local employment associated with wind plant. However, as discussed above, either these effects are too small, in relative terms, to allow for statistical significance, or localized direct employment is not attributed to the locality as a consequence of the method of collection of employment data in the QCEW. Given non-local ownership of the wind farms, it is quite possible that on-site employment is associated with non-local establishments or sub-contracted to local establishments that are not identified as utility industry firms.

Recognizing that any gains in employment are beneficial, if direct field-site employment is indeed on the order of .05-.1 jobs per MW, as indicated by Texas wind plant operators, proportional gains from direct employment in future large-scale wind development are not likely to move the needle much, even in relatively rural counties. There is a weakly significant effect on localized industry employment –apparently working through spillover effects– in only two industries, retail and waste management. This rather narrow spillover is not a surprising result given the lack of industrial diversity in rural

Texas counties that blunts potential cross-industry linkages. Based on the industry-level analysis, our results suggest a localized increase of 40 jobs per 100 MW of installed wind capacity, a result that is in line with Brown et al. (2012). However, since we do not find statistical evidence of gains in total county employment, we conclude that employment gains from wind development have drawn from an inelastic labor supply.

We identify a substantial impact from wind development on county per capita personal income which, if largely not from wage income, is most likely the effect of lease and royalty revenues. This conclusion is affirmed by the finding that installed wind capacity does not appear to affect median county incomes. Further to this point, since annual household income from industrial employment, particularly in retail activities, would likely be in the lower half of the household income ordering, this result is further evidence that any net gains in employment across the industrial landscape have been modest. Our finding that installed wind plant increases per capita county income by an average of $2,657 per MW, while appearing quite attractive to us, is low compared to previous estimates. There are a number of possible reasons for this finding –some of which have already been discussed– that may perhaps be specific to the Texas context or the period under study in this analysis. In particular, local wind power related incomes could have been affected because wind generated electricity in West Texas was subject to relatively high rates of curtailment in the pre-CREZ environment; a relatively large proportion of landowners in windy areas of Texas are absentee owners; there is a more elastic supply of windy land in development-friendly Texas and, thus, less bargaining power by landowners in lease and royalty negotiation; capacity factors have been systematically over-estimated; and a more competitive environment for wind power sales in ERCOT (lesser reliance on long-term contracts with off-takers) has resulted in lower prices for wind generated electricity.

Lastly, we observe a significant positive impact, as expected, from increases in wind capacity on the value of county property tax bases. At least for county governments, the increases in tax capacity appear to have resulted in decreases in county property tax rates while increasing total county property tax revenues. All county property tax payers can perceive a benefit from the reduction in property tax rates while all county residents enjoy any expansion or improvement in county services that might result from the increased general fund tax revenues.

The issue is rather more complicated in the case of school tax revenues and expenditures. While no effect of wind development on school tax rates (averaged at the county level) is found, the increases in the value of the property tax bases translate into higher local school tax revenues. While this should be a localized benefit, the system of school finance in Texas tends to transfer these benefits to the state-level budget for public education. Nevertheless, more generally, it appears that important localized school tax benefits would otherwise be available from wind power development. Insofar as the level of local school funding availability does not affect the State's estimate of basic district-level funding (at least in the short to mid-term), the institutional features of the Texas system of school finance appear to redirect the wind-related tax benefits from the local tax jurisdictions to the state-level taxpayer base. The effect of this system of school finance has been, as intended, to equalize real per student base-level expenditures across all districts. This has meant, in the context of wind power development, that real per student expenditure levels in the wind counties have remained on a par with the other counties in Texas, even after allowance for non-property tax payments from exempted wind projects to school districts.

This analysis finds that localized benefits are mostly concentrated in the form of lease and royalty income to landowners. On the other hand, localized environmental impacts, such as degradation of the landscape and effects on wildlife, will be borne more generally by the county residents. It is difficult to see how further development of wind energy will effectively alter the secular trends of population and employment loss in rural areas. More research needs to be undertaken to quantify the costs of the gamut of localized long-term effects from wind power development before the long-term localized benefit-cost ledger is complete.

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