Chicken and Egg: Electricity Transmission and Investment in Renewable Energy

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Section 1: Overview and Research Question

Massive investment in high-capacity electricity transmission lines is crucial for achieving rapid decarbonization (Larson et al. 2021). In the US, most renewable energy is generated far from the demand centers, necessitating high-capacity transmission lines to connect supply with demand. Large-scale grid expansion projects are massive government undertakings, often costing billions of dollars with several years of planning. However, the important spillover effect of transmission expansion on renewable generation markets remains an understudied topic in economics (Davis, Hausman, and Rose 2023).

In this paper, I provide the first causal estimates on the effect of transmission expansion on long-term investment in renewable energy. However, a classic 'chicken-and-egg' problem exists with transmission planning- building new transmission is dependent on generation, and the new generation is dependent on the availability of transmission capacity. Texas solved this problem in 2008 by announcing a massive grid expansion project aimed at integrating the existing and growing wind generation in West Texas to the demand centers in the East (Lasher 2008). The spatial aspect of this transmission project provides an excellent opportunity to study the long-run impacts of market integration on renewable investment.

Section 2: Research Methodology and Data

I answer this question using a unique combination of model and design-based approaches. I first use a discrete choice model to estimate the likelihood of siting a wind project in locations with grid expansion. Next, I use a Difference-in-Difference strategy to examine whether locations with grid expansion receive higher levels of wind investment than those without. I use results from both approaches to quantify the social benefits due to lower emissions and the private benefits due to higher lease payments to landowners.

I leverage rich spatial and temporal data from the rollout of a large-scale transmission expansion project called Competitive Renewable Energy Zones (CREZ) in Texas. I combine spatial data on location announcements of grid expansion in 2008 from the Public Utilities Commission of Texas, with wind project data from EIA Form 860, detailed wind resource quality data from NREL, and land characteristics from USDA and the Real Estate Center from Texas A&M University.

I write a model of location choice where a wind developer selects a project site to maximize profits. The model shows that conditional on wind resource quality and site characteristics, locating near transmission infrastructure is cost-minimizing. I take this model to the data and use a conditional logit model to estimate the probability of locating in a county with CREZ transmission. This analysis uses data on all utility-scale wind projects in Texas from 2000 to 2020.

Next, I use a difference-in-difference analysis in an event study framework to estimate whether counties announced to site transmission infrastructure saw higher wind-investments over time. I use the Callaway and Sant'Anna (2021) staggered treatment estimator to account for potential bias in the Two Way Fixed Effects estimator in cases of treatment effect heterogeneity and staggered treatment adoption.[1] I use Coarsened Exact Matching to overcome the common support problem in the conditioning covariates in the regression specification. The matching step creates a set of counties that are comparable across a wide set of characteristics: wind resource quality, terrain characteristics, and land value.

Section 3: Results and Insights

The estimates from the conditional logit model for the location choice model show that wind projects were 20 percentage points more likely to be located in a CREZ county than other counties. Using coefficient estimates from the conditional logit model, I compute a willingness to pay to locate in CREZ counties of about $1,137 per acre or $2,808 per MW of wind power. Heterogeneity analysis shows a positive relationship between project size and the likelihood of choosing a CREZ county. Interestingly, wind projects have become less likely to site in CREZ locations in recent years due to increasing congestion in these regions.

[1] I condition on a combination of pre-treatment and time-variant characteristics that are correlated with CREZ location selection and wind investment. These characteristics include detailed measures of wind resource quality, farm size and value, terrain elevation, and ruggedness.

The event study finds that locations with investment in transmission saw higher levels of wind investment post-CREZ announcement. The aggregate treatment effect from the Callaway and Sant'Anna (2021) estimator is about 100 MW greater wind investment per year. This effect is robust to several threats to identification which include the selection on unobservables- lobbying efforts for or against CREZ siting, investment spillovers to control counties, anticipation of CREZ announcement, and differential effects of CREZ locations on output and input prices of wind.

The wind investment due to transmission expansion in Texas led to large public benefits as a result of lower emissions and private benefits to land owners due to higher lease payments. A back-of-the-envelope calculation shows that the wind investment due to CREZ prevented approximately $1.71 billion worth of emissions annually. Combining the willingness to pay estimates from the choice model with the aggregate treatment effects from the event study, I find approximately $11 million higher annual payments from wind projects to land owners in the CREZ counties.

Section 4: Conclusions and Contributions to the Literature

While transmission expansions are expensive endeavors, the benefits accrue over time. This analysis shows that locations with transmission expansion saw higher wind investments in the long-run. The CREZ project cost about $6.8 billion with over $1.72 billion worth of annual public and private benefits. These benefits imply a payback period of about four years. The findings from this paper offer insights into renewable generation investments due to transmission expansion in other wholesale markets, such as the SPP and MISO. Recently, an increasing number of renewable projects have been dropping out of development due to inadequate transmission capacity and long interconnection wait times in these markets

This paper adds to several strands of literature in economics. Recent studies have looked at how the interaction between transmission constraints and changes in market structure affect allocative efficiency and other outcomes (Ryan 2021, Cicala 2022). By contrast, I analyze the investment effects of electricity transmission expansion while keeping the market structure fixed. This allows me to isolate the impact of transmission expansion from changes due to changes in market structure or dispatch mechanism.

I also add to the recent empirical literature looking at the impact of transmission expansion. This includes the impact of transmission expansion in lowering wholesale prices (LaRiviere and Lyu 2022), emissions due to lower congestion (Fell, Kaffine, and Novan 2021), reduction in market power and emissions from the fossil fuel sector (Doshi 2024), and anticipatory investment in solar energy in Chilean electricity market (Gonzales, Ito, and Reguant 2023). While recent studies have mainly examined short-run outcomes, I add to this literature by looking at the investment decisions of wind developers over two decades. Ignoring these long-run public and private benefits can vastly understate the true benefits of large-scale transmission expansion.

References

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