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

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Abstract (250-words)

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 remained the primary mode of treatment for 82% of patients. We examine 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 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 in Luo & Wang (2003) paper. We conduct longitudinal regressions with community random effects for the estimation.

Our analysis includes 284,909 community-years with at least one ESKD patient. We find that urban advantaged communities had the highest station counts (175% relative to urban average communities) and the highest growth rate, but second lowest demand-adjusted 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. Rural communities faced the greatest challenges; they were the most likely to lack stations, had the lowest number of stations and accessibility.

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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 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 that have advantaged, average, and disadvantaged socioeconomic status.

Data and Method

We obtain 2015–2025 dialysis center locations, station counts, and quality information from the Centers for Medicare & Medicaid Services (CMS) Dialysis Facility Compare (DFC) data. One dialysis center can operate multiple stations. These datasets are linked to a community-level drive-time database generated using web-based queries, where a community is defined by a ZIP code geographic area.

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) 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 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 calculated an accessibility index for each community using the two-step floating catchment area (2SFCA) method in 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 total number of stations within a 30-min drive time and potential competition for services from patients of other communities for the same set of stations. We report this as accessibility per 100 ESKD patients (referred to as "accessibility" hereafter).

Our longitudinal analysis includes 284,909 community-years with at least one ESKD patient from 2015 to 2025. We classified communities into four time-invariant categories: rural communities and three types of urban communities based on their Area Deprivation Index (ADI). Rurality was defined using the list of rural ZIP codes provided by the Federal Office of Rural Health Policy (FORHP). Urban communities were 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 combine Census and American Community Survey data) and constructed at the ZIP code community level per factor analysis method described in Singh (2003).

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 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 access 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 and Medicare Advantage penetration in the community j in year t. μ_j reflect the random effect for community j.

We further explore the variation in center openings and closures that potentially contribute 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 as an opening or closure.

Results

Results from Model 1 indicate that compared to urban average communities, urban advantaged communities were 3.19 percentage points (ppt) less likely to have no stations and had markable more stations (+482; 175% relative). However, their accessibility was 1.71 lower (12% relative). Regarding the quality of composite stations, urban advantaged communities had an 3.77 ppt higher proportion of high-quality stations (58% relative) and an 5.16 ppt lower proportion of low-quality stations (17% relative) (Table 1).

Urban disadvantaged communities showed 1.12 ppt more likely of having no stations, compared to urban average community. While they had approximately 25 more stations (9% relative), and 3.23 higher accessibility (22% relative), they possessed a lower quality profile. Their proportion of high-quality stations is 3.74 ppt lower than urban average communities (58% relative), and proportion of low-quality stations was approximately 4.66 ppt higher (16% relative).

Table 1. Regression Results of Model 1

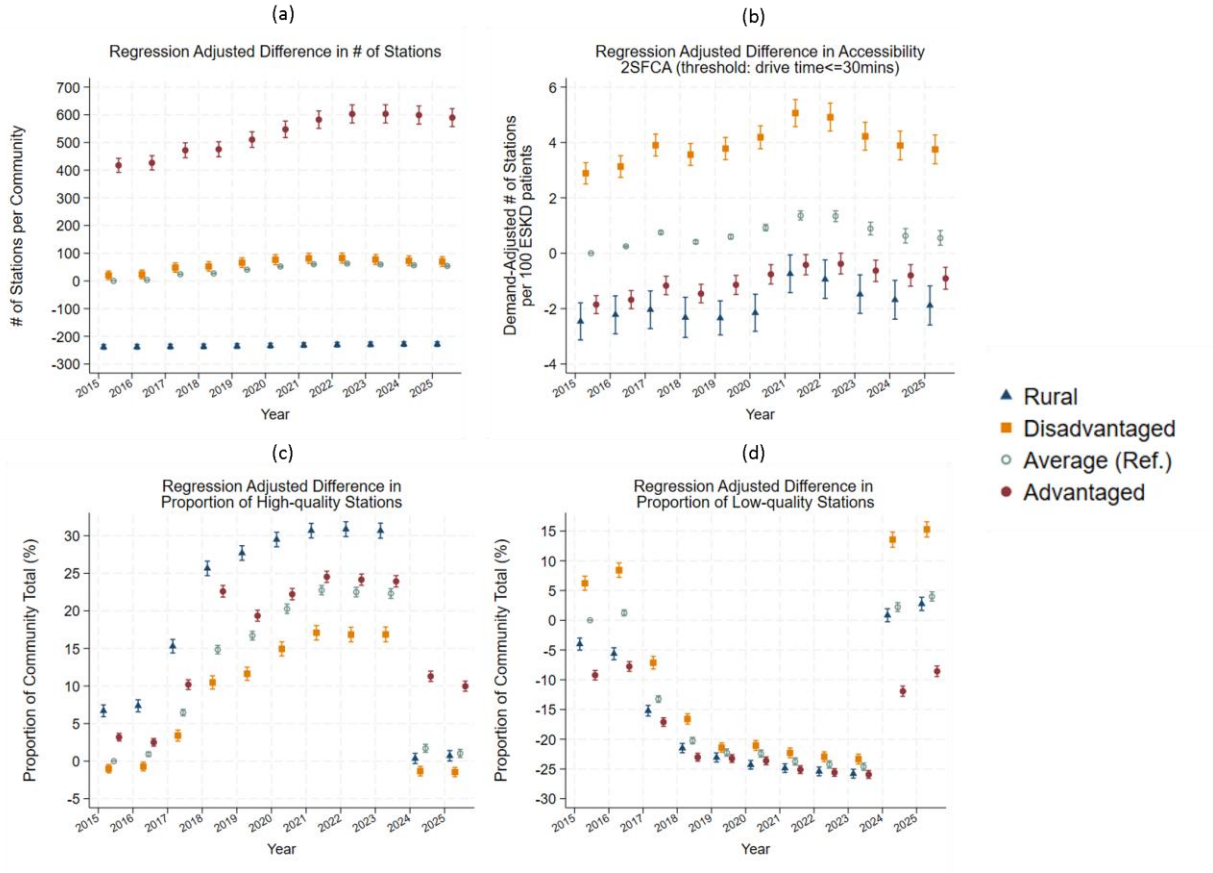
	(1)	(2)	(3)	(4)	(5)
	No Station (=100; 0 otherwise)	# of Stations (count)	Accessibility (demand-adjusted # of stations per 100 ESKD patients)	Proportion of High-quality Stations (%)	Proportion of Low-quality Stations (%)
Mean of Reference (Average, 2015)	6.02	274.99	14.71	6.47	29.52
Advantaged	-3.19***	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)
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)
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, 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

Rural communities faced the greatest challenges of access to dialysis stations. Compared to urban average communities, rural communities were about 29 ppt more likely to have no dialysis stations; they have approximately 276 less stations (100% relative), and 2.52 lower accessibility (17% relative). On the other hand, rural communities had the best quality profile, with a 6.68 ppt higher proportion of high-quality stations (103% relative) and a 2 ppt lower proportion of low-quality stations (7% 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 disadvantaged and average communities, while rural communities exhibited the lowest number. The differences in the number of stations widened over the study period because the urban advantaged communities had a higher growth rate.

Figure 1. Regression Results of Model 2



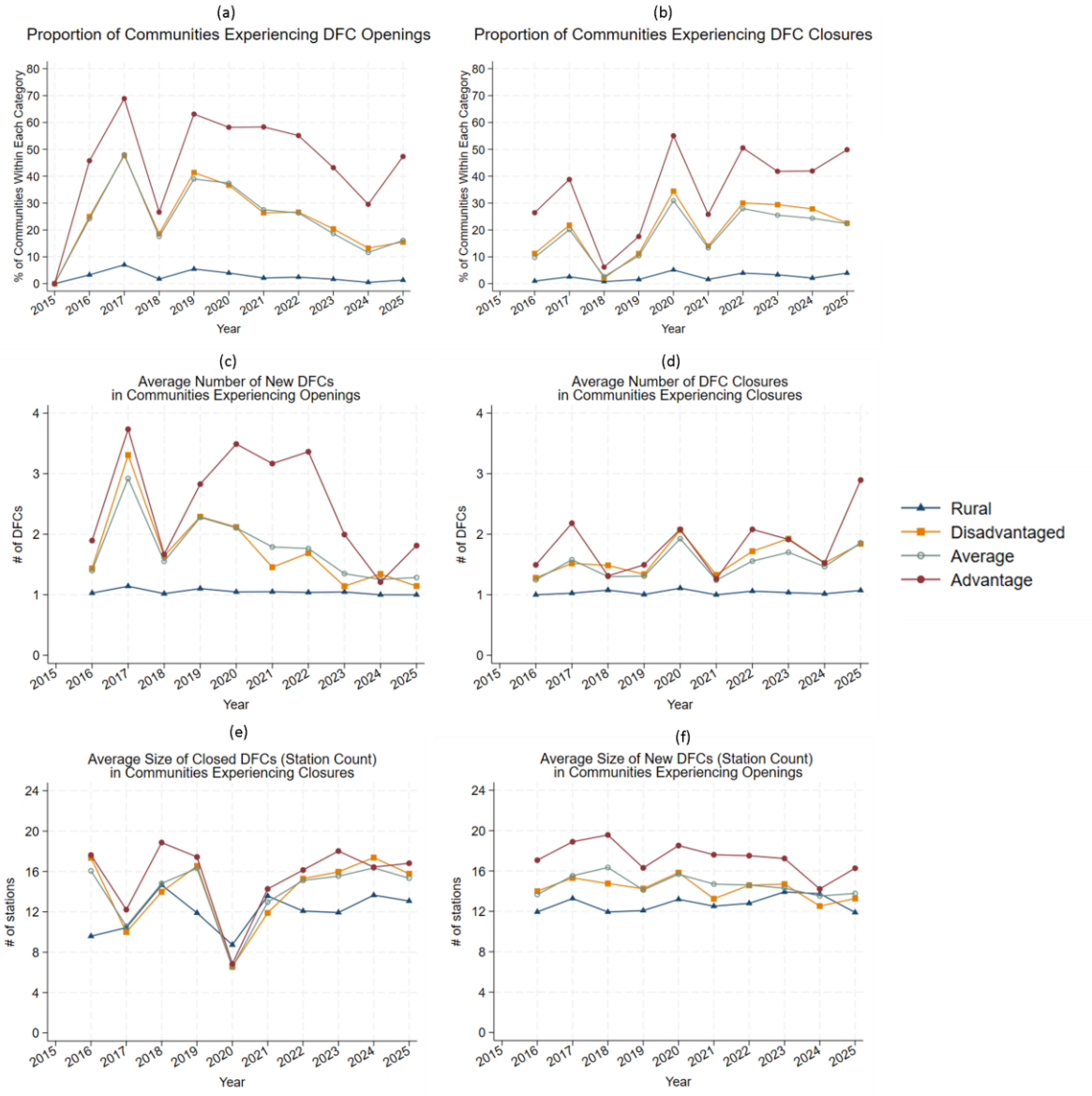
Note: Panels (a)-(b) include 284,909 community-years with at least one ESKD patients; panels (c)–(d) include 234,166 community-years with at least one ESKD patients and at least one dialysis stations.

In contrast, as shown in panel (b), urban advantaged communities and rural communities had lower accessibility than urban average communities, while 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 urban advantaged communities and rural communities had a lower proportion of low-quality stations, urban disadvantaged communities had a higher proportion of low-quality stations. The differences in proportion of low-quality became insignificant from 2019-2024.

Figure 2. Trends for DFC Openings and Closures



Note: Panels (a)-(b) include 284,909 community-years with at least one ESKD patients; panels (c) and (e) exclude 234,638 community-years without DFC opening; panels (d) and (f) exclude 248,366 community-years without DFC closure.

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

Conclusions

We find that urban advantaged communities had the highest number of stations and a higher growth rate than other community categories. However, after accounting for demand, these communities exhibit 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 have a higher number of stations and better accessibility compared to urban average communities, their proportion of high-quality stations is the lowest. Rural communities faced the greatest challenges of access to dialysis stations, with the highest likelihood of having no stations within 30-minute drive time, coupled with lowest number of stations and accessibility.

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

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