Title: Variation in Growth and Quality of Dialysis Stations by Community Socioeconomic Status

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Abstract

In the United States, more than half a million patients with end-stage kidney disease (ESKD) rely on thrice-weekly dialysis to sustain life. In-center hemodialysis remains the primary mode of treatment for 82% of patients. We examine the national geographic distribution, growth, quality, and accessibility of dialysis stations across rural communities and urban communities with advantaged, average, and disadvantaged socioeconomic status, where community is defined by ZIP code.

Combining dialysis center information from the Centers for Medicare & Medicaid Services Dialysis Facility Compare data and a community-level drive-time database generated using web-based queries, we measure the supply of dialysis stations by aggregating the total number of stations operated by centers (or high-/low-quality centers) within a 30-minute drive time for each community. We also generate a community-level accessibility index that accounts for both supply and demand using the two-step floating catchment area method from the Luo & Wang (2003) paper. We conduct longitudinal regressions with community random effects for the estimation.

Our analysis includes communities with at least one ESKD patient from 2015-2025, totaling 284,909 community-years. We find that rural communities faced the greatest challenges; they were the most likely to lack stations, had the lowest number of stations (-101% relative to urban average communities), and had the lowest demand-adjusted accessibility (-17% relative). Urban advantaged communities had the highest station counts (+175% relative) and the highest growth rate, but the second lowest accessibility (-12% relative). Their higher growth rate may be associated with higher center turnover, potentially disrupting care. Urban disadvantaged communities had more stations (+9% relative) and higher accessibility (+22% relative), but the lowest quality profile.

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Extended Abstract

Introduction

In the United States, more than half a million patients with end-stage kidney disease (ESKD) rely on thrice-weekly dialysis to sustain life. For the vast majority of patients—82% as of 2023—in-center hemodialysis remains the primary mode of treatment (MedPAC, 2024; NIDDK USRDS, 2025). In this study, we examine the national geographic distribution, growth, quality, and accessibility of dialysis stations across rural communities and urban communities with advantaged, average, and disadvantaged socioeconomic statuses.

Data and Method

Our study population consists of ZIP code communities from 2015-2025 that had at least one ESKD patient in a community, totaling 284,909 community-years. We obtained 2015–2025 dialysis center locations, station counts, and quality information from the Centers for Medicare & Medicaid Services (CMS) Dialysis Facility Compare (DFC) data. These datasets were linked to a community-level drive-time database generated using web-based queries (HERE, 2025), where a community is defined by a ZIP code geographic area. We also obtained county-level ESKD population sizes from the United States Renal Data System (USRDS) website and the Medicare Advantage enrollment data from the CMS.

For each community, we measure the supply of dialysis stations by aggregating the total number of stations operated by centers within a 30-minute drive time of that ZIP code. The supply is classified based on (1) all operating dialysis centers, (2) high-quality dialysis centers (defined by rating 5/5 stars), and (3) low-quality centers (defined by rating of 2/5 or lower). Our

analysis focuses on changes in the number of dialysis stations and the proportion of high- and low-quality stations for each community.

To account for demand from the ESKD population, we first redistribute the county-level ESKD population to the ZIP code level, assuming the distribution is proportional to the ZIP code general population. The redistribution is necessary because the smallest geographic unit for publicly available data on the ESKD population is at the county level. We then calculate an accessibility index for each community using the two-step floating catchment area (2SFCA) method from the Luo & Wang (2003) paper. Specifically, step one calculates the service-to-population ratio for each center by dividing its capacity (e.g., number of stations) by the total number of ESKD patients living within a 30-minute drive time. Step two calculates the accessibility index for each community by summing the ratios of all centers reachable within a 30-minute drive time from that community. This index represents the demand-adjusted number of stations available per ESKD patient in a specific community, accounting for both the total number of stations within a 30-minute drive time and potential competition for services from patients of other communities for the same set of stations. We report accessibility per 100 ESKD patients (referred to as "accessibility" hereafter).

We classify communities into four time-invariant categories: rural communities and three types of urban communities based on their Area Deprivation Index (ADI). Rurality is defined using the list of rural ZIP codes provided by the Federal Office of Rural Health Policy (FORHP). Urban communities are categorized into advantaged (bottom ADI quartile; least deprived), average, and disadvantaged (upper ADI quartile; most deprived). The ADI is a composite index incorporating 17 socioeconomic community characteristics, capturing employment, income, housing, and education, based on data from the Social Determinants of Health (SDOH) database

(which combines Census and American Community Survey data). The index is constructed at the ZIP code community level following the factor analysis method described in the Singh (2003) paper.

We conduct random effects regressions to estimate the differences in outcomes of interest by community category, while accounting for within-community correlations over time. Model 1 includes year fixed effects and controls for ESKD population size and Medicare Advantage penetration in the community (see Equation 1). In Model 2, we add an interaction term between community categories and year fixed effects to assess longitudinal differences in growth across community categories.

$$Model\ 1: y_{jt} = \alpha + \beta_1 Year_t + \beta_2 Community\ Category_j + \boldsymbol{\gamma' X_{jt}} + \mu_j + \rho_{jt} \quad (1)$$

Where $\boldsymbol{X_{jt}}$ represents ESKD population size and Medicare Advantage penetration in the community j in year t. μ_j reflects the random effect for community j.

We further explore the variation in center openings and closures that potentially contributes to changes in the supply of dialysis stations. Notably, we do not consider a center replacement at the same location or a relocation within a 30-minute drive time of a community to be an opening or closure.

Results

Results from Model 1 indicate that rural communities faced the greatest challenges regarding access to dialysis stations. Compared to urban average communities, rural communities were about 29 percentage points (ppt) more likely to have no dialysis stations; they had approximately 277 fewer stations (101% relative to the baseline mean of 275 of the reference community, urban average communities) and had a 2.52 lower accessibility (17%

relative). On the other hand, among rural communities that had at least one dialysis center within 30-minute drive time, they had a 6.68 ppt higher proportion of high-quality stations (103% relative) and a 2 ppt lower proportion of low-quality stations (7% relative) compared to urban average communities (Table 1).

Table 1. Regression Results of Model 1

	(1)	(2)	(3)	(4)	(5)
	No Station (=100; 0 otherwise)	# of Stations (count)	Accessibility (demand-adjusted # of stations per 100 ESKD patients)	Proportion of High-quality Stations (%)	Proportion of Low-quality Stations (%)
Mean of Reference (Average, 2015)	6.02	274.99	14.71	6.47	29.52
Rural	29.07***	-276.94***	-2.52***	6.68***	-2.00***
	(28.09 - 30.04)	(-286.83 - -267.05)	(-3.20 - -1.84)	(6.03 - 7.32)	(-2.48 - -1.51)
Advantaged	-3.19***	481.63***	-1.71***	3.77***	-5.16***
	(-3.95 - -2.42)	(452.13 - 511.13)	(-2.05 - -1.37)	(3.20 - 4.34)	(-5.58 - -4.74)
Disadvantaged	1.12*	24.54**	3.23***	-3.74***	4.66***
	(0.10 - 2.14)	(6.78 - 42.30)	(2.82 - 3.63)	(-4.37 - -3.12)	(4.04 - 5.27)
Observations (community-years)	284,909	284,909	284,909	234,166	234,166
Number of Communities	28,189	28,189	28,189	22,854	22,854

Note: Ordinary least squares (OLS) regression with community-level random effects and clustered standard errors. The model adjusts for year fixed effects, the End-Stage Kidney Disease (ESKD) population size, and Medicare Advantage penetration. Robust 95% confidence intervals are reported in parentheses. Reference: *** p<0.001, ** p<0.01, * p<0.05

Compared to urban average communities, urban advantaged communities were 3.19 ppt less likely to have no stations and had markedly more stations (482; 175% relative). However, they had a 1.71 lower accessibility (12% relative). Regarding the quality of stations, urban advantaged communities had a 3.77 ppt higher proportion of high-quality stations (58% relative) and a 5.16 ppt lower proportion of low-quality stations (17% relative).

Urban disadvantaged communities showed a 1.12 ppt higher likelihood of having no stations, compared to urban average communities. While they had approximately 25 more stations (9% relative), and a 3.23 higher accessibility (22% relative), they possessed a lower quality profile. Their proportion of high-quality stations was 3.74 ppt lower than that of urban

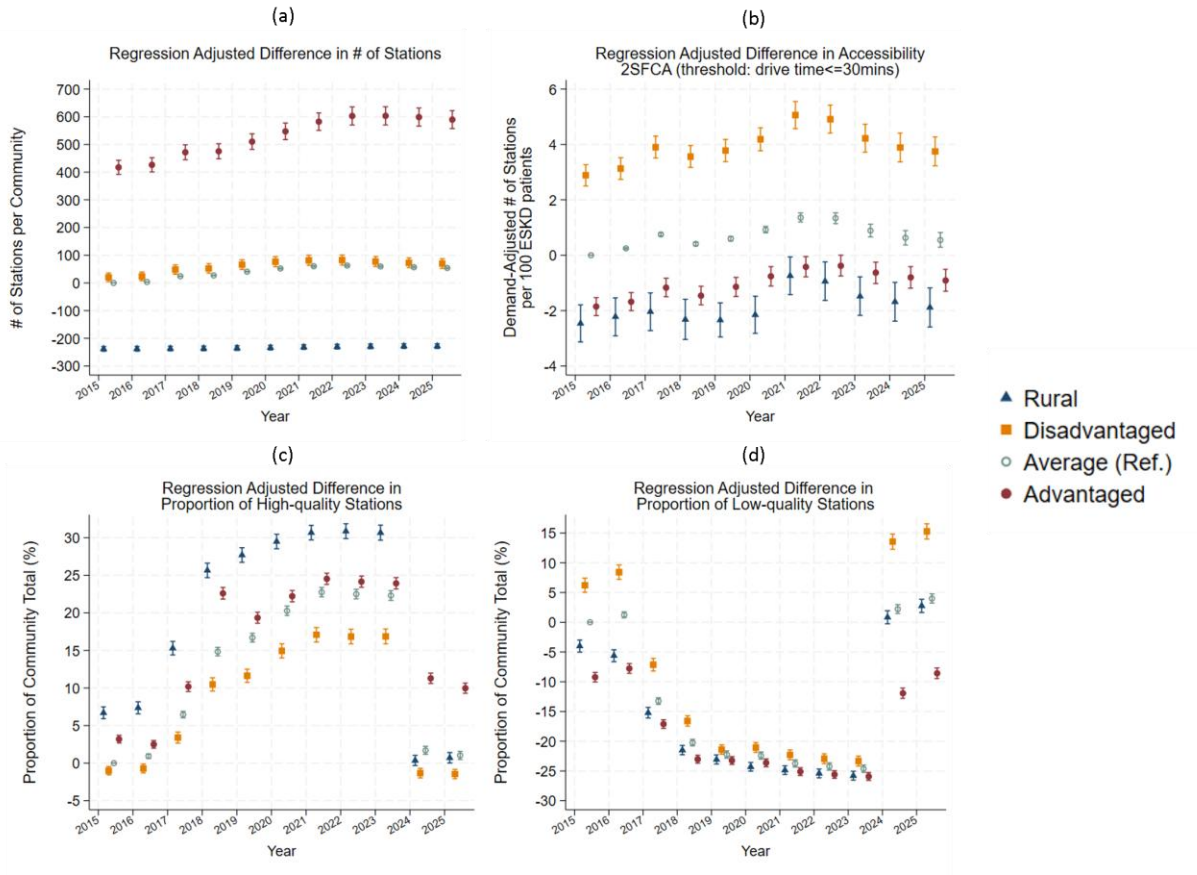
average communities (58% relative), and the proportion of low-quality stations was 4.66 ppt higher (16% relative).

Results from Model 2 are shown in Figure 1. As panel (a) shows, urban advantaged communities consistently possessed the largest number of dialysis stations, followed by urban disadvantaged and urban average communities, while rural communities exhibited the lowest number. The differences in the number of stations widened over the study period because urban advantaged communities had a higher growth rate.

In contrast, as shown in panel (b), urban advantaged communities and rural communities had lower accessibility than urban average communities, while urban disadvantaged communities maintained higher accessibility throughout 2015-2025.

As shown in Panels (c)–(d), the patterns of the proportion of high-quality and low-quality stations remained consistent until 2024, when quality ratings were systematically adjusted (KECC, University of Michigan, 2023). Among those with dialysis stations, rural communities maintained the highest proportion of high-quality stations, while urban advantaged communities had the second-highest proportion, and disadvantaged communities had the lowest. Compared to urban average communities, both rural communities and urban advantaged communities had a lower proportion of low-quality stations, while urban disadvantaged communities had a higher proportion. The differences in the proportion of low-quality stations became insignificant from 2019-2024.

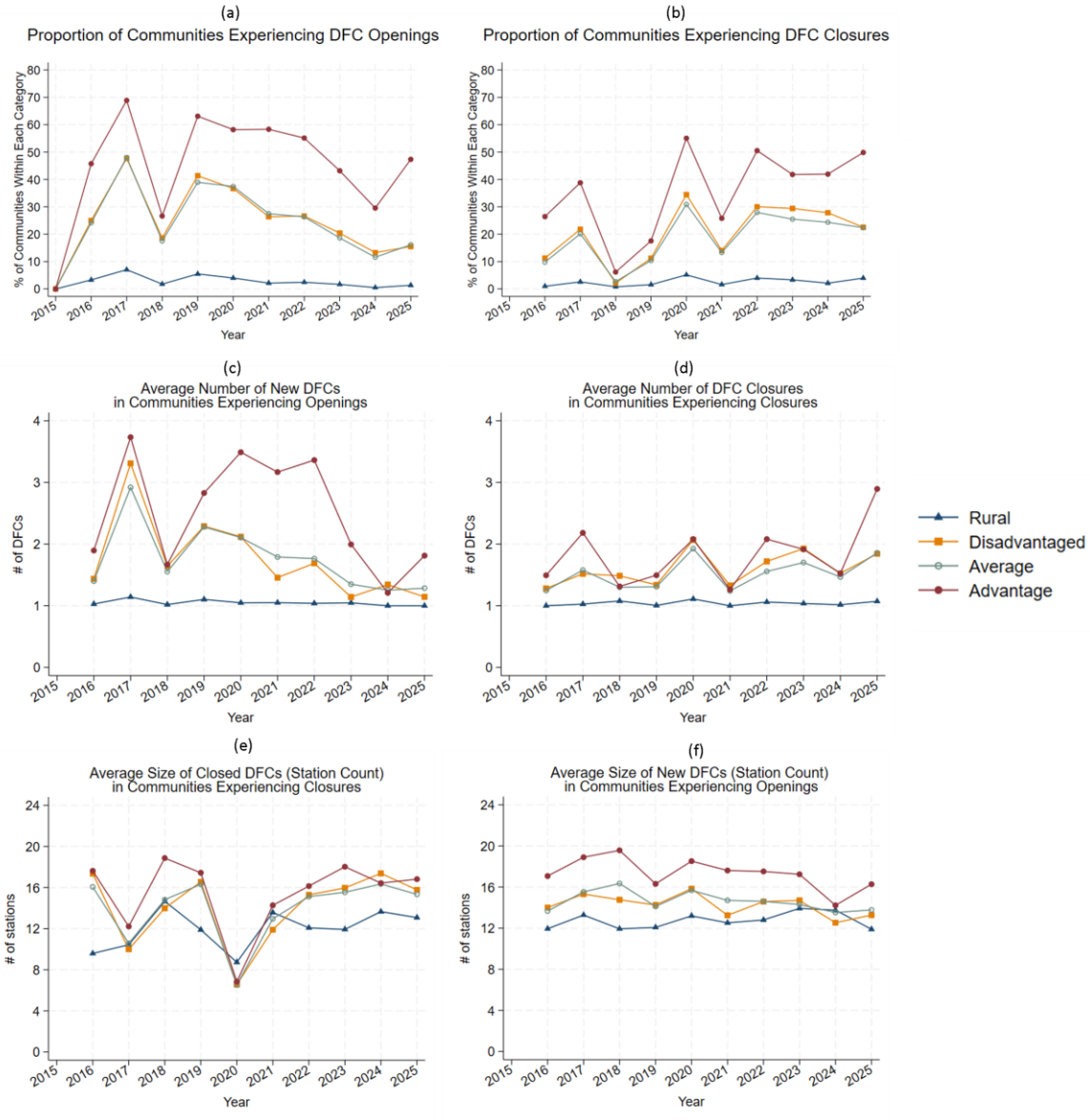
Figure 1. Regression Results of Model 2



Note: Panels (a)-(b) include 284,909 community-years with at least one ESKD patient; panels (c)–(d) include 234,166 community-years with at least one ESKD patients and at least one dialysis station.

As shown in Figure 2 panels (a)-(d), our exploration into the openings and closures of dialysis centers shows that urban advantaged communities were likely associated with a higher turnover rate. The higher growth rate in the number of stations among urban advantaged communities may be because the number of center openings was larger than the number of closures (panels (c)-(d)), and the size of new centers in advantaged communities was slightly larger (panels (e)-(f)).

Figure 2. Trends for DFC Openings and Closures



Note: DFC-dialysis facility center. Panels (a)-(b) include 284,909 community-years with at least one ESKD patient; panels (c) and (e) reflect 50,271 community-years experiencing DFC openings; panels (d) and (f) reflects 36,543 community-years experiencing DFC closures.

Conclusions

We find that rural communities faced the greatest challenges regarding access to dialysis stations, with an almost 30 percentage point higher probability of having no stations within 30-

minute drive time compared to urban average communities, coupled with the lowest number of stations and accessibility. Urban advantaged communities had the highest number of stations and a higher growth rate than other community categories. However, after accounting for demand, they exhibited a lower accessibility than urban average and urban disadvantaged communities. Their higher rate of growth may be associated with a higher turnover rate that could lead to disruptions in care for ESKD patients. Although urban disadvantaged communities had a higher number of stations and better accessibility compared to urban average communities, their proportion of high-quality stations was the lowest.

Policy tools that incentivize new center openings in rural communities remain a critical priority to mitigate the high likelihood of geographic access gaps. For urban advantaged communities, encouraging the stability of dialysis center operations—rather than just openings—may benefit ESKD patients by reducing care disruptions. For disadvantaged communities, targeted quality improvement initiatives are essential to address the relatively low proportion of high-quality stations.

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