Risk Adjustment in Performance Scores*

Han Ng†

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Abstract

In 2007, Medicare introduced risk-adjusted death rates to identify poor-performing kidney transplant centers. Why is risk adjustment necessary? To answer this question, I develop a two-period model of transplant center decisions with risk-adjusted performance. I find that centers decline high-risk transplants in the absence of risk adjustment. Furthermore, I show how prediction error, performance threshold, and center size can undermine the benefits of risk adjustment. The policy implications suggest that future designs of the risk-adjustment model should account for selection bias from using the survival outcomes of transplanted patients as the training set.

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

1 Introduction

Performance scores are ubiquitous in the healthcare industry. They are used to evaluate the quality of care provided by hospitals (Dranove et al., 2003; Vatter, 2023), dialysis centers (Ramanarayanan, 2011) and transplant centers(Ng, 2023). Built within each of these performance score model is an element of risk adjustment. Risk adjustment is necessary to promote fair and accurate comparison of health outcomes across measured entities.

In this paper, I ask what is the purpose of risk adjustment in performance scores and how does it interact with different elements in the model. I focus on the 2007 reform by Medicare to introduce risk-adjusted death rates to identify poor-performing kidney transplant centers. I develop a two period model of transplant center decisions with risk-adjusted performance. I find that risk adjustment is necessary to incentivize transplant centers to accept high-risk transplants. However, prediction error, performance threshold and center size can undermine the benefits of risk adjustment. The policy implications suggest that future designs of the risk-adjustment model should account for selection bias from using the survival outcomes of transplanted patients as the training set.

The paper is organized as follows. Section 2 provides background information on the 2007 reform by Medicare. Section 3 presents the model. Section 4 presents the solutions of the model. Section 5 discusses the purpose of risk adjustment and the comparative statics of the model. Section 6 concludes.

2 Background and Institutional Setting

2.1 Conditions of Participation (CoP)

Before July 2007, the Organ Procurement and Transplant Network (OPTN) was the primary organization responsible for monitoring a transplant center's number of post-transplant survivals(Stith and Hirth, 2016). 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 May 2007 to provide a foundation for improving quality and protecting the health and safety of transplanted patients(CMS, 2007). Transplant centers submit the 1-year post transplant outcomes to the Scientific Registry of Transplant Recipients (SRTR) on the first week of every January and July.

SRTR measures a center's performance by calculating the observed-expected (OE) 1-year death ratio. SRTR calculates expected deaths (E) by estimating a Cox regression model (Cox, 1972) using all the transplanted patients submitted by each transplant center. The model uses an extensive patient, donor, and match charactertistics[1]. Medicare flags a transplant centers for poor performance if the OE ratio exceeds the threshold, 1.5 (CMS, 2007)[2].

$$\text{OE ratio} = \frac{\text{Observed Deaths 1-year post transplant}}{\text{Expected Deaths 1-year post transplant}}$$

[1]Some examples include age, race, diabetic status, donor cause of death, human leckocyte antigen (HLA) mismatch, and cold ischemia time.

[2]Transplant centers that exceed the threshold are required to implement a data-drive quality assessment and performance improvement (QAPI) system. If the center is flagged again within the next 30 months, it risks losing its program certification and Medicare funding.

2.2 Transplant Centers

When a patient suffers from kidney failure, they register with a transplant center. After the centers upload the patient's medical history to OPTN, the patient joins the waitlist for a deceased donor.

When a deceased donor becomes available, the OPTN algorithm identifies patients biologically compatible with the kidney. The transplant centers will be the first to receive any notification about incoming kidney offers for their patients. They have 1 hour to accept or decline the kidney offer on behalf of their patients(OPTN, 2023)[3].

3 Model

My model has two periods, indexed by $t = \{1, 2\}$. Denote OE_{ct} as the OE ratio of center c at time t.

Period 1 Stage 1:

Center c observes the components of its OE ratio, O_{c1} observed deaths of all transplanted patients in center c, and E_{c1} expected deaths of all transplanted patients in center c. The OE ratio of center c is $OE_{c1} = \frac{O_{c1}}{E_{c1}}$

Period 1 Stage 2:

A patient-kidney pair arrives at the center[4]. The center observes the risk profile $R_i \in \mathbb{R}_+$ of the incoming patient-kidney pair i[5]. The center decides whether to accept or decline the patient-kidney pair i. If the center accepts, it proceeds with the transplant operation

[3]Due to the time constraint, patients are rarely informed of their kidney offer and rely on transplant center to make the decision for them (Husain et al., 2019; King et al., 2023)

[4]Here, I abstract from the fact that when transplant centers decline a patient-kidney pair, the patient returns to the waitlist, and the kidney is passed on to the next patient on the match run.

[5]Here, I abstract from the fact that calculating risk profile is a complicated issue, governed by both patient and kidney characteristics. I simplify it to a scalar.

and receives a fixed payment, $M > 0$, from Medicare. If the center declines, it receives no payment.

Period 2

The center observes the outcomes of the transplant operation and submits its latest OE_{c2} ratio to Medicare for evaluation. If OE_{c2} exceeds the threshold $k > 0$ set by Medicare, the center receives a fine, $F > 0$, from Medicare[6]. Else, the center receives no fine. Hence, the center's value function in period 2 is given by

$$V_2(O_{c2}, E_{c2}) = \begin{cases} -F & \text{if } \frac{O_{c2}}{E_{c2}} \geq k \\ 0 & \text{if } \frac{O_{c2}}{E_{c2}} < k \end{cases} \tag{1}$$

Next, I assume there exists a function that maps from patient-kidney pair risk profile into a probability of death. I denote this function as $P_d : \mathbb{R}_+ \to (0, 1)$. I assume it is strictly increasing, and only the transplant center observes $P_d(R_i)$. On the other hand, Medicare does not observe the actual probability of death. It relies on the set of transplants selected and submitted by centers to estimate its risk model. Thus, I denote Medicare's estimated probability of death as $\hat{P}_d : \mathbb{R}_+ \to (0, 1)$. For simplicity, I assume Medicare's model underestimates the actual probability of death by a constant $\varepsilon \in (0, 1)$ for every patient-kidney pair's risk profile R_i. Thus, we have:

$$\varepsilon = P_d(R_i) - \hat{P}_d(R_i) \tag{2}$$

[6]In reality, Medicare sets $k = 1.5$.

Finally, center c's value function in period 1 is given by:

$$V_1(O_{c1}, E_{c1}, R_i) = \max \left\{ \overbrace{M + \beta \left[P_d(R_i) \underbrace{V_2(O_{c1}+1, E_{c1}+\hat{P}_d(R_i))}_{\text{Value of Failed Transplant}} + (1-P_d(R_i)) \underbrace{V_2(O_{c1}, E_{c1}+\hat{P}_d(R_i))}_{\text{Value of Successful Transplant}} \right]}^{\text{Value of Accepting Transplant}}, \underbrace{\beta V_2(O_{c1}, E_{c1})}_{\text{Value of Declining Transplant}} \right\} \tag{3}$$

where $\beta \in (0,1)$ is the discount factor.

4 Solving the model

Before solving the model, I assume:

$$M < \beta F \tag{4}$$

This assumption ensures that the fine, F, is sufficiently large such that the center has incentives to reject the patient-kidney pair if it is likely to worsen its OE ratio. To solve the model, we consider the following cases in period 1:

- **Case 1:** $\frac{O_{c1}}{E_{c1}} \geq k$
- **Case 2:** $\frac{O_{c1}}{E_{c1}} < k$

Case 1: $\frac{O_{c1}}{E_{c1}} \geq k$

In this case, the center always accept a patient-kidney pair since it cannot be worse off. The center will receive a F fine in period 2 for declining. By accepting, it gets the fixed payment M in period 1 and the possibility of improving its OE ratio in period 2 if the transplanted patient's outcome is successful.

Case 2.1: $\frac{O_{c1}}{E_{c1}} < k$ **and** $\frac{O_{c1}+1}{E_{c1}+\hat{P}_d(R_i)} \geq k$

In this case, the center risks crossing the threshold k in period 2 if the transplant patient's outcome is unsuccessful. The center will only accept the patient-kidney pair if the value of accepting is greater than that of declining. This is true if the patient-kidney pair has sufficiently low risk:

$$P_d(R_i) < \frac{M}{\beta F} \Leftrightarrow R_i < P_d^{-1}\left(\frac{M}{\beta F}\right) \tag{5}$$

Conversely, the center will decline the patient-kidney pair if:

$$P_d(R_i) \in \left[\frac{M}{\beta F}, \frac{O_{c1}}{k} - E_{c1} + \frac{1}{k} + \varepsilon\right) \Leftrightarrow R_i \in \left[P_d^{-1}\left(\frac{M}{\beta F}\right), P_d^{-1}\left(\frac{O_{c1}}{k} - E_{c1} + \frac{1}{k} + \varepsilon\right)\right) \tag{6}$$

Case 2.2: $\frac{O_{c1}}{E_{c1}} < k$ **and** $\frac{O_{c1}+1}{E_{c1}+\hat{P}_d(R_i)} < k$

Regardless of the transplant outcome, the center will always have $OE_{c2} < k$. Thus, it accepts the patient-kidney pair, and the risk profile must satisfy:

$$P_d(R_i) > \frac{O_{c1}}{k} - E_{c1} + \frac{1}{k} + \varepsilon \Leftrightarrow R_i > P_d^{-1}\left(\frac{O_{c1}}{k} - E_{c1} + \frac{1}{k} + \varepsilon\right) \tag{7}$$

4.1 Policy Function

For brevity, I use the following notations:

$$\begin{aligned} \gamma_1 &= P_d^{-1}\left(\frac{M}{\beta F}\right) \\ \gamma_2 &= P_d^{-1}\left(\frac{O_{c1}}{k} - E_{c1} + \frac{1}{k} + \varepsilon\right) \end{aligned} \tag{8}$$

I combine the three cases discussed before, and the policy function of center c at period

1 is given by:

$$a_1(O_{c1}, E_{c1}, R_i) = \begin{cases} \text{accept} & \text{if } \frac{O_{c1}}{E_{c1}} \geq k \text{ and } \forall R_i \\ \text{decline} & \text{if } \frac{O_{c1}}{E_{c1}} < k \text{ and } R_i \in [\gamma_1, \gamma_2] \\ \text{accept} & \text{if } \frac{O_{c1}}{E_{c1}} < k \text{ and } R_i \in [0, \gamma_1) \cup (\gamma_2, \infty) \end{cases} \tag{9}$$

In the remainder of my paper, I focus on cases when the OE ratio is below the threshold k. For simplicity, I label γ_1 as the cutoff rule for low-risk transplants and γ_2 as the cutoff rule for high-risk transplants. I present the policy function in Figure 1:

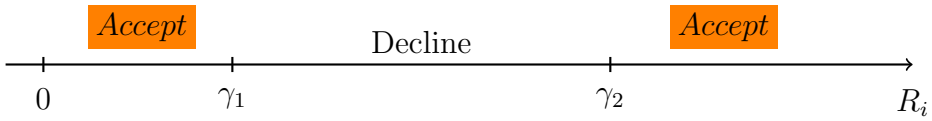

Figure 1: Policy Function when $\frac{O_{c1}}{E_{c1}} < k$

5 Why implement risk adjustment?

Before I proceed to the comparative statics of my model, I first show what is the value of risk adjustment. I follow this up with a discussion to show how different elements, such as prediction error ε, performance threshold k, and center size, can undermine the benefits of risk adjustment.

As a baseline, I explore the counterfactual scenario where Medicare only examines the proportion of unsuccessful transplant outcomes to determine a center's punishment in period 2. The setup is similar to Section 3. I replace E_{c1}, expected deaths with N_{c1}, total transplants performed by center c in period 1. Medicare punishes centers if the proportion of unsuccessful transplants exceeds the threshold k. The center's value function in periods 1 and 2 is given

by:

$$V_1(O_{c1}, N_{c1}, R_i) = \max \left\{ \begin{array}{l} \overbrace{M + \beta \left[P_d(R_i) \underbrace{V_2(O_{c1}+1, N_{c1}+1)}_{\text{Value of Failed Transplant}} + (1 - P_d(R_i)) \quad \underbrace{V_2(O_{c1}, N_{c1}+1)}_{\text{Value of Successful Transplant}} \right]}^{\text{Value of Accepting Transplant}} \\ , \quad \underbrace{\beta V_2(O_{c1}, N_{c1})}_{\text{Value of Declining Transplant}} \end{array} \right\} \tag{10}$$

$$V_2(O_{c2}, N_{c2}) = \begin{cases} -F & \text{if } \frac{O_{c2}}{N_{c2}} \geq k \\ 0 & \text{if } \frac{O_{c2}}{N_{c2}} < k \end{cases} \tag{11}$$

In this case, the center's policy function is:

$$a_1(O_{c1}, N_{c1}, R_i) = \begin{cases} \text{accept} & \text{if } \frac{O_{c1}}{N_{c1}} \geq k \text{ and } \forall R_i \\ \text{decline} & \text{if } \frac{O_{c1}}{N_{c1}} < k \text{ and } R_i \in [\gamma_1, \infty] \\ \text{accept} & \text{if } \frac{O_{c1}}{N_{c1}} < k \text{ and } R_i \in [0, \gamma_1) \end{cases} \tag{12}$$

where $\gamma_1 = P_d^{-1}\left(\frac{M}{\beta F}\right)$. I focus on cases where the proportion of unsuccessful transplants is below the threshold k. The policy function is given in Figure 2.

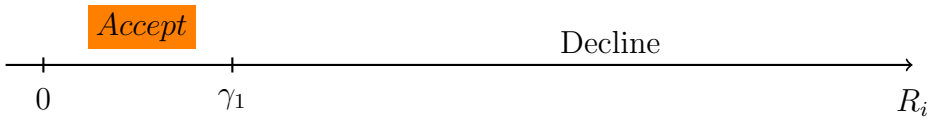

Figure 2: Policy Function when $\frac{O_{c1}}{N_{c1}} < k$

Comparing Figure 1 and Figure 2, the region (γ_2, ∞) is absent in Figure 2. This region is where centers decline high-risk transplants without risk adjustment. Thus, risk adjustment lowers opportunity costs and incentivizes centers to accept high-risk transplants.

Next, I present some comparative statics of my model. From equation 8, different parameters determine the cutoff rules for low-risk and high-risk transplants. I discuss each of

them in the following subsections.

5.1 Payments M and Fines F

As F increases, centers are less likely to accept low-risk transplants. Conversely, as M increases, centers are more likely to accept low-risk transplants. Surprisingly, payments and fines only affect the demand for low-risk transplants and not high-risk transplants.

I interpret this result as risk adjustment increasing the opportunity cost of accepting low-risk transplants. Low-risk transplants have a low probability of death, but when they fail, they hurt the OE ratio badly. Payments(fines) have to be sufficiently high(low) to offset the higher opportunity cost of accepting low-risk transplants in the presence of risk adjustment.

5.2 Prediction error ε

As ε increases, centers are less likely to accept a high-risk transplant. This result is intuitive. A higher prediction error means that the center's OE ratio is more likely to exceed threshold k if the transplant fails. Thus, centers are more cautious in accepting high-risk transplants.

Looking at Figure 1, we see that as ε increases, the region (γ_2, ∞) shrinks. This analysis highlights the importance of accurate risk adjustment. A higher prediction error can lead to centers declining high-risk transplants, undermining the benefits of introducing risk adjustment.

Under CoP, Medicare estimates the risk-adjustment model using the set of transplanted patients submitted by centers. This approach will likely introduce selection bias and underestimate the probability of death. This provides a clear policy implication that Medicare should address the concern of selection bias in its risk-adjustment model.

5.3 Threshold k

As k increases, centers are more likely to accept high-risk transplants. This result is consistent with the intuition that a higher threshold means that centers are more willing to accept high-risk transplants.

Looking at Figure 1, we see that as k increases, the region (γ_2, ∞) expands. This analysis highlights the importance of setting the threshold k appropriately. In hindsight, Medicare's decision to set $k = 1.5$ has its merits. If the threshold is too low (i.e., $k = 1$), transplant centers will not want to accept high-risk transplants, undermining the purpose of risk adjustment. Conversely, if the threshold is too high, it undermines the purpose of monitoring center performance.

5.4 Transplant center size, E_{c1}

E_{c1} is the expected death rate of transplanted patients in center c in period 1. I use this variable as a proxy for the size of the transplant center. As the center performs more transplants, E_{c1} will increase.

Looking at Figure 1, as E_{c1} increases, the region (γ_2, ∞) expands. Larger transplant centers are more likely to accept high-risk transplants. This result is consistent with the intuition that OE ratios are noisy estimates of a center's performance. A larger center's OE estimate thus has a lower standard error, making it less susceptible to fluctuations in its OE ratio.

6 Conclusion

This paper evaluates the purpose of risk-adjusted performance scores in deceased donor kidney transplant settings by studying a 2007 reform by Medicare. I find that risk adjustment is necessary to incentivize transplant centers to accept high-risk transplants. However, prediction error, performance threshold, and center size can undermine the benefits of risk

adjustment. The policy implications suggest that future designs of the risk-adjustment model should account for selection bias from using the survival outcomes of transplanted patients as the training set.

This paper focuses on who gets transplanted under risk adjustment. Future research should focus on how risk adjustment affects untransplanted patients-kidney pairs (i.e. (γ_1, γ_2) region in Figure 1). Do the patients die on the waiting list or get a kidney at a later date? Are the declined kidneys eventually transplanted or discarded? These questions are crucial in understanding the welfare effects of risk adjustment in kidney transplant markets.

References

Centers for Medicare & Medicaid Services (CMS). 2007. "Medicare program; hospital conditions of participation: requirements for approval and re-approval of transplant centers to perform organ transplants. Final rule." *Federal Register*, 72(61): 15197–15280.

Cox, D. R. 1972. "Regression Models and Life-Tables." *Journal of the Royal Statistical Society. Series B (Methodological)*, 34(2): 187–220.

Dranove, David, Daniel Kessler, Mark McClellan, and Mark Satterthwaite. 2003. "Is More Information Better? The Effects of "Report Cards" on Health Care Providers." *Journal of Political Economy*, 111(3): 555–588.

Husain, S. Ali, Kristen L. King, Stephen Pastan, Rachel E. Patzer, David J. Cohen, Jai Radhakrishnan, and Sumit Mohan. 2019. "Association Between Declined Offers of Deceased Donor Kidney Allograft and Outcomes in Kidney Transplant Candidates." *JAMA Network Open*, 2(8): e1910312–e1910312.

King, Kristen L., S. Ali Husain, Miko Yu, Joel T. Adler, Jesse Schold, and Sumit Mohan. 2023. "Characterization of Transplant Center Decisions to Allocate Kidneys to Candidates With Lower Waiting List Priority." *JAMA Network Open*, 6(6): e2316936–e2316936.

Ng, Han Loong. 2023. "Rationing Healthcare: Evidence from U.S. Deceased Donor Kidney Transplant." Pennsylvania State University Working Paper.

Organ Procurement Transplantation and Network (OPTN). 2023. "Policies."

Ramanarayanan, Subramaniam. 2011. "Reputations and Firm Performance: Evidence from the Dialysis Industry."

Stith, Sarah S., and Richard A. Hirth. 2016. "The Effect of Performance Standards on Health Care Provider Behavior: Evidence from Kidney Transplantation." *Journal of Economics & Management Strategy*, 25(4): 789–825.

Vatter, Benjamin. 2023. "Quality Disclosure and Regulation: Scoring Design in Medicare Advantage." *SSRN Electronic Journal*.