PRODUCT OFFERING AND CAPACITY CONSTRAINT IN HEALTHCARE: EVIDENCE FROM DIALYSIS INDUSTRY

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ABSTRACT.

Healthcare regulators possess the authority to set product prices, thereby influencing the strategic decision-making of service providers in terms of availability and quantity. Within this intricate environment, the consequences of inadequate pricing can be substantial, leading to a reduced variety of products, a limited supply of treatments, and ultimately, restricted access to healthcare for patients. This study examines the impact of Medicare payment strategies on the product offerings of dialysis facilities, taking into account their capacity constraints, and assesses the subsequent effects on patient welfare. Our findings indicate that increasing payments for less expensive products leads to a rise in the total supply of treatments and a greater diversity of products, but this is only observed in facilities operating near their capacity limits. Additionally, these facilities are motivated to augment their capacity by opening new affiliated branches in nearby locations. Ultimately, our research shows that patients benefit from the increased availability of treatment options, with 16.5% of patients being able to retain employment post-initiation of dialysis without experiencing negative health consequences.

KEYWORDS:

JEL CLASSIFICATION:

1. Introduction

In regulated industries such as healthcare, authorities set product prices, leading firms to make strategic choices about product availability and quantity. Given that patients usually have inelastic demand for treatments and benefit from a variety of treatment options, the product decisions made by healthcare providers are crucial for patient welfare. However, it is common for regulators to set varying prices to different treatment methods for a single diagnosis. This can lead healthcare providers to offer a reduced supply of less profitable treatments, ultimately constraining the range of accessible treatments for patients.

Capacity constraints, a common challenge in healthcare sector, further complicates the decision-making process related to product offerings. When the capacity for the most profitable product hits its limit, providers must decide whether to diversify their offerings. This decision is critical for patient welfare, as a failure to utilize available capacity for other products can lead to excess

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demand, forcing some patients out of the treatment queue. Thus, it is imperative for regulators to understand how pricing can be used as a lever to encourage providers to expand their offerings and capacity, ultimately safeguarding patient access to necessary treatments.

This paper studies how product prices affect providers' product offerings in the context of dialysis industry. We examine a Medicare payment reform, investigating how changes in product prices influence dialysis facilities' offerings and capacity decisions, and evaluating how patients benefit from a broader range of choices.

Dialysis is a life-sustaining treatment for end-stage renal disease (ESRD) patients. Outpatient dialysis facilities primarily offer two treatments: hemodialysis (HD) and peritoneal dialysis (PD). HD requires patients to visit a facility three times a week for 3-5 hour sessions. PD, on the other hand, allows patients to self-treat daily at home, necessitating only a singular monthly visit for routine maintenance. While both treatments yield comparable survival rates, their benefits differ. PD offers scheduling flexibility, while HD provides consistent medical supervision. Therefore, a variety of treatment options could enhance patient choice and improve welfare. However, only 44% of dialysis facilities offer PD, even though almost all provide HD. Among those offering both, a mere 24% of patients undergo PD.

This discrepancy in product offering is rooted in several institutional factors. First, Medicare's universal coverage for ESRD patients leads to an inelastic demand for dialysis. Second, dialysis exhibits economies of scale, with costs per treatment declining as the treatment volume increases. It may deter firms from diversifying and, instead, encourage a focus on treatments where they have a competitive advantage. Furthermore, prior to a 2011 reform, Medicare payments for PD and HD patients show great difference. The reimbursement at the time was a hybrid model: facilities received a fixed payment for each dialysis session and additional fees for related drugs. Given HD's heightened drug requirements, PD typically had lower reimbursements. For instance, in 2010, HD patients received an average annual outpatient payment of $31 thousand compared to PD's $25 thousand. This disparity in profitability could have dissuaded facilities from providing PD.

In 2011, the Centers for Medicare and Medicaid Services (CMS) restructured the payment system, bundling dialysis drugs into the fixed payment. This new Prospective Payment System (PPS) was phased in over a four-year period, equalizing the annual outpatient payment to approximately $34 thousand for both treatments by 2014. We exploit the Medicare PPS reform to investigate how increased PD payments impact firms' product offerings and capacity decisions. In 2018, ESRD-related expenditures for Medicare beneficiaries surged to $49.2 billion, representing 6.6% of total Medicare spending, while ESRD patients only comprise 1% of the Medicare patient population. Our analysis thus makes important policy implications.

In this work, we first examine the overall effects of the payment reform on HD offerings and then shift our focus to facilities grappling with capacity constraint. Given that HD entails a standardized process and its capacity is rigidly bound by the number of available HD stations, some facilities might only introduce PD upon reaching full HD capacity. We investigate whether facilities approaching capacity constraints adapt their offerings differently and if increased profit margins induce them to expand, either by upgrading existing infrastructure or opening new branches. Our empirical analysis is guided by a model of product choice under economies of scale and capacity constraints. The model sheds light on firms' optimal strategies given varied cost and price structures, highlighting varied responses to price changes between typical firms and those approaching their capacity limits.

We utilize the Medicare Dialysis Facilities data from 2007 to 2016, encompassing both facility and patient details, to study the above questions. Although the new payment system proposed a four-year phased implementation starting 2011, facilities could opt to adopt the PPS immediately. Therefore, we implement a difference-in-differences (DID) strategy, contrasting facilities that opted out of the transition with those adhering to the prescribed timeline. Ultimately, facilities abstaining from the transition are hypothesized to be more significantly impacted by the policy, experiencing a more immediate and substantial increase in PD price.

A primary challenge in our identification is the potential endogeneity of the decision to opt out. Facilities that foresee better performance under the new system may be predisposed to opt out and simultaneously be more adaptive to the reform. To counteract this selection bias, we leverage the consistent "opting-out" strategy of national chains. Large dialysis organizations (LDOs) uniformly implemented the PPS across all their national facilities in 2011, making this decision essentially exogenous at the individual facility level.

Therefore, we select LDO facilities as our treatment group to mitigate selection bias. To further refine our comparisons, we use propensity score matching (PSM) to match LDO facilities with their non-LDO counterparts, accounting for potential differences. Variables such as expected payments under both PPS and the previous system, input, output, and profit orientation are incorporated to reconcile disparities. Our core assumption is that any variation between the groups should be encapsulated by these observed attributes. Post-matching, we apply the DID approach using data from matched facilities.

Our findings indicate that the increased PD payment resulted in a 1.2 percentage point decrease in the HD patient ratio in LDO facilities. Furthermore, facilities operating close to their capacity constraints saw a 5.2% growth in their total patient count and a 5.9 percentage point rise in the proportion of PD patients. Interestingly, the growth in PD adoption is only seen in facilities that already provided PD - the intensive margin increase. We did not observe any notable changes on the extensive margin, which is the introduction of PD treatments, suggesting potential barriers for facilities to begin offering PD if they had not before.

We observed that facilities operating close to their capacity constraints experience the establishment of new affiliated branches within a 10-mile radius. These new units appear more responsive in adjusting their product offerings following price change. However, there is no notable investment in stations or staff at the existing facilities.

Additionally, the increased PD price leads to a 3.3 percentage point rise in patient employment rates in small metropolitan areas. This positive impact likely stems from the enhanced scheduling flexibility, enabling patients to better maintain employment upon beginning dialysis. Importantly, this does not appear to negatively affect health metrics, such as patient mortality.

The literature. This paper builds upon a robust body of literature that investigates the influence of Medicare payment policy on healthcare providers' behavior and the consequent effects on patient outcomes. Prior research has shown that an increase in payments correlates with a greater supply of healthcare services (Clemens and Gottlieb (2014)) and an improved quality of care, as indicated by a rise in the number of skilled nurses (Hackmann (2019)). However, the impact on actual health outcomes, such as mortality and readmission rates, appears to be minimal (Huckfeldt, Sood, Escarce, Grabowski, and Newhouse (2014); Clemens and Gottlieb (2014)).

Our study delves deeper by exploring how changes in Medicare payment policies affect providers' decisions regarding product offerings. Furthermore, we examine whether an enhanced diversity in treatment options can exert a positive impact on patients' quality of life. Different from previous observational studies (Wang, Coffman, Sanders, Lee, Hirth, and Maciejewski (2018); Hornberger and Hirth (2012)), we employ exogenous variation to analyze product offering decisions in the dialysis industry. We find that higher payments lead to increased product diversity, which in turn benefits patient welfare. In particular, the enhanced diversity offers greater scheduling flexibility for patients, which enables them to maintain their employment without adversely affecting their health.

Second, our work extends the existing literature examining the influence of capacity constraints on public service delivery and associated outcomes. The previous research has shown that hospitals with tight capacity often manage by speeding up discharges (Sharma, Stano, and Gehring (2008)), whereas hospitals with expanded capacity see a rise in admissions (Freedman (2016)). Furthermore, the presence of capacity constraints often prevents patients from opting for their most preferred choice (Kleiner (2019)). Notably, increased funding can alleviate these constraints, leading to improved outcomes in public sectors. (See Mello (2019); Evans and Owens (2007) for examples of policing services.)

We contribute to the existing literature by highlighting the influence of capacity constraints on product diversity. Notably, providers under capacity constraints tend to diversify their product offerings, whereas those without such limitations lean towards specialization, especially in the presence of economies of scale. Furthermore, we have documented a growth in the provision of healthcare services and an expansion in capacity following payment increases.

Finally, Our research offers a fresh perspective within the emerging literature on the economics of the dialysis industry. Noteworthy studies by Dai (2014) and Dai and Tang (2015) respectively examine the product choices and capacity decisions of dialysis providers. Their simulations indicate that reducing Medicare payments results in a rise of multi-product providers and a reduction in overall market capacity. Building on these insights, our study integrates both product selection and capacity constraints into a cohesive framework. Moreover, we identify the effects of price change by leveraging the exogenous variations introduced by the PPS reform. Our analysis reveals the heterogeneous impacts on facilities operating near the capacity constraint and demonstrates enhancements in patient welfare.

The rest of this paper is organized as follows. We introduce the background of dialysis industry in Section 2. We present the model of product choice in Section 3 and discuss the model implications in the same section. We explain our data and methodology in the following section. Empirical results are presented in Section 5. The last section concludes.

2. Background

2.1. Dialysis in the US

Dialysis serves as a renal replacement therapy for those diagnosed with end-stage renal disease (ESRD). This procedure purifies the body by eliminating waste products and excess fluids. While ESRD patients are dependent on dialysis for life, a successful kidney transplant can negate this need. However, due to the scarcity of available kidneys and varying patient eligibility for transplantation, out of 783,925 ESRD patients in 2018, 70.7% relied on dialysis. Over the years, the US has experienced a growing ESRD population, largely attributed to an aging population and increased prevalence of diabetes, resulting in heightened demand for dialysis.

Dialysis comes in two primary types: hemodialysis (HD) and peritoneal dialysis (PD), each with its distinct method of waste removal. HD employs an external dialyzer with an artificial membrane to purify the patient's blood. Typically, patients visit a dialysis center thrice a week, with each session spanning 3-5 hours. In contrast, PD utilizes the patient's abdominal lining as a natural filter. This method allows patients to self-administer the treatment, often in the comfort of their home or workplace, five to seven times a week.

Recent medical studies have highlighted comparable patient survival rates between HD and PD.[1] However, each modality presents its own set of benefits and limitations. PD provides patients with greater flexibility and autonomy in their treatment regimen, but it demands dedicated space at the patient's residence. Conversely, HD offers the assurance of continuous medical supervision but confines patients to a predetermined schedule and involves frequent commuting to a medical facility. It shows that PD and HD suit patients with different demographics and suggests that a variety of treatment options could enhance patient choice and improve welfare.

2.2. Medicare Payment Policy

In 1972, an act of Congress expanded Medicare benefits to encompass all ESRD patients, irrespective of age. By 2018, the ESRD-related expenditures for Medicare beneficiaries escalated to $49.2 billion. This figure signifies 6.6% of the overall Medicare spending, even though ESRD patients only comprise 1% of the Medicare patient population (USRDS, 2020).

Starting in 1983, Medicare began compensating dialysis facilities with a fixed payment known as the "composite rate" for each dialysis session. This rate encompasses the costs of nursing, equipment, and supplies integral to the dialysis process. In addition, Medicare offers separate reimbursements for specific drugs and routine laboratory tests under a fee-for-service model.

[1] See, for example, Jaar and Gimenez (2018); Wong, Ravani, Oliver, Holroyd-Leduc, Venturato, Garg, and Quinn (2018); Quinn, Hux, Oliver, Austin, Tonelli, and Laupacis (2011).

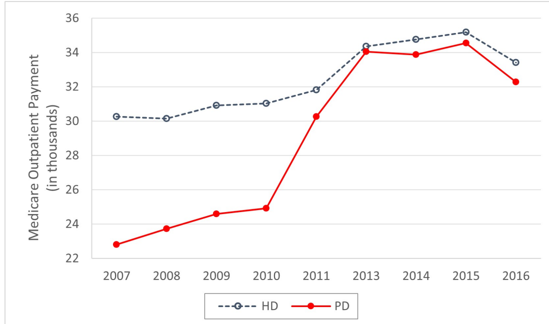

FIGURE 1. Medicare Payment for ESRD Patients: Outpatient

Consequently, while the payment for the dialysis procedure remains fixed, the compensation for dialysis-related drugs varies based on the amount dispensed. Within this hybrid system, payments for PD are typically lower than those for HD, largely attributed to the greater pharmaceutical demands associated with HD procedures. For instance, the annual outpatient payment for dialysis treatment approximates $17.6 thousand for HD, in contrast to $17.8 thousand for PD. However, when considering dialysis-related drugs, the payment is $8.5 thousand for HD compared to a notably lower $3.9 thousand for PD.[2]

The Medicare Improvements for Patients and Providers Act of 2008 (MIPPA) restructured the aforementioned hybrid payment system to incorporate dialysis drugs into the composite rate payment, starting in 2011. Following this reform, CMS unveiled a proposed rule in September 2009 and finalized it by July 2010, outlining the new dialysis Prospective Payment System (PPS). This revised system bundled injectable dialysis drugs, their oral counterparts, separately billable equipment, supplies provided by the facility, and self-dialysis training services into a unified payment structure.

The CMS was mandated to gradually introduce the new PPS over a four-year period. The transition payments were set as follows: 75% from the existing system and 25% from the PPS in 2011, an even 50-50 split in 2012, 25% from the existing system and 75% from the PPS in 2013, and fully adopting the new PPS by 2014. Nevertheless, dialysis facilities were given a one-time option in 2010 to bypass the transition and paid entirely under the new PPS starting from 2011.

We plot the annual Medicare outpatient payment per patient for the period 2007 to 2016 in Figure 1. We first find that the implementation of the PPS reform led to an increase in dialysis pricing. This increment remained consistent for a span of five years, witnessing a decline in 2016. Notably, before 2010, the price of PD was approximately 23% lower than HD. The PPS reform, however, elevated the PD pricing, thereby narrowing this previously observed price disparity. In this study, our objective is to delve into how these pricing changes, induced by the PPS reform, influenced the product choices and expansion strategies of dialysis facilities.

[2]Source: Annual Data Report from USRDS, 2007-2010. Outpatient dialysis-related drugs include ESA, vitamin D, iron and other injectables.

3. Model

In this section, we introduce a model that explores product offerings under capacity constraints when product prices are fixed. The model captures the trade-offs between offering two products with different markups, providing insights into how firm adjust product offerings in response to price change.

3.1. A Model of Product Choice

Consider a typical firm, denoted as j, offering two types of products: HD and PD. The regulator sets the prices for these products, with $\bar{p}_1$ for HD and $\bar{p}_2$ for PD. In particular, the price is determined by the regulator using the firm's cost information, and it will not impact patient demand.

We assume the total demand of treatment $q \geq 0$ for firm j arises from an exogenous factor $\tilde{q}$ and an idiosyncratic shock ϵ. In each period, the firm observe $\tilde{q}$, which is unknown to economists, and chooses to produce quantities q_1 and q_2 of HD and PD, respectively, to meet this demand. In other words, the firm decide the product offering before the realization of demand shock. Notably, the quantity of HD offered is bound by the firm's capacity T_k, which hinges on the number of HD stations k.

In this model, we adopt a concave cost structure, mirroring the industry observation that the cost per treatment decreases as the number of dialysis treatments increases.[3] This suggests the presence of economies of scale in the industry. Additionally, the production costs differ between HD and PD. The average cost for HD, denoted as $c(q_1)$ diminishes with the increase in HD quantity and is represented by $c(q_1) = c_0 - c_1 q_1$ with positive c_0 and c_1. In contrast, the average cost for PD, labeled as c_2, remains constant.

3.1.1. **Firm's Problem.** Before the realization of demand, the facility selects a product offering (q_1, q_2) to maximize its profit based on $\tilde{q}$. Its actual profit, which depends on the realized demand q, remains unknown at the time of decision-making. We assume that each product offering decision is fully adjustable between periods without affecting subsequent decisions. Essentially, the firm chooses (q_1, q_2) to optimize the static problem,

$$\begin{aligned} \max_{q_1, q_2} \quad & \pi = [\bar{p}_1 - c(q_1)]q_1 + [\bar{p}_2 - c_2]q_2 - F(k) \\ \text{s.t.} \quad & q_1 + q_2 \leq \tilde{q} \\ & q_1 \leq T_k \end{aligned} \tag{3.1}$$

Let $m_1(q_1) = \bar{p}_1 - c(q_1) = \bar{p}_1 - c_0 + c_1 q_1$ and $m_2 = \bar{p}_2 - c_2$ represent the markups for HD and PD, respectively. Our analysis centers on scenarios with $m_1(T_k) > 0$. Otherwise, HD would never be offered.

[3] Refer to Figure 6.5 in the Report to the Congress: Medicare Payment Policy, 2018.

3.1.2. **Firm's Cutoff Strategy. (Case 1)** Let us first examine the scenario where the PD markup is positive, $m_2 > 0$, resulting in the first constraint of 3.1 being bounded. By substituting $c(q_1)$ with $c_0 - c_1 q_1$ and q_2 with $\tilde{q} - q_1$, we can reformulate the profit π as a function of HD offering q_1:

$$\pi(q_1) = c_1 q_1^2 + [(\bar{p}_1 - c_0) - (\bar{p}_2 - c_2)]q_1 + (\bar{p}_2 - c_2)\tilde{q} - F(k) \tag{3.2}$$

Given the convex nature of the profit function, we can only arrive at corner solutions. In particular, if $m_1(\tilde{q}) > m_2$, it is optimal for the firm to maximize HD production, denoted as $q_1 = \max(T_k, q)$, and then allocate any remaining demand to PD, i.e., $q_2 = \max(q - T_k, 0)$. Conversely, if $m_2 > m_1(\tilde{q})$, the firm should provide PD only and thus set $q_1 = 0$ and $q_2 = q$.

As the HD markup monotonically increases with q_1, the firm's optimal strategy can be formulated as:

$$(q_1, q_2) = \begin{cases} (\max(T_k, q), \max(q - T_k, 0)) & \text{if } \tilde{q} \geq T_0 \\ (0, q) & \text{otherwise} \end{cases} \tag{3.3}$$

where $T_0 = \frac{(\bar{p}_2 - c_2) - (\bar{p}_1 - c_0)}{c_1}$ represent a cutoff for $\tilde{q}$, above which the firm maximizes HD offering, and otherwise opts for PD. At T_0, the markup from producing HD and PD should be equivalent, i.e., $m_1(T_0) = m_2$ and $\pi(T_0) = \pi(0)$.

(Case 2) Next, we address the scenario wherein the PD markup is negative, represented as $m_2 < 0$. In this situation, the firm's optimal strategy invariably dictates an offering of $q_2 = 0$. Consequently, the profit function can be reformulate as follows:

$$\pi(q_1) = c_1 q_1^2 + (\bar{p}_1 - c_0)q_1 - F(k) \tag{3.4}$$

Then, the firm's optimal strategy is to maximize HD production when its markup is positive:

$$(q_1, q_2) = \begin{cases} (\max(T_k, q), 0) & \text{if } \tilde{q} \geq T_1 \\ (0, 0) & \text{otherwise} \end{cases} \tag{3.5}$$

This strategy aligns with the previous one but introduces a new cutoff, $T_1 = \frac{-(\bar{p}_1 - c_0)}{c_1}$. Notably, the firm will not offer PD, even if HD production is limited by capacity and falls short of meeting the total demand.

3.2. Model Implications and Discussions

In this subsection, we discuss how cost structure, price change and capacity constraint may affect firm's product offering decisions.

3.2.1. **Cost Structure.** In this model, we allow for firm heterogeneity in the cost structures. Specifically, firms with a lower c_0 or a higher c_1 indicate a smaller marginal cost for HD, suggesting they have a competitive advantage in producing HD.

Proposition 3.1. *Firms that have a comparative advantage in HD production are inclined to produce more HD when* $0 < T_0 < T_k$.

The cutoff value T_0 depends on cost parameters. A lower c_0 or a higher c_1 both lead to a decreased cutoff T_0. This effectively lowers the threshold at which the firm selects the product offering $(q_1, q_2) = (\max(T_k, q), \max(q - T_k, 0))$. As a result, firms that have a competitive advantage in HD production tend to select larger HD quantities, holding others constant.

However, this implication is not applicable when $T_0 < 0$ or $T_0 > T_k$. Given the non-negativity of $\tilde{q}$, any situation where $T_0 < 0$ means HD will be produced to its utmost capacity for all firms. Conversely, if $T_0 > T_k$ - indicating HD becomes more profitable only when its production surpasses the firm's capacity constraint - then all firms will abstain from HD production entirely. In such cases, the cost structure will not affect the firm's decisions.

3.2.2. **Price Change.** We then explore the effects of rising PD price from $\bar{p}_2$ to $\bar{p}_2'$ such that $m_2' = \bar{p}_2' - c_2 > 0$. Notice that neither of the following proposition will hold when $m_2' < 0$, that is, the increase in PD price is not sufficient to make PD markup positive.

Proposition 3.2. *Raising PD price leads to a reduction in HD quantity if* $T_0' = \frac{(\bar{p}_2' - c_2) - (\bar{p}_1 - c_0)}{c_1} > 0$.

The cutoff value T_0 depends on prices of both products. An increased PD price elevates the value of T_0, raising the threshold at which the firm selects the product offering $(q_1, q_2) = (\max(T_k, q), \max(q - T_k, 0))$. Consequently, the firm becomes more inclined to adopt the strategy $(q_1, q_2) = (0, q)$, leading to a decrease in HD quantity as the PD price rises. However, this observation will not hold when $T_0' < 0$, that is, the increase in PD price cannot make PD more profitable than HD for all firms.

Proposition 3.3. *In the scenario where* $m_2 = \bar{p}_2 - c_2 < 0$*, raising PD price leads to an increased PD quantity for firms operating near their capacity. Moreover, these firms' HD quantity may remain unchanged and thus results in a larger supply of treatment.*

If the price change leads to a positive PD markup, the firm's strategy shifts from $(T_k, 0)$ to $(T_k, q - T_k)$ when $\tilde{q} > T_k$. Essentially, for firms operating near their capacity, a rise in the PD markup can prompt an increase in PD quantity form 0 to $q - T_k$, while HD quantity remain unchanged. It increases the supply of treatment from T_k to q. This observation does not depend on conditions on the cutoff value.

Proposition 3.4. *Raising PD price prompts firms operating near their capacity to enhance capacity by introducing new affiliated branches in the neighborhood, when the fixed cost* $F(k)$ *is a convex function of capacity* k.

We have established that a firm will optimally select $(q_1, q_2) = (T_k, 0)$ when $T_k < q$ and $m_2 < 0$. In this context, the firm's existing capacity is not sufficient to address the demand. A more favorable profit margin from the treatment could incentivize the firm to expand its capacity, aiming for greater profit opportunities.

Suppose the firm targets to increase its capacity by αk. The fixed cost associated with operating at this enhanced capacity would be $F(k + \alpha k)$. Alternatively, should the firm decide to open a new nearby branch with a capacity of αk, the fixed cost would be $F(k) + F(\alpha k)$. If the condition

$F(k) + F(\alpha k) < F(k + \alpha k)$ holds true, which suggests a convex fixed cost function, the firm would be more inclined to launch a new nearby branch rather than invest further in the existing establishment.

4. Data and Methodology

4.1. Data

We constructed our sample utilizing the Medicare Dialysis Facilities data, annually published by the Centers for Medicare and Medicaid Services (CMS) from 2007 to 2016. This dataset provides comprehensive information about each Medicare-certified dialysis facility, capturing aspects like patient demographics, treatment modalities, and medical conditions. For facility characteristics, such as address, chain affiliation, nonprofit status, and number of dialysis stations, we leveraged the Medicare provider data for dialysis facilities. CMS updates this data quarterly and makes it available online.

TABLE 1. Descriptive Statistics

	Mean	St.Dev.
Panel A. Facility Information		
LDO	0.786	-
For-profit	0.867	-
Freestanding	0.942	-
Providing PD	0.410	-
PD share	0.200	0.219
Utilization rate	0.556	0.276
No. of station	18.219	8.177
No. of staff	14.630	8.791
No. of patient	74.848	47.835
Panel B. Patient Information		
Age	61.751	5.209
Years on ESRD therapy	4.538	1.120
Female	0.444	0.085
Black	0.342	0.299
Hispanic	0.134	0.204
Empolyed 6-months prior to treatment	0.332	0.267
No Pre-ESRD nephrologist care	0.264	0.211
No. of facility	6577	
No. of facility-years	52700	

LDO: chains owning ≥ 20 facilities in more than 1 state.

Table 1 provides a summary of both facility and patient information extracted from the data. Noteworthy variables within this data can be highlighted as follows: Firstly, a predominant majority of the dialysis facilities operate on a for-profit basis and are freestanding, thereby focusing on maximizing profits. Secondly, Large Dialysis Organizations (LDOs) significantly dominate the market, comprising over 78% of the dialysis facilities. Thirdly, on average, each facility is equipped with 18 stations and operates at a utilization rate of 56%.[4] Furthermore, 41% of these facilities offer PD services, with PD patients constituting an average of 20% of the total patient population within these establishments.

4.2. Empirical Strategy

We exploit the differential effects of the Prospective Payment System (PPS) reform on dialysis pricing, contrasting facilities that chose to participate or abstain from the transition period, to employ a difference-in-differences empirical design. As previously noted, while the new payment system necessitates a phased implementation over a four-year period, facilities have had the option to forego the transition and fully adopt the PPS as of 2011. Consequently, facilities that opted out of the transition are more significantly impacted by the price alterations and are thus designated as the treatment group.

A notable identification challenge within this strategy arises from the endogeneity of the opting-out decision. Specifically, the choice to opt-out is intrinsically linked with how facilities fare under the new payment system. Facilities that perform better under the new system are inherently more likely to opt out of the transition. Simultaneously, these facilities may also exhibit a more progressive adaptation to the reform. For instance, facilities with a comparative advantage in PD stand to receive higher compensation under the new system and are generally more equipped to increase their PD offerings. Consequently, the endogeneity embedded in the opting-out decision introduces a selection bias into the analysis.

TABLE 2. Share of Facilities Opting-out-of Transition in 2010

	LDO	Non-LDO
Opting-out	0.997	0.797
Observations	3397	1768

LDO: chains owning $\geq$ 20 facilities in more than 1 state.

In this study, we address selection bias by leveraging the consistent "opting-out" strategy employed by national chains. Table 2 delineates the opting-out decisions for Large Dialysis Organizations (LDO) and non-LDO entities, respectively. The table indicates that, immediately following 2011, LDOs adopted the PPS uniformly across all facilities at the national level. This uniformity implies that the opting-out decision may be perceived as exogenous to individual LDO facilities. As a result, we designate LDO facilities, which abstained from the transition, as the treatment group in order to mitigate selection bias.[5]

[4]We calculate utilization rate by considering the number of HD stations, the number of HD patients, and the facility's operating hours. Specifically, for facilities without a night shift, the utilization rate is given by: $\frac{\text{No. of HD patient}}{6\times\text{No. of station}}$. While for facilities operating a night shift, the formula is: $\frac{\text{No. of HD patient}}{8\times\text{No. of station}}$.

[5]We have excluded the 12 LDO facilities that opted into the transition from our analysis. This is because they may possess unobserved characteristics causing their decisions to deviate from the uniform strategy.

We employ the propensity score matching (PSM) method to address potential disparities between LDO and non-LDO facilities. Specifically, we pair LDO facilities that have forgone the transition with analogous non-LDO facilities that have opted into the transition. We first run a logit model in which the dependent variable is set to one for LDO facilities. Subsequently, we calculate the probability of being LDO for facility j utilizing estimates derived from the logit regression,

$$\text{LDO}_j = \alpha X_j + \epsilon_j. \tag{4.1}$$

The efficacy of this PSM method hinges on the assumption that the difference between LDO and non-LDO facilities is influenced by their observable characteristics. To account for this, we integrate several facility attributes into X_j in equation 4.1. This includes the expected payment ratio under the PPS compared to the current system, aiming to gauge a facility's performance adaptability to the new system. It also factors in elements of a facility's production, such as station count, staff size, and total treatments, as well as their HD and PD offerings. We further consider variables highlighting the facility's profit orientation, like its non-profit status and its affiliation with a hospital. These inclusions aim to comprehensively represent the nuances distinguishing LDO from non-LDO facilities.

We proceed to utilize the predicted probabilities as the propensity scores for matching facilities. Specifically, for each individual LDO facility that has foregone the transition, we employ the nearest neighbor matching within a specified radius, with replacement, to identify comparable non-LDO facilities that have opted into the transition. The balance of covariates is assessed via the standard percentage bias. Our findings indicate that biases are reduced by approximately 80%, falling to less than 5% for nearly all covariates within the matched sample.[6]

Several technical nuances of our matching method merit discussion. Firstly, we constrain the matched patient propensity scores to remain within a caliper radius of 0.047. This caliper size approximates to about 0.25 standard deviations of the propensity score. Although we explored various caliper widths, our results demonstrated robustness across these choices. Secondly, we employ a sampling method for matching that allows replacement, meaning non-LDO facilities can be matched multiple times. This approach was adopted due to the number of LDO facilities being more than eight times that of non-LDO facilities undergoing transition. While aiming to preserve as large a sample size as possible for our analysis, we also assign weights to observations in our empirical exercises to account for this replacement. All LDO facilities are weighted by 1, whereas the matched non-LDO facilities that have opted into the transition are weighted according to their individual frequencies used in the matching process.

Finally, we implement the DID approach with the sample of matched patients. Our baseline model is specified as follows:

$$Y_{j,t} = \theta(LDO_j \times Post_t) + \alpha X_{j,t} + \beta Z_{j,t} + \lambda_t + \mu_j + \epsilon_{j,t} \tag{4.2}$$

Let $Y_{j,t}$ represent the outcome variable for facility j in month t, with outcomes encompassing aspects such as product choice, capacity expansion from new entrants, and patient welfare. LDO_j

[6]Findings from the logit regression can be found in Table xx, Appendix xx. Meanwhile, the balancing test results are presented in Table xx of the same appendix.

acts as an indicator, being set to one if the facility is an LDO and opts out of transition, and zero if it is a non-LDO and opts into transition. $Post_t$ signifies the implementation of the PPS in 2011. $X_{j,t}$ pertains to the characteristics of a facility, inclusive of the modality, station count, and staff size. Meanwhile, $Z_{j,t}$ relates to the characteristics of patients within a facility, which includes factors like age, sex, race, years on ESRD therapy, and share of nursing facility patients. For incident patients, we also embed information pertaining to employment status 6 months prior to treatment and pre-ESRD nephrologist care. λ_t and μ_j are the corresponding fixed effects. The key parameter of interest is θ which measures the effect of price change in LDO facilities.

5. Empirical Results

5.1. Product Choice

TABLE 3. Effects on HD-Share

	DID			PSM-DID		
	(1)	(2)	(3)	(4)	(5)	(6)
LDO × Post	-0.005	-0.008***	-0.007**	-0.020***	-0.013***	-0.012***
	(0.005)	(0.003)	(0.003)	(0.001)	(0.005)	(0.004)
Year FE		Yes	Yes		Yes	Yes
Facility info. ($X_{j,t}$)		Yes	Yes		Yes	Yes
Patient info. ($Z_{j,t}$)			Yes			Yes
Observations	35169	35162	35131	61118	61118	61048
Adjusted R^2	0.479	0.916	0.919	0.490	0.892	0.895

Note: Standard errors in parentheses are adjusted for clustering at the facility level when fixed effects (FE) are added. * $p < .10$, ** $p < .05$, *** $p < .01$

We first evaluate how the facilities adjust their product offerings in response to price changes in our data application. As previously noted in proposition 3.2, a rise in PD price would lead to a reduced HD offering. Table 3 illustrates the policy effect on the facility's ratio of HD patients to the overall patient population. For a comparative perspective, columns (1)-(3) display results employing the DID method with the full sample. Meanwhile, columns (4)-(6) present outcomes using the PSM-DID method with a subset of matched patients.

The matched patient sample reveals a more pronounced and statistically significant impact of price changes on LDO facilities, suggesting that LDO facilities might generally possess a competitive advantage in providing HD, as shown in proposition 3.1. Specifically, we observe that a rise in PD price led to a 1.2 percentage point reduction in HD offerings. This result aligns with proposition 3.2. The effect's magnitude represents approximately 1.3% of the average HD offerings. The relatively modest size of this effect might be attributed to the challenge of switching treatment modalities for prevalent patients who have been undergoing dialysis for several years. Additionally, making significant short-term adjustments in PD and HD offerings can be challenging for facilities.

We next consider the scenario where PD's markup might have been negative prior to the PPS reform. As stated in proposition 3.3, a rise in PD price should primarily boost PD offerings at

TABLE 4. Effects on Incident PD-Share

	Low HD-utilization			High HD-utilization		
	(1)	(2)	(3)	(4)	(5)	(6)
	ln(No.Pt)	WithPD	PD-Share	ln(No.Pt)	WithPD	PD-Share
LDO × Post	-0.025	0.002	-0.000	0.052***	-0.019	0.059***
	(0.050)	(0.033)	(0.025)	(0.016)	(0.036)	(0.013)
Observations	28771	28771	7350	29480	29480	8571
Adjusted R^2	0.896	0.611	0.848	0.947	0.747	0.523

Note: Standard errors in parentheses are adjusted for clustering at the facility level. Facility and year fixed effects are included. Facility and patient characteristics are added. PSM-DID is used.

facilities with high utilization rates. Since these high-utilization facilities face capacity constraints, they would offer PD to accommodate excess demand when PD becomes profitable, resulting in increased supply of dialysis treatments. Therefore, we examine the policy effect on treatment supply in column (1) and (4) of Table 4. Consistent with proposition 3.3, we find a higher PD price led to a 5.2% increase in the number of patients treated in facilities with high utilization rate.

We then present the outcomes related to PD offerings in columns (2)-(3) and (5)-(6) of Table 4. In this analysis, we specifically concentrate on incident patients to eliminate any effects stemming from patients' reliance on previous treatment modalities. We focus on two key outcome variables: the provision of PD (WithPD) and the percentage of incident patients primarily undergoing PD treatment when it is offered (PD-Share). Differentiating between these two metrics helps us understand if changes in PD services arise from extensive or intensive margin.

Our findings indicate that a rise in PD price resulted in a 5.9 percentage point increase in the fraction of incident patients primarily receiving PD treatment, but this was observed solely in facilities with high utilization rates. This impact amounts to 27.7% of the average PD offerings for such patients. However, no significant shifts are observed in the extensive margin, hinting at potential obstacles for facilities to integrate PD treatments if they had not offered them previously.

Next, we investigate the timing of reactions to the price change. This exploration aids in refining our understanding of the effects we have previously identified. To this end, we repeat the empirical exercises in the baseline model (4.2), substituting $Post_t$ with a series of indicators: $Year_h$. Here, h denotes each year in the range from 2007 to 2016.

$$Y_{j,t} = \sum_h \theta_h (LDO_j \times Year_h) + \alpha X_{j,t} + \beta Z_{j,t} + \lambda_t + \mu_j + \epsilon_{j,t} \tag{5.1}$$

We plot the estimated effects in Figure 2. The horizontal axis depicts the timeline, where $+1$ indicates the first year post-policy implementation, and -1 signifies the year just before the policy's introduction. Panel A illustrates the estimated impacts on HD offerings for all facilities, Panel B shows those on patient count, while Panel C details those on PD offerings for facilities with high utilization rate. Prior to the policy's introduction, there weren't significant shifts in product offerings. However, post-PPS reform, there was an immediate decrease of 0.6 percentage

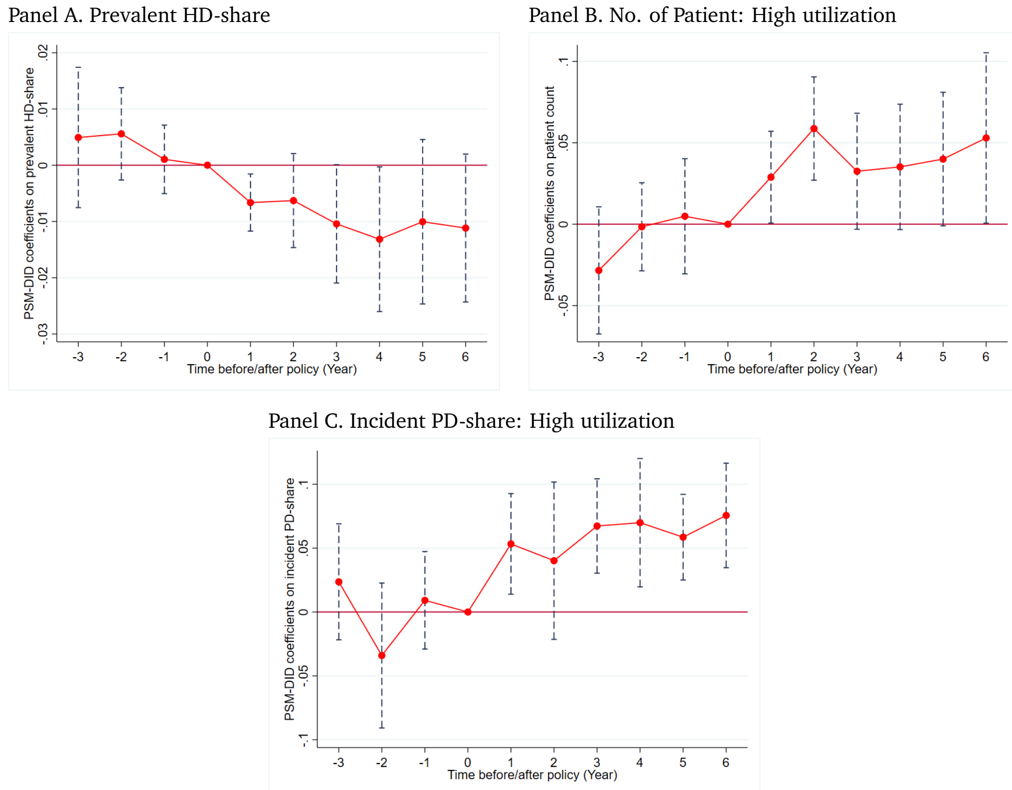

FIGURE 2. Time Trend of Effects on Product Choice

points in HD patient share and a rise of 3% in patient count and 5 percentage points in PD patient share. This trend not only continued but also intensified over the subsequent five years.

5.2. Capacity Expansion

As illustrated in Figure 1, the PPS reform consistently elevated the prices of both dialysis types until 2016. This increased profit margin should motivate capacity-constrained facilities to expand, enhancing their revenue potential.

In general, facilities can expand capacity by either enhancing current facilities or by opening new branches affiliated with the same chain in nearby locations. The strategy behind such expansion often hinges on the fixed cost of operating a facility. For instance, when there is a convex fixed cost structure – where operating one large facility is costlier than running multiple smaller ones nearby – a firm might be more inclined to introduce new operations rather than invest in its current establishments.

We begin by evaluating investments made to existing facilities, showcasing changes in dialysis stations and staff in Figure 3. We observe that net investment trends closer to zero post-price change, with no discernible difference between facilities that opted in or out of the transition. These observations indicate a lack of substantial enhancements to existing facilities. This aligns

Panel A. Net investment in station | Panel B. Net investment in staff

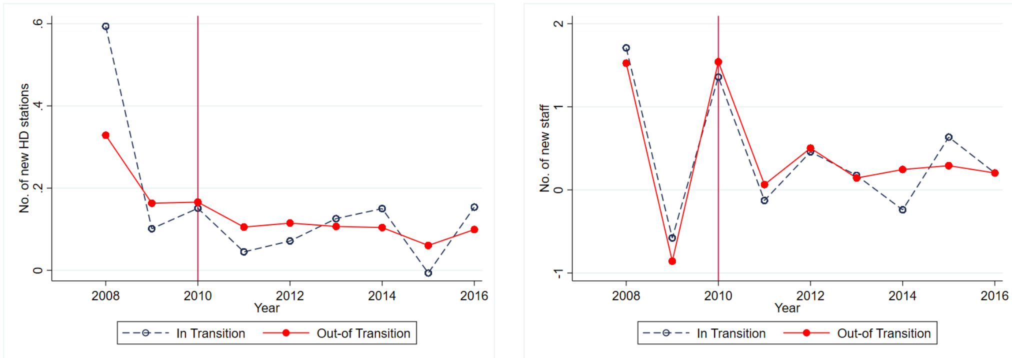

FIGURE 3. Trends of Net Investment in Input

Panel A. Providing PD or not | Panel B. Share of PD patients if provided

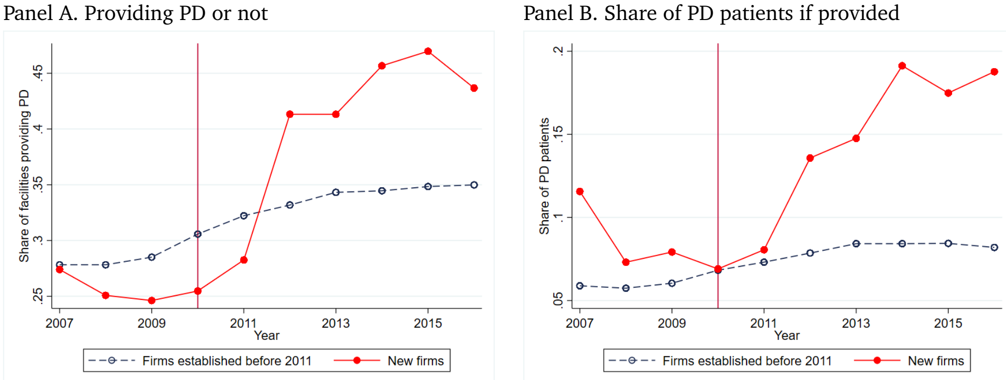

FIGURE 4. Trends of Product Choice for Incident Patients

with the characteristics of the dialysis market, where adding stations to the existing facility demands extra space, maintenance, and staff – resources that tend to have relatively inelastic supply.

We next contrast the product choices of facilities established prior to the PPS reform with those inaugurated afterward. Panels A and B of Figure 4 depict the trends in PD provision and the share of PD patients, respectively. Notably, newer facilities appear more agile in tailoring their product offerings in light of price shifts. We observe both extensive and intensive margin increases in PD offerings beginning one year post-PPS reform, a trend that continues for the subsequent four years. These insights suggest that companies are launching new facilities as a strategy to adapt to price changes, leveraging the greater flexibility new establishments offer in adjusting product choices compared to their pre-existing counterparts.

We finally explore the potential of facilities broadening their capacity by establishing new branches in the neighborhood. We also factor in market variations by differentiating between large metro and small metro areas.[7] The results are presented in Table 5. Our findings indicate

[7]We categorize markets by Urban Influence Codes. "Large metro" encompasses areas with populations over 1 million and micropolitan regions adjacent to these large metros. Conversely, "Small metro" covers areas with populations under 1 million and micropolitan regions neighboring these smaller metros.

TABLE 5. Effects on 10-mile Entrants with Both Modalities

	Large-Metro			Small-Metro		
	(1)	(2)	(3)	(4)	(5)	(6)
	All	LowUT	HighUT	All	LowUT	HighUT
LDO × Post	0.009	0.007	0.023**	0.011***	0.010***	0.019**
	(0.006)	(0.006)	(0.010)	(0.003)	(0.003)	(0.008)
Observations	33631	22505	10878	21955	17240	4572
Adjusted R^2	0.122	0.184	0.234	0.113	0.137	0.147

Note: Standard errors in parentheses are adjusted for clustering at the facility level. Facility and year fixed effects are included. Facility characteristics are added. 75 percentile is used as the threshold for high and low utilization.

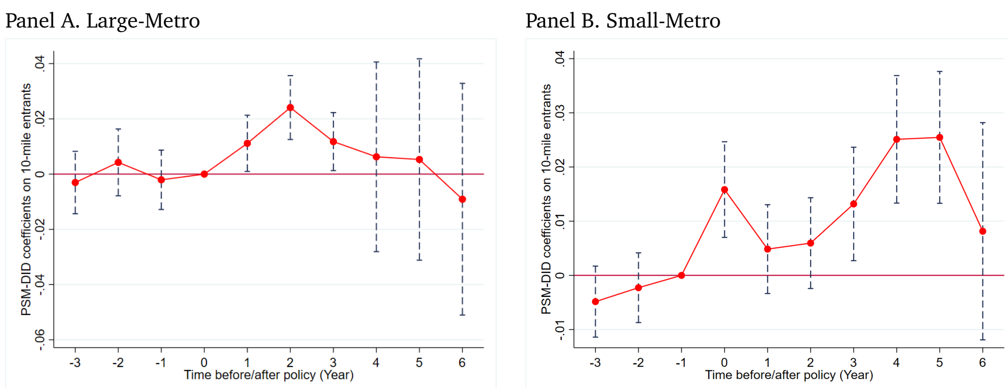

FIGURE 5. Time Trend of Effects on New Entrants

that high utilization facilities, within both market types, experience the establishment of new affiliated branches within a 10-mile radius. This aligns with proposition 3.4.

We plot the trends of these effects in large and small metro areas in Panels A and B of Figure 5, respectively. The responses to price changes, in terms of new entries, differ markedly between these two market types. For large metro facilities, there was an uptick in new entries immediately after the reform's inception, but this surge faded three years later. In contrast, small metro facilities saw an increase in new entrants a year prior to the PPS implementation, and this trend continued for the subsequent five years.

5.3. Patient Welfare

We have demonstrated how firms adjusted their product offerings and capacity expansion strategies in response to the price changes brought about by the PPS reform. However, the impact of these changes on patient welfare remains to be explored. In this subsection, we assess patient welfare by examining changes in their employment status and mortality rates.

Patients with ESRD often grapple with employment challenges. The combined medical and logistical hurdles make it arduous for dialysis patients to maintain consistent employment. However, those who initiate PD typically exhibit higher employment rates compared to their counterparts starting on HD. Even when accounting for employment rates six months prior to the onset of

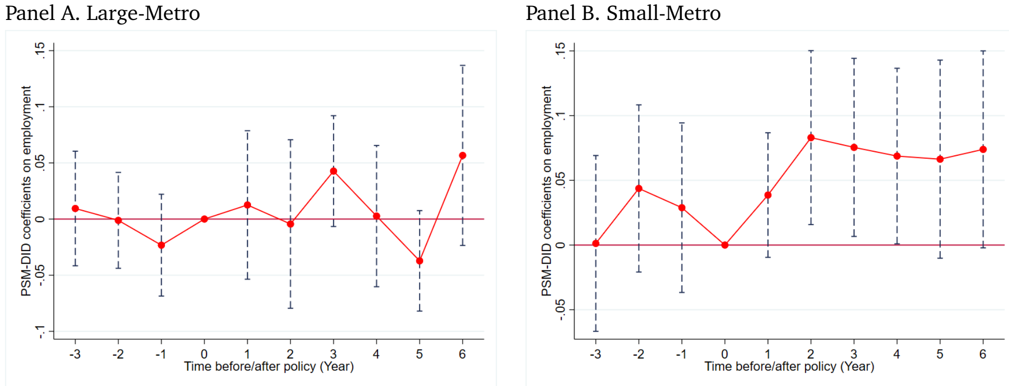

FIGURE 6. Time Trend of Effects on Employment

ESRD, PD patients are more likely to remain employed upon beginning dialysis. This hints at the scheduling flexibility and autonomy associated with PD potentially aiding patients in sustaining their employment.

TABLE 6. Effects on Current Employment

	Large-Metro			Small-Metro		
	(1) All	(2) LowUT	(3) HighUT	(4) All	(5) LowUT	(6) HighUT
LDO × Post	0.016	-0.028	0.016	0.033**	0.006	0.049***
	(0.015)	(0.029)	(0.018)	(0.015)	(0.036)	(0.018)
Observations	32589	8396	23934	21165	4986	16028
Adjusted R^2	0.645	0.729	0.624	0.614	0.611	0.635

Note: Standard errors in parentheses are adjusted for clustering at the facility level. Facility and year fixed effects are included. Patient characteristics, incident PD-share, insurance type, and county population and per capita income are added. 25 percentile is used as the threshold for high and low utilization.

We present the effects of price change on the employment of incident patients at initiation of dialysis in Table 6. To provide a comprehensive view, we incorporate factors such as patients' insurance type, as well as county population and per capita income, which can shed light on the nature of employment opportunities. Our analysis reveals that a rise in PD price corresponded to a 3.3 percentage point increase in the employment rate of patients in small metro areas. This change represents approximately 15.9% of the average employment rate. Notably, this impact predominantly stems from facilities with high utilization rates.

In Figure 6, Panels A and B illustrate the trends of these effects for high utilization facilities in large and small metro areas, respectively. In large metro areas, the employment rates remained relatively stable. However, in smaller metro areas, there was an immediate uptick in employment one year after the PPS reform, a trend sustained for the next five years. The disparities between these markets might reflect variations in job types. For instance, in large metro areas, sustaining employment could be challenging for patients needing extended treatments, irrespective of the treatment modality.

TABLE 7. Effects on Mortality

	Large-Metro			Small-Metro		
	(1)	(2)	(3)	(4)	(5)	(6)
	All	LowUT	HighUT	All	LowUT	HighUT
LDO × Post	0.020	0.036	0.012	-0.006	0.001	-0.007
	(0.015)	(0.026)	(0.008)	(0.011)	(0.019)	(0.012)
Observations	33585	15209	18075	21933	11344	10413
Adjusted R^2	0.589	0.570	0.711	0.256	0.279	0.344

Note: Standard errors in parentheses are adjusted for clustering at the facility level. Facility and year fixed effects are included. Facility and patient characteristics are added.

Finally, inadequate dialysis can compromise treatment efficacy and potentially reduce life expectancy. Thus, we delve into the potential impact of price changes on patient mortality, with our findings detailed in Table 7. We do not observe any significant impact of price changes on mortality in all specifications. This implies that the shift from HD to PD following the PPS reform doesn't adversely affect patient health outcomes.

6. Conclusion

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