# Performance scores and Strategic Choices of Kidney Transplant Centers*

Han Ng†

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**Abstract**

Medicare introduced the Conditions of Participation (CoP) in 2007. This policy examines a transplant center's performance every six months. If observed deaths exceed expected deaths by 50%, Medicare flags the center for poor performance and threatens decertification. I analyze the effect of this policy using a difference-in-differences design. The key assumption is that centers with a low observed-expected (OE) death ratio are unaffected by CoP's introduction. I show that transplant centers respond to the threat of punishment by rejecting transplants as the OE ratio approaches the CoP threshold, 1.5. This rejection pattern occurs more often for medium and high-risk transplants and low-volume transplant centers. Secondly, I found no evidence that CoP reduced the post-transplant death rate across low/medium/high-risk transplants. My results suggest that strategic behavior among transplant centers is more widespread than previously thought.

*JEL* codes: I11, I18, L38

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†Department of Economics, Pennsylvania State University, Kern Building, University Park, PA 16802, hln14@psu.edu.

# 1 Introduction

Centers for Medicare and Medicaid Services (CMS) strives to enact policies that protect patient health and safety. One prominent effort to achieve this is the Conditions of Participation (CoP) program, which requires hospitals to report outcomes of patient operations every six months. Medicare uses this report to monitor and penalize poor performers after suitable risk adjustments. An advantage of this program is that it incentivizes improving service quality and patient outcomes. However, one drawback is hospitals may ignore clinical guidelines for proper care and ration health care under the guise of quality.

This paper examines a section of the U.S. healthcare market influenced by CMS CoP policy, the deceased donor kidney transplant program. Under CoP, transplant centers submit the outcomes of their transplanted patients to CMS every six months. If observed deaths exceed expected deaths by 50%, CMS flags centers for poor performance. Since CMS is the primary insurer for kidney transplants, such a ruling can close a transplant program (Hamilton, 2013). In this paper, I show that the threat of punishment from CoP affects a transplant center's behavior even when their observed-expected (OE) death ratio is below 1.5.

Previous reports suggest that the threat of government penalties has made surgeons reject kidney offers when their performance deteriorates. For instance, a 2012 *New York Times* article described a conversation with the director of Columbia Hospital: "... if you have had a couple of bad outcomes recently you say, 'Well, why should I do this?'... You can always find a reason to turn organs down."(Sack, 2012).

Based on the anecdotal evidence referenced above, the threat of punishment seems to induce transplant centers to reject patient-kidney offers. To cleanly link it to Medicare's CoP policy, however, we must first overcome several empirical challenges. First, we do not observe the many unobservable factors influencing a center's behavior, such as center quality. I use a difference-in-difference research design to account for unobserved quality. Using time-series

variation and within-center variation, I find that transplant centers are less likely to accept a kidney offer as their OE scores approach the CoP threshold within a six-month period.

Furthermore, if centers reject transplants solely for clinical reasons and not performance concerns, we would expect a uniform distribution of acceptance over the range of OE scores; instead, I observe a decrease in the likelihood of accepting a kidney offer as the OE scores approach the CoP threshold. The strong association between the OE scores and the likelihood of accepting a kidney offer suggests that centers strategically reject transplants to avoid being flagged for poor performance.

Another threat to identification is that UNOS offers the kidney to multiple patients simultaneously to avoid organ spoilage. But only record the acceptance of the final recipient. UNOS records the remaining acceptances as rejections. This misclassification is problematic because we might misinterpret some genuine acceptance as declining the kidney offer. I overcome this issue by relying on the top-ranked patient of every kidney offer whose final response is independent of other patients' decisions.

My paper contributes to the literature on the effect of CoP on transplant center behavior. Hamilton (2013), Schold et al. (2013), and White et al. (2015) show that transplant centers change their behavior after being flagged for poor performance. But they only study the behavior of the 10% of transplant centers that were flagged. I show that all transplant centers exhibit strategic behavior and that incentive increases when they approach the threshold. I highlight how a policy aimed at improving quality of care resulted in hospitals cherry-picking patients.

# 2 Background on Deceased Donor Kidney Transplant

A patient diagnosed with end-stage renal disease (ESRD) has two options: dialysis or kidney transplant [1]. Dialysis requires two to three treatments a week. Sessions are time-consuming; patients can be infected if nurses do not disinfect stations appropriately after use. These disadvantages make kidney transplants the cheaper and preferred option (Matas and Schnitzler, 2004). In this study, I focus exclusively on deceased donor kidney transplants that account for 60% of all kidney transplants in the U.S. (AKF, 2003)[2]. This section describes how patients get on the waitlist, how kidneys are allocated, details of Conditions of Participation (CoP), and trends in kidney transplant.

## 2.1 Registration at Transplant Centers

The physician refers patients to a local transplant center when they have kidney failure. The center's selection committee will evaluate if the patient is eligible for a kidney transplant (i.e., started dialysis or had a glomerular filtration rate (GFR) below 20mL per minute). The evaluation process may take up to months. The transplant center will then register accepted patients on the deceased donor waitlist and upload important information such as immunological profile, health conditions, and factors to compute priority into the UNet system(AKF, 2003).

## 2.2 Kidney Allocation and Transplant Process

The Organ Procurement and Transplantation Network (OPTN) designs and administers the deceased donor kidney allocation process. Hospitals upload a deceased donor's medical

[1]Dialysis is a treatment that removes waste and excess water from the blood. There are two types of dialysis: hemodialysis and peritoneal dialysis.

[2]Kidney exchange is an alternative way of getting a kidney transplant (Roth et al., 2004). However, patients need a willing living donor, which can be logistically cumbersome. Hence, kidney exchange is considered a different program to deceased donor kidney transplant.

history and organ condition into UNet when brain or cardiac death is imminent. The system identifies biologically compatible patients and ranks them according to their priority order. Many factors contribute to the order, including, but not limited to, blood type, duration on the waitlist, where the patient lives, and, in some instances, weight and size compared to the donor.

UNet simultaneously informs all centers of their patients compatible with the kidney to maintain organ viability [3]. Centers have 1 hour to indicate their decision for all the patients who received a kidney offer. Patients are only informed if the transplant center accepts the kidney offer[4]. The kidney offer goes to the highest priority patient accepted by the center. Even though there might be multiple acceptances for a kidney, UNet only records the acceptance of the final recipient in the data. The remaining acceptances are recorded as declining the kidney offer. This is problematic because we might misinterpret some genuine acceptance as declining the kidney offer. I discuss how I handle this in Section 3.

UNet removes the patient from the waitlist 24 hours after a successful transplant. In the case of a failed transplant or declining a kidney offer, UNet returns the patient to the waitlist without any penalty on their priority for the next kidney offer (OPTN, 2023).

Centers discharge transplant patients within 3 - 5 days. Patients are offered immunosuppressive drugs to prevent organ rejection. Patients are required to visit the transplant center for regular check-ups. The transplant center will inform UNet if the patient dies within 365 days after the transplant (OPTN, 2023).

[3]Centers are informed about their patient's ranking but do not observe the identity of other patients.

[4]Not every patient is informed of the kidney offer due to the transplant center's tight deadline. Furthermore, there are no regulations mandating transplant centers to notify patients of their kidney offers.

## 2.3 Conditions of Participation (CoP)

Before July 2007, OPTN was the primary organization responsible for monitoring transplant centers' performance [5] but only twice recommended to the Department of Health and Human Services to remove a transplant center's certification (Stith and Hirth, 2016). Center for Medicare and Medicaid Services (CMS) became concerned that the lack of severe penalties for poor performance may have led to a decline in the quality of kidney transplants. As stated in the Final Rule establishing the increase in CMS oversight:

> " The OPTN generally takes a collegial approach and assists the center in improving their performance, while we generally take a regulatory approach which sometimes may lead to termination ..." (CMS, 2007)

CMS introduced CoP in July 2007 to reduce post-transplant deaths and mitigate patient-kidney selection. Transplant centers must submit the 1-year deaths of all their transplant operations in the past 2.5 years to the Scientific Registry of Transplant Recipients (SRTR) on the first week of every January and July. Figure 1 illustrates an example of a 2.5-year rolling cohort. The OE score released in July 2011 (red box) consists of transplants from January 2008 to July 2010 (red line). The same rule applies to the OE score released in Jan 2011 (black box and line).

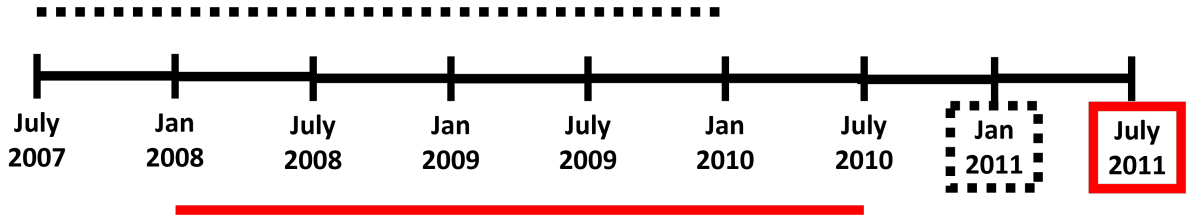



Figure 1: An illustration of the 2.5-year rolling cohort for CoP

SRTR measures a center's performance by calculating the OE ratio: the ratio between observed failures (O) and expected failures (E)[6]. A transplant center has poor performance

[5] The primary performance metric is the number of patient survival post-transplant.
[6] A failure is if the patient dies within 365 days after the transplant.

if all of the following criteria are satisfied:

1. OE ratio = $\frac{\text{Observed failures (O)}}{\text{Expected failures (E)}} > 1.5$

2. 1 sided p-value = Pr(O-E$\geq$ 0) $< 0.05$

SRTR estimates a Cox proportional hazards model using all the 2.5-year rolling cohorts submitted by each transplant center. The model includes patient, donor characteristics, and donor-recipient match characteristics. The model excludes transplant center characteristics. An example is available in Figure 13 in the Appendix. The expected failure rate of a transplant center is then the sum of the expected failure rate of each patient-kidney pair in its 2.5-year rolling cohort. SRTR updates the list of variables in the model every six months (Dickinson et al., 2008). The 1-sided p-value describes the probability that the observed difference is due to chance[7]. SRTR calculates the p-value by comparing the differences across all transplant centers in the U.S., accounting for the number of transplants by each center. The 5% critical value highlights Medicare's tolerance of misclassifying a center as underperforming.

Medicare flags a transplant center for poor performance if it meets all the conditions above. Medicare then implements a data drive quality assessment and performance improvement (QAPI) system. If the transplant center is flagged again within the next 30 months, it risks losing its program certification and Medicare funding.[8].

## 2.4 Trends in Kidney Transplant

Figure 2 illustrates the significant change in the deceased donor market from 2003 - 2012. First, the post-transplant death rate (solid lines) has dropped by five percentage points.

[7]The p-value calculation does not consider cases when expected failures exceeds observed failures.

[8]However, most transplant centers have 210 days to appeal that their poor performances are due to mitigating circumstances.

Second, total transplants (dash lines) increased from 2003 to 2007 and stagnated before rising again in 2010. Although these patterns coincide with the CoP's implementation, many factors can also explain the trends. For instance, medical technology is improving over time. Surgeons are improving at treating and identifying bad transplants. A routine before and after CoP comparison of the deceased donor market is insufficient to determine the causal effect of CoP. Hence, it motivates the difference-in-differences research design in section 3.

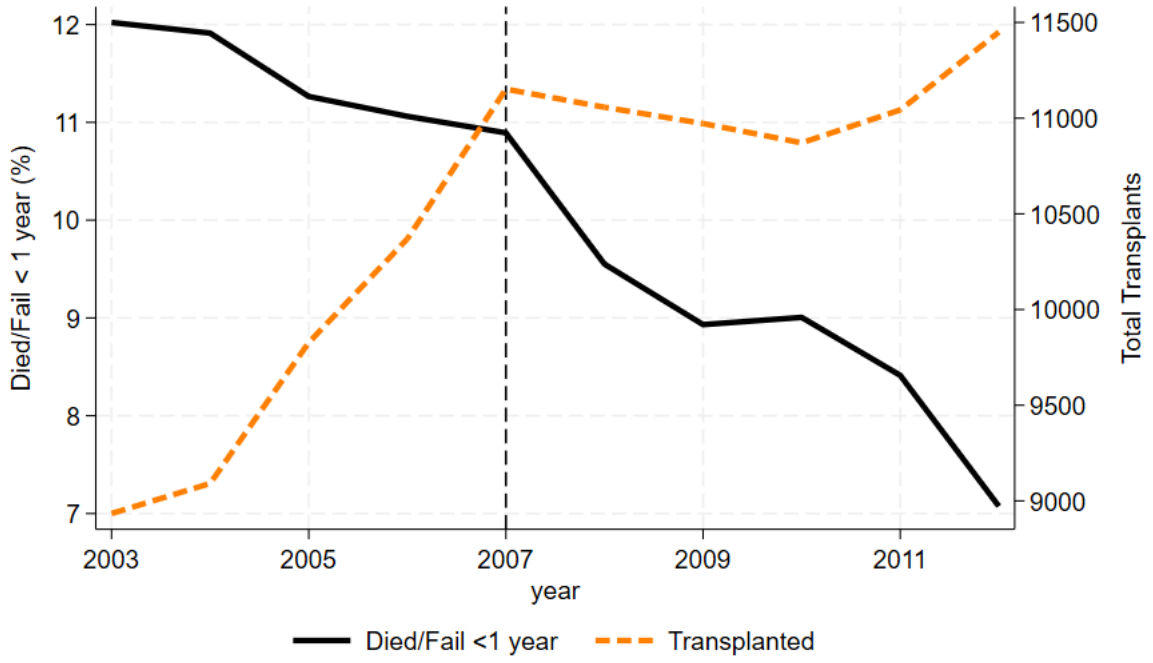



Figure 2: Post-transplant death rate and total transplants over 2003 - 2012. The vertical dash line indicates the introduction of CoP.

# 3 OE Scores and Research Design

A primary contribution of my paper is to analyze how the CoP changed transplant center behavior. The micro-level data I use in my analysis provides essential information on patient and kidney risk profiles. This lets me observe changes in a transplant center's strategic choices and how they affect patient outcomes. In this section, I describe my data, research design, and how to construct OE scores.

## 3.1 Data Sources

I draw information on the universe of patient kidney offers from the OPTN database from 2003 to 2012. Our primary data is the Potential Transplant Recipient (PTR) file. It contains all kidney offers made to a patient on the waitlist and documents when the kidney offer arrived, the final decision, reasons for rejection (if applicable), and the patient's ranking on the waitlist.

My second dataset is the Standard Transplant Analysis and Research (STAR) file managed by OPTN. It contains information on the patient's and deceased donor's demographics, health conditions, and immunological profile.

My third dataset is the center-specific report (CSR) file. SRTR publishes CSR every six months, in the first week of January and July. Each CSR details the transplant center's performance and activity within six months[9]. CSR also contains the statistical model and variables Medicare uses to calculate a transplant's expected death rate. We use this information in Section 3.2 to construct OE scores between intervening kidney offers of transplant centers. In the Appendix, we provide examples of CSR in Figure 12 and 13. I merged the three datasets to conduct our analysis at the patient-kidney offer level.

[9]For example, CSR reports the number of transplants, the number of patients on the waitlist, and the number of patients removed from the waitlist due to death.

## 3.2 Constructing OE Scores $OE_{ct(k)}$

CSR reports the transplant center's final OE score in the first week of January and July. I construct a measure of OE scores between intervening kidney offers to analyze the threat of punishment on center behavior. We assume transplant centers use the latest CoP statistical model to construct their OE score whenever they receive a kidney offer. We call this the prevailing OE score, $OE_{ct(k)}$ for center $c$ when kidney $k$ arrives on day $t$. This measure was motivated by conversations with surgeons who shared how their transplant center monitors performance after CMS introduced CoP[10]. $OE_{ct(k)}$ is dynamic and increases whenever a past transplant fails between intervening kidney offers for the center.

Figure 3 presents the pre and post-CoP density plot for $OE_{ct(k)}$. I want to highlight two patterns in this figure. First, the post-CoP density (solid lines) has more weights in the $[1, 1.5)$ region than the pre-CoP density (dashed line). I interpret this as suggestive evidence that transplant centers are more likely to reject transplants when $OE_{ck(t)}$ is close to 1.5, resulting in some form of "bunching" in the post-CoP period. Secondly, there is not a lot of weight in the $[2, 3)$ region for both periods. I interpret this as most transplant centers doing their best to ensure they do not have too many unexpected deaths.

### 3.2.1 An example

Figure 4 illustrates how $OE_{ct(k)}$ is constructed for a kidney $k$ arriving at center $c$ on $t$ =April 28, 2010. If this offer is accepted, it will be a part of the 2.5-year rolling cohort for center $c$'s July 2011 CSR. The 2.5-year rolling cohort in July 2011 consists of all transplants from January 2008 to July 2010. Thus, I use the January 2010 CSR (white arrow) and all the transplant outcomes from January 1, 2008, to April 27, 2009 (red solid line) to construct $OE_{ct(k)}$.

[10]CSR was only available after January 2007. So I use the January 2007 CSR to construct $OE_{ct(k)}$ for the pre-CoP sample.

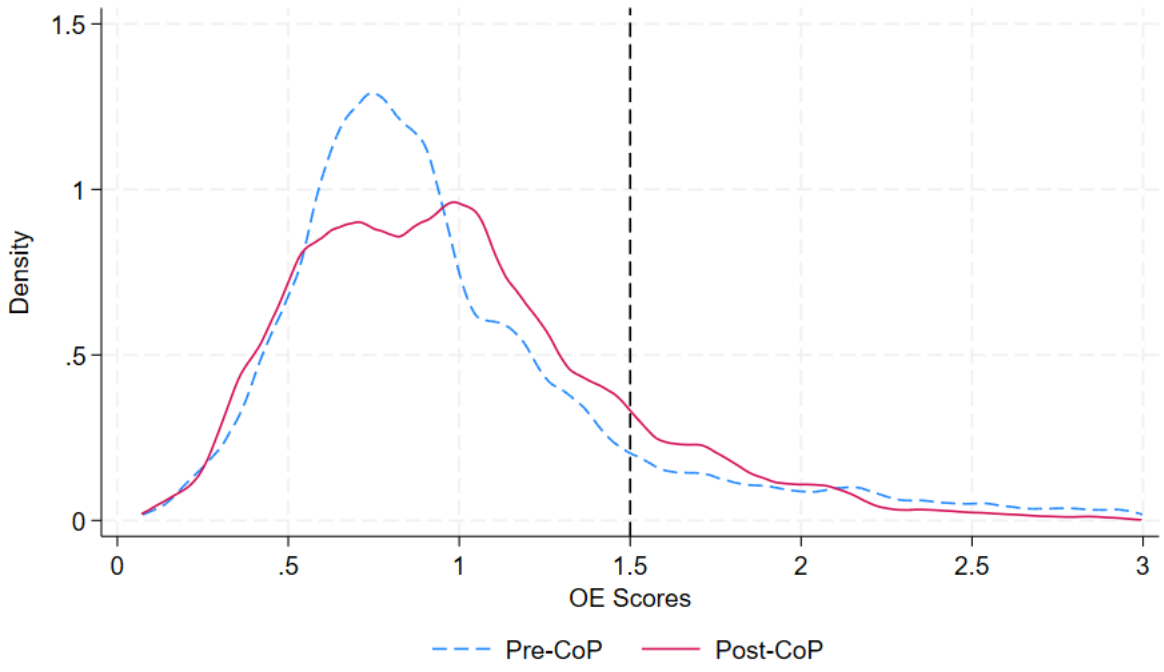



Figure 3: Kernel density estimate of $OE_{ct(k)}$. The vertical dash line is the CoP threshold.

If a patient is alive and has not met the 1-year post-transplant mark (red dashed line), I assume centers regard this as a successful transplant and do not consider the patient in observed deaths. This assumption is motivated by conversations with surgeons who shared that they generally do not count patients who are alive and have not met the 1-year post-transplant mark as failures. Finally, we calculate $OE_{ct(k)}$ by taking the observed and expected-death ratio.

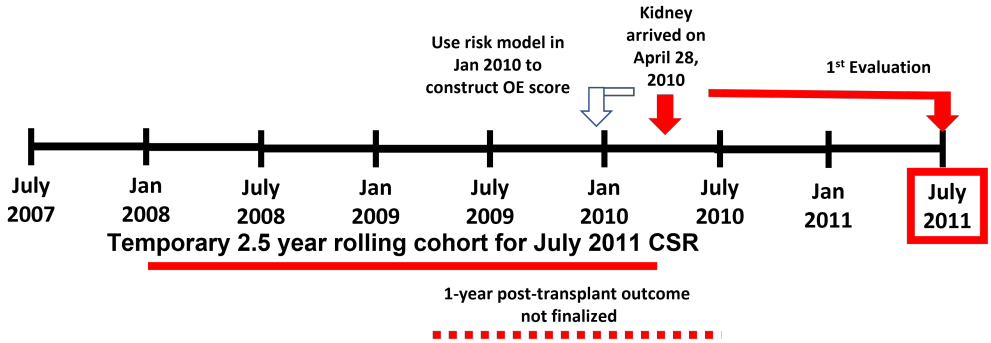



Figure 4: An illustration of how $OE_{ck}$ is constructed

## 3.3 Research Design

My main research design is a difference-in-differences framework[11]. I compare the change in acceptance behavior of transplant centers pre and post-CoP according to their OE scores $OE_{ct(k)}$. My data described in Section 3.1 runs from 2003 to 2012. For kidney offers that arrive after July 1, 2007, we have $CoP_k = \mathbb{1}\{\text{kidney } k \text{ arrives after July 1, 2007}\}$ to indicate the post-CoP period.

I categorize patient-kidney offers based on $OE_{ct(k)}$. The assumption is transplant centers with $OE_{ct(k)}$ far from 1.5 are unlikely to exceed 1.5. Therefore, their incentives are the same before and after CoP. These observations are the control group. Conversely, transplant centers with $OE_{ct(k)}$ close to 1.5 face different incentives before and after CoP. These are in the treatment group. Our main empirical specification defines the control group as $T_0 = \mathbb{1}\{OE_{ct(k)} < 0.5\}$. We divide the remaining $OE_{ct(k)}$ into groups of 0.1, forming 14 treatment groups. For example, a treatment group $m$ is $T_{m(ct)} = \mathbb{1}\{OE_{ct(k)} \in [m - 0.1, m)\}$ for all $m \in \{0.6, 0.7, ...1.9\}$.

My main empirical specification is:

$$\begin{aligned} Accept_{ickt} = \alpha_0 + \sum_{m=0.6}^{1.9} \alpha_m \times T_{m(ct)} + \sum_{m=0.6}^{1.9} \beta_m \times T_{m(ct)} \times CoP_k \\ + \delta_{w(t)} + \gamma_c + \gamma_1 X_i + \gamma_2 Z_k + \varepsilon_{ickt} \end{aligned} \tag{1}$$

where $Accept_{ickt}$ indicates if center $c$ accepted kidney $k$ for patient $i$ on day $t$. $\delta_{w(t)}$ is a six-month fixed effect that captures how acceptance pattern changes over time. $\gamma_c$ is center fixed effects that capture time-invariant characteristics within a center. $X_i$ and $Z_k$ are characteristics of patient $i$ and kidney $k$ respectively. $\varepsilon_{ickt}$ is the idiosyncratic error term, capturing exogenous logistical shocks that affect the center's acceptance decision. For

[11]CMS introduced CoP for all centers on July 1, 2007. Hence, my analysis does not apply the insights from the literature on staggered difference-in-differences (Callaway and Sant'Anna, 2021).

example, a center may have a shortage of surgeons on a particular day, or the center could not contact the patient within the 1-hour deadline.

Our parameter of interest is $\beta_m$. It measures the differential impact of CoP on the acceptance behavior of the treatment group $m$ relative to the control group. We expect $\beta_m$ to be negative if CoP affects the acceptance behavior of transplant centers.

There are two potential threats to identification. First, UNOS offers the kidney to multiple patients simultaneously to avoid organ spoilage and only records the acceptance of the final recipient. The remaining acceptances are recorded as rejections. This misclassification is problematic because we might misinterpret some genuine acceptance as declining the kidney offer. I address this issue by relying on the top 2 patients of every deceased donor because humans have two kidneys. Hence, the decisions of the top 2 patients are independent of the decisions of other patients.

Secondly, there might be concerns about anticipatory behavior before CoP. For instance, transplant centers may reject more transplants before CoP to give themselves a good head-start. I address this by dropping observations from 2007 in my pre-CoP sample.

Table 1 compares patient covariates for the top 100 patients of each deceased donor and my subsample. From Panel A, my subsample spent more time on the waitlist. This is unsurprising because time on the waitlist is a criterion for getting a higher priority in a kidney match. Since they spend more time on the waitlist, they are also less likely to have a working income or education. Furthermore, Panel B suggests patients in my subsample are healthier than the full sample.

All in all, there are differences between my subsample and the full sample. However, the richness of the STAR data lets me control for clinically relevant covariates in my regressions.

Table 1: Patient covariates summary statistics

| | Top 100 patients | Top 2 patients + no 2007 |
|---|---|---|
| **Panel A: Medical Information** | | |
| Years on Waitlist | 3.177 | 4.602 |
| | (2.575) | (4.356) |
| Age | 51.85 | 48.19 |
| | (13.60) | (15.07) |
| % White | 41.54 | 45.25 |
| | (49.28) | (49.77) |
| % Have working income | 18.51 | 15.87 |
| | (38.84) | (36.54) |
| % Only High School | 66.28 | 64.06 |
| | (47.28) | (47.98) |
| % Completed Uni. | 17.20 | 15.58 |
| | (37.74) | (36.26) |
| % Medicare as primary insurer | 59.57 | 60.28 |
| | (49.08) | (48.93) |
| **Panel B: Demographics** | | |
| Body Mass Index (B.M.I) | 27.87 | 26.82 |
| | (5.800) | (5.940) |
| Expected Post Transplant Survival | 65.99 | 69.85 |
| | (28.94) | (29.24) |
| % Diabetic | 34.95 | 26.51 |
| | (47.68) | (44.14) |
| % On dialysis | 73.34 | 69.99 |
| | (44.22) | (45.83) |
| Observations | 2242824 | 113009 |

mean coefficients; sd in parentheses

$^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$

### 3.3.1 Summary statistics for treatment groups $T_{m(ct)}$ and $T_{0(ct)}$

Next, I describe the treatment $T_{m(ct)}$ and control $T_{0(ct)}$ groups. $OE_{ctk}$ increases whenever a past transplant fails between intervening kidney offers for the center. In Figure 5, 20% of centers do not switch between treatment groups in a six-month period. The remaining 80% of centers switch between treatment groups at least once.

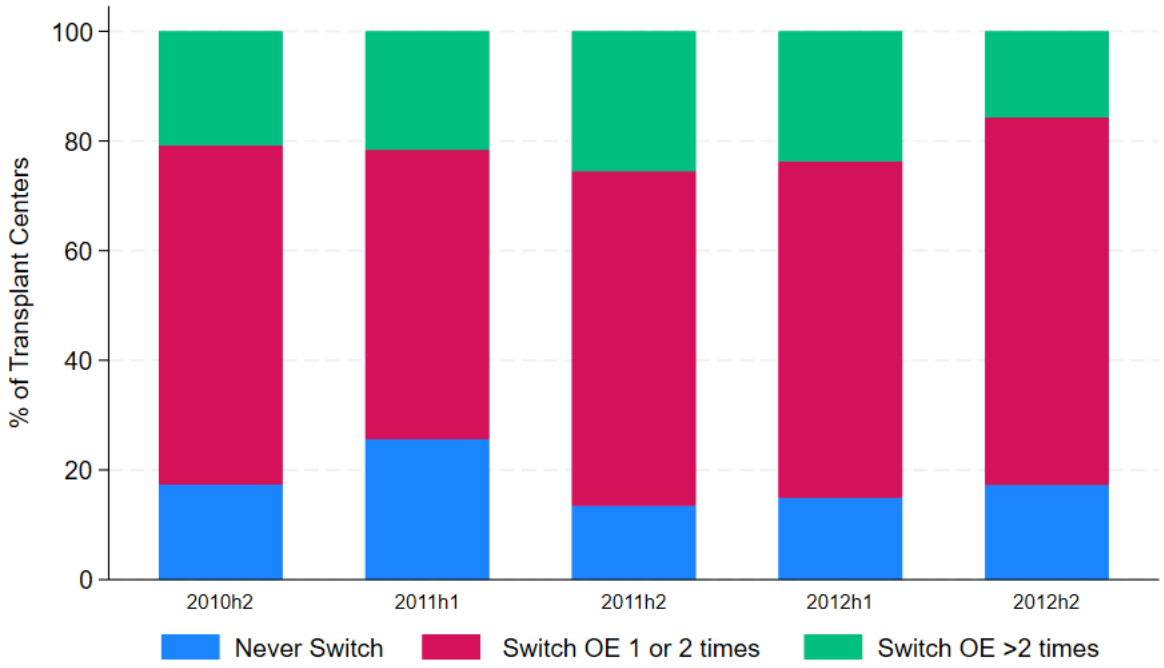
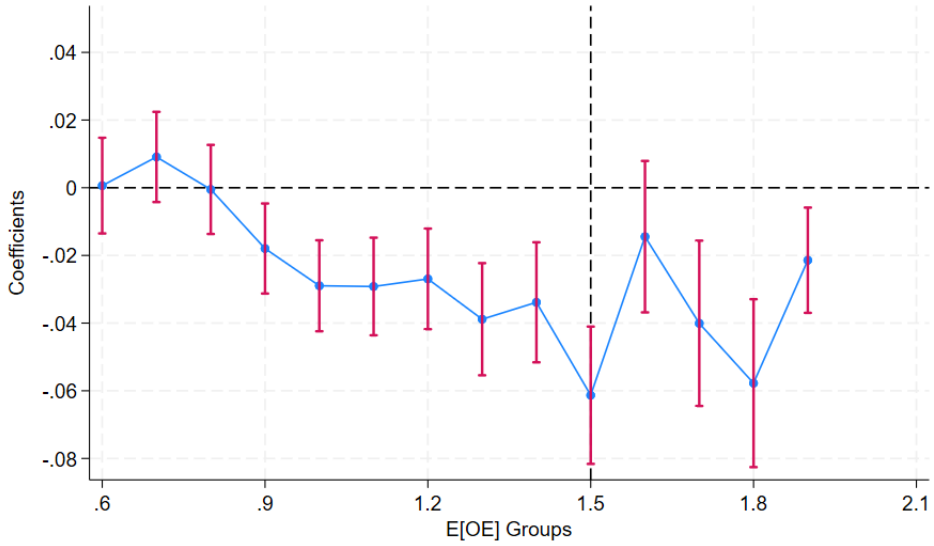



Figure 5: How often do transplant centers switch between treatment groups for selected six-months period.

# 4 Results for acceptance behavior

I plot the full range of $\beta_m$ from equation 1 in Figure 6. Transplant centers are less likely to accept a kidney offer as their OE score approaches the CoP threshold.The results suggest that transplant centers consider their OE scores when accepting the kidney offer for the patient and are less likely to conduct transplants. A similar pattern persists even as we cross the threshold.

Figure 6: Acceptance behavior across different $OE_{ck}$ groups




*Note:* The figure shows the acceptance behavior for each OE group $m$ after CoP. We plot the OLS estimates and 95% confidence intervals of the coefficients $\beta_m$ from equation 1. We cluster standard errors at the center level.

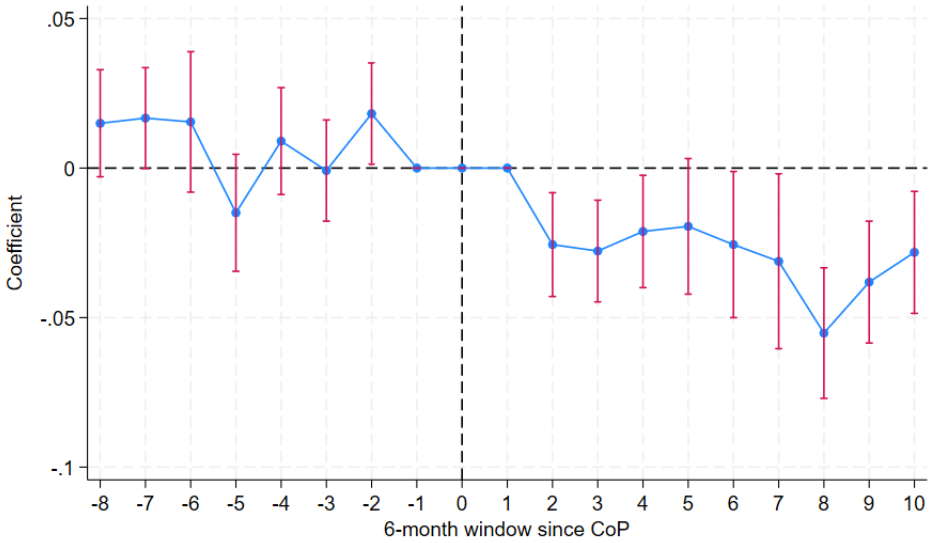
To interpret this estimate as the causal effect of CoP, we assume that CoP created a discontinuous change in center behavior and that any trends between the treatment and control groups are parallel in the absence of CoP. To support the parallel trends assumption, we

estimate the following events-study specification:

$$Accept_{ick} = \alpha_0 + \alpha \times T_{-0} + \sum_{s=-8, s\neq -1}^{10} \beta_{t-s} \times T_{-0} \times \delta_{t-s} + \sum_{s=-8, t\neq 1}^{10} \delta_{t-s} + \gamma_1 X_i + \gamma_2 X_k + \varepsilon_{ik} \tag{2}$$

We group all the treatment groups together and define $T_{-0} = \mathbb{1}\{OE_{ck} \geq 0.5\}$. The coefficient $\beta_{t-s}$ measures the differential impact of CoP on the acceptance behavior of the treatment group relative to the control group. $s$ measures the six-month periods relative to CoP implementation in July 2007. We plot the $\beta_{t-s}$ coefficients in Figure 7 and find no evidence of pre-trends in acceptance behavior.

Figure 7: Acceptance behavior dynamic for $T_{-0}$




*Note:* The figure shows OLS estimates and 95% confidence intervals of the coefficients $\beta_t$ form equation 2. We plot all coefficients relative to when CMS introduced CoP (t=0). We cluster standard errors at the center level.

### 4.0.1 Differences by risk profiles

Next, I extend the baseline specification to investigate if the effect of CoP on acceptance behavior differs by risk profiles. In my sample, I use information on patient risk to categorize patients into low and high risk. I follow a similar procedure for kidneys. Then, I group patient-kidney offers into low, medium, and high-risk transplants [12]. The regression equation in this case is:

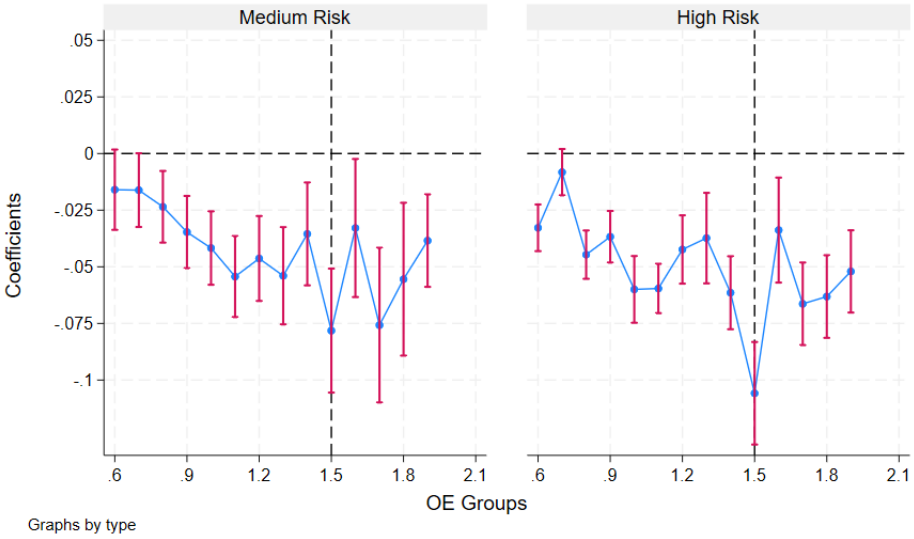
$$
\begin{aligned}
Y_{ik} = & \sum_{r=med,high} \alpha_r \times R_{r(ik)} + \sum_{m=0.6}^{1.9} \alpha_m \times T_{m(ck)} \\
& + \sum_{r=med,high} \gamma_r \times R_{r(ik)} \times CoP_k + \sum_{m=0.6}^{1.9} \gamma_m \times CoP_k \times T_{m(ck)} \\
& + \sum_{r=med,high} \sum_{m=0.6}^{1.9} \gamma_{mr} \times T_{m(ck)} \times R_{r(ik)} \\
& + \sum_{r=med,high} \sum_{m=0.6}^{1.9} \beta_{mr} \times CoP_k \times T_{m(ck)} \times R_{r(ik)} \\
& + \sum_{t=1}^{20} \delta_t + \gamma_1 X_i + \gamma_2 Z_k + \varepsilon_{ick}
\end{aligned} \tag{3}
$$

We have a triple difference-in-differences equation where we interact $R_{r(ik)}$, the risk indicator for patient $i$, kidney $k$ with $CoP_k$ and $T_{m(ck)}$. The omitted group for $R_{r(ik)}$ is low-risk transplants. Our parameter of interest is $\beta_{mr}$ and measures the differential impact of CoP on the acceptance behavior of risk group $r$ relative to the low-risk group. We plot the coefficients of $\beta_{mr}$ in Figure 8.

We see that as OE scores approach the threshold, transplant centers are less likely to accept a medium/high-risk transplant than a low-risk one. The decrease is most significant at $m = 1.5$ for both risk types. The pattern persists even as we cross the threshold.

[12] Low-risk transplants are patient-kidney offers that are both low-risk. High-risk transplants are patient-kidney offers that are both high-risk. Medium-risk transplants are the remaining patient-kidney offers.

Figure 8: Acceptance behavior between different risk groups




*Note:* The figure shows the acceptance behavior for each risk group $r$ after CoP. We plot the OLS estimates and 95% confidence intervals of the coefficients $\beta_{mr}$ from equation 3. We cluster standard errors at the center level.

### 4.0.2 Differences by center size

Next, we use a similar specification to equation 3 to investigate if the effect of CoP on acceptance behavior differs by center size. The intuition is that OE scores are noisy estimates of transplant center performance. Some centers have a higher standard error due to the low volume of transplants.

We categorize transplant centers into low and high-volume centers based on the number of transplants they perform every six months from 2003 - 2012. We regard transplant centers below the median number of transplants as low-volume centers. The regression equation in

this case is:

$$
\begin{aligned}
Y_{ick} = \alpha \times LV_c + \sum_{m=0.6}^{1.9} \alpha_m \times T_{m(ck)} \\
+ \gamma \times LV_c \times CoP_k + \sum_{m=0.6}^{1.9} \gamma_m \times CoP_k \times T_{m(ck)} \\
+ \sum_{m=0.6}^{1.9} \delta_m \times T_{m(ck)} \times LV_c \\
+ \sum_{m=0.6}^{1.9} \beta_m \times CoP_k \times T_{m(ck)} \times LV_c \\
+ \sum_{t=1}^{20} \delta_t + \gamma_1 X_i + \gamma_2 Z_k + \varepsilon_{ick}
\end{aligned}
\tag{4}
$$

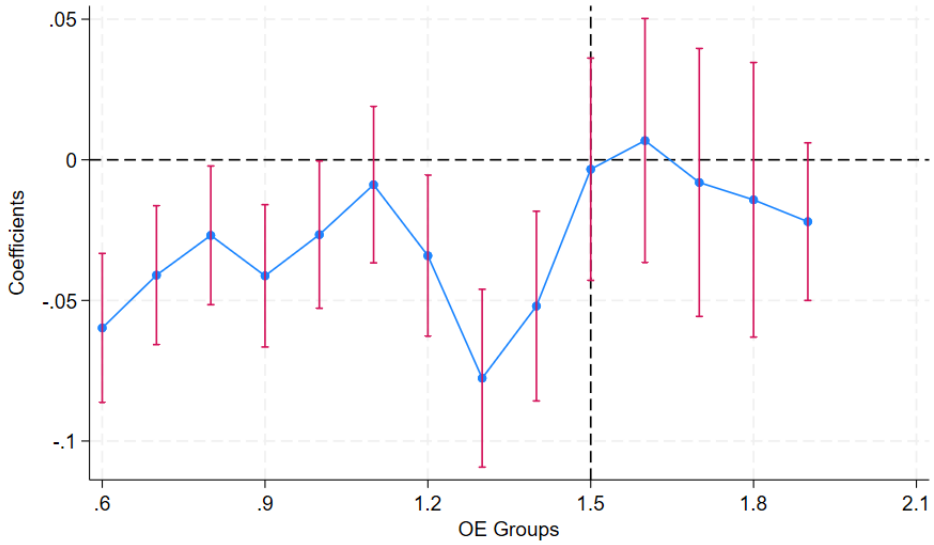
We have a triple difference-in-differences equation where we interact $LV_c$, the indicator for low-volume centers, with $CoP_k$ and $T_{m(ck)}$. Our parameter of interest is $\beta_m$ and measures the differential impact of CoP on the acceptance behavior of low-volume centers relative to high-volume centers. We plot the coefficients of $\beta_m$ in Figure 9.

Before OE scores approach the threshold, low-volume centers are less likely to accept a patient-kidney offer than high-volume centers. However, the difference is not statistically significant once we reach or cross the threshold. The result differs from previous results where the effect of CoP is the greatest at the threshold. Low-volume centers seem more sensitive to CoP than high-volume centers before the threshold.

## 4.1 Patient Outcome

The richness of our data allows us to connect the changes in transplant center behavior to patient outcomes. We consider whether transplanted patients are more likely to die within 365 days after the transplant. We estimate equation 1 using only the set of transplanted patients as Section **??** but with $Y_{ick}$ indicating whether patient $i$ dies within 365 days after

Figure 9: Acceptance behavior for low-volume centers compared to high-volume centers




*Note:* The figure shows the acceptance behavior for low-volume centers after CoP. We plot the OLS estimates and 95% confidence intervals of the coefficients $\beta_m$ from equation 4. We cluster standard errors at the center level.

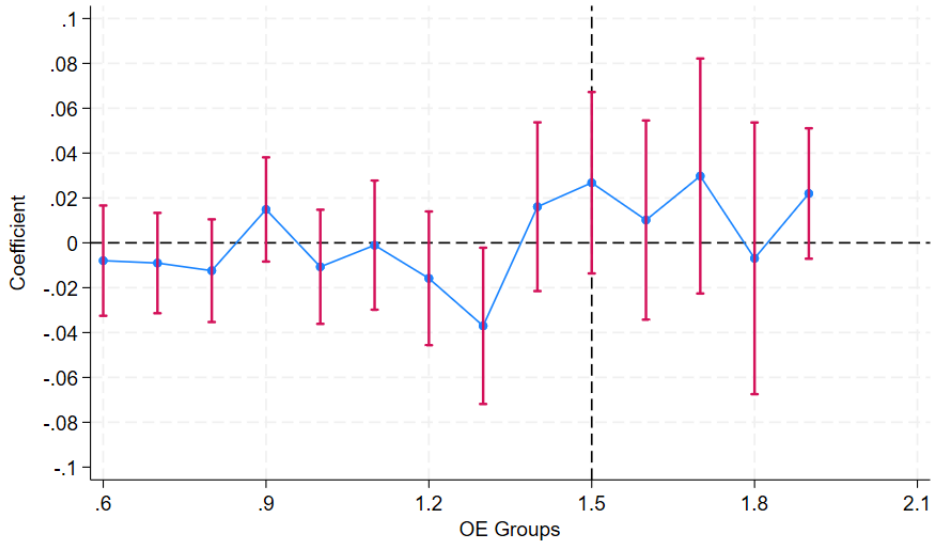
the transplant by center $c$ with kidney $k$. We plot the full range of $\beta_m$ in Figure 10.

Unlike the results in **??**, we do not see a significant change in patient survival rates across the OE groups. There is no evidence to suggest that taking a kidney offer near or far from the threshold impacts patient survival.

Next, we examine if the effect of CoP on patient survival differs by risk profiles. We follow section 4.0.1 and categorize transplanted patient-kidney offers into low, medium, and high-risk. We use a similar specification to equation 3 to investigate if the effect of CoP on patient survival differs by risk profiles. We have $Y_{ick}$ as an indicator for patient death within 365 days after the transplant for patient $i$ with kidney $k$ at center $c$. We estimate equation 3 for the subsample of transplanted patients and plot the coefficients of $\beta_{mr}$ in Figure

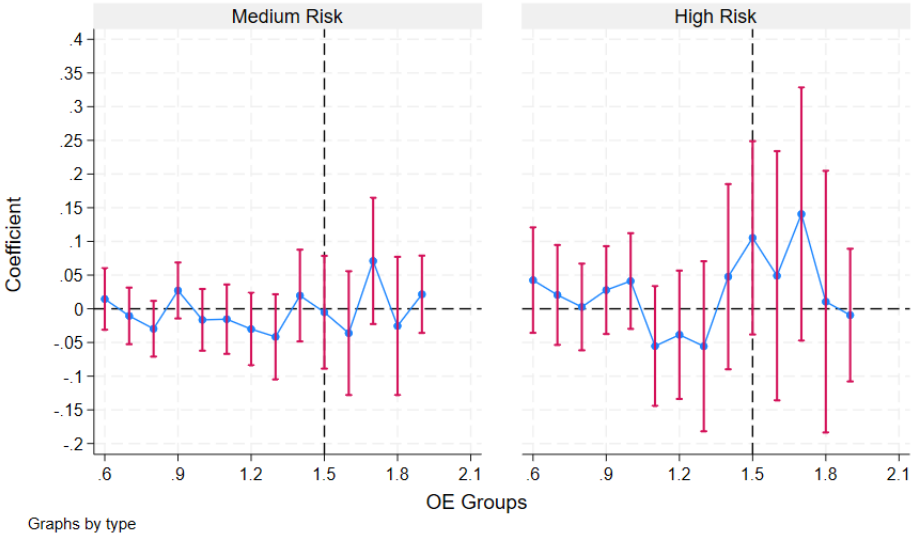
There is no evidence in Figure 11 to suggest accepting a medium/high-risk transplant at the threshold affects patient survival compared to a low-risk transplant

Figure 10: Transplanted patient survival across different $OE_{ck}$ groups




*Note:* The figure shows the survival rate for each OE group m after CoP. We plot the OLS estimates and 95% confidence intervals of the coefficients $\beta_m$ from equation 1. We cluster standard errors at the center level.

Figure 11: Transplanted patient survival between different risk groups




*Note:* The figure shows the transplanted patient's survival for each risk group $r$ after CoP. We plot the OLS estimates and 95% confidence intervals of the coefficients $\beta_m$ from equation 3. We cluster standard errors at the center level.

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# Appendices

## A CSR Report

| Line | | Center 1 Year | National 1 Year |
|---|---|---|---|
| | **Adult (Age 18+)** | | |
| 1 | Transplants (n=number) | 90 | 10,781 |
| 2 | **Percent (%) of Patients Surviving at End of Period** | | |
| 3 | Observed at this Center | 87.78 | 86.26 |
| 4 | Expected, based on national experience | 89.41 | |
| 5 | **Deaths During Follow-up Period** | | |
| 6 | Observed at this center | 11 | 1,392 |
| 7 | Expected, based on national experience | 8.48 | 1,392 |
| 8 | Ratio: Observed to Expected (O/E) | 1.30 | 1.00 |
| 9 | (95% Confidence Interval) | (0.65-2.32) | |
| 10 | P-value (2-sided), observed v. expected | 0.469 | |
| 11 | How does this center's survival compare to what is expected for similar patients? | Not Significantly Different (a) | |
| 12 | Percent retransplanted | 5.5 | 4.4 |
| 13 | Follow-up days reported by center (%) | 91.7 | 93.9 |
| 14 | Maximum Days of Follow-up (n) | 365 | 365 |

Figure 12: A page of a July 2007 CSR report.

**Deceased Donor Graft Survival Model Description**
**1 Year (and 1 Month) after Transplant**
**Organ: Kidney**
**Adult (Age 18+)**

**93.6% graft functioning at 1 Year when all covariates=0. 97.7% graft functioning at 1 month when all covariates=0.**
**The indexes of concordance are 65.9%, 65.8%, and 66.2%, respectively.**

| | CSR Cohort Released 01/10/2006 Transplants between 07/01/2002 and 12/31/2004 | | |
|---|---|---|---|
| **Characteristic Covariates** | **beta** | **standard error** | **p-value** |
| Cold ischemia time: continuous (per 1 hour) | 0.0106 | 0.0031 | 0.0007 |
| Cold ischemia time: missing | 0.4744 | 0.0844 | <0.0001 |
| Deceased donor kidney was pumped: missing (ref=no) | 0.2558 | 0.3561 | 0.4725 |
| Deceased donor kidney was pumped: yes (ref=no) | -0.0551 | 0.0621 | 0.3753 |
| Deceased donor with history of diabetes: missing (ref=no) | 0.3919 | 0.2804 | 0.1622 |
| Deceased donor with history of diabetes: yes (ref=no) | 0.2188 | 0.0868 | 0.0117 |
| Deceased donor with history of hypertension: yes (ref=no) | 0.1669 | 0.0597 | 0.0052 |
| Diagnosis: Diabetes* | 0.1122 | 0.0669 | 0.0932 |
| Diagnosis: Hypertensive Nephrosclerosis* | -0.0305 | 0.0691 | 0.6589 |
| Diagnosis: Polycystic Kidney Disease* | -0.3838 | 0.1064 | 0.0003 |
| Diagnosis: Renovascular & Other Vascular Diseases* | -0.0354 | 0.1040 | 0.7338 |
| Diagnosis: other or missing (includes tubular, congenital)* | -0.0380 | 0.0736 | 0.6057 |
| Donation after cardiac death: yes (ref=no) | 0.3368 | 0.0977 | 0.0006 |
| Donor DSA different from recipient DSA: yes (ref=no) | 0.1158 | 0.0621 | 0.0620 |
| Donor age: 0-10 (ref=35-49) | 0.3189 | 0.1262 | 0.0116 |
| Donor age: 11-17 (ref=35-49) | 0.0035 | 0.1028 | 0.9731 |
| Donor age: 18-34 (ref=35-49) | -0.1131 | 0.0702 | 0.1070 |
| Donor age: 50-64 (ref=35-49) | 0.1757 | 0.0764 | 0.0215 |
| Donor age: 65+ (ref=35-49) | 0.3006 | 0.1250 | 0.0162 |
| Donor meets expanded donor criteria for deceased donor kidney: yes (ref=no) | 0.2174 | 0.0888 | 0.0143 |
| Donor race: Hispanic/Latino | 0.0406 | 0.0709 | 0.5666 |
| Donor race: Asian | 0.1553 | 0.1384 | 0.2620 |
| Donor race: Black | 0.0673 | 0.0674 | 0.3177 |
| Donor race: multi-racial, other, unknown or missing | 0.1637 | 0.2525 | 0.5168 |
| Donor serum creatinine: continuous (per 1 mg/dL) | 0.1040 | 0.0395 | 0.0086 |
| Donor serum creatinine: missing | 0.0112 | 0.3061 | 0.9708 |
| Donor to recipient weight ratio: continuous | -0.1621 | 0.0765 | 0.0340 |
| Donor to recipient weight ratio: missing | 0.1952 | 0.1339 | 0.1450 |
| Donor: deceased, COD cerebrovascular/stroke | 0.2768 | 0.0547 | <0.0001 |
| Functional Status: performs activities of daily living with some or total assistance or is hospitalized (ref=no assistance) | 0.3727 | 0.0624 | <0.0001 |
| Functional Status: unknown or missing (ref=no assistance) | 0.0080 | 0.0844 | 0.9248 |

Figure 13: An example of the risk adjustment model in the CSR report.