Impacts of Uncertainty in Transmission Interconnection on Energy Transition

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Section 1: Motivation and Research Question

All generators that plan to connect to the grid are required to go through an interconnection process. During this process, they must submit requests for connection and undergo a series study to ensure transmission reliability. However, a surge in requests in recent years and high project withdrawal rate have created a severe backlog, causing significant delays and threatening grid resilience. Given that more than 97% of these requests are for renewable generators, the challenges of interconnection seriously impede the integration of renewable generation, posing major barriers to achieve a carbon-free economy by 2035 (House, 2023).

In this paper, I investigate the impact of cost allocation uncertainty on generators' decision to stay in the interconnection process. Interconnection costs include physical attachments for self-use and network upgrades that can benefit multiple generators. A key reason for the high project withdrawal rate is the cost uncertainty, particularly regarding network upgrades due to the cost allocation rule, also known as the "first to cause" rule. This rule states that a generator (or group of generators) that triggers a network upgrade bears the costs (Federal Energy Regulatory Commission, 2012). This allocation rule allows generators to benefit from the upgrade without sharing the costs, creating "free-ride" incentives for some that further complicates cost allocation. Interconnection cost information is disclosed and updated to generators in each round during the process to reflect the latest cost adjustment.

Section 2: Model and Contributions

This study focuses on all generation interconnection requests submitted between 2016 and 2020 in PJM and models the generator's decision to stay in the interconnection process with a dynamic discrete choice model incorporating Bayesian learning. I treat the physical cost and network upgrade cost signals as information shocks to generators at each round of the study. Generators make decisions based on a forward-looking reward function that considers the transition of these cost signals. I employ a mean-variance framework with Bayesian learning to capture the dynamics of uncertainty in network upgrade costs.[1] The model parameters are estimated using the Method of Simulated Moments (MSM) by minimizing the squared differences between observed and simulated choice probabilities of staying at each study stage.

This paper contributes to energy transition literature by focusing on interconnection challenges. Previous studies have discussed various challenges related to energy transitions, including cost considerations (e.g., Boer, Pescatori and Stuermer, 2023; Heal, 2020), renewable energy intermittencies (e.g., Gowrisankaran, Reynolds and Samano, 2016; Joskow, 2019; Lamont, 2008; Wolak, 2020), and insufficient transmission infrastructure (Davis, Hausman and Rose, 2023). However, there is a gap regarding the challenge of interconnection. The only working paper in this regard is by Johnston and Yang (2022), where they focused on the waiting costs and high total interconnection costs during the process. My paper differs from their work and focuses on cost uncertainty in the process by distinguishing between two types of interconnection costs to illustrate the source of uncertainty. My model treats the cost signals at each stage as information shocks and focuses on the learning behavior of decision-makers as new information is added in their decision set in each subsequent stage during the process. This crucial feature allows me to estimate the probability for a generator to stay in the queue as uncertainty reduces throughout the process.

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[1] Dynamic discrete choice models have been extensively applied in various context, including storable goods demand (e.g., Erdem, Imai and Keane, 2003; Hendel and Nevo, 2006a,b), durable goods (e.g., Gowrisankaran and Rysman, 2012; Melnikov, 2013; Song and Chintagunta, 2003), and career choices (e.g., Keane and Wolpin, 1994, 1997). Bayesian learning is also commonly integrated into discrete choice models to capture brand choice dynamics (e.g., Crawford and Shum, 2005; Erdem and Keane, 1996; Hitsch, 2006). Forward-looking models have also applied in the environmental field to discuss learning-by-doing (e.g., Kellogg, 2011, 2014; Ma and Shi, 2015).

Section 3: Results

This paper presents findings on the impacts of network upgrade cost, considering both uncertainty and magnitude. First, I find a positive effect of cost uncertainty on generator's probability of staying in the process, which reflects the benefit of learning. With high cost uncertainty at the outset of the interconnection process, generators benefit from staying in the process to acquire more accurate cost estimates as the process progresses before making any decisions. My counterfactual analysis shows that providing accurate information early in the process can help resolve the interconnection backlog without compromising the total number of actual connections. Second, I find a heterogeneous effect regarding network upgrade costs among generators with different fuel sources. Wind generators exhibit the highest sensitivity to changes in upgrade costs, possibly because they are located in areas with less developed transmission infrastructure. Subsidy policies for interconnection may be most effective when tailored as a fuel-specific approach.

Section 4: Policy Implications

This paper provides important policy implications through counterfactual analyses related to cost uncertainty and cost magnitude. Regarding the resolution of the interconnection backlog in the context of FERC Order 2023, I inform the policy by showing that the benefits of early learning can encourage decision-making at an earlier stage. These benefits not only help in addressing the current backlog but also result in cost savings for generators. Consequently, it is imperative for interconnection studies to prioritize providing more accurate information early in the process.

On the other hand, I discuss the impact of interconnection cost magnitude. My analysis show that an increase in withdrawal penalties may not have considerably affect a generator's decision to stay in the process, given the small coefficient estimate of the certain information. Additionally, I examine a simulated policy scenario involving network upgrade subsidies to promote future interconnections. The results indicate that generators are more likely to stay with network upgrade subsidies, with wind generators being the most responsive among different fuel types. Subsidy policies may be most effective when tailored to specific fuel types.

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