The Strategic Location Choice of For-profit Hemodialysis Facilities in the U.S.

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Abstract

This paper identifies key factors related to the location choice of for-profit hemodialysis facilities using a dataset from the United States Renal Data System (USRDS) and structural methods. All patients with kidney failure need to receive hemodialysis treatment regularly and permanently. Because dialysis treatments are homogeneous across facilities, patients are likely to choose a treatment facility based on the distance from their homes. The strategic model introduced by Seim (2006) involves a static and incomplete information game among dialysis facilities for entry and positioning in a market. The estimation results show that in choosing an optimal location, a tradeoff occurs between local demand and competition with potential entrants.

Keywords: location choice, hemodialysis, spatial differentiation
JEL Codes: I10; I11; L10; L11

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[*]The data reported here have been supplied by the United States Renal Data System (USRDS). The interpretation and reporting of these data are the responsibility of the author(s) and in no way should be seen as an official policy or interpretation of the U.S. government.

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1 Introduction

The kidneys are a pair of organs in the human body that remove waste from the blood and control the body's fluid balance. When both kidneys fail, blood wastes accumulate in the patient's body and the risk of death increases. Two representative treatments for patients with kidney failure are kidney transplants and dialysis. Unlike transplants, which place a healthy kidney in a patient's body, dialysis uses a machine that substitutes the work of the kidneys. Due to the high shortage of transplantable kidneys, in 2016, more than seventy percent of 726,331 patients with kidney failure were dependent on dialysis treatment for survival (United States Renal Data System 2018). As depicted in Figure 1, with the steady increase in the incidence of kidney failure and demand for dialysis treatment, the dialysis industry has expanded. In 2016, there were approximately 7,100 dialysis facilities in the United States, four times the number of facilities in 1988. Furthermore, because Medicare covers nearly all populations with kidney failure regardless of age, the financial burden of the government for supporting those patients is high. According to United States Renal Data System (2018), although less than 1 percent of patients covered by Medicare had kidney failure in 2016, these patients accounted for approximately 7 percent of Medicare fee-for-service coverage.

Despite the fast growth of the dialysis industry and the huge financial burden on Medicare, little is understood about how dialysis facilities decide whether to enter a certain market and where to locate within the market. In the general market, profit-maximizing firms wish to differentiate their products by lowering prices or improving quality to appeal to consumers and gain more profits. However, the dialysis industry has characteristics that make product differentiation difficult. First, the price of dialysis is fully controlled by the government because most patients with kidney failure are eligible for Medicare. Additionally, the performance of dialysis treatment is somewhat homogeneous across facilities because most of the dialysis process is performed using a dialysis machine. Therefore, the location of dialysis facilities could be the most important factor allowing for product differentiation.

The goal of this paper is to identify key factors that affect dialysis facilities' strategic decisions for market entry and location choice by using a structural model. First, dialysis facilities are likely to choose a location where the demand for dialysis treatment is high. However, they also need to consider the expected competition with other facilities that might choose the same location. Because of the limited options for differentiating the product, namely, dialysis treatment, across facilities in the same location, higher competition will lower a facility's expected profits.

This paper applies the structural methods from modern industrial organization to study dialysis facility behaviors. The analysis of firm entry and location decisions is based on the literature on discrete entry games proposed by Bresnahan et al. (1991) and Berry (1992). These studies show that the level of competition affects the entry decision of firms because an additional entrant in a market reduces profits in an oligopolistic market structure. More recent studies (Mazzeo 2002; Seim 2006) extend this literature by incorporating the product differentiation concept. In Mazzeo (2002)'s model, firms not only determine whether to enter a market but also select product types under the complete information assumption. That is, firms do not have the information on the profit shocks of the other competing firms. On the other hand, in Seim (2006)'s model, video rental stores determine their market entry and their location under the assumption of homogeneous product type and incomplete information status. I contribute to this literature by examining the dialysis industry using the estimation model of Seim (2006).

To date, literature on the hospital competition has focused on the effect of competition on the quality of health care services. In many situations, prices for health care services are administered by regulators such as Medicare. Hence, hospitals are likely to compete for quality and empirical studies support this. Kessler et al. (2000) find higher one year mortality rates for Medicare patients with acute myocardinal infarction (AMI) and lower expenditures in less concentrated markets. Two studies (Cooper et al. 2011; Gaynor et al. 2013) also find similar results and identify lower mortality rates among AMI patients in less concentrated markets by using a reform in the English National Health Service (NHS) that promotes competition among hospitals. Using the same set of data from the English NHS, Propper et al. (2010) find that having more local competitors has a large impact on hospital management quality based on Bloom et al. (2007). I contribute to this literature by suggesting that facility location could also be a factor that allows health care providers, i.e., dialysis facilities, to differentiate their quality.

Several studies have analyzed the spatial competition in the dialysis industry. Wilson (2016) studied differences in the entry and exit patterns of for-profit and non-profit dialysis facilities. Exploiting 20 years of longitudinal data on dialysis facilities in the U.S., this author finds that for-profit facilities are quicker to enter growing markets and slower to exit declining ones compared to non-profit facilities. Additionally, the existence of for-profit facilities in a market has a larger impact on the entry and exit of competitors. Eliason (2017) estimates an entry game where dialysis facilities choose both the capacity and quality, and he finds that dialysis facilities can compete more effectively in terms of capacity rather than quality because increasing quality is very costly to dialysis providers and patients may not be responsive to the quality. Although these studies consider the market entry decision of dialysis providers, they do not consider location selection upon entry in their estimation models. Wilson (2016) uses counties as their market unit, and Eliason (2017) exploits Core-Based Statistical Areas as a market definition. This paper contributes to this literature by analyzing the location choice problems in a census tract-level assuming that competing dialysis facilities are symmetric.

Detailed information on the dialyis market in the United States is obtained from the United States Renal Data System (USRDS). The data contain the exact locations of dialysis facilities and the demographic characteristics of patients with kidney failure, including their zip code-level residence information. Information on the socio-economic status of each census tract-level location, such as the per capita income, education level, median gross rent, etc., is obtained from the 2015 American Community Survey (ACS).

The estimation results show that dialysis facilities are usually located in areas with a larger number of patients with kidney failure. A 10 percent larger number of patients with kidney failures increases the location choice probability by 2.01 percent. In terms of competition, I find that the expected probability of having competitors in the location reduces profits significantly and makes firms avoid locations in which high competition is expected. This result supports the idea that dialysis facilities use spatial differentiation to differentiate their products.

When dialysis facilities consider future local demand more than the current demand, the effect of local demand variables increases while the competition effect shrinks. I use the number of population with age 65 years and above and socioeconomic status as the measures of future local demand and find that a 10 percent increase in the elderly population increases the location choice probability by 3.85 percent. As socioeconomic status is negatively related to kidney failure incidence, the estimation results show that dialysis facilities prefer locations with lower socioeconomic status.

This evidence of the strategic location choice of dialysis facilities is meaningful for the discussion on the relationship between profit status and patient outcomes. Previous literature (Lee et al. 2010; Brooks et al. 2006) finds longer hospital days per patient but no evidence of an effect on patient mortality in for-profit dialysis facilities. To address the possible bias in a patient's choice of dialysis facility, those studies use an instrumental variable regression method with the relative proximity of dialysis facilities to the patient's residence as the instrument. The evidence of strategic location choice of for-profit dialysis facilities implies that the relative distance instruments may not fully address the selection biases. For-profit dialysis facilities are more likely to be located in areas with low socioeconomic status, and patient outcomes in those areas could be different from those in the other areas.

The rest of the paper is organized as follows. The following section provides background information on dialysis and the dialysis industry. Section 3 describes the data used for the estimation, while Section 4 discusses the estimation model. Section 5 presents the parameter estimates of key factors that affect the location choice of dialysis facilities. Section 6 provides key robustness factors, and Section 7 presents the conclusions.

2 Background

2.1 Treatments for Patients with Kidney Failure

When a person's kidneys are no longer able to work on a permanent basis, he/she is diagnosed with the end-stage renal disease (ESRD)[1]. As shown in Figure 2, the number of ESRD occurrences has increased steadily from 1988 to 2016. In 1988, there were 28,927 incidences of patients newly diagnosed with ESRD in the United States, although this figure increased to 101,334 in 2016[2]. The figure shows that the increase in ESRD incidences is driven primarily by people aged 65 and older. This result could be related to an increasing number of elderly people thanks to medical advances (Administration on Aging 2018). Figure 3 shows the share of primary causes among patients with ESRD. The most common causes of ESRD are diabetes (48%, 2016) and hypertension (29%, 2016). Stevens et al. (2010) shows that the prevalence of these conditions is higher for elderly individuals than for middle-aged adults[3].

ESRD patients need to receive either a kidney transplant or dialysis treatments to prolong their lives. A kidney transplant is a surgery that places another person's kidney into the ESRD patient's body. Unlike patients with other organ failures, ESRD patients can survive by undergoing dialysis treatments without receiving a kidney transplant. Dialysis is a treatment that filters ESRD patients' blood using a machine that performs the work of the kidneys. As blood wastes and fluids continuously accumulate after each dialysis, ESRD patients regularly need to receive dialysis, which takes approximately 4 hours, and is usually

[1] https://www.cms.gov/Medicare/Coordination-of-Benefits-and-Recovery/Coordination-of-Benefits-and-Recovery-Overview/End-Stage-Renal-Disease-ESRD/ESRD

[2] This paper excludes ESRD occurrences in U.S. territories - Puerto Rico (PR), Virgin Islands (VI), Guam (GU), Northern Mariana Islands (MP), American Samoa (AS) -, and with unknown age, race, sex, zip codes, and profit status of the dialysis center.

[3] Approximately 11% of middle-aged adults have diabetes and 33% have hypertension, with the prevalence of these conditions increasing to 23% and 66%, respectively, by age 60.

performed three times a week. Previous studies have shown that patients who receive kidney transplants may have better outcomes in terms of survival and quality of life on average than those who continue receiving dialysis (Schold et al. 2014; Wolfe et al. 1999; Overbeck et al. 2005). However, Figure 4 shows that most ESRD patients choose dialysis and do not even register for kidney transplant waitlists. The share of patients who are waitlisted for deceased donor kidneys or receive living donor kidneys within 1 year after ESRD diagnosis is less than 10 percent.

2.2 Medicare and the Dialysis Industry

If the cost of dialysis treatment is high[4], many patients will not receive the treatment and the mortality risk of ESRD patients will increase. In the United States, Medicare plays an important role in financing dialysis treatment. The Social Security Amendments of 1972 provided Medicare coverage to nearly the entire U.S. population with ESRD regardless of age[5]. On December 31, 2015, more than 80 percent of ESRD-prevalent patients were receiving dialysis treatments covered by Medicare (Kirchhoff 2018). Since 2011, Medicare has reimbursed the dialysis facilities using a prospective payment system (PPS) that provides a bundled amount of money per patient per treatment for dialysis and necessary support, such as tests and medications (Collins 2012). As the amount of the reimbursement is determined in advance (the base rate in 2020 is $239.33[6,7]), and beneficiaries pay coinsurance equal to 20 percent of the Medicare-approved amount; the price of dialysis treatment for the majority of ESRD patients is stable across dialysis facilities.

As the number of ESRD patients has increased, with certain Medicare payments, the

[4]Childers et al. (2019) found that the cost of dialysis varies across insurers of ESRD patients. For-profit dialysis facilities charge $248 per treatment when the government is the insurer, compared with $1,041 per treatment for private insurance.

[5]When a patient enrolls in Medicare based on ESRD, Medicare coverage usually starts at 90 days from the ESRD diagnosis (https://www.medicare.gov/manage-your-health/i-have-end-stage-renal-disease-esrd).

[6]https://www.federalregister.gov/documents/2019/11/08/2019-24063/medicare-program-end-stage-renal-disease-prospective-payment-system-payment-for-renal-dialysis

[7]Actual amount of reimbursement is driven by adjusting multiple factors, such as patient characteristics, facility-level characteristics, etc. Detailed information on the reimbursement amount calculation is available in Kirchhoff (2018).

number of dialysis facilities has steadily increased since 1988. Figure 5 shows that there were approximately 1,800 dialysis facilities in 1988, and this figure increased to approximately 7,100 in 2016[8]. Dialysis facilities can be classified as either hospital-based or freestanding units, i.e., units not affiliated with a hospital (Center for Medicare and Medicaid Services 2019). Additionally, the facilities are operated on either for-profit or not-for-profit bases, similar to other health care providers. The growth in the number of dialysis facilities in each category is shown in Figure 5. The figure implies that the major growth in the dialysis industry has been driven by freestanding and for-profit dialysis facilities. The share of this category increased from 51 percent (1988) to 84 percent (2016).

3 Data

3.1 Market Definition

In the dialysis industry, dialysis treatment is somewhat homogenous. As most ESRD patients are eligible for Medicare coverage, the treatment cost is well controlled by the government and similar across dialysis facilities. Furthermore, the process of dialysis treatment is performed by the dialysis machine, which provides standardized care. To recruit more patients, dialysis facilities tend to compete in terms of amenities, such as TVs and heated chairs. However, as ESRD patients need to receive dialysis regularly (at least 3 times a week) and permanently, they are likely to choose dialysis facilities close to their residences; thus the effect of distance may dominate the effect of amenities. Therefore, dialysis facilities may primarily compete against other facilities located in a local area and choose a location that could be the most profitable. Table 1 shows these characteristics of the dialysis industry derived from the USRDS data. Column (1) reports that the median distance between their preferred dialysis facility and their residence among patients diagnosed with ESRD from 1988 to 2016 was only

[8] This paper counts only Medicare-certified hospitals and outpatient dialysis facilities and excludes facilities with unknown for-profit status.

7.404 miles. Columns (2) to (5) show the median distance to different subgroups of dialysis facilities classified according to the profit status or affiliation with a hospital. Although the distance to for-profit and freestanding facilities (7.236 miles) is shorter than that to the other types of facilities (7.636 - 8.269 miles), the difference is not great.

Because ESRD patients are sensitive to the distance from their residence, this paper focuses on mid-sized cities to identify well-defined markets. Using 2015 population data from the United States Census Bureau, this paper focuses on mid-sized cities and groups of small cities close to each other with populations ranging from 50,000 to 300,000. All cities within 5 miles from a city boundary are categorized as the same market, and the distance between cities is calculated using population-weighted centroids of census tracts[9] located in each city boundary. To minimize the effect of neighboring markets on the dialysis facility choice of ESRD patients, I only include markets whose largest neighboring market within 20 miles had a population below 25,000. After this process, eighty-one markets are defined as the sample markets for the analysis. In Table 2, the market size by population ranges from 56,548 to 304,016, with an average of 127,485 people. On average, there are 30 census tracts in a market. The smallest market consists of 9 census tracts, and the largest market consists of 70 census tracts. As this paper focuses on the midsized dialysis market, each market contains three facilities on average.

3.2 Dialysis Facilities

The data on dialysis facility locations are obtained from the USRDS, which collects information about ESRD patients, their treatments, and treatment provider. The facility data include detailed information on each facility's for-profit status, whether the facility is affiliated with a hospital, the date of certification, etc. I use the facility-level location information for 2015, when the number of dialysis facilities was maximized in the available data periods. Dialysis facilities that closed before or opened after 2015 are not considered in the analysis.

[9] https://census.missouri.edu/geography/

This paper focuses on the location decision of freestanding and for-profit dialysis facilities[10], which have increased rapidly as shown in Figure 5.

For the minimum unit of location decision of dialysis facilities, this paper uses United States census tracts because they are not overlapping and contain various demographic characteristics available in the United States Census data. To match the locations of dialysis facilities to census tracts, the precise location information of facilities is necessary, although the USRDS data provide only zip code-level information. To address these limitations on location information, I use the Dialysis Facility Compare Dataset from the Centers for Medicare and Medicaid (CMS), which contains the exact address of dialysis facilities. Using the address and the geocoding Stata module - OPENCAGEGEO[11], I derive the precise latitude-longitude coordinates of dialysis facilities. The matched census tract for each dialysis facility is identified through the ArcGIS program.

3.3 Local Demand for Dialysis Treatments

The number of ESRD patients in each census tract can be assumed as the local demand for dialysis treatments because all ESRD patients need to receive dialysis immediately and permanently for survival. Patients who received kidney transplants or died before 2015 are excluded from the analysis because they are not active ESRD patients. Because USRDS patient data only include zip code-level residence information, the number of ESRD patients in a census tract is calculated by weighting the percentage of the total population of each zip code in each census tract[12]. Using ESRD patients as the local demand for dialysis treatment is not sufficient because dialysis facilities could determine their locations based on not only current demand but also the long-run expected local demand for dialysis treatments. As the alternative proxy for current and future local demand, I also consider the census tract-level

[10] Not-for-profit facilities are excluded as their goal of operation may not be the profit maximization that this paper is assuming. Hospital-based facilities are excluded as their location decision may depend on the location of the affiliated hospitals.

[11] https://fmwww.bc.edu/repec/bocode/o/opencagegeo.pdf

[12] 2010 Zip Code Tabulation Area (ZCTA) relationship files from the United States Census Bureau were used for the calculation.

population age 65 and older, which is the major group of ESRD patients (Figure 2), and compare the estimates with the results using census tract-level ESRD patients. According to the study of Ward (2008), the incidence of ESRD could be affected by the socioeconomic status of the population, such as income and education[13]. These variables are available for census tracts from the Census Bureau's ACS data. As this paper analyzes the location choice of dialysis facilities actively operating in 2015, the 2015 Census of Population data are used for the estimation.

Table 3 provides descriptive statistics of the variables used to estimate the location choice model. As dialysis treatment is needed by patients with permanent kidney failure, I use the census tract population diagnosed with ESRD or older than 65 years of age rather than the total tract population. I also use per capita income and the share of people with low education (high school or below), which could be highly related to ESRD incidence. From the cost perspective, the property lease cost might be important when each dialysis facility chooses the location. As the Census Bureau does not provide information about commercial rent, I use the median gross rent, which represents the housing cost including contract rent and utilities.

4 Model of Dialysis Facility Location Choice

4.1 Location Choice

The model in this paper assumes that all dialysis facilities choose their locations simultaneously. Additionally, this choice is structured as an incomplete information game, which is similar to the framework of Seim (2006). That is, dialysis facilities have private information about their profit shocks specific to their own location that may not be observed by other competitors. I define a series of M markets as explained in Section 3.1. The set of census

[13]Ward (2008) found that the socioeconomic status of the population is highly associated with ESRD caused by diabetes mellitus.

tract-level locations is indexed by $l = 0, 1, \ldots, L^m$ in each market m[14]. Let the set of potential dialysis facilities be $f = 1, \ldots, F$. The facilities simultaneously determine whether to enter each market m and where to locate their facility in the market m.

This paper assumes that dialysis facility f's payoff at location l in market m is a linear function of market and location characteristics and competition effects in their own location. Therefore, the payoff function can be written as,

$$\Pi_{flm} = \lambda_m + X_{lm}\beta + \gamma N_{lm} + \varepsilon_{flm} \tag{1}$$

where λ_m is the market-level characteristics of market m, X_{lm} is the characteristics of location l in market m, and N_{lm} is the number of dialysis facilities located at location l in market m. ε_{flm} is the facility-specific unobservable data for dialysis facilities operating at location l in market m. I assume that each facility's ε is private information and independently and identically distributed (i.i.d) from the type-I extreme value distribution. Because the idiosyncratic error of each firm, ε, is private information, each facility will choose the optimal location that maximizes the expected payoff based on the expected location choices of other facilities and the distribution of private information, ε. To simplify the solution process, I assume that all dialysis facilities are homogeneous as explained in Section 3.1. The expected payoff of a firm at location l in market m is

$$\mathbb{E}(\Pi_{flm}) = \lambda_m + X_{lm}\beta + \gamma\{(\eta_m - 1)p_{lm} + 1\} + \varepsilon_{flm} \tag{2}$$

where $(\eta_m - 1)$ is the total number of competitors that entered market m and p_{lm} is the probability that competing facilities choose location l in market m, $p_{lm} = Pr[\mathbb{E}(\Pi_{lm}) \geq \mathbb{E}(\Pi_{km}),\ \forall k \neq l]$.

Due to the assumption on the distribution of private information, ε, the conditional probability of choosing location l given entry in market m can be simplified as follows:

[14]The decision of no entry is labeled as 0.

$$
\begin{aligned}
p_{lm} &= Pr(locate\ at\ l\ \mid\ Entry\ in\ m) \\
&= \frac{exp[\lambda_m + X_{lm}\beta + \gamma\{(\eta_m - 1)p_{lm} + 1\}]}{\sum\limits_j exp[\lambda_m + X_{jm}\beta + \gamma\{(\eta_m - 1)p_{jm} + 1\}]} \\
&= \frac{exp\{X_{lm}\beta + \gamma + (\eta_m - 1)\gamma p_{lm}\}}{\sum\limits_j exp\{X_{jm}\beta + \gamma + (\eta_m - 1)\gamma p_{lm}\}}
\end{aligned} \tag{3}
$$

In a free market assumption, dialysis facilities will enter the market until they can earn nonnegative profits by providing dialysis treatment. Hence, at equilibrium, an additional entrant in the market will gain negative profit. Based on this idea, I assume that the outside payoff of not entering market m is zero. Given the assumption of private information, ε, the probability of entry in market m can be derived as the combination of the average expected payoff for each location in the market and the outside payoff.

$$
Pr(Entry\ in\ m) = \frac{exp(\lambda_m)[\sum\limits_j exp\{X_{jm}\beta + \gamma + (\eta_m - 1)\gamma p_{jm}\}]}{1 + exp(\lambda_m)[\sum\limits_j exp\{X_{jm}\beta + \gamma + (\eta_m - 1)\gamma p_{jm}\}]} \tag{4}
$$

Therefore, the expected number of entrants in market m can be derived by calculating the following:

$$
\eta_m = Pr(Entry\ in\ m) \times F_m \tag{5}
$$

where F_m is the number of potential entrants in market m.

4.2 Identification

A joint equilibrium that predicts the probability of location choice and market entry can be derived by using Equations (3) and (5). The system of equations is highly nonlinear and difficult to solve because the market characteristics, λ, are unobserved. To simplify the solution process, I follow the logic of Seim (2006), which assumes that the expected number of entrants in each market is the same as the number of actual entrants observed in the data by adjusting the market characteristics, λ. When we solve equations (4) and (5), market characteristics λ can be derived as a function of location characteristics.

$$\lambda_m = ln(\eta_m) - ln(F_m - \eta_m) - ln[\sum_j exp\{X_j\beta + \gamma + (\eta_m - 1)\gamma p_{jm})] \tag{6}$$

If we substitute the number of actual entrants in η_m of Equation (6), the market characteristic λ equalizes the number of expected entrants as the number of actual entrants. As λ is unobserved in the data, I assume that it is independently and identically distributed and drawn from the normal distribution with mean μ and variance σ^2.

The parameters to be estimated are $\theta = (\beta, \gamma, \mu, \sigma)$ where β captures dialysis facilities' preference over location characteristics, γ shows the competitive effects across firms, and μ and σ determine the distribution of market characteristics. To estimate the model, I nest the fixed-point algorithm in Equation (3) into a maximum likelihood routine. Given the parameters, the fixed point solution, $p_m(X, \beta, \gamma, \eta_m; \lambda_m)$, can be found which shows the structural probability vector of each location choice in market m. When we solve this problem for M markets, the estimation problem maximizes the following log-likelihood function:

$$lnL = \sum_{m=1}^{M}\sum_{j=1}^{L^m} n_{jm} ln(p_{jm}) - \frac{M}{2}[ln(2\pi) + ln(\sigma^2)] - \frac{1}{2\sigma^2}\sum_{m=1}^{M}(\lambda_m - \mu)^2 \tag{7}$$

where n_{jm} is the actual number of dialysis facilities at location j in market m. The second part of the log-likelihood function shows the market-level characteristics drawn from the normal distribution.

5 Results

Table 4 reports the parameter estimates of the factors that affect the location of dialysis facilities. I obtain the parameter estimates by maximizing Equation (7) using a pattern search algorithm. Because dialysis facilities might operate differently when the demand is measured by the current ESRD patients than when the demand is measured by the population age 65 and older, I estimate separate models for each local demand measure. I assume that the number of potential entrants, F_m, is twice the actual number of facilities in each market. As depicted in Equation (3), changing the size of the potential entrants does not change the location choice decision of the entrants in each market, and its effect is absorbed by the estimates of market characteristics, λ_m. The table additionally shows marginal effect for each exogenous variable. For each location, I calculate the change in the location-choice probability conditional on the market entry when its exogenous variable increases by 10 percent. The reported marginal effects are derived by averaging the change in location-choice probabilities across all census tracts.

As expected, the parameter estimates show that the attractiveness of a location is affected by two opposing forces; local demand and potential competition. Column (1) shows the parameter estimates using the number of current ESRD patients as the local demand. The number of ESRD patients positively affect the dialysis facility's profit. A 10 percent increase in the number of ESRD patients for a specific location makes dialysis facilities 2.01 percent more likely to choose the location. On the other hand, dialysis facilities are less likely to be located in areas with high property rental costs because high rent would increase the cost of operating dialysis facilities. A 10 percent increase in the gross rental cost for a location implies 1.17 percent lower probability of the location choice.

The parameter for potentially competing facilities is large and negative. As rivals entering in the same location will reduce profits, dialysis facilities have a strong incentive to avoid competition by choosing locations where the other facilities are not located. When one additional dialysis facility enters a market, the likelihood of choosing the location where it was most preferred decreases in all markets. On average, the probability decreases by 1.61%. However, the change increases the likelihood of choosing the location where it was least preferred by 1.18%, which means that more expected competitors leads to a more even distributino of dialysis facilities among locations.

Column (2) reports the parameter estimates using the population over 65 years and socioeconomic status factors as the measure of the long-run expected local demand of dialysis treatment. Dialysis facilities prefer locations with more at-risk patients who are over 65 years of age and have a lower income per capita and a cheaper property rental cost. When a location's population with age 65 and above increases by 10 percent, dialysis facilities are 3.85 percent more likely to select this location. However, income per capita is negatively related to the location-choice probability. For the same level of change in income per capita, the likelihood of the location-choice decreases by 3.73 percent. With regard to education level, I find that dialysis facilities are less likely to be located in areas with a high share of poorly educated individuals. The negative effect of the gross rental cost is larger in Column (2). A 10 percent increase in the gross rental cost of a location reduces the location-choice probability by 2.97 percent, which is twice as high as the magnitude of the marginal effect in Column (1). The effect of competition still negatively affects the dialysis facility's location choice in Column (2). Although the size of the competition parameter, γ, is smaller in Column (2), the impact of one additional entrant in a market is similar to that in Column (1). When one additional facility enters a market, the probability of choosing the previously most preferred location decreases by 1.2% and the probability of choosing the least preferred location increases by 0.89%.

6 Robustness Check

This section presents a series of analyses to test the robustness of the main parameter estimates. First, in Table 5, I loosen the restrictions on the population size of the largest city within 20 miles from each sample market to include more markets in the analysis sample. In the original sample, I excluded markets where the largest city within a distance of 20 miles has a population greater than 25,000, and the parameter estimates are shown in Columns

(1) and (2). Columns (3) and (4) show parameter estimates when I loosen the restriction of the population size to 40,000. With this adjustment, 19 additional markets are included in the analysis sample. Finally, in Columns (5) and (6), I increase the population cutoff to 50,000, which is the minimum population size of the sample market. Although more markets are added in the analysis sample, the sign of most parameter estimates is the same as that of the main parameter estimates of the base model. The magnitudes of the estimates slightly increase as the number of sample markets increases, although the change is not that huge when we consider the standard errors. With regard to the competition effect, the magnitudes of the estimates in Columns (5) and (6) were the largest for both of the dialysis demand assumptions.

Second, I examine whether the main parameter estimates are affected by the size of potential entrants. As shown in Columns (1) and (2) of Table 6, in the base model, I assumed that the number of potential entrants is twice the number of actual entrants in each dialysis market. In Section 4.2, the market characteristics, λ, equalize the number of expected entrants as the number of actual entrants. Hence, the location decision upon market entry should not be affected by the change in the number of potential entrants. For the test, I increased the number of potential entrants by threefold and fourfold, and the estimates are reported in Columns (3) to (6). If a smaller share of potential entrants enter the market, it would mean that the markets are not attractive to potential entrants. This change would be indicated by a lower estimate of the mean market characteristics, μ. This result is not found in the estimates using the number of current ESRD patients as the demand factor. The estimates of μ in Columns (3) and (5) are similar to that in Column (1). On the other hand, the estimates using key factors related to ESRD incidence follow our expectations. The estimate decreases from -2.0027 in Column (2) to -3.3038 in Column (6). Except for the estimate of μ, the other estimates are similar in magnitude as expected.

7 Conclusions

In this paper, I estimate a simultaneous game for the entry and location choice decisions of dialysis facilities. The model is set up as an incomplete information game among potential entrants in the dialysis industry where facilities have private information on their location-specific profit shocks. The results show that dialysis facilities choose their locations strategically and there is a tradeoff between local demand and expected competition. Firms prefer locations with more at-risk people, such as ESRD patients or a high population of individuals with ages over 65, and lower per capita income. From the cost perspective, these firms prefer locations with low property rental costs. In terms of competitive interactions, all firms exert a negative impact on their potential competitors in the same location.

There are several caveats to this paper and directions for future research. First, I consider only the effects of local demand and competitive interactions in the immediate location. The related literature (Seim 2006; Orhun 2006; Zhu et al. 2009; Gowrisankaran et al. 2011) incorporates distance band terms in models to observe how the effects change as distance from the targeted location increases. Because I assume that dialysis facilities consider overall ESRD patients in a market as their demand, this approach would lead to more reasonable parameter estimates. Second, this paper only analyzes entry and location choice decisions of freestanding and for-profit dialysis facilities because the other types of facilities, such as hospital-based or not-for-profit facilities, may have objective functions other than profit maximization. Although the goal of these facilities is different from that of the facilities studied here, the existence of those facilities might exert negative impacts on expected profits and result in a different site selection in a market. Third, the model in this paper might simplify the dialysis industry too much and be not enough to analyze the spatial competition among dialysis facilities. The key assumption of the model used in this paper is that dialysis facilities are symmetric. However, the existence of a dialysis chain could weaken the assumption. In 2012, approximately 76 percent of dialysis facilities are chain-affiliated, such as Davita and Fresenius (Eliason 2017). Because chain-affiliated facilities could have lower cost of operation, they might not be symmetric with the other dialysis facilities. Additionally, this model does not consider the dynamics in the dialysis industry and focuses on the distribution of dialysis facilities in 2015. Because the USRDS dataset includes all the information on the entry and exit of dialysis facilities in the U.S. and their characteristics, the estimation model that can analyze the longitudinal data will provide valuable insights on the overall dialysis market.

References

Administration on Aging. 2018. *2018 profile of older Americans.*

Berry, Steven T. 1992. "Estimation of a Model of Entry in the Airline Industry." *Econometrica: Journal of the Econometric Society:* 889–917.

Bloom, Nicholas, and John Van Reenen. 2007. "Measuring and explaining management practices across firms and countries." *The quarterly journal of Economics* 122 (4): 1351–1408.

Bresnahan, Timothy F, and Peter C Reiss. 1991. "Entry and competition in concentrated markets." *Journal of political economy* 99 (5): 977–1009.

Brooks, John M, Christopher P Irwin, Lawrence G Hunsicker, Michael J Flanigan, Elizabeth A Chrischilles, and Jane F Pendergast. 2006. "Effect of Dialysis Center Profit-Status on Patient Survival: A Comparison of Risk-Adjustment and Instrumental Variable Approaches." *Health services research* 41 (6): 2267–2289.

Center for Medicare and Medicaid Services. 2019. "Medicare Benefit Policy Manual, Chapter 11: End Stage Renal Disease (ESRD)."

Childers, Christopher P, Jill Q Dworsky, Gerald Kominski, and Melinda Maggard-Gibbons. 2019. "A Comparison of Payments to a For-profit Dialysis Firm From Government and Commercial Insurers." *JAMA internal medicine* 179 (8): 1136–1138.

Collins, Allan J. 2012. "ESRD payment policy changes: the new "bundled" dialysis prospective payment system (PPS) in the United States." In *National Kidney Foundation Spring Clinical Meeting, Washington, DC.*

Cooper, Zack, Stephen Gibbons, Simon Jones, and Alistair McGuire. 2011. "Does hospital competition save lives? Evidence from the English NHS patient choice reforms." *The Economic Journal* 121 (554): F228–F260.

Eliason, Paul. 2017. *Market Power and Quality: Congestion and Spatial Competition in the Dialysis Industry.* Technical report. Working Paper.

Gaynor, Martin, Rodrigo Moreno-Serra, and Carol Propper. 2013. "Death by market power: reform, competition, and patient outcomes in the National Health Service." *American Economic Journal: Economic Policy* 5 (4): 134–66.

Gowrisankaran, Gautam, and John Krainer. 2011. "Entry and pricing in a differentiated products industry: Evidence from the ATM market." *The RAND Journal of Economics* 42 (1): 1–22.

Kessler, Daniel P, and Mark B McClellan. 2000. "Is hospital competition socially wasteful?" *The Quarterly Journal of Economics* 115 (2): 577–615.

Kirchhoff, Suzanne M. 2018. "Medicare Coverage of End-Stage Renal Disease (ESRD)." *Congressional Research Service (R45290).*

Lee, Donald KK, Glenn M Chertow, and Stefanos A Zenios. 2010. "Reexploring differences among for-profit and nonprofit dialysis providers." *Health services research* 45 (3): 633–646.

Mazzeo, Michael J. 2002. "Product choice and oligopoly market structure." *RAND Journal of Economics:* 221–242.

Orhun, Yesim. 2006. "Spatial differentiation in the supermarket industry." *Work. paper, Graduate School of Business, University of Chicago.*

Overbeck, I, M Bartels, O Decker, J Harms, J Hauss, and J Fangmann. 2005. "Changes in quality of life after renal transplantation." In *Transplantation proceedings,* 37:1618–1621. 3. Elsevier.

Propper, Carol, Nicholas Bloom, Stephan Seiler, John Van Reenen, et al. 2010. "The impact of competition on management quality: Evidence from public hospitals." *University of Bristol Centre for Market and Public Organisation Working Paper* 10:237.

Schold, Jesse D, Laura D Buccini, David A Goldfarb, Stuart M Flechner, Emilio D Poggio, and Ashwini R Sehgal. 2014. "Association between kidney transplant center performance and the survival benefit of transplantation versus dialysis." *Clinical Journal of the American Society of Nephrology* 9 (10): 1773–1780.

Seim, Katja. 2006. "An empirical model of firm entry with endogenous product-type choices." *The RAND Journal of Economics* 37 (3): 619–640.

Stevens, Lesley A, Gautham Viswanathan, and Daniel E Weiner. 2010. "CKD and ESRD in the elderly: current prevalence, future projections, and clinical significance." *Advances in chronic kidney disease* 17 (4): 293.

United States Renal Data System. 2016. "2016 USRDS Annual Data Report: Epidemiology of kidney disease in the United States." *National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, Bethesda, MD.*

———. 2018. "2018 USRDS Annual Data Report: Epidemiology of kidney disease in the United States." *National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, Bethesda, MD.*

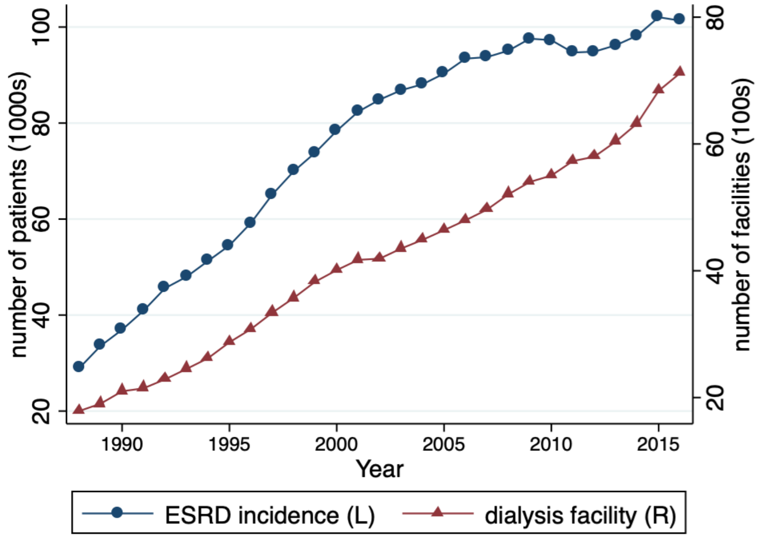
Ward, Michael M. 2008. "Socioeconomic status and the incidence of ESRD." *American Journal of Kidney Diseases* 51 (4): 563–572.

Wilson, Nathan E. 2016. "For-profit status and industry evolution in health care markets: evidence from the dialysis industry." *International journal of health economics and management* 16 (4): 297–319.

Wolfe, Robert A, Valarie B Ashby, Edgar L Milford, Akinlolu O Ojo, Robert E Ettenger, Lawrence YC Agodoa, Philip J Held, and Friedrich K Port. 1999. "Comparison of mortality in all patients on dialysis, patients on dialysis awaiting transplantation, and recipients of a first cadaveric transplant." *New England Journal of Medicine* 341 (23): 1725–1730.

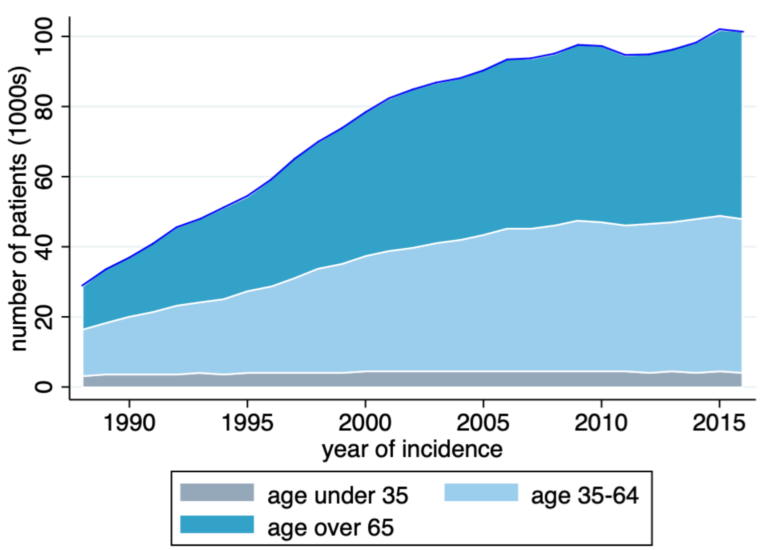
Zhu, Ting, and Vishal Singh. 2009. "Spatial competition with endogenous location choices: An application to discount retailing." *QME* 7 (1): 1–35.

8 Figures



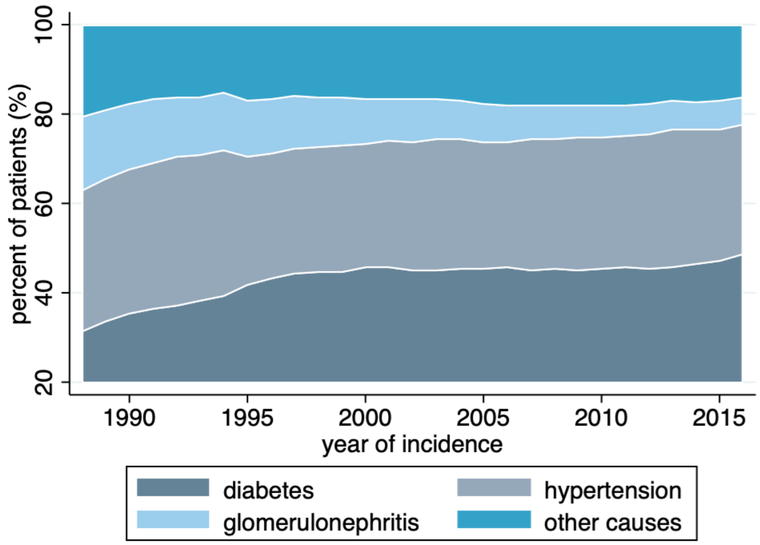
Source: 2016 USRDS data
Notes: The number of ESRD incidences is computed by counting patients who received their first ESRD services in each year. I restrict the sample to ESRD patients who chose in-center hemodialysis as their first treatment modality (73 percent among total ESRD patients). Therefore, the real number of ESRD incidences needs to be scaled up. To calculate the number of dialysis facilities, I count facilities that responded the CMS ESRD Annual Facility Survey in each year.

Figure 1: Trend of ESRD incidences and dialysis facilities



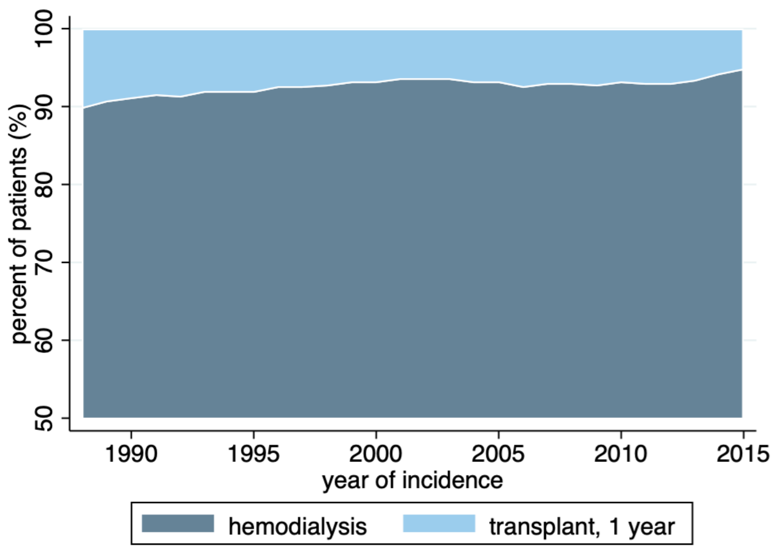
Source: 2016 USRDS data

Figure 2: Trend of ESRD incidence by age



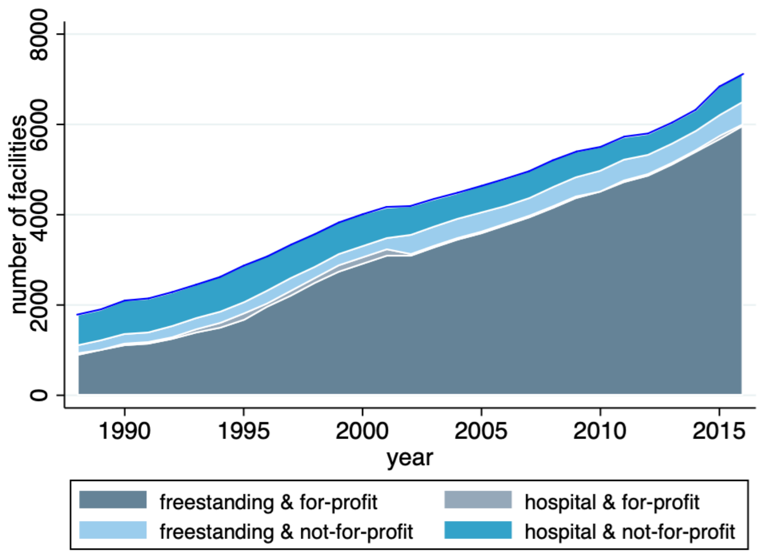
Source: 2016 USRDS data
Notes: Glomerulonephritis is diagnosed for patients with inflammation of the tiny filters in the kidneys.

Figure 3: Trend of primary causes of ESRD



Source: 2016 USRDS data
Notes: I restrict the sample to ESRD patients who chose in-center hemodialysis as their first treatment modality (73 percent among total ESRD patients). Approximately 6 percent of all ESRD patients receive kidney transplant as their first treatment. Transplant treatment choice in this plot is defined as a broader concept. It counts not only actual transplant, such as decesed or living donor kidney transplants, but also waitlist registration for deceased donor kidneys.

Figure 4: Treatment choice within 1 year of ESRD incidence



Source: 2016 USRDS data
Notes: Hospital-based facilities are either hospital units or hospital satellites, and freestanding facilities are defined as units not affiliated with a hospital.

Figure 5: Trend of dialysis facilities

9 Tables

Table 1: ESRD patient distance to dialysis facilities

Percentile	(1) All	(2) For-profit	(3)	(4) Not-for-profit	(5)
		Freestanding	Hospital	Freestanding	Hospital
10	1.681	1.761	1.386	1.806	0.786
20	2.887	2.928	3.091	2.956	2.500
30	4.134	4.120	4.439	4.227	4.157
40	5.568	5.489	6.044	5.788	5.949
50	7.404	7.236	7.951	7.636	8.269
60	10.109	9.744	10.650	10.227	12.150
70	14.422	13.708	15.231	14.628	18.610
80	22.073	20.658	23.769	21.826	31.272
90	40.846	37.280	46.869	39.932	62.723
Observations	2,183,149	1,639,252	17,759	172,754	353,384

Source: 2016 USRDS data
Notes: The distance between a residence of a patient and the patient's registered dialysis facility is computed by using the GEODIST stata command and coordinates of the two locations. Resident coordinates in ZCTA-level come from United States Census Gazetteer files (https://www.census.gov/geographies/reference-files/time-series/geo/gazetteer-files.html). Dialysis facility coordinates are found based on the facility address available from CMS Dialysis Facility Compare Dataset.

Table 2: Market characteristics (81 sample markets)

	(1) Mean	(2) Std Dev	(3) Min	(4) Max
Market population	127,484.70	49,771.10	56,548	304,016
Largest market population within 20 miles	10,964.71	7,161.52	-	24,526
Number of census tracts	29.62	12.72	9	70
Number of for-profit dialysis facilities	2.65	1.60	1	7

Sources: 2015 U.S. Census ACS, 2016 USRDS data
Notes: The largest market within 20 miles is relative to the market's boundary census tracts. The distance between locations is computed as the distance between the census tract's population-weighted centroids.

Table 3: Census tract-level characteristics

	(1) Mean	(2) Std Dev	(3) Min	(4) Max
Population				
Total	4,304.40	2,081	0	30,256
Diagnosed with ESRD	7.24	5.15	0	43
65 years and older	591.82	378	0	4,093
Per capita income ($)	24,304.92	9,919.54	0	90,249
Education with high school or under (%)	41.49	16.51	0	88.60
Median gross rent ($)	783.36	230.64	0	2,108

Sources: 2015 U.S. Census ACS, 2016 USRDS data
Notes: Median gross rent shows the monthly housing cost expenses for renters. This variable contains the contract rent and the estimated cost of utilities paid by renters. The number of ESRD patients includes the accumulated number of patients whose ESRD status was active in 2015.

Table 4: Parameter estimates

	(1) Coefficient	(2) Marginal Effect (%)	(3) Coefficient	(4) Marginal Effect (%)
ESRD patients	0.3265	2.01		
(units: 10 people)	(0.0977)			
Population over 65 years			0.6810	3.85
(units: 1,000 people)			(0.0209)	
Education with high school			-0.7484	-2.70
or under (units: 1%p)			(0.3709)	
Per capita income			-1.7498	-3.73
(units: \$100,000)			(0.3714)	
Median gross rent	-0.0193	-1.17	-0.0434	-2.97
(units: \$100)	(0.0278)		(0.0164)	
Competition effect (γ)	-1.8753		-0.6295	
	(0.9524)		(0.0211)	
Mean of market-level effect	-2.8078		-2.0027	
distribution (μ)	(1.0166)		(0.2842)	
Standard error of market-level	0.3905		0.3768	
effect distribution (σ)	(0.0291)		(0.0279)	
Log-likelihood	775.198		769.766	

Notes: Standard errors are reported in parentheses. Parameter estimates are based on 2015 demographic and dialysis facility location data. The marginal effect shows the average change in the probability of location choice conditional on entry for the response to a 10% increase in each demographics.

Table 5: Robustness to the restrictions on the largest city within 20 miles

	(1)	(2)	(3)	(4)	(5)	(6)
	Pop $<$ 25,000 (81 markets)		Pop $<$ 40,000 (100 markets)		Pop $<$ 50,000 (108 markets)	
ESRD patients	0.3265		0.3813		0.3801	
(units: 10 people)	(0.0977)		(0.0742)		(0.0702)	
Population over 65 years		0.6810		0.7762		0.7780
(units: 1,000 people)		(0.0209)		(0.1025)		(0.0801)
Education with high school		-0.7484		-0.7873		-0.8190
or under (units: 1%p)		(0.3709)		(0.1694)		(0.1087)
Per capita income		-1.7498		-2.1708		-2.5712
(units: \$100,000)		(0.3714)		(0.1907)		(0.1144)
Median gross rent	-0.0193	-0.0434	-0.0128	-0.0328	-0.0100	-0.0235
(units: \$100)	(0.0278)	(0.0164)	(0.0238)	(0.0240)	(0.0090)	(0.0168)
Competition effect (γ)	-1.8753	-0.6295	-1.8353	-0.8490	-2.1761	-0.9450
	(0.9524)	(0.0211)	(0.1366)	(0.1909)	(0.1514)	(0.1143)
Mean of market-level effect	-2.8078	-2.0027	-1.5499	-1.7927	-1.2147	-1.6640
distribution (μ)	(1.0166)	(0.2842)	(0.2586)	(0.2967)	(0.2260)	(0.1931)
Standard error of market-level	0.3905	0.3768	0.4020	0.3970	0.4018	0.3915
effect distribution (σ)	(0.0291)	(0.0279)	(0.0282)	(0.0280)	(0.0266)	(0.0260)
Log-likelihood	775.198	769.766	903.732	896.320	1,025.564	1,015.205

Notes: The table shows the parameter estimates with different restrictions on the population size of the largest city within 20 miles from each sample market. Standard errors are reported in parentheses. Parameter estimates are based on 2015 demographic and dialysis facility location data.

Table 6: Robustness to the assumption on the size of potential entrants

	(1)	(2)	(3)	(4)	(5)	(6)
	2 × entrants		3 × entrants		5 × entrants	
ESRD patients	0.3265		0.3205		0.3817	
(units: 10 people)	(0.0977)		(0.0969)		(0.0968)	
Population over 65 years		0.6810		0.6819		0.6824
(units: 1,000 people)		(0.0209)		(0.1397)		(0.1245)
Education with high school		-0.7484		-0.7495		-0.7504
or under (units: 1%p)		(0.3709)		(0.3858)		(0.2553)
Per capita income		-1.7498		-1.7752		-1.7809
(units: $100,000)		(0.3714)		(0.8694)		(0.3382)
Median gross rent	-0.0193	-0.0434	-0.0189	-0.0425	-0.0191	-0.0426
(units: $100)	(0.0278)	(0.0164)	(0.0276)	(0.0292)	(0.0276)	(0.0275)
Competition effect (γ)	-1.8753	-0.6295	-1.6942	-0.6880	-1.6927	-0.7092
	(0.9524)	(0.0211)	(0.9480)	(0.8354)	(0.9461)	(0.3403)
Mean of market-level effect	-2.8078	-2.0027	-2.3045	-2.6348	-2.9962	-3.3038
distribution (μ)	(1.0166)	(0.2842)	(1.0125)	(1.0142)	(1.0109)	(0.4542)
Standard error of market-level	0.3905	0.3768	0.3903	0.3768	0.3902	0.3768
effect distribution (σ)	(0.0291)	(0.0279)	(0.0291)	(0.0283)	(0.0291)	(0.0281)
Log-likelihood	775.198	769.766	775.171	769.764	775.171	769.764

Notes: The table shows parameter estimates with the different assumptions on the number of potential entrants in each market. Standard errors are reported in parentheses. Parameter estimates are based on 2015 demographic and dialysis facility location data.