The Hidden Cost of the Cloud: Data Centers and Electricity Market Inefficiency

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1 Motivation, Research Question, and Contributions

The United States energy landscape is being shaped by the rapid expansion of data centers (DCs), driven by the surge in artificial intelligence (AI) and high-performance computing (Shehabi et al., 2024). Yet, this technological progress brings significant energy challenges. DCs are among the most energy-intensive types of infrastructure, driving substantial shifts in electricity demand at the local level (EIA, 2025; Masanet et al., 2020). Moreover, because DCs operate continuously and require high reliability, their demand can exacerbate transmission congestion and line losses, especially in regions where network capacity is already constrained. These effects may raise wholesale electricity prices not only locally but also across interconnected nodes, altering price formation and welfare distribution in ways that are not yet well quantified. Despite the rapid growth of DCs, the localized impacts of these facilities on the power system remain unclear.

This paper examines the impact of large localized demand shocks from DCs on wholesale electricity prices through spatially heterogeneous channels of congestion and transmission losses. With this set-up, we isolate the portion of price increases attributable to inefficiencies introduced by grid constraints - namely, congestion and line losses. The estimated effects allow us to quantify the associated welfare losses and provide policy implications for regulatory design.

This paper contributes to the current literature in three ways. First, it adds to the literature on the impact of DCs. While there has been a growing literature that examines changes in energy consumption from DC growth, these studies primarily rely on engineering simulations (Cameron Wade, 2025; Masanet et al., 2020, 2011; Norris et al., 2025; Shehabi et al., 2018; Wilson et al., 2022; Zhang et al., 2025) or ex-ante economic modeling (Knittel, Senga and Wang, 2025). Our paper, on the other hand, estimates the impact of DC development from an ex-post perspective. To the best of our knowledge, we are among the first papers to provide a causal estimate of the impact of DCs on local electricity prices.

Second, it contributes to the literature on infrastructure challenges. Previous work has focused on insufficient transmission infrastructure (Davis, Hausman and Rose, 2023) and allocative inefficiencies arising from transmission constraints under large loads (Hausman, 2025). Our paper adds to this literature by identifying the effect of another large, localized load — DCs — on the transmission system, highlighting an additional type of allocative inefficiency resulting from technological innovation.

Lastly, it contributes to the broader literature on energy demand shifts induced by technological change. Prior studies have examined shifts associated with electric vehicles (Bailey et al., 2025;

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Bushnell, Muehlegger and Rapson, 2022), solar panels and energy storage adoption (Bollinger et al., 2024), and energy efficiency measures (Bernard et al., 2024). This paper extends this literature by examining another technological innovation — DC expansion driven by AI — and providing causal estimates of its effects on local electricity demand and prices.

2 Theoretical Framework

We build on the merit order framework to identify how DC development affects locational marginal prices (LMPs), which in turn guide the hypotheses tested in our empirical analysis. LMPs comprise three components: the system energy price, the congestion price, and the marginal loss price. DCs act as large, inelastic demand shocks at their interconnection points, shifting the demand curve outward. Systemwide, this can raise the uniform energy price if higher-cost generation is dispatched. Locally, additional demand can intensify transmission constraints, increasing congestion prices and reducing allocative efficiency. DC growth can also raise marginal loss prices, as higher power flows increase resistive losses and reliance on more distant generation. The extent of these effects may depend on local factors such as generation mix, existing demand, and network capacity. Areas with limited nearby generation or constrained infrastructure are particularly vulnerable to DC-driving congestion price increase and marginal line loss.

3 Data

We construct a census tract–year panel dataset to examine how DC development affects electricity market prices in Virginia from 2015 to 2024. We combine real-time hourly LMP data from PJM Data Miner 2 with DC location and operation information from the Data Center Map. The analysis leverages tract-level variation in DC entry while decomposing LMP into system energy, congestion, and marginal loss components. To control for local economic and energy factors, we incorporate demographic data from the U.S. Census American Community Survey and generation capacity at the plant level from EIA Form 860.

4 Empirical Strategy

We estimate the impact of new DC connections on annual average hourly LMPs at the census tract level using a staggered difference-in-differences (DiD) design combined with propensity score matching based on demographic information in the pre-treatment period. The propensity score matching accounts for variation in observed variables, ensuring balance between treated and control groups, while the DiD model addresses confounding variables that are unobserved. To mitigate concerns about potential bias in DiD models with multiple time periods, we estimate the impact using the standard two-way fixed effects model, as well as estimators proposed by Sun and Abraham (2021) and Callaway and Sant'Anna (2021). We show that estimates are consistent across all methodologies.

The key identifying assumption is that the observed price changes are driven by demand-side shocks. We support this assumption by leveraging institutional constraints: long lead times for new generation (permitting and construction) and PJM interconnection delays (2015–2024), both of which significantly limited short-run supply responses. As a robustness check, we re-estimate the effect by including controls for gradual supply changes (e.g. number of power plants) and obtain similar results.

5 Results

Our results show that DC entry increases hourly total LMPs by $2.40/MWh in treated tracts relative to matched control tracts, which corresponds to an approximately 6.78% increase from their pre-treatment LMP level. By decomposing total LMPs into the energy system price, congestion price, and marginal loss price, we find that the overall increase is driven by inefficiencies introduced by grid constraints - specifically, increases in congestion and marginal loss components. In particular, congestion prices rise by $2.11/MWh, or 66.57% relative to the pre-treatment level, reflecting exacerbated transmission constraints, while marginal loss prices increase by $0.16/MWh, or 38.94%, due to higher power flows over resistive lines.

We also examine heterogeneity by co-location with generation capacity. DCs located in tracts with greater generation capacity experience a larger reduction in congestion prices but no significant change in marginal loss prices relative to those without such co-location. When disaggregating by fuel type, we find that co-location with higher fossil fuel and nuclear capacity is associated with significantly lower congestion prices, likely due to reliable local dispatch. In contrast, co-location with higher renewable capacity is associated with higher marginal loss prices, likely reflecting intermittency and reliance on distant generation. These findings highlight trade-offs between grid reliability and decarbonization.

6 Policy implications

Our results highlight the localized impacts of DC development, focusing on inefficiency prices driven by grid congestion and line losses. Based on these findings, we provide two policy implications for addressing the rise in inefficient prices. First, our results show the urgency of expanding transmission capacity in response to DC growth to prevent further increases in inefficient prices. The causal evidence that DCs raise both congestion and marginal loss prices indicates that existing transmission networks are insufficient to deliver growing, spatially concentrated loads efficiently. Therefore, we provide an additional source of benefit of transmission line expansion which was not previously identified. Second, co-location decisions between DCs and generators reveal a trade-off between decarbonization and network efficiency. Co-locating with consistent dispatchable generation can reduce congestion but may increase emissions if the generation is fossil-fuel-based. In contrast, co-locating with renewable energy supports decarbonization but may offer limited congestion relief and could increase marginal loss prices due to output intermittency. Therefore, both the emissions and network efficiency aspects of co-location should be jointly considered to ensure that DC development generates overall social benefits.

Relatedly, our results suggest a potential misalignment between private and social welfare in DC development. A growing number of states offer tax exemptions to attract DC investment (Joint Legislative Audit and Review Commission, 2024); however, the externalities associated with increased inefficiency costs remain largely uninternalized. Increased congestion and line losses raise electricity costs for consumers, while forgone tax revenues reduce public resources available for infrastructure upgrades or climate mitigation. Our paper highlights the need for coordinated policy design that aligns private incentives with social objectives, ensuring that DC expansion contributes to both economic growth and overall welfare.

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