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3 October 2011

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October 10, 2012

Abstract:

Employment in electricity generation from renewable resources has expanded rapidly in the US and in Texas during the last decade. Availability of the Production Tax Credit has been an important driver of this growth. Using establishment-level employment and payroll data for Texas at the NAICS-6 level, we analyze the differences in average wages between firms generating electricity from fossil fuels and those generating electricity from wind power. We compare relative average wages before and after the rapid expansion of wind power development that followed the *ex ante* renewal of the Production Tax Credit (PTC) in 2006. Our main finding using both parametric and the nonparametric estimation technique proposed by Racine and Li (2004), is that average payrolls for wind power generators increased relative to fossil fuel-based electricity generators after 2006.

JEL: J31, Q20, Q28.

Key words: Wages, Production Tax Credits, Wind energy, Clean Energy.

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The authors would like to thank Andres Vargas, Ian Walker, David Peel, and the conference participants at the Western Economic Association International (2010) and Internal Industrial Organization (2011) for their valuable comments. We are grateful to the Department of Energy for financial support (Award Number DE-FG36-06GO86092).

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1. Introduction

The Production Tax Credit was introduced in the United States to enhance incentives for the development of wind powered electricity generation. The PTC, as it is known, is widely viewed as having achieved this objective. Periods of rapid expansion in wind power capacity have followed legislative renewal of the subsidy. By reducing tax liabilities of wind generators that qualify for the subsidy, the PTC has the effect of increasing after-tax rates of return to qualifying capital in the sector. Using a Difference-in-Differences methodology, we seek evidence that the subsidy may have indirectly benefited labor as well as capital.

Economic theory suggests that reductions in corporation tax rates can have an indirect incidence on labor. By increasing after-tax rates of return to capital, more capital, and thus investment, is attracted. With increases in the capital stock, the marginal product of labor increases and the (pre-tax) wage rental ratio rises. However, for this outcome to be observed in the case of a single tax-favored sector, either the favored sector has to be large relative to the economy or the supply of specific labor must be less than perfectly elastic over the term of the analysis.

The objective of this paper is to estimate the effect of the rapid expansion in wind power capacity in Texas on wage differentials between fossil fuel electricity generators and wind-powered electricity generators in Texas.[1] To the extent relative wages were affected by the rapid growth in wind power that occurred as a consequence of the PTC, we deem the wage effect to reflect an indirect incidence of the production subsidy. Thus, we are specifically interested in asking whether there may have been an increase in relative wages in wind energy generation that accompanied the sharp expansion in installed wind generation capacity following the *ex ante*

[1] Installed capacity in Texas has increased from 181MW in 2000 to 6,967MW in 2008.

extension of the Production Tax Credit (PTC) in 2006.[2] This study is restricted to an analysis of wages in the power generation sector, as narrowly defined, and thus excludes activities in fuel extraction, processing and transport.

We find evidence that average wage rates have increased more rapidly for workers in the wind power generation industry than for workers in fossil fuel generation in Texas in the post-2006 period. Since employment in the wind power industry tends to be located in more rural areas than employment in fossil fuel generation, and rural wages generally tend to be lower, we focus on wages in power generators relative to the county-average wage in all other non-farm industries. We refer to these ratios as relative wages. We find that average relative wages across the wind power sector have progressed relative to fossil fuel generation as wind production capacity has expanded in Texas. In fact, the relative wages of workers in wind energy establishments across the middle of the average wage distribution, which lagged those in fossil fuel generation prior to 2006, have caught up to relative wages for fossil fuel-based generators in the period following 2006.

As far as we know, this is the first paper to attempt to estimate the indirect impact of the PTC on wind energy industry wages. This issue is important for reasons beyond the perspective of the relative wage differentials between thermal and renewable energy power industries. The transition from thermal to wind power generation also has implications for the location of employment, regional economic activity, and the geographic distribution of income. It has relevance to discussions of policies designed to foster the expansion of renewable energy production in which questions of regional development and income inevitably enter the policy discussions.

[2] Legislation to renew the PTC was enacted in August, 2005 (see Table 1), prior to the acceleration of fuel prices that began to be observed from the mid-2006 through the summer of 2008. Therefore, the *ex ante* renewal of the PTC in 2005 could not have been a response to rapidly escalating fossil fuel prices.

In the next section we discuss the economic context and in Section III we describe our data and data sources. Section IV discusses the empirical results and Section V provides a summary of the study.

2. The Economic Context

Texas has enjoyed the largest growth in wind power capacity in the United States during the decade of the 2000s. Installed wind capacity in Texas increased from 184 MW at year-end 2000 to 10,085 MW at year-end 2010, representing about one-fourth of total installed capacity in the United States, according to the U.S. Department of Energy. The Electrical Reliability Council of Texas (ERCOT), the Texas grid operator, reported that 7.8 percent of the power on the grid in 2010 was generated by wind.[3] This growth in wind power has taken place largely at the expense of gas-powered generation since gas most readily substitutes for intermittent wind. In fact, 2010 was the first year since 1990 that the share of coal in electricity generation in Texas exceeded that of natural gas.

The explosive growth in wind power in Texas appears to have resulted primarily from the presence of the high quality wind resource, technological advances in wind turbine technology that have led to lower production costs, and the assured, *ex ante* availability of the Production Tax Credit that was enacted in 2006 (see Gulen, *et al.*, page 7). Wiser *et al.* (2007), among others, conclude that the main driver of this recent growth of wind power in the United States has been the federal production tax credit (PTC).

[3] The grid operated by the Electrical Reliability Council of Texas is wholly contained within the state. There are, however, significant portions of the state that are not within the ERCOT grid. Much of the wind resource is located in the South Plains and Panhandle regions of the state which are contained in the Southwest Power Pool. Nevertheless, most of the wind power generated in Texas is delivered to load centers in the ERCOT region. With the construction of significant new transmission capacity to deliver West Texas wind power into ERCOT, beginning as early as 2012, curtailment issues should be mitigated and new opportunities for wind power development will be realized in the Panhandle region.

Texas does have a Renewable Portfolio Standard (RPS).[4] Originally enacted in 1999, the Texas RPS mandated that electricity providers were to generate 2,000 MW of additional renewable energy by 2009. The Texas Legislature amended the RPS in 2005 to require 5,880 MW by 2015 and 10,000 MW by 2025. The obligation to satisfy the RPS is apportioned to each electricity provider based on their market share of electricity sales (to end-users) times the RPS goal. However, since installed capacity in wind largely met or exceeded the modest requirements of the state's RPS well ahead of schedule (both for the original RPS passed in 1999 and the increased goal in 2005), RPS constraints do not appear to have been binding and thus cannot explain the sharp increase in wind development. The creation of tradable Renewable Energy Certificates (RECs) in 1999 (with the original RPS legislation) provided financial incentives for installation of qualifying renewable energy production. But the availability of RECs does not provide a good explanation for the acceleration in wind development that was observed after 2006 since the price of RECs collapsed in early 2006 (from over $10 to around $3 per MWh).

Cullen (2010) provides a good overview of the federal Production Tax Credit. The PTC, originally enacted in 1992, allowed an inflation-adjusted tax credit of $15 per MWh of power generated and delivered onto the grid during the first ten years of the facility's operation. This represents a 40% to 67% increase in revenues to the operator. The PTC currently stands at $22 per MWh. To have value, of course, the owners of the facility must have sufficient tax liabilities in order to benefit fully from the tax credit (carryover provisions are available). Moreover, the PTC can only be claimed in proportion to equity shares in the qualifying facility and cannot be sold or otherwise transferred outside of selling or transferring equity ownership.

[4] RPS is a regulation that requires the increased production of energy from renewable energy sources, such as wind, solar, biomass, and geothermal.

The PTC is for new wind investment. That is, to qualify for the PTC, installed capacity must be initially brought on line during the period for which the PTC is in force. Although the PTC was originally put in place in 1992, it was allowed to expire in 1999. It has since been renewed for one to two year intervals, although the renewal was occasionally retroactive following a period of expiration. Thus, new plant installed after expiration of the PTC bore the risk that legislators would not agree to a retroactive renewal of the subsidy. Despite the fact that the PTC has technically been in place continuously since 1992, the uncertainty of the policy environment is reflected in a boom-bust cycle of wind power development surrounding the periods of renewal and expiration of the PTC.

With the renewal of the PTC in 2005, continuous *ex ante* provision for the PTC with a guaranteed two year window has been available to new wind development. Thus, an important structural shift in the PTC took place for the first time since its original expiration in 1999. It was not until the American Recovery and Reinvestment Act of 2009 that the option of a 30% investment tax credit was available in lieu of the PTC to wind turbine owners that qualify for the PTC. Table 1 and Figure 1 provide a history of PTC and related development activity.

The shift toward wind and solar has clear implications for the nature and location of employment in the electricity power generation industry. Thermal generation is preferably located close to the load, so most O&M employment in thermal generation is often proximate to more populous areas. Wind power, on the other hand, is tied to the location of the energy resource and thus tends to be located in largely rural and often remote areas. Since wage rates are lower in more rural areas of Texas than in metropolitan areas, a systematic study of wage differentials must take into account the location as well as the type of power generation under consideration. Simple contemporaneous comparisons of nominal wages across industries fail to capture regional differences that influence both real and nominal wages.

Summers (1981) makes an argument, in a general equilibrium setting, that elimination of corporation income taxes in favor of consumption taxation will lead to increased capital accumulation and an increase in real income as labor productivity is enhanced. Arulampalam et al (2010) find evidence that corporate income taxes are partially shifted onto labor. Although neither study is exactly analogous to the question of an industry subsidy, the PTC is functionally equivalent to a reduction in qualifying wind power producers' corporate profits tax rates. One would still expect that an industry specific subsidy would attract capital and lead to a higher marginal product of labor, *ceteris paribus*. If the supply of labor is less than perfectly elastic, this increased investment should be reflected in rising wage rates.

Texas on-shore wind resources are mostly located in sparsely populated and economically declining regions of West Texas, although some significant development has occurred on-shore in the coastal areas near Corpus Christi. The labor force in these rural locations is small and skills are sparse. As a consequence, matching between skills and new industry development is not as probable as it would be in more metropolitan areas in which thermal generation is the predominant form of electricity employment. In part, this underlies some of the difficulty these rural areas have in attracting industrial employment. Since wind power has arrived in order to exploit the wind resource rather than the available labor force, wind power producers either have to import labor or train locally available workers. Either way, frictionless adjustments in employment are not available, and labor supply has been relatively inelastic over the time frame of this study.

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 Renewable Portfolio Standard (RPS), it has nevertheless been widely recognized as a significant benefit mostly as a consequence of growth in the school and property tax base. Employment considerations are also important in rural counties that have been losing jobs and population for decades. Relatively good paying jobs with full benefits are of course particularly welcome in these rural areas.

3. Data

To accomplish our objective of comparing wage differentials between the two forms of electricity generation and identifying any wage effects from the rapid growth in installed wind capacity that followed the 2006 extension of the production tax credit, we use fully disclosed establishment level data for Texas from the Quarterly Census of Employment and Wages (QCEW) from the Texas Workforce Commission. Establishments are identified at the six-digit level of the North American Industrial Classification System (NAICS). We separate employment and wages in wind power from fossil fuel (221112) and renewable energy (221119) electricity generation. The data provide us with establishment names and geographic locations. Thus, we can identify establishments that are producing wind energy even though they are categorized more broadly as a renewable energy industry. Since our focus is on wind-powered generation only, we exclude the other forms of renewable energy powered electricity generation. In reality, utility scale electricity generation using solar and geothermal energy is almost non-existent in Texas. Wind is by far the dominant form of renewable energy generation. Nor has there has been any change in hydro-electric generating infrastructure over the period of this analysis, so it can safely be ignored.

This data set provides establishment specific monthly employment and quarterly total wages as required under the Texas unemployment insurance (UI) program. Monthly employment data under the QCEW program represent the number of covered workers who worked during, or received pay for, the pay period including the 12th of the month. While there are some excluded groups, such as the self-employed, most of the full-time, non-farm employment in Texas is captured by the QCEW. Payroll is the total compensation paid during the calendar quarter, regardless of when services were performed and includes such items as vacation pay and bonuses. An important limitation to the QCEW data is that only aggregate payroll information is provided. Since this variable is the product of total hours worked and wage rates, no specific information on hours worked or wage rates can be directly identified. However, QCEW data have been used for estimating wage differences in previous studies (see Addison et al., [2009]; De Silva et al., [2010]; Dube et al., [2007 & 2010]).

In addition, each record includes the specific geographic location (address) of the establishment and business start-up date (the date on which UI liability begins). Note that these establishments could be owned by a single firm that produces energy using both renewable and wind resources. However, if the generation takes place in different establishments, as would be expected, we can identify them separately since they are reported in separate records. This *unbalanced* panel data set is comprised of observations from Q1:2000 through Q4:2008.[5] Overall there were 2,723 observations for fossil fuel power generators in Texas before 2006 and 1,217 after 2006. Similarly, there were 422 observations for wind farms in Texas before 2006

[5] It should be pointed out that the authors obtained these data under an agreement of confidentiality and disclosure of the actual data is subject to certain restrictions. For example, we are not allowed to indicate the number of firms in a given county if there are fewer than four firms in the NAICS code in the county.

and 132 after 2006. This gives us a total of 3,940 observations for fossil fuel power generators and 554 observations for wind energy producers.

Table 2 presents summary statistics for wages and employment by production type before and after 2006. There are no official data that suggest staffing patterns in the wind power generation industry. However, a recent study of the California renewable energy industry concluded that employment on wind turbine farms consists primarily of wind turbine technicians and wind farm operations managers.[6] Both of these occupations would appear to require some degree of technical expertise and training and result in specific skills. On the other hand, according to the U.S. Bureau of Labor Statistics May 2003 staffing patterns for electrical power generation, dominated by fossil fuel generation, about 40% of employment is in production and maintenance. The balance is in office and administrative support, management, financial management, and engineering/architecture. While the proportions of workforce with technical skills may differ between the two types of power generation, there is no reason to suppose that staffing patterns changed in either type over the course of this analysis.

On average, compared to fossil fuel employees, unconditional quarterly real wages for wind employees were about $2,000 less than their fossil fuel counterparts before 2006, but about $300 more after 2006. However, as pointed out by Pollin (2009), geographic location plays an important role when comparing wage differences in renewable and non-renewable industries. To control for this possibility, we examine the differences between renewable and non-renewable generation using the *relative* wage in each activity. The relative wage is calculated as the ratio of quarterly average wages for the given power producing establishments to the located county's

[6] See Lindstrom, E. (2011) "Renewable Energy in the Inland Empire," Center of Excellence, Desert & San Diego/Imperial Regions, available at http://pdc.sbccd.cc.ca.us/Docs/ES_Reports/Renewable_Energy_in_the_IE_Apr2011.pdf

non-power producing, non-farm industries. This captures location specific factors that influence wage levels and which are essential to making valid comparisons between urban and rural locations. A relative wage greater than one indicates that the average wages in the power industry are greater than average wages in all other non-farm industries in that county. More importantly, it provides a relative measure based on prevailing county wages. Using this ratio, renewable energy industry wages are not penalized for the fact that they often reflect locations where prevailing nominal wages across the industrial landscape are relatively low compared to metropolitan regions.

Table 2 summarizes the unconditional average payrolls and relative average wages. It can also be noted that workers in the fossil fuel industry earn, on average, about two and half times more than workers in other non-farm industries after 2006. Workers in the wind power industry earn about 2.2 times more than workers in the other non-farm industries in the relevant counties after 2006. In terms of quarterly real average wages, wages in wind power rose by 18.9% ($3,168) compared to an increase of only 5.5% ($900) in fossil fuel generation after 2006. More importantly, the relative average wage in the wind power sector increased by about 10.8% after 2006 compared to an increase of about 4.2% in fossil fuel generation, suggesting a gain of about 6.5%.

While real average quarterly wages in wind power increased by some 13.5% against real average quarterly wages in fossil fuel generation, the increase in *relative* wages for wind was clearly more modest. This difference may be a reflection of a broader effect of wind power on average county wages in the rural areas in which significant wind development has taken place. It could also reflect rising wages in oil and gas production in areas where wind and petroleum resources coincide. Anecdotal evidence in West Texas points to a substantial localized increase in overall economic activity associated with spillovers from the expansion of wind power. If so, this suggests an even broader incidence of the PTC in the rural counties that witnessed significant wind development as average non-farm payrolls outstripped their counterparts in the more metropolitan regions. Note, this means that our estimates for the change in wind wages relative to wages in fossil fuel generation can only represent a lower bound for the actual change. Since, if investment and employment in wind power has raised average payrolls across all local industries, using the relative wage for wind power workers, expressed as relative to average county wages for all non-wind power employers, would understate their absolute change in comparison to thermal generation wages.

With respect to employment, fossil fuel generators tend to employ about 35 more workers per establishment than wind power generators after 2006. When considering the relative importance of the employer in total county employment in power generation, we compute the employment ratio of the establishment. The employment ratio is calculated as the ratio of quarterly average employment for a power producing establishment relative to located county's total power producing industry employment for a given quarter. Note that the maximum value for this variable is one and, in this case, that establishment has monopsony power within that industry in terms of demand for workers with the appropriate skill sets.

4. Empirical Analysis

4.1 *Difference-in-Differences (DID) empirical model*

All wage comparisons in Table 2 are unconditional and, thus, should be viewed in that light. They serve the function of underscoring the importance of conditional analyses. Since we are interested in examining the indirect effect of the PTC on wages of "wind energy" producers relative to "brown energy" producers across the distribution, we specify the following simple Difference-in-Differences (DID) empirical model

$$\log(w_{ict}) - \log(w_{\bar{j}ct}) = \alpha_t + \beta_1 W_i + \beta_2 A_t + \beta_3 (W_i \times A_t) + x'_{ict} + \mu_{ict} \qquad (1)$$

where w_{ict} is the wages of energy establishment *i* in county *c* at time *t* and $w_{\bar{j}ct}$ is the average wage for the power producing establishments' located county's non-power producing, non-farm industries. W_i is the dummy that identifies wind energy producers. The omitted group is the fossil fuel generators. A_t is a dummy to capture the structural shift that occurs with the availability of the PTC after 2006. We interact W_i with A_t to focus on structural changes following 2006. The vector x'_{ict} controls for establishment and market characteristics, and μ_{ict} are the error terms. The terms α_t is quarter (seasonal) fixed effects.

Next, if we to assume that the general trend in wage growth is not the same for energy producers and non-power producing, non-farm industries, then we can rewrite Equation (1) in the following form:

$$\log\,(w_{ict}) = \alpha_t + \beta_1 W_i + \beta_2 A_t + \beta_3 (W_i \times A_t) + \log(w_{\bar{j}ct}) + x'_{ict} + \varepsilon_{ict} \qquad (2)$$

which is the form we estimate.

Our main interest is in the coefficients β_1 and β_3. β_1 measures the average difference in relative wind wages compared to fossil fuel wages in Texas prior to the policy change while β_3 captures the log change in the wind-fossil fuel wage gap in Texas from before to after the availability of the PTC.

When considering establishment controls, we include each establishment's employment ratio. As a market condition indicator, we include the fossil fuel cost index. The data for the fossil fuel cost index is acquired from U.S. Energy Information Administration (see http://www.eia.doe.gov).

We also estimate a slight variation of Equation (1) as expressed in the following form.

$$rw_{ict} = \gamma_t + \beta_1 W_i + \beta_2 A_t + \beta_3 (W_i \times A_t) + x'_{ict} + \eta_{ict} \qquad (3)$$

where, rw_{ict} is the relative wage of energy establishment *i* in county *c* at time *t* and term γ_t controls for time (seasonal) effects.

We estimate Equations 2 and 3 with quarter effects that control for unobservable heterogeneities across quarters (seasons.) We do not use establishment level fixed effects since the variable of interest, the wind dummy, does not vary within a power generator.[7] Results are reported in Table 3. In the first column of Table 3, we report the results for log of real wages. Results indicate that, before the implementation of PTC, wind energy producers' relative wages are low compared to fossil fuel energy generators (β_1). Note that our main interest is in the coefficient on the dummy for the interaction of the wind energy dummy and period following the renewal of the PTC in 2006, β_3. The estimation suggests that there is a statistical difference between relative wages for wind and fossil generators after 2006 compared to before. This means that the wind energy generators' wages have 'caught up' with fossil fuel based energy producers' wages after 2006.

[7] Also note that it will be ideal to use county fixed effects to control for unobservable regional heterogeneities. Due to limited number of wind energy producers locate in few counties we do not use county fixed effects in the estimation.

In general, estimates on the coefficient of the employment ratio, i.e., the variable that captures possible market power, indicates that greater monopsony power appears to result in lower wages, as would be expected. Next we estimate Equation 3 and report them in column two. Qualitative results for β_1 and β_3 are similar to the results reported in Column 1. In general, the estimate for the coefficient on the fuel cost index variable suggests that the relative wages for energy industry employees increased as fuel costs increased.

4.2 *Nonparametric Results using Racine and Li Method*

We are also interested in observing if there has been a distributional shift in wages after 2006. In this case a mean regression is insufficient to make predictions regarding wage distributions. We therefore draw conditional log wage density graphs for wind and fossil fuel power generators. We estimate the conditional log wages for wind and fossil fuel-based energy generators before and after 2006 using the non-parametric regression technique proposed by Racine and Li (2004.)

There are many advantages to using the Racine and Li (2004) estimation technique compared to others. Mainly, their method handles mixed discrete and continuous data in a satisfactory manner unlike other conventional nonparametric techniques. It is widely noted that a frequency estimator can be used to obtain consistent nonparametric estimates of a joint probability density function (PDF) in the presence of discrete variables. However, this frequency-based approach divides the sample into many cells. In some cases, the number of observations in each "bin" may be insufficient to ensure the accurate nonparametric estimation of the PDF of the remaining continuous variables.[8] In these situations, the conventional frequency estimator cannot be applied.

[8] Furthermore, Racine and Li (2004) also note that it is common to encounter situations where the number of cells exceeds the number of observations.

Aitchison and Aitken (1976) proposed a nonparametric kernel method for estimating a joint distribution defined over binary data. The main advantage that their method has over the conventional frequency estimator is that it does not divide the sample into cells. A weakness of their method is that in mixed discrete and continuous variable settings, it is known to "fail" when modeling "fat / thin-tailed" continuous data.[9]

There are several theoretical papers on the properties of cross-validation methods with only continuous variables (e.g.,Häardle and Marron [1985]), or with only discrete variables (e.g., Hall [1981], Grund [1993] and Grund and Hall [1993]). Other than papers by Tutz (1991) and Ahmad and Cerrito (1994), not much attention has been paid to the more general and interesting case of mixed discrete and continuous variables. However, Racine and Li (2004) notes that these papers only demonstrate that their estimators are consistent. They do not establish the asymptotic distributions of their estimators.

In their paper, Racine and Li (2004) have closed this gap by establishing the asymptotic distribution of an estimator and its consistency. They provide a theoretical foundation for a consistent kernel estimator of a joint PDF defined over mixed continuous and discrete data that employs least-squares cross-validation selection of the smoothing parameters.[10] Their technique is even valid for finite samples. Note that we have very few "wind power generators" observations compared to "fossil fuel-based power generators" observations. Therefore, we employ the Racine and Li (2004) data driven method to estimate Equations 2 and 3 and analyze the differences in wage distributions before and after 2006.

Consider the following empirical model:

[9] Hall (1987a, 1987b) notes that this weakness results, in part, from the use of the likelihood cross-validation bandwidth selection process.
[10] Note that they obtain rates of convergence of the smoothing parameters to benchmark optimal values, and establish the asymptotic normality of the estimator.

$$w_{ict} = g(X_{ict}) + u_{ict} \quad (4)$$

where $g(\cdot)$ has an unknown functional form. We use $g(X_{ict}) = g(X_{ict}^k, X_{ict}^d)$ to denote the joint density function of (X_{ict}^k, X_{ict}^d) where $X_{ict}^k$are continuous variables and X_{ict}^d are discrete variables. Optimal smoothing parameters for $g(\cdot)$ were chosen using the "leave-one-out cross-validation" method for estimating the fitted values. Bandwidths were chosen using Silverman's rule of thumb and bi-weight kernels. The continuous variables we employ are power producing establishment's average real log of wages, non-farm industries average real log of wages, employment ratio, and fossil fuel cost index. The dummy variables are the post-2006 period, wind energy production dummy, and quarter dummies. In essence we can estimate Equation 2 and 3 using Equation 4. Then the predicted values for *before* and *after* 2006 log wages from this estimation (using Equation 1) are graphed in Figure 2. In Figure 3 we graph wind and fossil fuel-based generators' wage distribution before and after for clear comparison. As can be seen, the estimated log wages for wind energy generators are lower before 2006 and not different after 2006 compared to fossil fuel-based power produces.

A Kolmogorov-Smirnov (K-S) test for equality of distribution functions rejects the null hypothesis of equality of distributions at 95 percent confidence for both logs of wind and fossil based energy producers' wages before and after 2006 (Figure 2). We next test for equality of wage distributions of wind and fossil fuel-based energy generators before 2006 and after 2006 as drawn in Figure 3. Again the K-S test rejects the null hypothesis of equality of distributions at 95 percent confidence between wind and fossil fuel power generators before 2006 (first panel).

However, K-S test fails to reject the null at 95 percent confidence for wage distributions between wind and fossil fuel based energy producers after 2006 (second panel).

We also conduct a two sample *t*-test on the predicted conditional densities from the Racine and Li (2004) method. These results are reported in Table 4. Results indicate that, after 2006, both wind and fossil fuel power generators' wages have increased. However, one can see that wind power wages have increased more (by about 20%) compared to fossil fuel power producers (5.8%). Table 4 also notes that there is no statistical difference between wind and fossil fuel generators' wages after 2006.

Next we re-estimate the model using relative wages (Equation 3). In Figure 4 we have drawn the conditional distributions. Qualitative results are in agreement with what we find using the log wage.[11] However, relative wages indicate that wind based energy producers' wages have increased compared to fossil fuel-based energy generators. This result is statistically significant.

4.3 *Robustness Checks*

In order to check the robustness of our results, we estimate a number of alternative specifications. First, we address the problem of within-group correlation raised by Moulton (1990). If this is the case, the standard errors in our model may be underestimated. We employed clustered standard errors at the establishment level to overcome this potential problem. Bertrand, Duflo, and Mullainathan (2004), however, show that clustered standard errors can be biased downward in panel data if serial correlation is present. One approach that they recommend is to collapse the time dimension of the data down to two periods. To do this in our application, we focus only on establishments that were present both before and after 2006. We

[11] We also conduct a two sample *t*-test on the predicted conditional densities and results are qualitatively similar to the log density results. We have excluded the Table in order to save space and can provide these results upon request.

then aggregate the pre and post-2006 quarterly data by per-establishment and re-estimate equations 1 and 2. When collapsing the data we lose a large number of observations and hence the degrees of freedom. We end up with 274 observations with 192 degrees of freedom. This is a very common problem in DID models. These results are presented in Table 5, Columns 1 and 2.

One could question whether the wind wages were already experiencing an upward trend prior to 2006 either in absolute terms or relative to the fossil fuel wages. To investigate this issue, we estimate the log and relative wage models using only establishment-level data from the pre-2006 time period and include time variables to measure the trends in wages over the relevant period. To test for differences in the trend across fossil fuel and wind generators, the model includes an overall trend term interacted with indicator variables for the wind sector. We report the results in the last two Columns of Table 5. The estimation results indicate that the wind wages had been declining before 2006 but the estimated effect is statistically insignificant. Hence, we conclude that, prior to 2006, the wind wages were not trending upwards.

Finally one could use an alternative control group to check the validity of the original DID results. Gruber, (1996) notes that if the results with the alternative control group are different from the DID with the original control group, then the original DID is likely to be biased. We consider hydro-electric as an alternative control since it is another renewable energy source of power for electricity generation but one that is not affected by PTCs. We report these results in the last two columns of Table 5. Results indicate that wages for wind energy generators have increased since 2006 and results are consistent with original DID findings. However, one should note that there have not been any additional hydro-electric power generators built in TX during this sample period.

5. Conclusion

As far as we know, this is the first field study to analyze the relative wages in the wind power industry. Our parametric and nonparametric results indicate that relative wind industry wages increased across the wage distribution, by establishment, and demonstrated significant improvement in the post-2006 period. These wage effects followed the capacity expansion in wind power that occurred right after the assured, *ex ante* extension of the Production Tax Credit was legislated in 2006. In short, conditional wind energy wages have reached at least approximate equivalence to wages in thermal power generation after correction for location-specific factors.

To the extent that the PTC encouraged the expansion of the wind power industry in Texas during this period, the subsidy was at least partially captured by workers in the form of higher compensation. While the PTC is widely regarded as a policy tool to promote sustainable and clean electricity generation by attracting private sector investment, its indirect incidence should be kept in mind. Advocates of balanced regional growth, or rural development, may find additional support for arguments in favor of establishing long-term availability of wind energy subsidies.

This paper also validates the observation made by Pollin et al. (2009), that investment expenditure in green industry infrastructure increases wages at all levels. Moreover, geographic location plays an important role when comparing wage differences in renewable and non-renewable industries.

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Table 1: History of PTC and Related Development activity

Legislation	Date enacted	Wind capacity (MW) built in PTC window
Section 1914, Energy Policy Act of 1992 (P.L. 102-486)	10/24/92	894 (1994-June 1999)
Section 507, Ticket to Work and Work Incentives Improvement Act of 1999 (P.L. 106-170)	12/19/99	1764 (July 1999-2001)
Section 603, Job Creation and Worker Assistance Act (P.L. 107-147)	03/09/02	2078 (2002-2003)
Section 313, The Working Families Tax Relief Act, (P.L. 108-311)	10/04/04	2792 (2004-2005)
Section 1301, Energy Policy Act of 2005 (P.L. 109-58)	08/08/05	7703 (2006-2007)
Section 201, Tax Relief and Health Care Act of 2006 (P.L. 109-432)	12/20/06	18262 (8545*) (2008-2009)

*For 2008

Figure 1: Net Capacity Additions

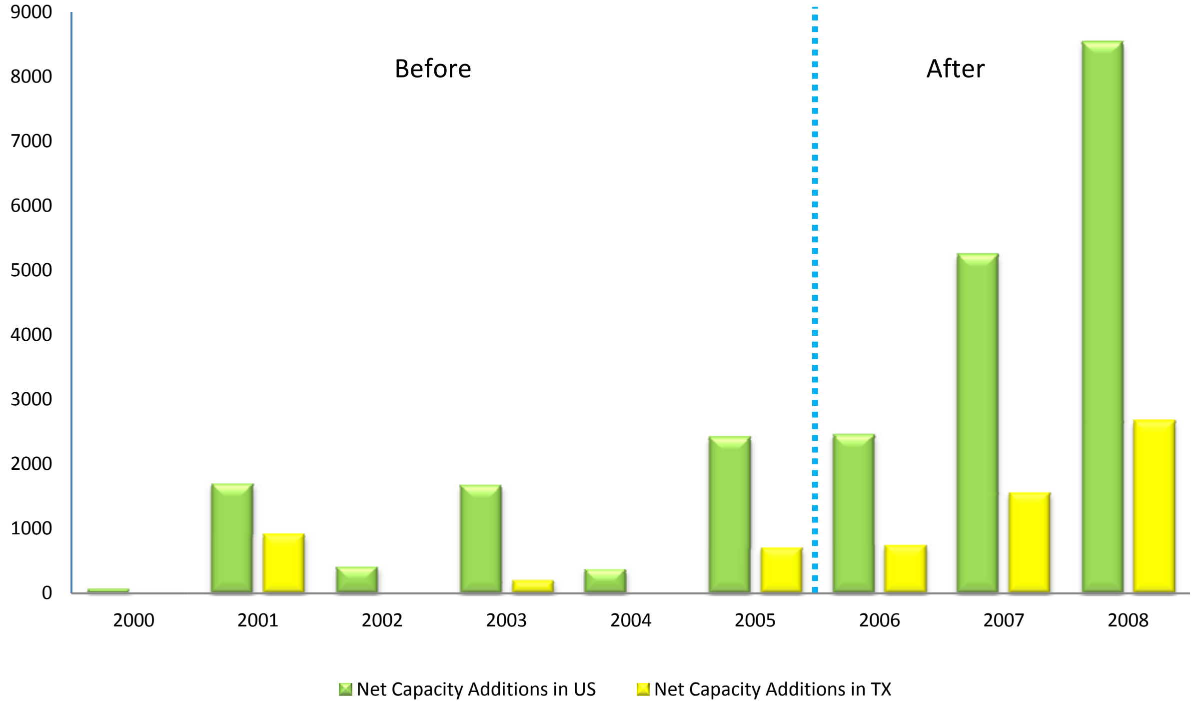

Table 2: Establishment Level Summary Statistics

	Power generation type			
	Wind		Fossil fuel	
	Before	**After**	**Before**	**After**
Average real quarterly wages ($)	13,536.79	16,704.10	15,521.99	16,420.23
	(4,828.72)	(6,549.77)	(5,536.91)	(5,752.71)
Log (average real quarterly wages)	9.456	9.655	9.590	9.648
	(.337)	(.366)	(.351)	(.347)
Relative wages	1.966	2.206	2.365	2.469
	(.546)	(.726)	(.764)	(.871)
Average employment	73.562	72.667	91.136	102.384
	(94.369)	(66.127)	(336.543)	(363.442)
Employment ratio	.273	.233	.248	.330
	(.327)	(.333)	(.335)	(.350)

Standard deviations are in parentheses.

Table 3: Regression Results for Wages

Variable	**Log of real wages**	**Relative wages**
	(1)	**(2)**
Wind (β_1)	-.148**	-.390**
	(.016)	(.031)
Since 2006 (β_2)	.029**	.060
	(.014)	(.035)
Wind × Since 2006 (β_3)	.088**	.134*
	(.035)	(.074)
Log of non-farm industries average real wages	.524***	
	(.120)	
Employment ratio	-.083***	-.029
	(.014)	(.031)
Log of fossil fuel cost index	.071**	.121**
	(.025)	(.056)
Quarter Effects	Yes	Yes
Number of observations	4494	4494
Adjusted R^2	.164	.093

Robust standard errors are in parentheses. *** Denotes statistical significances of 99%, ** denotes statistical significances of 95%, and * denotes statistical significances of 90%.

Table 4: Conditional Log Wage Distributions' Mean Differences using Racine and Li Method

Power generation type	**Before**	**After**	**Difference (*After – Before*)**
Fossil fuel	9.592	9.649	**.058*** **
	(.004)	(.008)	**(.009)**
Wind	9.453	9.655	**.201*** **
	(.013)	(.026)	**(.029)**
Difference (*Fossil fuel – Wind*)	**.139*** **	**.005**	
	(.014)	**(.027)**	

Standard deviations are in parentheses.

Figure 2: Conditional Log Energy Wage Densities for Before and After 2006.

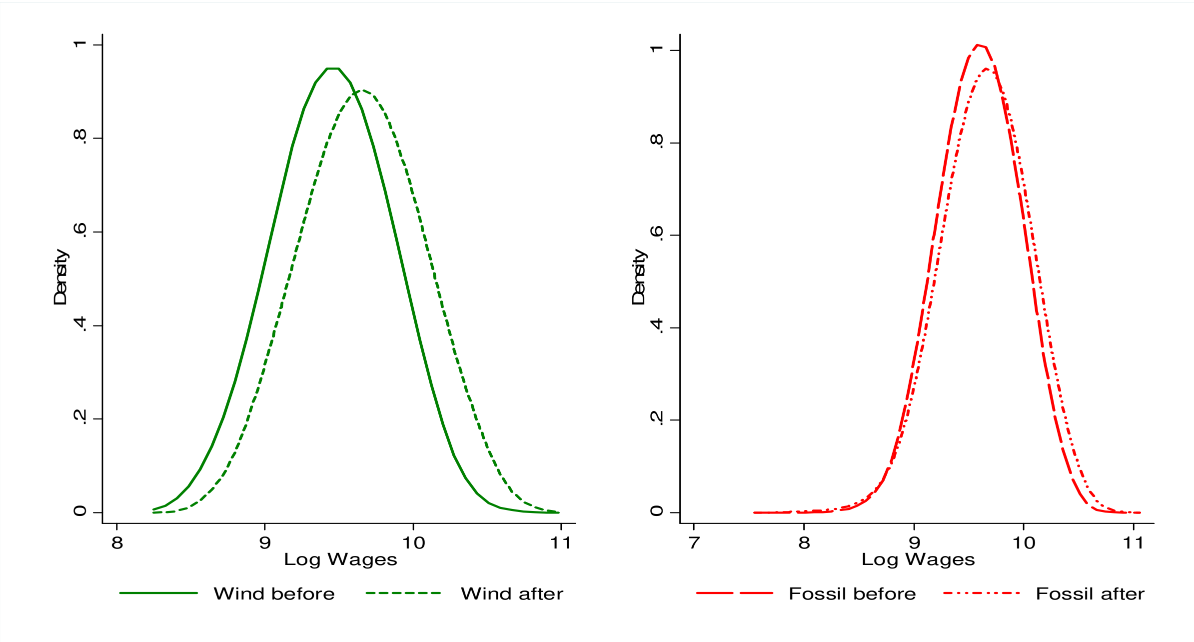

Figure 3: Conditional Log Energy Wage Densities for Before and After 2006.

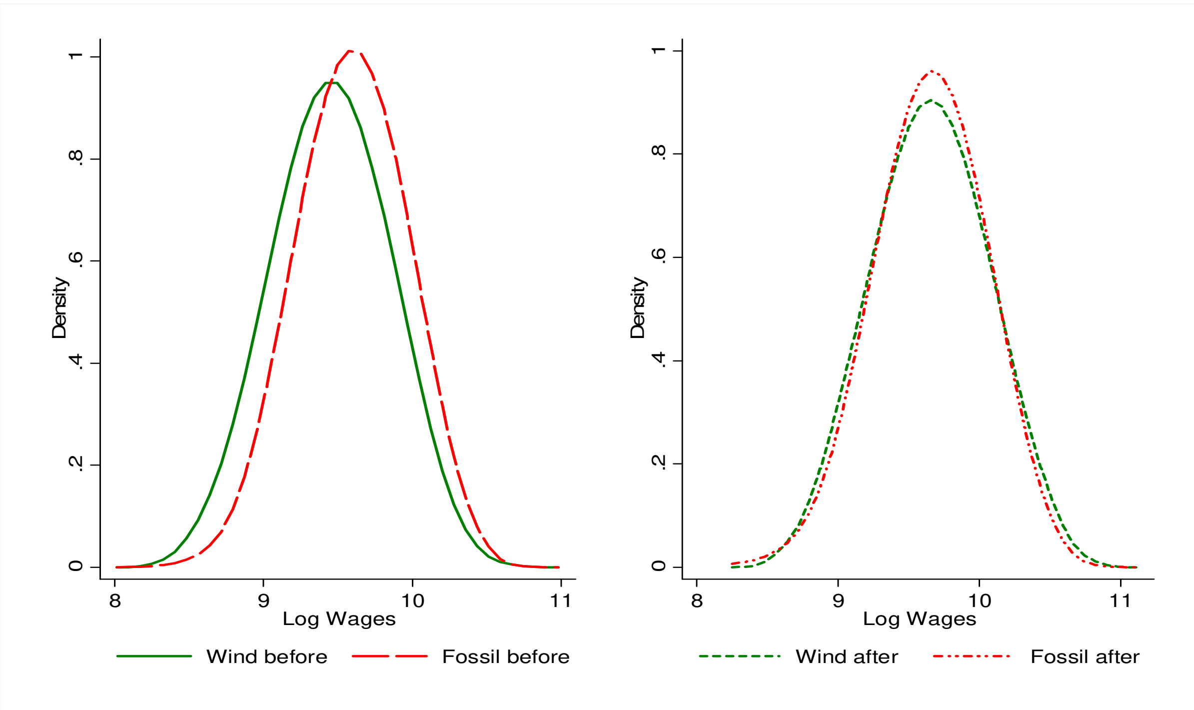

Figure 4: Conditional Relative Energy Wage Densities for Before and After 2006.

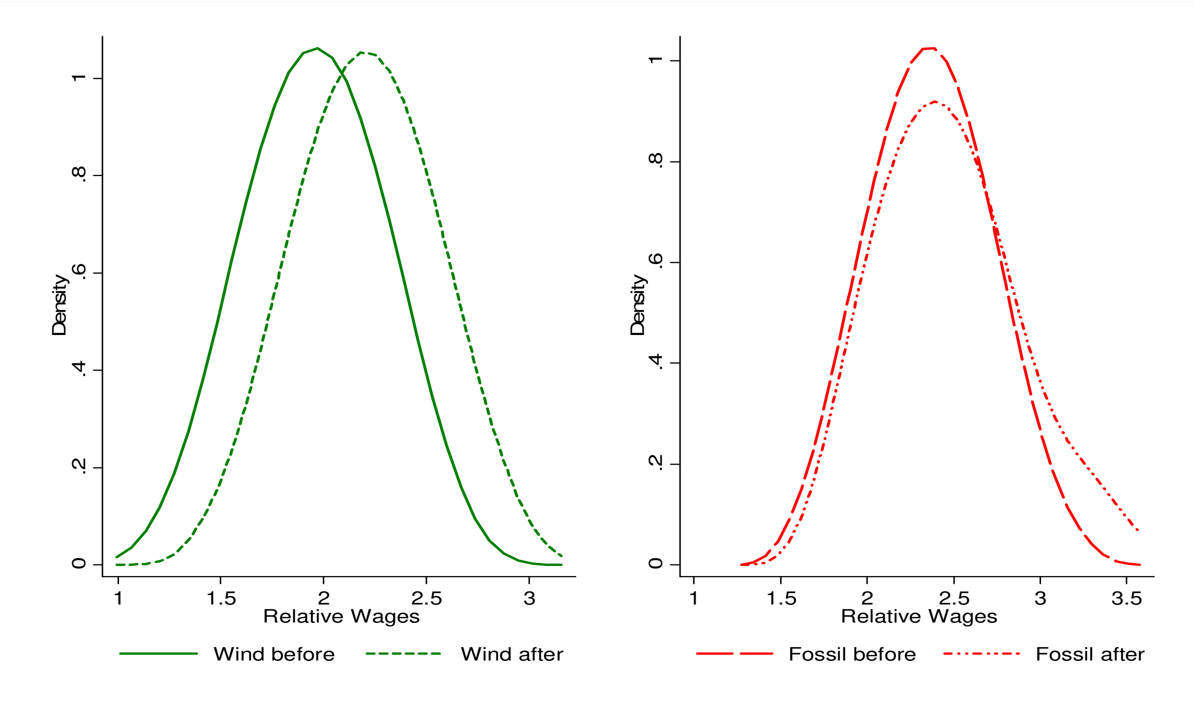

Table 5: Alternative Specification Regression Results

Variable	**Per-real average relative wages – averaged by before and after**		**Time trend analysis**		**Alternative control group (Hydro power)**	
	Log of real wages	**Relative wages**	**Log of real wages**	**Relative wages**	**Log of real wages**	**Relative wages**
Wind (β_1)	-.194*	-.442**	-.099**	-.307***	-.087***	-.288***
	(.104)	(.177)	(.040)	(.072)	(.015)	(.028)
Since 2006 (β_2)	.003	.073			-.032***	-.109***
	(.041)	(.093)			(.009)	(.018)
Wind × Since 2006 (β_3)	.103	.129			.152***	.284***
	(.080)	(.143)			(.035)	(.070)
Time			.008***	.010***		
			(.002)	(.003)		
Time × Wind			-.004	-.006		
			(.003)	(.005)		
Log of non-farm industries average real wages	.425**		.483***		.426***	
	(.106)		(.030)		(.016)	
Employment ratio	-.090	-.015	-.081***	-.017	.058***	.336***
	(.060)	(.136)	(.016)	(.036)	(.007)	(.015)
Fossil fuel cost index	.122	.001	-.129**	-.211**	.100***	.209***
	(.150)	(.334)	(.045)	(.099)	(.015)	(.031)
Quarter Effects			Yes	Yes	yes	yes
Number of observations	274	274	3145	3145	13195	13915
Adjusted R^2	.406	.014	.306	.237	.247	.092

Robust standard errors are in parentheses. *** Denotes statistical significances of 99%, ** denotes statistical significances of 95%, and * denotes statistical significances of 90%.