Information Processing: Simplified Metrics and Physician Decision-Making in Kidney Transplants

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Abstract

Despite a shortage of kidneys available for transplantation, the median candidate who dies while on the waitlist for a transplant declines 16 organ offers. Physicians decline or accept offers on behalf of their patients on the basis of kidney quality, which is difficult to evaluate. Starting in 2012, the Organ Procurement and Transplantation Network provided a simplified single-score metric, the Kidney Donor Profile Index (KDPI), to estimate the quality of a donor kidney relative to the median kidney recovered. Using a rich dataset provided by the Scientific Registry of Transplant Recipients containing all 28 million kidney transplant offers and decisions over a 5-year period, I exploit the provision of KDPI to evaluate the salience of this metric in physician decision-making. I utilize the natural experiment resulting from the exact timing when the values were calculable but not provided prominently with each offer. The introduction of the metric increased the weight placed upon KDPI in terms of individual offer acceptance, demonstrating that KDPI became increasingly salient to physicians. However, there was no corresponding increase in discard rates for low-quality organs as opposed to high-quality organs following the introduction of KDPI. I also find evidence of substantial preference shifts among physicians with regards to the individual donor characteristics.

1 Introduction

For those suffering from chronic kidney disease and failure, transplantation represents the best solution, as opposed to a lifetime of dialysis. Most patients

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seeking a transplant end up registering on a waitlist for a deceased-donor kidney. However, in 2022, 5,454 persons out of the nearly 90,000 on the waitlist for a kidney transplant passed away before receiving one (Organ Procurement and Transplantation Network (OPTN), 2023). The gap between the supply of kidneys and candidates needing one for transplant continues to grow, as far more candidates join the waitlist than donor kidneys are transplanted each year (Figure 1). The OPTN attempts to allocate these scarce organs with a balance of equity and medical utility so that the number of transplants performed and recipient survival are maximized (OPTN, 2018).

When a kidney is recovered, it is offered to physicians representing transplant candidates, who have one hour to decide whether to accept or decline the offer. Despite the scarcity of organs, a shocking number of physicians choose, on behalf of their patient, to decline the offer. The median candidate who passes away while awaiting a kidney transplant declines 16 offers while on the waitlist (Husain et al., 2019). In addition, from 2007 to 2012, an average of 229 offers were made for each organ recovered. In 2015, more than 3,000 procured kidneys, many of which may have been viable, were eventually discarded before transplantation because a willing recipient could not be found before the organ expired (Stewart et al., 2017a). Thus, policy-makers increasingly focus on decreasing physician risk-aversion, along with the usual goal of improving outcomes for those receiving transplants (Executive Order on Advancing American Kidney Health, 2019).

In order to aid physicians in their decision-making and information processing, the Kidney Donor Risk Index (KDRI) and its corresponding percentile score Kidney Donor Profile Index (KDPI) were developed and provided alongside kidney offers beginning in 2012 (OPTN, 2023). They are single-score metrics that synthesize previously-provided information about a donated kidney's quality,

where quality is assessed on a 0 to 100 scale, with 0 being the highest quality kidney donor. These metrics ideally would assist in improving outcomes for transplant recipients, as physicians would more easily and confidently ascertain the quality of an offered kidney.

However, physicians are concerned about a possible "labeling" effect, whereby the use of KDPI drives demand and selection away from poorer-quality, but still viable, kidneys, increasing the number of offers that are made before a kidney is accepted, which decreases viability and increases discard rates (Kott, 2023). Stewart et al. (2017b) and Bae et al. (2016) find evidence that the labeling effect may be resulting in higher-discard rates for high-KDPI (low quality) kidneys. On the other hand, Stewart et al. (2013) find no evidence of increased discard rates among the worst quality kidneys as measured by KDPI. Guan et al. (2024) find that, within similar KDPI categories, organs from Black donors and those with Hepatitis C (HCV+), both of whom have a higher KDPI compared to current survival expectations, are discarded at lower rates than organs from non-Black and HCV negative donors. They suggest that this discrepancy is due to physicians making decisions outside the KDPI scale.

This paper studies the changes in physician behavior after KDPI began being included with kidney offers. Using data from the Scientific Registry of Transplant Recipients (SRTR), I compile files containing information for the universe of match-run offers made, donor characteristics including calculations of KDPI, and patient characteristics. Then, utilizing the sharp timing when KDPI began being included alongside the offer on March 26, 2012, I examine whether the provision of KDPI altered kidney offer acceptance. I find that physician decision-making changes after the provision of KDPI. Once KDPI becomes salient, physicians are more likely to accept high quality kidneys (as measured by KDPI) than low quality kidneys compared to before. That is, the

gradient of acceptance with respect to KDPI becomes steeper after KDPI is provided. In addition, more offers have to be made for low quality kidneys to be accepted than high quality kidneys relative to before KDPI became salient. Despite this, discard rates do not increase for low quality kidneys relative to high quality kidneys in the post-KDPI period.

This paper contributes to a growing body of economic literature surrounding the transplant networks in the United States. Much of the prior research in this area concentrates on the allocation system from a mechanism design perspective (Kessler and Roth, 2012; Agarwal et al., 2020). Other papers study policy changes that affect allocation or supply of organs and subsequent effects on demand (Dickert-Conlin, Elder, and Teltser, 2019; Teltser, 2019; Choi, 2023, Bae, 2024). Other papers study changes to waitlisting patterns and transplant center behavior as a result of policy changes (Stith and Li, 2021; Stith and Hirth, 2016).

This paper uniquely describes how changes to the information set presented to physicians affects behavior and the resulting placement and use of organs. In this way, it contributes to the economics literature exploring the salience of simplified metrics. Pope (2009), Luca and Smith (2013), Chartock (2023), Chevalier and Mayzlin (2006), and Katusmoto et al. (2022) all find that published metrics can alter demand in different settings, including hospital patients, book reviews, and college rankings. This work provides a unique distinction in that it studies the change when a metric merely synthesizes already available information, rather than introducing new data that were not previously provided.

This work extends prior work published in the epidemiological and transplant journals surrounding KDPI by scrutinizing how the provision of KDPI affects the entire range of donor kidneys and physician behavior. To my knowledge, there is no research estimating the changes over time in actual preferences for

organs at the decision level as physicians learned to use KDPI following its provision. Earlier research is entirely focused around discard rate alone, rather than the actual responses of individual transplant teams. This research into the provision of KDPI also did not control for candidate or transplant center attributes when evaluating the provision of KDPI.

Section 2 presents institutional background on the kidney transplant waitlist and physician choice. Section 3 presents a conceptual framework of physician decision-making and the salience of KDPI. Section 4 describes the data. Section 5 details the empirical design. In Section 6, I show empirical estimates of the effects of providing KDPI on transplant decision-making. Section 7 concludes.

2 Institutional Background

For a patient experiencing kidney failure, there are two treatments: transplantation and dialysis. Dialysis, an ongoing treatment that artificially filters a patient's blood, is not a cure, must be repeated 3-times a week for 3-4 hours a session, and is costly. Transplantation, on the other hand, has reduced costs, no weekly sessions, and increased life expectancy relative to dialysis (Kaballo et al., 2018). If a patient seeks a kidney transplant, they can search for a compatible living donor and/or register on a wait list for a kidney from a deceased donor (National Kidney Foundation, 2015). Most candidates end up seeking and receiving deceased donor transplants. Out of 26,309 kidney transplants performed in 2022, 78% were deceased donor transplants (OPTN, 2023). Living donor transplants require the candidate to locate a healthy, compatible, and willing prospective donor, which can be quite difficult to do.

For a patient seeking a deceased donor transplant, the process begins by registering with a transplant center. There are more than 250 transplant centers operating in the United States, and each has their own criteria for registration,

including the health of the patient, the patient's support system in place, and ability of the patient to follow up with post-transplant care. Once registered with a transplant center, a candidate with sufficiently poor kidney function is eligible to receive offers of deceased-donor organs. Patients report that the waitlist characteristics that are the most important factors when selecting with which transplant center to register are the ease of getting placed on the waitlist at that center, the time on the waitlist at that center until they receive an offer, and the percent of patients at that center who never receive a transplant (Husain et al., 2018).

Organ Procurement Organizations (OPOs) manage deceased donor organ recovery for their respective geographic regions across the United States. Once an OPO secures an organ, they generate a priority list based on the donated organ's match to the candidates' blood type, Panel Reactive Antibody Score, wait time, time on dialysis, geographic location, and other factors (United Network for Organ Sharing, 2015). These factors are combined using a pre-determined formula into a points scale, which is then ordered to create the priority list. After generating this list, offers begin to be sent to the transplant teams.

The donated organ is simultaneously offered to the first n candidates on the priority list registered within the OPO's region. In practice n varies depending upon the OPO and organ. There is significant regional variation in the probability of receiving an offer, as well as the average quality of donors recovered (Husain et al., 2019).

Transplant teams representing the candidate typically have one hour to accept or decline the offered organ. These transplant teams are an amalgamation of surgeons, nephrologists, and fellows. For most transplant centers, both medical and surgical transplant teams evaluate the prospective donor organ (Israni et al., 2014). These teams are primarily responsible for making the decision to

accept or refuse an offer, not the candidate. Often, the candidate is unaware of offers declined on their behalf until after the fact. The organ is awarded to the highest-ranked candidate within the n candidates who accepts the offer. If no candidate accepts an offer, the organ is then offered to the next set of candidates on the priority list, and the process continues iteratively. Organ quality decreases with time since recovery, so if no willing candidate is found within an a reasonable amount of time, the organ must be discarded. Kidneys are typically considered viable up to 48 hours post-recovery.

There are many potential reasons a physician may decline a kidney offer, including a mismatch between the size of the transplanted organ and the candidate's size and the ability of the candidate to undergo the procedure at that time. However, poor organ quality is the main and overwhelming reason that teams decline offers. 92.8% of all offers were declined due to organ or donor quality concerns in 2018 and early 2019 (Husain et al., 2019).

When deciding whether to accept an offer, physicians are presented with a bevy of information on the prospective organ with only one hour to synthesize and evaluate. If a physician declines the offer, their patients will be placed back into the waiting pool and will continue to undergo dialysis as their health gradually worsens while awaiting a better transplant offer. If a physician accepts, the candidate may receive the transplant immediately and will receive the survival benefit from the offered organ. However, the opportunity cost of acceptance is that the patient misses out on the chance to receive a better kidney. In addition, the patient risks complications arising from the surgical procedure. Declining the offer at hand does not penalize future waitlist placement. This makes the decision to accept or decline a "marginal" offer for physicians a complicated and difficult one, as they must determine the tradeoff between reduced survival from a "marginal" organ transplant and increased mortality while remaining on

dialysis awaiting a better offer.

To aid this decision, physicians are provided information on a large variety of donor attributes. Transplant teams receive offers via the DonorNet portal, which lets them view pages of medical information about the donor, including the donor's age, weight, height, race, diabetes status, cause of death, serum creatinine (a measure of kidney function), and history of hypertension, among many other data points (OPTN, 2023). Many of these characteristic are statistically significant predictors of transplant graft function, but the magnitude and relationships between them can be difficult to estimate. For example, older-aged donors and donors with hypertension both have increased rates of graft failure, but determining the trade-off between an organ from one donor who is five years younger but has hypertension versus an organ from another older donor without hypertension is difficult (Chertow et al., 1996). Physicians abstractly guessed donor quality based on their prior beliefs and training. In addition, prior to 2012, physicians sometimes used Standard Criterion Donor (SCD) and Expanded Criterion Donor (ECD) as a binary designation to indicate donated kidney quality. ECD donors included those over the age of 60, or donors between 50 and 60 with two of the following conditions: 1) serum creatinine more than 1.5 mg/dL, 2) death from cerebrovascular accident, or 3) a history of hypertension. This binary measure was rather blunt, necessitating a more precise scale, KDRI/KDPI, although some physicians may have continued to utilize ECD and SCD designations (Lee and Abramowicz, 2015).

To rank order the quality of kidneys by aggregate population relative risk, Rao et al. (2009) developed the Kidney Donor Risk Index (KDRI) and its corresponding percentile scale Kidney Donor Profile Index (KDPI). KDRI, developed using data from around 70,000 deceased donor kidney transplant recipients, is based on the association between graft survival and 10 donor characteristics:

age, weight, height, ethnicity, history of hypertension, history of diabetes, cause of death being cerebrovascular arrest (CVA Death), serum creatinine, hepatitis C serology (HCV+), and donation after cardiac death (DCD). Graft failure means that patients must start dialysis again, as their transplanted kidney is no longer fully functioning. Around 75% of these patients will not receive a second transplant and will remain on dialysis until death (Van Loon et al., 2020). The equations for calculating KDRI and $KDRI_{Rao}$, its non-normalized form, are shown below.

$$\begin{aligned} KDRI_{Rao} = exp[&.0128(Age - 40) - .0194(Age - 18)\mathbb{I}(Age < 18) \\ &+ .0107(Age - 50) * \mathbb{I}(Age > 50) - .0464((Height - 170)/10) \\ &- .0199((Weight - 80)/5)\mathbb{I}(Weight < 80kg) + .1790 * \mathbb{I}(Black) \\ &+ .1260 * \mathbb{I}(Hypertension) + .1300 * \mathbb{I}(Diabetes) + .0881 * \mathbb{I}(CVADeath) \\ &+ .2200(Creatinine - 1) - .2090(Creatinine - 1) * \mathbb{I}(Creatinine > 1.5) \\ &+ .2400 * \mathbb{I}(HCVPositive) + .1330 * \mathbb{I}(DCD)] \end{aligned}$$

$$KDRI = \frac{KDRI_{Rao}}{Scalingfactor}$$

The scaling factor is the median $KDRI_{Rao}$ among all donors recovered the previous calendar year. KDPI is simply a remapping of KDRI into percentiles based on organs recovered the prior year, and is the metric more commonly used by physicians. The interpretation of KDPI is simple: it is the relative risk of post-transplant graft failure in an average recipient for this donor compared to all donors recovered the year prior (OPTN, 2023). A higher KDPI is indicative of *lower* organ quality.

KDPI was not originally meant to be used to determine acceptance/declination of an individual kidney offer (Gupta et al., 2014). However, transplant teams received KDPI alongside other donor information in the portal beginning on March 26, 2012. Because calculation of KDPI utilizes previously collected donor data, the only major change during this time was an update to the portal's code and resulting dispaly interface. By providing a more precise but easily interpretable and single-number scale, donor kidney quality may be more identifiable, particularly given the time constraints and multi-dimensionality of the decision physicians must make (Bae et al., 2016). KDPI is one of the first pieces of information a transplant team sees regarding a prospective donor, appearing just after the donor's age.

3 Conceptual Framework

I describe a simple, discrete-time model in which transplant teams make decisions to accept or decline kidney offers on transplant candidates behalf[1]. I designate a candidate's baselines health as h_t. Lower values of h_t indicate lower candidate health. h_t evolves stochastically over time according to a Markov process, $f(h_{t+1}|h_t)$, which physicians and patients predict. I also assume that f is monotonically decreasing, so that $h_{t+1} < h_t$ (patients have less health in subsequent periods).

Once a candidate is placed on the waitlist, there are two ways that the candidate can leave: they can become too sick to transplant / die, or they can receive a transplant[2]. I denote H^w as the boundary beyond which a patient's health is too poor to transplant, so all patients with $h_t < H^w$ leave the waitlist due to poor health or death.

[1]This model extends the frameworks of Callison et al., 2023, and Howard, 2002

[2]I simplify the waitlisting outcomes for candidates for the purposes of this framework. In actuality, candidates can also leave the waitlist by transferring to another transplant center.

In a given period, a candidate receives an offer with probability $p(t, N_t, D)$. The probability of receiving an offer is increases in t. This reflects the allocation rules currently in place, which reward candidates with more time spent on the waitlist with increased waiting list priority. The probability is decreasing in N_t, the number of individuals ahead on the waiting list, and increasing in D, the number of potential donors in that period. If an offer of a kidney is made, it has quality $q \in [0, Q]$, for which higher values of q represent a higher-quality kidney.

The transplant team must then solve an optimal stopping problem. Progressing from period $t-1$, in period t, a candidate with health h_t receives an offer of quality q with probability $p(t, N_t, D)$. The transplant team then chooses to accept or decline ($A_t \in \{0, 1\}$). If they accept, the candidate receives the transplant, and the candidate's new health is given by $g(h_t, q)$. If they decline, the candidate's health transforms in state $t+1$ as governed by $f(h_{t+1}|h_t)$.

3.1 Offer Valuation and Acceptance

Once a candidate is offered a kidney, they must choose to accept or decline the offer based upon the relative values of each option. I assume that the true value of accepting an offer of quality q can be reflected as a cash-out value dependent upon organ quality, patient health h_t, and lifetime income I, net any transplant costs p_x. Thus,

$$V^A(h_t, q_t) = B^A(g(h_t, q_t), I - p_x) \tag{1}$$

where A represents accepting the cash-out value of the kidney transplant. Because the value of a transplant diminishes as patient health worsens, future cash-out values will be reduced and there is increased incentive for a patient to accept an offer now.

The value of refusing the offer is the same as if the offer had never been made:

$$V^R(h_t, q_t) = V^B(h_t) = U(h_t, I) + \delta EV(h_{t+1}) \tag{2}$$

Utility in period t is a function of current health and income, while future expected health is discounted by δ, with this expectation taken over the distrubtion from $f(h_{t+1}|h_t)$. The value of sickness too great to transplant or death, when $h_t < H^w$, is normalized to 0.

With perfect information, a patient will accept a kidney offer if and only if $V^A(h_t, q_t) > V^B(h_t)$, where the value of receiving a transplant is greater than the value of waiting to receive a better offer. For now, assume that candidates and their transplant teams have rational expectations about their health, h_t, likelihood to receive future offers, p, and qualities of offers, $q \in [0, Q]$. As h_t decreases (health worsens), the value of accepting a kidney relative to waiting likewise increases.

For a given health h, I define $\bar{q}$ as the kidney quality that leaves an individual indifferent between accepting and declining an offer (that is, $V^A(h_t, \bar{q}) = V^R(h_t)$). Then, $\bar{q}$ is a function of health, waiting list count, and the number of donors: $\bar{q}(h_t, N_t, D)$. Conditional on receiving an offer, this function characterizes the acceptance behavior of transplant teams. The number of candidates on the list in front of a candidate, N_t, decreases $\bar{q}$ as this increase in individuals listed ahead of a person decreases their future probability of receiving an offer, which then decreases the value of declining an offer in the present period and decreases the reservation kidney quality. The number of donors, D, increases $\bar{q}$ for similar reasons: as D increases, the probability of receiving a future offer increases, increasing the value of declining an offer in the present period and increasing the reservation kidney quality.

3.2 Imperfect Knowledge and Quality Revelation

Thus far, I have assumed that candidates and their transplant teams have perfect knowledge of an offered organ's quality, q. In actuality, the quality of a kidney can be hard to discern, particularly during the time period before KDPI was provided to physicians.

Now, assume that transplant teams must estimate $E(q_t)$, rather than using q_t directly. This alters the prior value of acceptance so that Equation 1 is changed to:

$$V^A(h_t, E(q_t)) = B^A(h_t, E(q_t), I - p_x) \tag{3}$$

The level of kidney quality that leads to indifference is still $\bar{q}$, but physicians only decide to accept if $E(q_t) > \bar{q}$.

Suppose that there is a true measure of quality, $\mathbf{q}$, where $\mathbf{q}$ is normally distributed with mean m and variance σ^2: $\mathbf{q} \sim N(m, \sigma^2)$.

In the pre-period, transplant teams received a matrix of donor data, $\mathbf{X}$. They have prior beliefs about the relative importance, $\boldsymbol{\psi}$, of each attribute contained within $\mathbf{X}$. Then, they form an aggregation of these attributes, $\boldsymbol{\psi}\mathbf{X}$, to create a noisy signal of quality, which I designate as X_1.

Let us suppose that the signal has mean centered around $\mathbf{q}$, with the noise in the signal, ϵ_1, being orthogonal to true quality. Thus,

$$X_1 = \mathbf{q} + \epsilon_1$$
$$\epsilon_1 \sim N(0, v_1)$$

After observing X_1, by Bayesian updating the transplant team's posterior expectation of q should be a weighted average of the mean quality m and the

signal X_1, with weights related to the relative precision as follows:

$$E(q_t|X_1) = \frac{v_1}{v_1 + \sigma^2} m + \frac{\sigma^2}{v_1 + \sigma^2} X_1. \tag{4}$$

However, in the post-KDPI regime, transplant teams receive a signal of kidney quality, KDPI, estimating the relative value of a recovered kidney. Suppose KDPI also has mean $\mathbf{q}$, with noise ϵ_2 orthogonal to true quality.

$$KDPI = \mathbf{q} + \epsilon_2$$

$$\epsilon_2 \sim N(0, v_2)$$

Transplant teams therefore now estimate quality as a function of both the signal from the provided donor matrix, X_1, and KDPI: $E(q_t|X_1, KDPI)$. Under Bayesian updating, this new expected quality takes the weighted average of:

$$\begin{aligned} E(q_t|X_1, KDPI) = \frac{v_1 v_2}{v_1 v_2 + v_1\sigma^2 + v_2\sigma^2} m + \frac{v_2\sigma^2}{v_1 v_2 + v_1\sigma^2 + v_2\sigma^2} X_1 \\ + \frac{v_1\sigma^2}{v_1 v_2 + v_1\sigma^2 + v_2\sigma^2} (-KDPI) \end{aligned} \tag{5}$$

Thus, transplant teams now incorporate KDPI into their expectations of kidney quality. The weight on KDPI is:

$$\frac{v_1\sigma^2}{v_1 v_2 + v_1\sigma^2 + v_2\sigma^2}.$$

Then, as the precision of KDPI increases (v_2 decreases), the weight placed on KDPI in the team's expectation of quality will increase. Meanwhile, if the signal X_1 is more imprecise, that also means that the weight placed upon KDPI will increase. Therefore, if transplant teams believe that KDPI presents a more accurate signal of kidney quality, it should play a larger role in their estimation of

kidney quality. Furthermore, this means that in the period after KDPI becomes salient, as KDPI increases, $E(q_t)$ will decrease relative to where it would be in the pre-KDPI period.

On the other hand, the weight placed upon X_1 now simplifies to:

$$\frac{\sigma^2}{v_1 + \sigma^2 + \frac{v_1}{v_2}\sigma^2} X_1$$

This weight of X_1 has declined compared to the situation in Equation 4 when KDPI was unavailable due to the presence of $\frac{v_1}{v_2}\sigma^2$ in the denominator. In addition, the degree to which this weight declines is directly proportional to the relative precision of X_1 and KDPI. When v_2 decreases relative to v_1 (KDPI becomes a more informative signal than X_1), then the denominator increases, decreasing the overall weight placed upon X_1. When v_2 increases relative to v_1 (KDPI becomes a less informative signal than X_1), then the denominator decreases and the overall weight placed upon X_1 decreases.

Thus, if physicians believe KDPI to be a more accurate signal of the quality of an organ, we would expect the weight placed upon the individual characteristics comprising X_1 to decrease after KDPI becomes salient. However, this may not necessarily be true. Transplant teams may have additional information and/or beliefs about the value of an individual characteristic that they do not feel are reflected in the KDPI formulation. Say a team has a strong preference against HCV-positive donors. If the team believes that KDPI does not fully reflect the potential harms of an HCV-positive transplant, this may result in them double-counting by increasing the weight on that characteristic beyond what Bayesian updating would suggest. This could result in a decreased $E(q_t)$ not only due to the HCV status but also for an increased KDPI.

3.3 Hypotheses

Hypothesis 1 After KDPI is revealed to physicians, a low KDPI will lead to increased $E(q)$ compared to the $E(q)$ for that organ in the pre-KDPI period. As a result, V^A will increase for low KDPI kidneys (high quality) relative to high KDPI kidneys. This means that the weight placed upon KDPI will have a larger magnitude in the post-KDPI regime than in the pre-regime.

Hypothesis 2 The difference in the probabilities of offer acceptance for low KDPI kidneys relative to high KDPI kidneys will increase after KDPI becomes salient.

Hypothesis 3 The probability of a donor never having an offer accepted will increase for high KDPI (low quality) kidneys relative to low KDPI kidneys after KDPI becomes salient.

Hypothesis 4 The number of offers made until a donor has an organ accepted will increase for high KDPI (low quality) kidneys relative to low KDPI kidneys after KDPI becomes salient.

Hypothesis 5 Conditional on KDPI, the effect of individual characteristics that make up the KDPI formulation on probability of acceptance should decrease after KDPI becomes salient.

4 Data

This study uses data from the Scientific Registry of Transplant Recipients (SRTR). The SRTR data system includes data on all donors, waitlisted candidates, and transplant recipients in the United States, as submitted by the members of the Organ Procurement and Transplantation Network (OPTN). The Health Resources and Services Administration (HRSA), US Department of Health and Human Services, provides oversight to the activities of the OPTN

and SRTR contractors.

I construct a dataset for all deceased-donor, non-emergency, adult kidney-only offers made to candidates between January 1, 2010 and December 3, 2014 [3]. I trim the data at December 3, 2014, because this is the final date before the revised Kidney Allocation System took effect. Each observation is an offer of one kidney to one candidate. To create this dataset, I first link a record of all offers made and their responses during this time period to a file containing detailed information for the donor from whom the kidney was recovered using a unique ID. This information includes donor demographic and health measures. From these donor files, I also retroactively calculate KDRI and KDPI for each donor, including during the period when KDPI was not provided to transplant teams. Next, using another unique ID, I link the resulting dataset with candidate files which contain detailed information as to candidate demographics, health, listing, transplant dates, graft failure, and death dates.

In practice there are four possible responses to an offer: accept, reject, bypass, and provisional accept. For the empirical analysis, I code accept and provisional accept as accepting an offer, as these responses indicate that the transplant team either accepts the offer or would accept the offer were they first in priority. I code rejecting as declining an offer, and remove offers denoted bypass. These bypass offers are non-offers which are used to make offers out of sequence. The bypass response comes from the offer system itself, and is not an actual response from the transplant teams.

My final sample includes 27,099,653 complete observations of deceased-donor, adult, non-emergency, kidney-only offers. I then also collapse this dataset at the donor level to evaluate how a given donor's organs progress through the offer cycle. I collapse at the donor level because the KDPI for both organs recovered

[3] Pediatric offers undergo separate allocation from adult offers, as do kidney-pancreas combined offers.

from a donor will necessarily be the same.

5 Empirical Strategy

I utilize the sharp timing of the provision of KDPI to identify the changes in physician decision-making. At the individual offer level, I examine offer acceptance (either accepted or declined). For this analysis, I estimate the following equation:

$$Y_{ijt} = \alpha + \gamma KDPI_i + \tau Provided_t + \beta KDPI_i * Provided_t + \phi C_j + \lambda_j + \epsilon_{ijt} \quad (6)$$

Y_{ijt} is a binary variable indicating acceptance or declination of an offer from donor i to candidate j at time t. $KDPI_i$ is the KDPI of donor i, and $Provided_t$ indicates if KDPI was provided to the transplant team, C_j are candidate health characteristics[4] at that time, and λ_j are transplant center fixed effects. The coefficient of interest, β, indicates the additional effect of increased KDPI on offer acceptance after physicians directly observe it with offers compared to before. In other words, β represents the change in the weight placed on KDPI because of its revelation.

I then consider the effect of KDPI at the donor level, rather than offer level. I examine the probability of never acceptance (none of the donor's offers were accepted). I also refer to this as discard. Even if an organ was accepted but later found to be unsuitable for transplant, I treat these cases as accepted, as the transplant team initially decided that the organ was acceptable for transplant based on the information provided to them at the time of offer. I estimate the

[4]Candidate age, dialysis status, previous transplant, and days on dialysis. All candidate characteristics are components of Expected Post-Transplant Survival (EPTS), the most commonly calculated measure of candidate health. For more information, see https://optn.transplant.hrsa.gov/media/1511/guide_to_calculating_interpreting_epts.pdf.

following:

$$Y_{it} = \alpha + \gamma KDPI_i + \tau Provided_t + \beta KDPI_i * Provided_t + \lambda_i + \epsilon_{it} \qquad (7)$$

In this equation, Y_{it} indicates that a donor never had an offer accepted, λ_i are fixed effects for the OPO who recovers the donor organ and distributes it. Again, the coefficient of interest is β, which indicates the additional effect of a one-unit increase of KDPI on whether the donor never had an accepted offer after physicians directly observe KDPI with offers compared to before.

Next, in order to examine the effect of KDPI on how long it may take to place an organ, I determine how many offers are made for a donor before at least one offer is accepted. Because some donors never have an accepted offer, the number of offers made until acceptance is censored at the tails. In addition, these donors may see varied numbers of total offers made. Thus, I construct a series of n variables identifying if the donor had an acceptance within the nth offer. I denote acceptance for offer $i \leq n$ with a value of 1. If the donor did not have an offer accepted within the nth offer, they receive a value of 0. If there was no nth because the organ was discarded by this point, the donor is given a missing value which removes them from the observations for this variable. This can also be expressed as:

$$Y_n = \begin{cases} 1 & \exists \quad i \leq n \text{ such that } (A_i) = 1 \\ 0 & \forall \quad i \leq n, \ (A_i) = 0 \\ Missing & (A_n) = Missing \end{cases}$$

This is similar in construction to how Kaplan-Meier curves address censoring, in that only donors for whom the result is observed are given values for that level. As an example, suppose a donor has 65 offers, with 0 accepted. For variables

1-65, the response will be 0. For variables 66 and up, the donor is treated as missing and removed on the sample.

$$Y_n = \begin{cases} 0 & n \leq 65 \\ Missing & n > 65 \end{cases}$$

On the other hand, suppose the 43rd offer from this donor were accepted. Than all variables 43 and up will have a response of 1, indicating acceptance.

$$Y_n = \begin{cases} 0 & n < 43 \\ 1 & n \geq 43 \end{cases}$$

Using this, I then created linear probability models mirroring Equation 5, where Y_{it} indicates whether the offer was accepted within the first n offers. I calculate these models for n ranging from 1 to 100. The coefficient of interest is again β, which captures how the provision of KDPI changes the effect of a one-percentile increase in KDPI on the probability of a kidney being accepted by the nth offer.

To deal with censoring when studying the outcome of the number of offers made until acceptance or discard, I perform quantile regression mirroring Equation 7, where I instead estimated the median number of offers made until acceptance or discard.

Finally, to assess weight placed upon an individual characteristic x_i conditional on KDPI, I estimate the probability of offer acceptance, Y_{ijt}, as:

$$Y_{ijt} = \alpha + \gamma KDPI_i + \tau Provided_t + \psi x_i + \beta x_i * Provided_t + \phi C_j + \lambda_j + \epsilon_{ijt} \quad (8)$$

The variable of interest, β, represents the change in excess weight placed upon variable x_i from before KDPI is salient to after, conditional on KDPI. Most importantly, if β has the opposite sign of ψ and lower magnitude, it means that the initial "excess weight" placed upon that characteristic has decreased once KDPI becomes salient. I use the term "excess weight" here because the variables x_i are components of the KDPI formula. For two individuals to have an identical KDPI but different values for x_i, some other variable contained in the KDPI formula must also be different between the donors. Thus, the coefficients ψ and β reflect the value placed on that specific variable relative to the other other components in the KDPI formulation.

6 Results

6.1 Descriptive Statistics

Descriptive statistics for offers, donors, and candidates are shown in Table 1. 10.91% of offers were accepted overall, with an acceptance rate of 10.63% before and 11.07% after KDPI were provided.

Overall, 37,546 donors had kidneys offered. 12.33% of organs were discarded. The average donor was 39.34 years old, with mean KDPI of 47.74. Mean KDPI before March of 2012 was 47.49, and mean KDPI after was 47.93. 16.27% of donors were Black, 32.27% had hypertension, 4.39% were HCV positive, 14.34% were deceased cardiac donors, and 10.17% had diabetes. The mean creatinine[5] level was 1.22 mg/dL.

There were 208,797 candidates who received at least 1 offer during the period in question. The mean EPTS[6] at first offer was 44.76, with an average starting

[5] A waste product filtered by kidneys

[6] EPTS is a commonly used measure of candidate health. It operates on a 0-100 percentile scale, where lower values indicate longer expected survival from a transplant of the median donor kidney.

EPTS of 46.70 before the KDPI period and an average starting EPTS of 42.01 after. This means that the health of the average candidate who receives an offer was greater in the post-KDPI period than the pre-KDPI period. The average age of candidates at listing was 50.83. 41.27% of candidates had diabetes, 77.88% were on dialysis, and 30.33% were Black.

Figure 2 shows, as expected, that the probability that an individual offer is accepted decreases as KDPI increases (donor quality decreases) across the entire sample from above 40% to below 10%. Figure 3 shows that at the donor level, the probability that a donor's offers are never accepted increases with an increase in KDPI, particularly for KDPI's above 60. The probability that a donor's organs are never accepted rises to nearly 50% for the lowest-quality kidneys with KDPI greater than 80. Figure 4 shows the CDF of the probability of acceptance of an organ within the first n offers. Among donors with an accepted organ, the mean number of offers until acceptance was 101.73 (with median of 3), indicating a long-tailed distribution. More than 60% of organs are accepted within their first 20 offers, yet some organs are offered thousands of times before they are eventually accepted or discarded due to nonviability. Figure 5 shows the same CDF as Figure 4 for the highest quartile of KDPI and the lowest quartile. High-quality organs have a significantly greater probability of acceptance within the initial few offers compared to low-quality organs. Lower-quality organs also have a less steep initial slope, meaning that the probability of acceptance does not increase greatly over the first few offers compared to the highest quality organs. This, in conjunction with Figure 4 and the highly skewed number of offers until acceptance, indicates that low-quality organs can get offered a large number of times, with low probability of any individual offer being accepted, before eventually finding a willing recipient. On the other hand, high quality (and even moderate quality) organs will likely get accepted within a handful of

offers.

6.2 Probability of Offer Acceptance

The effect of the salience of KDPI on offer acceptance is shown in Table 2. Columns 1-4 show the estimate of the effect of offer salience for various model specifications: with no candidate controls or transplant center fixed effects (1), with only EPTS as a candidate control (2), with the individual candidate characteristics that make up EPTS as controls (3), and with both candidate controls and transplant center fixed effects as specified in Equation 6. I dispaly all coefficients and standard errors multiplied by 100. Thus, for the model without candidate controls and transplant center fixed effects, the point estimate of KDPI*100 (-.353) implies that in the period before KDPI is provided increase of KDPI from the 10th to the 90th percentile would result in an decrease in the probability an offer is accepted of 28.24 percentage points. The magnitude of these effects remain consistent across all four model specifications. Transplant teams accepting low KDPI kidneys at greater rates before KDPI became salient is expected, as these teams are highly trained and attempting to optimize their patients' survival. However, after KDPI becomes salient, KDPI has an even greater effect on offer acceptance. The coefficient on KDPI*Provided*100 in column 1, with no patient controls or fixed effects, is -.00858, which means that an increase from the 10th to the 90th percentile in KDPI after KDPI becomes salient results in an additional .69 percentage point reduction in the probability of offer acceptance. Moving to the full specification in column 4, which estimates Equation 6, the coefficient's magnitude increases to -.01947, meaning that a the increase from the 10th to the 90th percentile in KDPI after KDPI becomes salient results in an additional 1.56 percentage point decrease in the probability of offer acceptance beyond the pre-period effect. This confirms Hypothesis 2 -

physicians do in fact place more weight upon KDPI after it becomes salient to them. Although the additional effect may initially appear small, this change is quite meaningful. In the pre-KDPI period transplant teams were equally incentivized to increase their patients' survival. They had all of the same donor information available as in the salient period. However, these transplant teams were not provided with a patient's KDPI, and as a result, the salience of this metric did shift their preferences and affect the probability that an offer would be accepted.

6.3 Never Accepted Probability

Table 2, columns 5 and 6 show the estimation of Equation (7), with and without OPO center fixed effects. Columns 5 and 6 show similar point estimates, so I will focus on the full specification of column 6, which includes OPO center fixed effects. From column 6, including OPO fixed effects, in the pre-KDPI period, a one-point increase in KDPI would increase the probability of never being accepted by .41 percentage points. An increase from the 10th percentile in KDPI to the 90th percentile would result in a 32.8 percentage point increase in nonacceptance. On the other hand, the coefficient for the interaction term is .019, implying that the same increase in KDPI after it became salient would result in an additional increase in the probability of never being accepted of 1.52 percentage points relative to the pre-KDPI period. This coefficient is not statistically significant. This fails to confirm Hypothesis 3, and seems to rebuke the worries of physicians that the "labeling" of low-quality kidneys would increase their discard rate. After KDPI became salient, there was not a statistically significant increase in the weight placed upon KDPI in a donor's kidneys never being accepted. This is perhaps due to the long-tail nature of the offer process, where even if the probability of offer acceptance declines slightly, over the course

of thousands of offers they are still similarly likely to find a willing recipient. This would also explain why prior work that examines the effect of KDPI on the discard rate finds mixed results. Even though I find evidence that individual offer acceptance is affected by the salience of KDPI, this effect is washed out over the course of the thousands of declinations that a kidney must have before it is discarded.

6.4 Offers Until Acceptance

Figure 6 shows the coefficients β for the linear probability model of acceptance within the first n offers. A 1-percentile increase in KDPI results in an additional .05 percentage point decrease in acceptance within the first 25 or more offers relative to the pre-KDPI period. Thus, moving from the 10th to the 90th percentile in KDPI after KDPI became salient would lead to an *additional* 4 percentage point decrease in the probability of acceptance within the first 25 offers relative to the pre-KDPI period. This suggests that Hypothesis 4 is true, and that the salience of KDPI may increase the effect KDPI has on the timeliness with which offers are accepted. Figure 7 shows probability of acceptance within the first n offers for both the pre- and post-KDPI periods. In the post-KDPI period, an increase in KDPI reduces the probability of acceptance within the first 7th through 100 offers. The gap between the effect of KDPI before and after it becomes salient expands initially before stabilizing for the 20th through 100th offers. This too supports the conclusion that physicians increased the weight placed upon KDPI after its salience, and shows that this may result in an increased number of offers being made before the organ is eventually placed.

6.5 Offers Until Acceptance or Discard

Quantile regression shows that for a 100-unit increase in KDPI, the median number of offers made until acceptance or discard increased by 12.5 in the period before KDPI was provided to physicians (see Table 3). An increase in KDPI from the 10th percentile to the 90th percentile would result in an increase of 10 offers made before a kidney is accepted or discarded. After the provision of KDPI, the additional effect of a 100-unit increase in KDPI among this period is an increase in the median number of offers of 2.34, which was significant. This means for the same increase in KDPI from the 10th percentile to the 90th percentile after KDPI is salient, there is a total increase in the number of offers of 11.872 offers, of which 1.872 can be attributed to the salience of KDPI alone. Although this effect is statistically significant, it may not be practically significant. Since offers are often made in large blocks of 100 or more, an increase in the number of offers made of 1.872 is unlikely to increase the number of blocks of offers made. As a result, the time between organ recovery and offer acceptance is unlikely to change, as the offer will still likely be accepted within the same offer block. This is important because cold ischemia time, or the amount of time that an organ is stored in a cold solution for preservation, is associated with delayed graft function and increased risk of graft failure (Ponticelli, 2015).

6.6 Salience of Individual Donor Characteristics

Table 4, panels A and B describe the changes in weight placed upon individual donor characteristics once KDPI became salient, conditional on KDPI, as specified in Equation 8.

Conditional upon KDPI, in the pre-KDPI period an additional year in age led to a decrease in the probability that an offer was accepted of .0389 percentage points (Table 4, panel A). However, after KDPI became salient, the effect of this

additional year of age was attenuated by .000135 percentage points. Because increased age decreases KDPI and is associated with decreased kidney function, this suggests that physicians are aware of the age's presence in the KDPI formula and do not weigh it as much as in the pre-KDPI era. However, the magnitude of this attenuation is quite small, as it represents a .35% decrease in the excess weight placed upon age.

Moving to panel B, we see similar results for Deceased Cardiac Death status and Serum Creatinine clearance. In the pre-KDPI period, conditional on KDPI, a DCD donor had a 3.7 percentage point reduction in the probability of offer acceptance. This suggests that physicians in the pre-KDPI period preferred lower age donors more than the KDPI formula suggests they should, presuming the KDPI formula reflects the true value of donor attributes. However, in the post-KDPI period the gap between DCD and non-DCD donors was attenuated by 0.711 percentage points. In other words, for two donors with the same KDPI, the donor who is DCD in the pre-KDPI period has probability of offer acceptance that is 3.70 percentage points lower than their non-DCD counterpart, while in the post-KDPI period the DCD donor has a probability of offer acceptance that is only 2.99 percentage points lower. This represents a relative decrease in the excess weight placed on DCD status of approximately 20%. Likewise, in the pre-KDPI period, for two donors with equivalent KDPI, an increase in Serum Creatinine resulted in a decreased acceptance probability of 2.87 percentage points. However, in the post-KDPI period, this effect was attenuated by 0.222 percentage points, which represents a 12% relative reduction in the "excess weight" placed upon Serum Creatinine clearance. Thus, the salience of KDPI drew Age, DCD status, and Serum Creatinine clearance more in line with the KDPI formula's valuation of these attributes and their effects on survival. These findings are in agreement with Hypothesis 5, that the weights placed on donor

characteristics will decrease once the KDPI signal is provided.

In the KDPI formula, both donor height and weight decrease KDPI (indicating higher quality). However, in the pre-KDPI period, conditional on KDPI, donor height and weight were associated with a .0579 and .0482 percentage point reduction in the probability that an offer was accepted (Table 4, panel A). Thus, it suggests that physicians preferred taller and heavier donors less than the KDPI formula suggests they should in the pre-KDPI period. After KDPI became salient, this negative "excess weight" of height was attenuated by .0165 percentage points, or a relative decrease of 28.5%. For donor weight, the salience of KDPI did not result in a statistically significant attenuation of the "excess weight."

Hepatitis C status, donors who are Black/African-American, and donors who had a Cerebrovascular Accident (CVA) all have increased KDPI (lower quality) in the formula. However, in the pre-KDPI period, conditional on KDPI, all were associated with increased probability of offer acceptance. HCV+ donors had a 1.45 percentage point increase in offer acceptance, Black donors had a 4.40 percentage point increase, and donors with a CVA had a 2.12 percentage point increase (Table 4, panel B), which suggests that physicians were under-weighting these characteristics relative to what KDPI would suggest. This could be due to physicians failing to fully take into account these attributes, as perhaps they were more focused on characteristics such as Age, DCD status, or Diabetes. However, after KDPI was revealed, this under-weighting reversed or attenuated, bringing the net coefficients closer to 0 and therefore more in line with the KDPI formula's suggestion of their relative value. For HCV+ donors, the probability of acceptance after KDPI became salient decreased by 2.96 percentage points compared to the pre-period, resulting in an overall effect in the post-period of a 1.51 percentage point decrease in offer acceptance. This is a complete reversal

from the pre-KDPI period, as now physicians are less likely to accept offers from HCV+ donors with equivalent KDPI's than their HCV- counterparts. In effect, physicians began to overshoot the survival penalty for an HCV+ donor after underestimating it before KDPI became salient. For Black donors, KDPI's salience resulted in a decrease in offer acceptance by 1.18 percentage points relative to the pre-KDPI period. This represents a 27% attenuation in the "excess preference" for kidneys from Black donors, meaning that the value placed by physicians for these organs more closely aligns with the KDPI formula. A similar result holds for CVA donors: after KDPI became salient, the probability of acceptance decreased by 0.721 percentage points, which is 34% decrease in the "excess preference" for CVA kidneys.

Hypertensive donors have higher KDPI relative to non-hypertensive donors. However, in the pre-period, hypertensive donors have an increased probability of offer acceptance of 0.356 percentage points, conditional on KDPI. This means that if KDPI is a perfect proxy of kidney quality, physicians are under-weighting the effect of a donor having hypertension. In the post-KDPI regime, the probability of offer acceptance for hypertensive donors rises by an additional 0.226 percentage points, or a relative increase of 63%. This suggests that the salience of KDPI does not bring physicians more in line with KDPI's evaluation of organ characteristics. It could be that physicians do not believe that hypertensive donors present as great of a risk as the KDPI formula calculates, and that after the KDPI formula becomes salient these physicians do more to counteract the effects of the formula.

Finally, diabetic donors in the pre-KDPI regime have a decreased probability of acceptance by 1.34 percentage points, conditional on KDPI. This suggests that diabetes status is highly weighted by physicians relative to what the KDPI formula suggests, which makes intuitive sense as diabetes is a leading cause of

chronic kidney disease and a highly salient donor characteristic for physicians to consider. In the post-KDPI period, the offer acceptance probability for diabetic donors increases by a further 0.127 percentage points, or a relative increase of 9.5%. This could potentially be due to double-counting or private information - physicians believe that diabetic donors have lower quality organs than their KDPI would suggest.

7 Conclusion

Providing physicians with simplified metrics aims to help their decision-making and improve efficiency and welfare. In the case of deceased-donor kidney transplants, physicians have limited time to scroll through pages of information about the donor before making a life-altering decision on behalf of their patients. Ideally, the introduction of the Kidney Donor Profile Index in 2012 would ease the cognitive burden that physicians face by clearly and simply signaling kidney quality.

Utilizing the sharp timing of KDPI's introduction in the DonorNet database, I find that when KDPI becomes salient to physicians, their acceptance behavior changes compared to before this metric was provided. I find that after the provision of KDPI, physicians showed a stronger preference for low-KDPI (high-quality) organs relative to high-KDPI organs than when KDPI was not salient. Specifically, the effect of moving from the 10th to the 90th percentile of KDPI decreases the probability of offer acceptance by an additional 1.56 percentage points compared to the effect of a similar movement in the period prior to KDPI. This aligns with the predictions of my theoretical model. Because physicians are receive a more precise signal of kidney quality, even though the information utilized to calculate it was already provided, they exhibit a shift in their estimations of kidney quality, which affects the probability that any given offer will

be accepted.

I also find that there is a decreased probability of a timely acceptance of offers, but not so great as to suggest that donor kidneys will have to be preserved for longer periods. The salience of KDPI causes a strengthening of the relationship between KDPI and the probability of offer acceptance within the first 100 offers. However, I find that for a 100 percentile increase in KDPI, the added effect of the salience of KDPI will only increase the median number of offers made by 2.34. This change is small within the context of the 100 or more offers that are submitted at a time.

Physicians are most concerned with the potential of increased discard rates resulting from a "labeling" effect of KDPI. Prior literature is mixed regarding whether this "labeling effect is occurring." In this study, I do not find strong evidence to suggest that the salience of KDPI has led to an increased chance of low quality organs being discarded compared to before. This is likely because the small change in the probability that an offer is accepted fades over the thousands of offers that can be made for each kidney.

The emphasis placed on the individual donor variables that are used to calculate KDPI varied greatly after KDPI became salient. The extra weight placed on increased age, DCD status, and Serum Creatinine clearance attenuate after KDPI becomes salient. In particular, the extra emphasis placed on DCD donors decreased by 20% once KDPI became salient. These results suggest that physicians, upon receiving KDPI, weigh the value of these three attributes more in line with the value suggested by the KDPI formula.

Physicians initially also seemed to select against taller and heavier donors more than the KDPI formula would suggest. However, after KDPI became salient, physicians decreased their departure from the KDPI suggestion of the value of height by 28.5%, while not changing their valuation of weight.

For Hepatitis C positive donors, Black donors, and donors with a Cerebrovascular Accident, physicians initially appeared to underweight the effect of these attributes on patient survival. However, after KDPI became salient, the effect of a donor being HCV+ actually reversed compared to before KDPI was salient, as now physicians increased the probability of acceptance for an HCV+ donor compared to a HCV- donor with equal KDPI. For Black donors and donors with a CVA, the "underweighting" of these attributes attenuated by 27% and 34%, respectively, indicating again that physicians were operating more in line with the KDPI formula.

Contrary to my conceptual model, the reweightings resulting from KDPI salience did not always lead to preferences that align more closely with the KDPI formula. For both hypertensive and diabetic donors, the salience of KDPI resulted in the weight placed upon both hypertensive and diabetic donors drifting further from that suggested by KDPI. One plausible explanation for this is that physicians with private information do not believe that the KDPI formula accurately reflects the relative value of hypertensive and diabetic donors.

These results come at a time when the utility of KDPI is under debate. The Organ Procurement and Transplantation Network, the public-private partnership connecting all actors involved in organ transplant in the United States, recently released a public comment and proposal to consider remove race and HCV status from the KDPI calculation out of concern that their inclusion does not improve the predictive accuracy of KDPI, and only makes certain donors appear to have lower kidney quality, reducing utilization from these donors (OPTN, 2024). Others argue that physicians already depart from the KDPI formulation (Guan et al., 2024). I provide evidence that once KDPI became salient, physicians did shift their estimated quality to mirror that of the formula, suggesting that physicians can be influenced by the published number even after

receiving the full information set from which it is constructed. This is also more broadly applicable to medicine as a whole, where new metrics are continuously created and provided to physicians in an attempt to aid their decision-making, such as in the risk assessment of diabetes or diagnosis of delirium (Nguyen et al., 2023; Wang et al., 2022). This paper suggests that even in situations when the information that is captured by the metric is entirely unoriginal, the salience of the metric causes a shift in physician behavior.

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Table 1: Descriptive statistics for deceased-donor kidney transplant offers, donors, and candidates from 2010-2014

Level	Variable	Mean	Mean Before[1]	Mean After[1]	N
Offer	Acceptance Probability	10.91%	10.63%	11.07%	27,099,653
Donor	Not Accepted	12.33%	12.10%	12.51%	37,546
	Age	39.34	39.56	39.16	
	KDPI	47.74	47.49	47.93	
	Black	16.27%	16.61%	16.00%	
	Hypertension	32.27%	32.81%	31.84%	
	HCV+[2]	4.39%	4.16%	4.57%	
	DCD[3]	14.34%	13.06%	15.35%	
	Diabetes	10.17%	10.22%	10.12%	
	Creatinine	1.22	1.20	1.23	
	Offers Until Accept	101.73	89.87	111.16	
Candidate	Transplants	60,252	26,730	33,522	208,797
	EPTS[4]	44.76	46.70	42.01	
	Age	50.83	50.58	51.20	
	Diabetes	41.27%	40.51%	42.36%	
	Dialysis	77.88%	76.91%	79.26%	
	Black	30.33%	31.09%	30.33%	

1: March 26, 2012

2: Hepatitis C Positive

3: Deceased Cardiac Death

4: Expected Post-Transplant Survival

Source: Scientific Record of Transplant Recipients. Non-medically urgent deceased donor kidney offers, 18+, matched between January 1, 2010 and December 04, 2014.

Table 2: Linear Probability Models of Offer Acceptance and Donor Discard

	Acceptance Probability Offer Level				Discard Probability Donor Level	
	(1)	(2)	(3)	(4)	(5)	(6)
KDPI*Provided*100	-.00858***	-.00866***	-.009***	-.01947***	.0190	.0187
	(.0000573)	(.0000573)	(.0000572)	(.0000538)	(.0129)	(.0127)
KDPI*100	-.353***	-.352***	-.354***	-.324***	.413***	.407***
	(.0000451)	(.0000452)	(.0000452)	(.0000427)	(.00957)	(.00946)
Provided	.0143***	.0143***	.0166***	.0216***	-.00688	-.00661
	(.000430)	(.000430)	(.000429)	(.000401)	(.00451)	(.00451)
EPTS		X				
Patient Health Controls			X	X		
Transplant Center FE's				X		
OPO Center FE's						X
Observations	27,099,653	27,099,653	27,099,653	27,068,332	37,546	37,546
R-squared	.0843	.0843	.0856	.1588	.1335	.1479

Source: Scientific Record of Transplant Recipients. Non-medically urgent deceased donor kidneys, 18+, matched from January 1, 2010 to December 04, 2014. *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Quantile Regression Model of Number of Offers Made for Donor Until Offer is Accepted or Discarded

	Offers Until Acceptance/Discard	
	(1)	(2)
KDPI*Provided*100	1.80*	2.34**
	(1.05)	(1.09)
KDPI*100	13.5***	12.5***
	(.780)	(.819)
Provided	-.244	-.438
	(.580)	(.607)
OPO Center FE's		X
Observations	37,456	37,456
Pseudo R-squared	.0019	.0026

Source: Scientific Record of Transplant Recipients.
Non-medically urgent deceased donors, 18+, matched from January 1, 2010 to December 04, 2014.
** p<0.01, ** p<0.05, * p<0.1.

Table 4A: Linear Probability Model of Changes to Salience of Individual Characteristics on Probability of Offer Acceptance Conditional on KDPI

	Acceptance Probability				
	Age	Height (cm)	Weight (kg)	Hypertension	Diabetes
Characteristic*Provided	.00000135**	.000165***	3.04×10^{-6}	.00226***	-.00127***
	(6.75×10^{-6})	(4.85×10^{-6})	(3.84×10^{-6})	(.000222)	(.000223)
Characteristic	-.000389***	-.000579***	-.000482***	.00356***	-.0134***
	(5.89×10^{-6})	(4.02×10^{-6})	(3.09×10^{-6})	(.000183)	(.000174)
Provided	.00866***	-.0177***	.00995***	.00858***	.00960***
	(.000366)	(.000806)	(.000339)	(.000182)	(.000137)
KDPI*100	-.321***	-.346***	-.340***	-.342***	-.329***
	(.0000315)	(.0000269)	(.0000267)	(.0000308)	(.0000277)
Patient Health Controls	X	X	X	X	X
Transplant Center FE's	X	X	X	X	X
Observations	27,068,332	27,068,332	27,068,332	27,068,332	27,068,332
R-squared	.1591	.1601	.1607	.1588	.1590

Source: Scientific Record of Transplant Recipients.
Non-medically urgent, deceased, adult, kidney-only offers, 18+, matched from January 1, 2010 to December 04, 2014.
** p<0.01, ** p<0.05, * p<0.1.

Table 4B: Linear Probability Model of Changes to Salience of Individual Characteristics on Probability of Offer Acceptance Conditional on KDPI

	Acceptance Probability				
	HCV+	DCD	Serum Creatinine	Black	CVA
Characteristic*Provided	-.0296***	.00711***	.00222***	-.0118***	-.00721***
	(.00179)	(.000274)	(.0000834)	(.000284)	(.000220)
Characteristic	.0145***	-.0370***	-.0287***	.0440***	.0212***
	(.00148)	(.000219)	(.0000669)	(.000233)	(.000179)
Provided	.00972***	.00868***	.00795***	.0117***	.0130***
	(.000117)	(.000131)	(.000192)	(.000129)	(.000166)
KDPI*100	-.336***	-.338***	-.341***	-.351***	-.351***
	(.0000267)	(.0000267)	(.0000266)	(.0000277)	(.0000288)
Patient Health Controls	X	X	X	X	X
Transplant Center FE's	X	X	X	X	X
Observations	27,068,332	27,068,332	27,068,332	27,068,332	27,068,332
R-squared	.1588	.1605	.1698	.1607	.1594

Source: Scientific Record of Transplant Recipients.
Non-medically urgent, deceased, adult, kidney-only offers, 18+, matched from January 1, 2010 to December 04, 2014. HCV+ = Positive for Hepatitis C. DCD = Deceased Cardiac Death. CVA = Cerebrovascular Accident.
** p<0.01, ** p<0.05, * p<0.1.

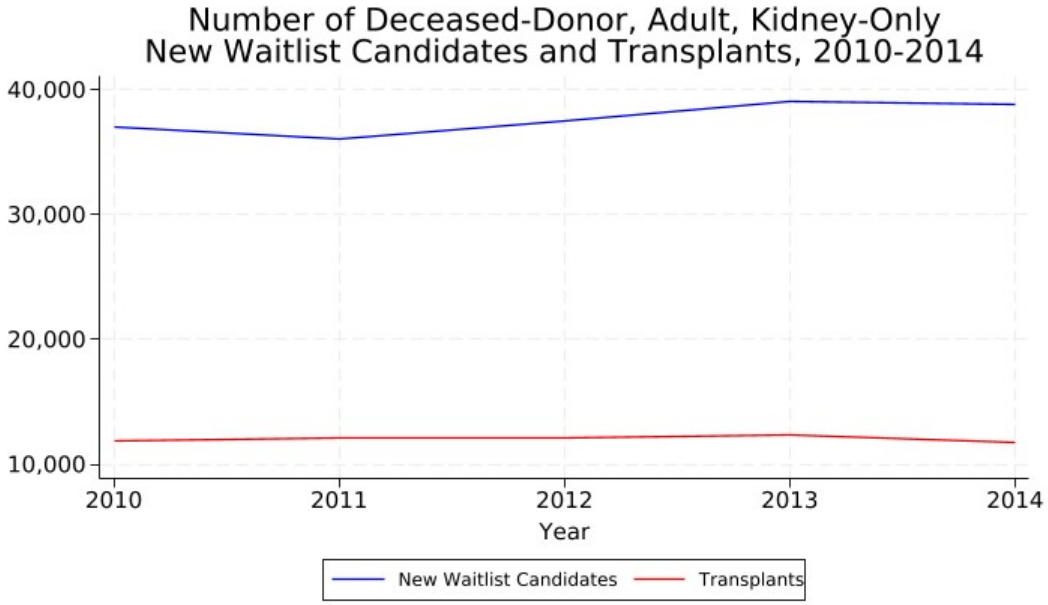


Figure 1: Number of Deceased-Donor, Adult, Kidney-Only Candidates and Transplants, 2010-2014. Source: Scientific Record of Transplant Recipients

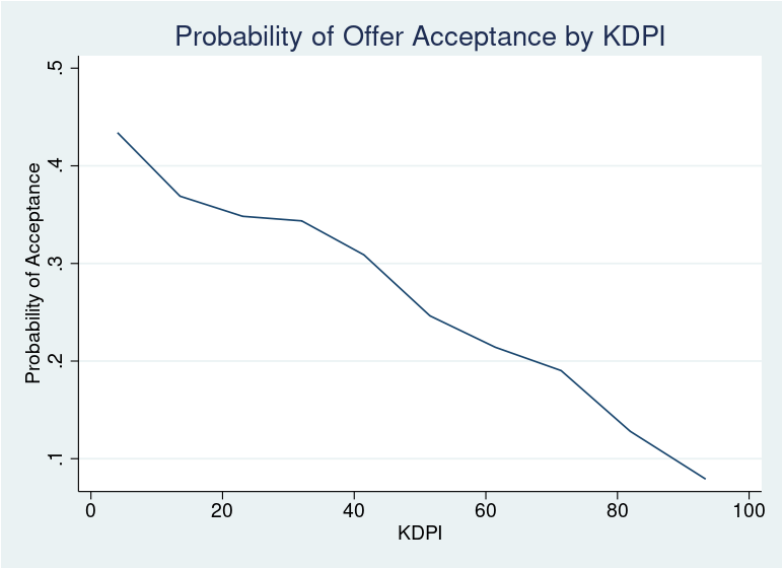


Figure 2: Probability of Offer Acceptance by KDPI
All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

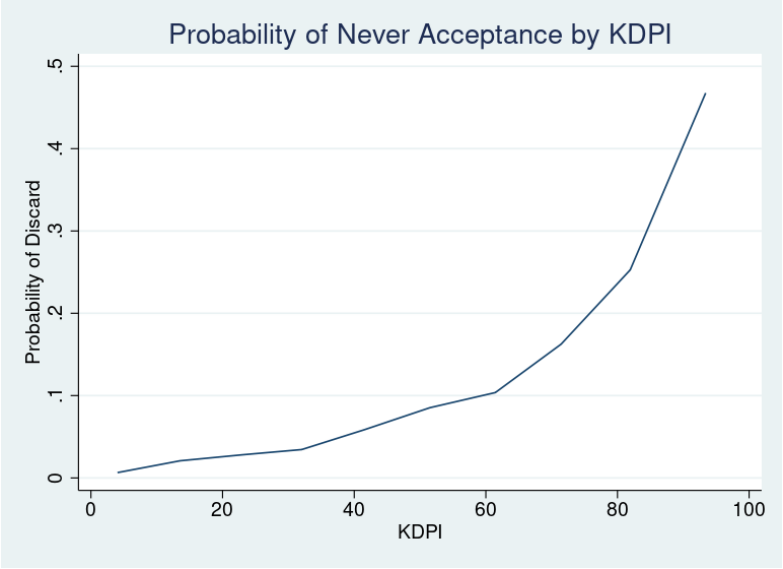


Figure 3: Probability of Discard by KDPI
All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

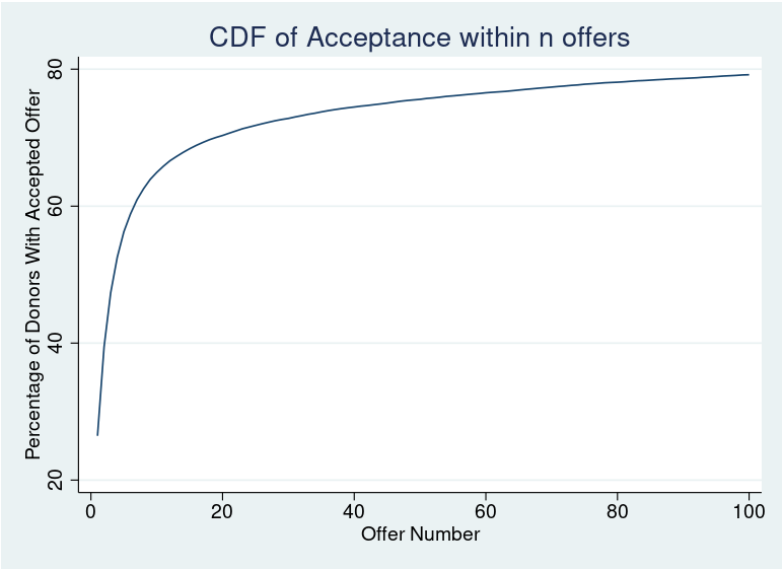


Figure 4: CDF of Probability of Acceptance within n Offers
All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

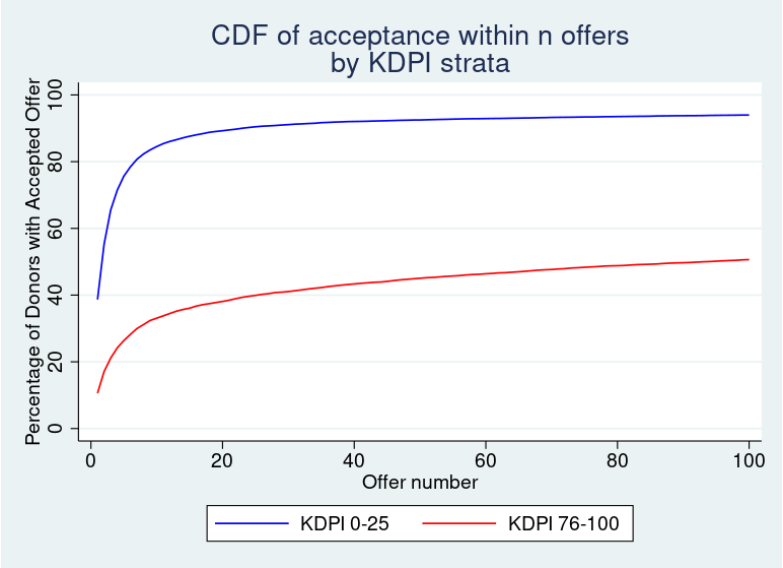


Figure 5: CDF of Probability of Acceptance within n Offers for Upper and Lower KDPI Quartiles
All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

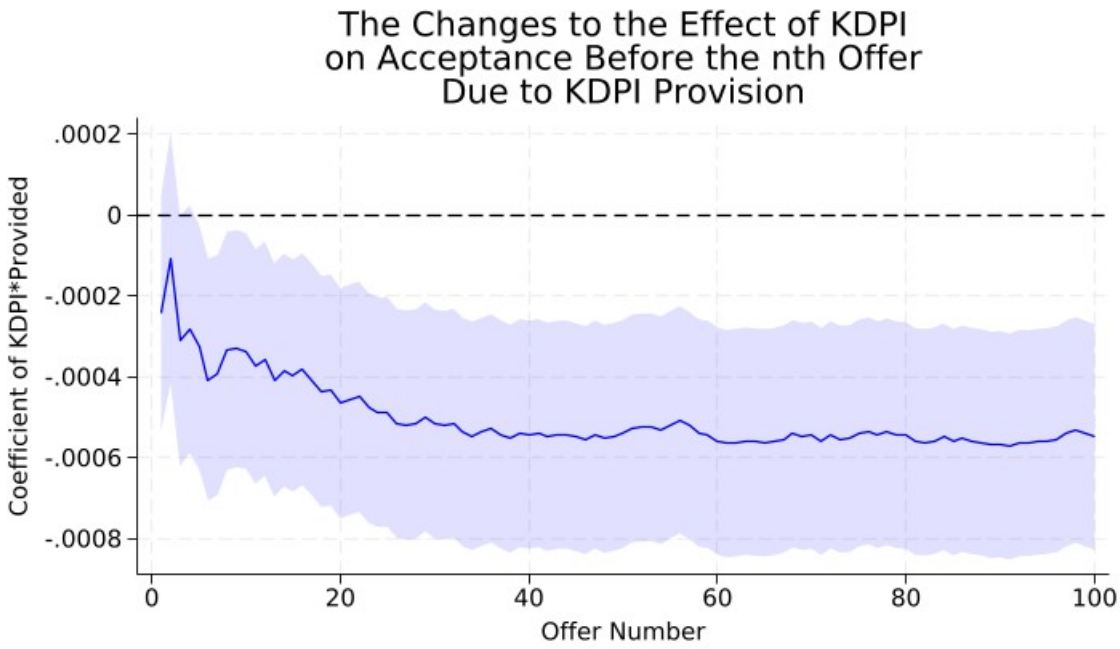


Figure 6: The Changes to the Effect of KDPI Due to Provision of KDPI on Acceptance Before the nth Offer
All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

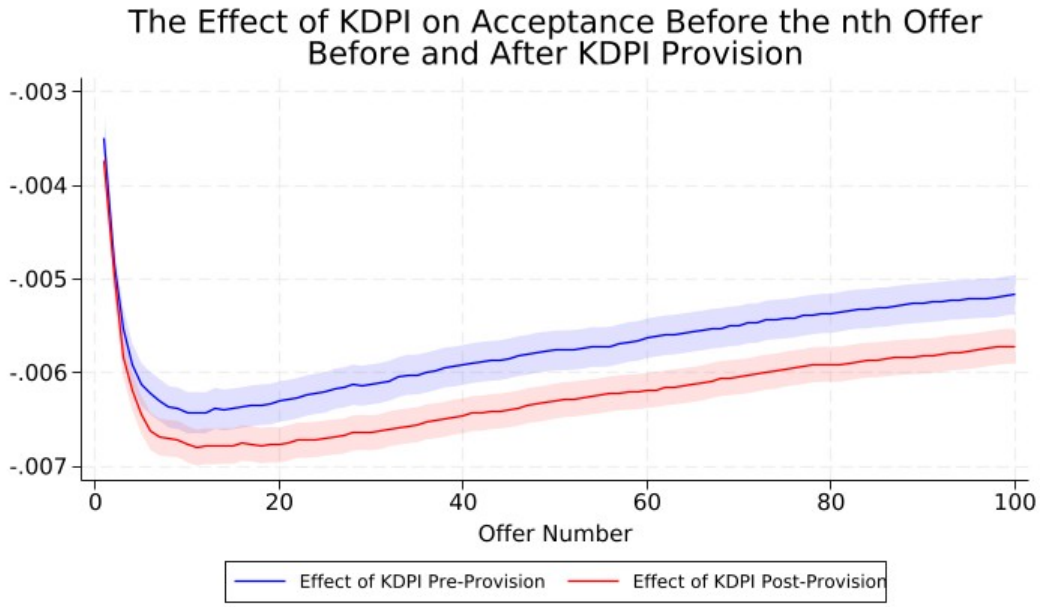


Figure 7: The Effect of KDPI on Offer Acceptance Before the nth Offer Both Before and After KDPI Provision
All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

[7]

Appendix

A Differences in Recipient Composition Following the Salience of KDPI

I investigate whether the transplant recipient composition changes pre- and post-KDPI's revelation. Specifically, I test whether the relationship between KDPI and the probability that a recipient is Black or African-American changes after KDPI becomes salient to physicians. Achieving equity is a primary goal of the allocation system and OPTN, and the procedures for allocation have changed significantly in order to address this. Beginning in 2010, adjusted deceased-donor transplantation rates were equivalent for Black and non-Black candidates.[1] However, it is unclear whether Black transplant candidates are receiving transplants from donors of similar quality, and whether the revelation

*The data reported here have been supplied by the Hennepin Healthcare Research Institute (HHRI) as the contractor for the Scientific Registry of Transplant Recipients (SRTR). The interpretation and reporting of these data are the responsibility of the author and in no way should be seen as an official policy of or interpretation by the SRTR or the US government. All errors are my own

**

[1] **Sood, Akshay, Newaj Abdullah, and Firas Abdollah**, 2015. "Rates of Kidney Transplantation From Living and Deceased Donors for Blacks and Whites in the United States, 1998 to 2011". *JAMA Internal Medicine* 175(10): 1716-1718

of KDPI attenuates the quality gradient for candidates across race or increases it.

First, I estimate the effects of the salience of KDPI on offer acceptance probability separately for Black and non-Black candidates. To do this, I mimic Equation 6, but I also add indicators for whether the candidate who receives the offer is Black

$$Y_{ijt} = \alpha+\gamma KDPI_i+\tau Provided_t+\beta KDPI_i*Provided_t+\delta Black_j+\zeta Black_j*Provided_t+\xi Black_j*KDPI_i+\chi Bl$$

Here, Y_{ijt} indicates whether an offer was accepted or not, $Black_j$ indicates whether the offered candidate was Black or African-American, C_j are candidate health controls, and λ_j are transplant center fixed effects.

A negative value of ξ would indicate that, given a fixed increase in KDPI, Black candidates in the pre-KDPI period would have experience a greater decrease in the probability of offer acceptance than non-Black candidates. A positive value of χ would suggest that this gap decreases once KDPI becomes salient. The results of these estimations are shown in the Table 5.

Across all three specifications, the coefficient on the interaction between Black and KDPI is around -.0005 and statistically significant, indicating that for a 10 percentage point increase in KDPI in the pre-period, the probability of offer acceptance for Black candidates will decrease by an additional .05 percentage points compared to non-Black candidates. This means that Black candidates show an increased preference for low-KDPI as opposed to high-KDPI organs in the pre-period.

The coefficients on the triple interaction between the race of the candidate, KDPI status, and whether KDPI is provided are either .000163 or .000114 and statistically significant, which means that the gap between Black and non-Black

candidates mentioned prior will decrease. For the full model specification (Column 3), the salience of KDPI means that the 10 percentage point increase in KDPI will result in a decrease in the gap in offer acceptance between Black and non-Black candidates by .0114 percentage points, or roughly a 20% narrowing of this gap.

This evidence would suggest that the effect of the salience of KDPI is not evenly distributed among Black and non-Black candidates. Before KDPI became salient, Black candidates showed increased preference for low-KDPI kidneys relative to high-KDPI kidneys, but after KDPI was provided to physicians, the strength of this additional preference attenuated.

Black candidates are more likely to accept a kidney offer altogether. The predictive margins estimated for Table 5 Column 3 (the full specification) show the probability of offer acceptance for Black candidates to be 11.02% (95% CI: [11.01%; 11.05%]) as opposed to 10.86% for non-Black candidates (95% CI: [10.85%; 10.87%].

Table 5: Linear Probability Models of Offer Acceptance

	Probability of Offer Acceptance		
	(1)	(2)	(3)
Black*KDPI*Provided	.000163***	.000163***	.000114***
	(.0000124)	(.0000124)	(.0000117)
Black*KDPI	-.000533***	-.000532***	-.000480***
	(9.79×10^{-6})	(9.78×10^{-6})	(9.23×10^{-6})
KDPI*Provided	-.000137***	-.000141***	-.000229***
	(6.87×10^{-6})	(6.86×10^{-6})	(6.42×10^{-6})
KDPI	-.00336***	-.00338***	-.00309***
	(5.40×10^{-6})	(5.40×10^{-6})	(5.07×10^{-6})
Black*Provided	-.0150***	-.0151***	-.0154***
	(.000934)	(.000933)	(.000877)
Black	.0520***	.0571***	.0365***
	(.000732)	(.000731)	(.000691)
Provided	.0190***	.0218***	.0263***
	(.000514)	(.000513)	(.000477)
Candidate Health Controls		X	X
Transplant Center FE's			X
Observations	27,099,653	27,099,653	27,068,332
R-squared	.0852	.0869	.1591

Source: Scientific Record of Transplant Recipients.
Non-medically urgent deceased donor kidneys, 18+, matched from January 1, 2010 to December 04, 2014.
*** p<0.01, ** p<0.05, * p<0.1.

This then prompts the question as to whether these changes in offer acceptance probability affect the distribution of kidneys which are transplanted into Black candidates compared to non-Black candidates. I estimate the following regression for transplant recipients, where Y_{it} reflects whether the recipient is a Black or African American candidate:

$$Y_{ijt} = \alpha + \gamma KDPI_i + \tau Provided_t + \beta KDPI_i * Provided_t + \phi C_j + \lambda_j + \epsilon_{ijt}$$

C_j are candidate health controls λ_i are transplant center fixed effects. The coefficients of interest are γ and β. If γ is positive, it means that the share

of Black candidates is increasing as KDPI increases across the entire sample. This means that Black candidates are receiving lower-quality kidneys relative to their counterparts. Meanwhile, if β is positive, it means that once KDPI becomes salient Black candidates are even more likely to receive lower-quality kidneys than other races. On the other hand, if β is negative and γ is positive, then after KDPI becomes salient Black transplant recipients receive kidneys of a more similar KDPI to non-Black candidates.

The results are shown in the table below. In the pre-KDPI period, the share of Black transplant recipients increases by roughly 1 percentage point for every 10 percentage point increase in KDPI for the models without transplant center fixed effects. For the model with these fixed effects, the share of Black transplant recipients increases by .5 percentage points for every 10 percentage point increase in KDPI. This indicates that Black transplant recipients may be receiving lower-quality kidneys. The effect of the salience of KDPI, however, has opposite sign, indicating a potential attenuation of this effect. Column 1 would indicate that KDPI's salience would decrease the share of Black transplant recipients resulting from a 10 percentage point increase in KDPI by .0366 percentage points. However, this effect is not statistically significant after accounting for candidate health controls or candidate health controls with transplant center fixed effects.

These results suggest an interesting puzzle. In the pre-KDPI period, Black candidates express stronger preferences for low-KDPI organs compared to non-Black candidates. However, as KDPI increases, Black candidates receive a larger share of transplanted organs. This suggests that the distributions of the quality of organs offered to Black and non-Black candidates may not be equal. KDPI's salience leads to a decrease in the gap in preference for low-KDPI organs between non-Black and Black candidates. However, this gap is not significantly reflected

Table 6: Linear Probability Model of Share of Black Transplant Recipients

	Share of Black Transplant Recipients		
	(1)	(2)	(3)
KDPI*Provided	-.000366***	-.000263*	-.000152
	(.000146)	(.000143)	(.000130)
KDPI	.00110***	.00131***	.000453***
	(.000110)	(.000110)	(.000102)
Provided	.00112	-.0190***	-.0133**
	(.00739)	(.00725)	(.00666)
Candidate Health Controls		X	X
Transplant Center FE's			X
Observations	60,252	60,252	60,162
R-squared	.0029	.0462	.2186

Source: Scientific Record of Transplant Recipients.
Non-medically urgent deceased donor kidneys, 18+, matched from January 1, 2010 to December 04, 2014.
*** p<0.01, ** p<0.05, * p<0.1.

in the actual share of Black transplant recipients.

B Graphs of Excess Weight Placed on Characteristics After Introduction of KDPI on Acceptance Within First n Offers

I combine the "excess weight" approach used in Equation 8 to determine the salience of individual characteristics with the probability of acceptance within n offers. This results in graphs mirroring those of Figures 6 and 7, but for the changes to the effect of individual characteristics before and after KDPI provision and conditional upon KDPI.

Thus, I am estimating the following equation for a characteristic x_i:

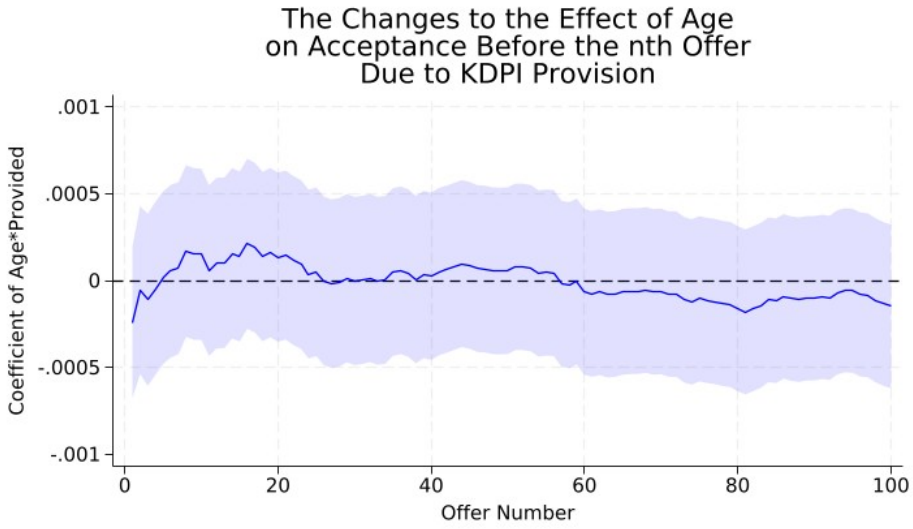
$$Y_{it} = \alpha + \gamma KDPI_i + \tau Provided_t + \psi x_i + \beta x_i * Provided_t + +\lambda_i + \epsilon_{it}$$

In the above, λ_i are OPO center fixed effects. The Y_{it} are formed as following,

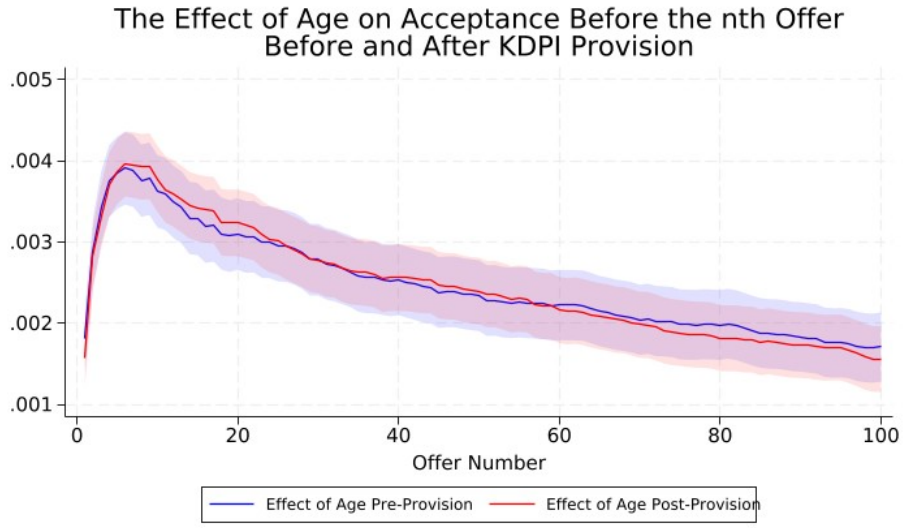
where A_i is an indicator for offer acceptance:

$$Y_n = \begin{cases} 1 & \exists \quad i \leq n \text{ such that } (A_i) = 1 \\ 0 & \forall \quad i \leq n, \ (A_i) = 0 \\ Missing & (A_n) = Missing \end{cases}$$

B.1 Age

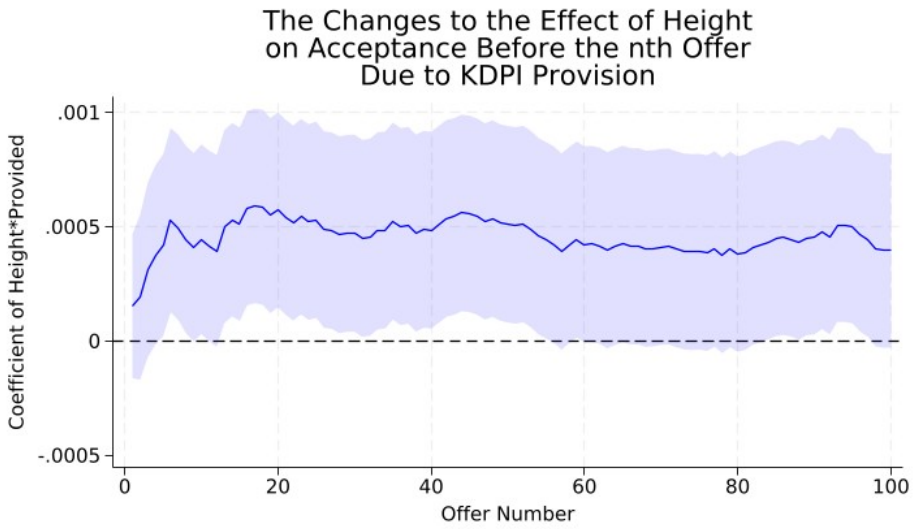


All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

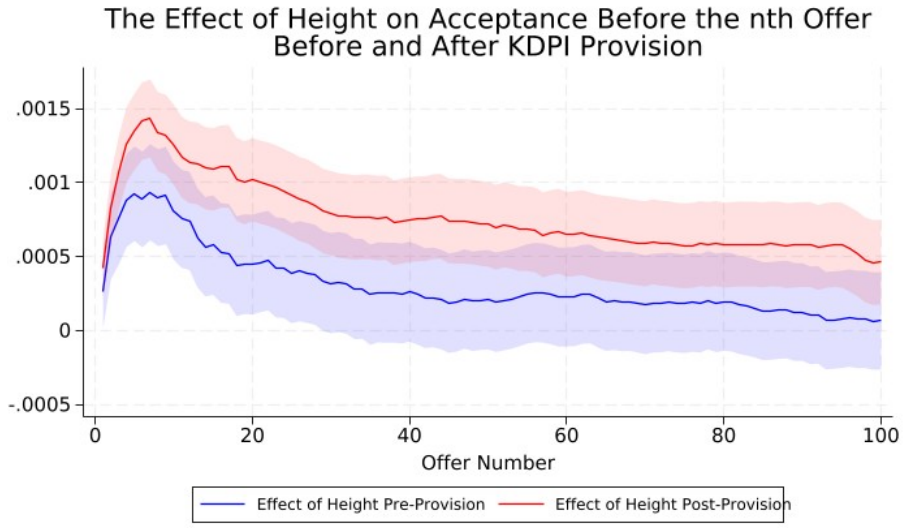


All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

B.2 Height

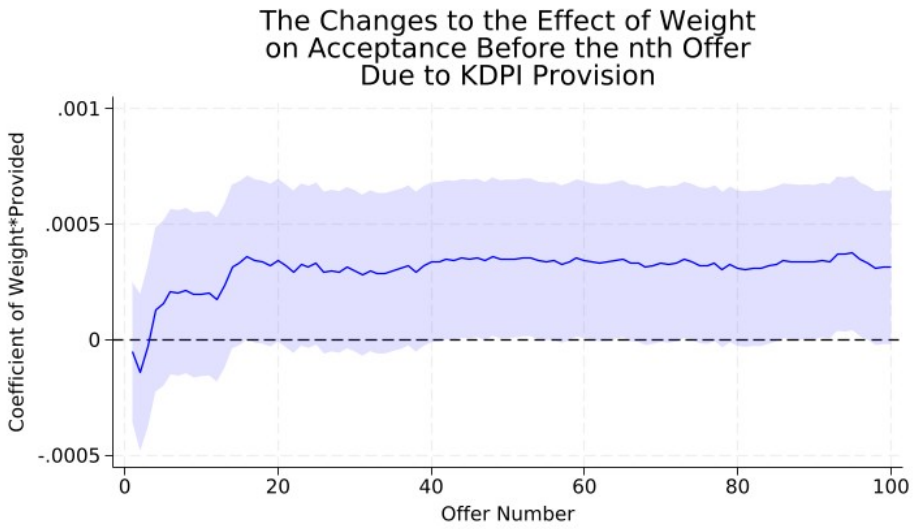


All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

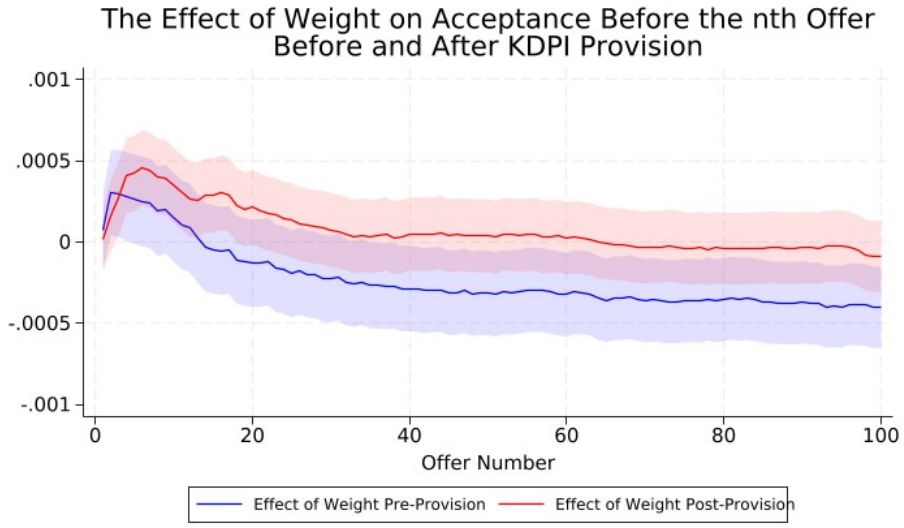


All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

B.3 Weight

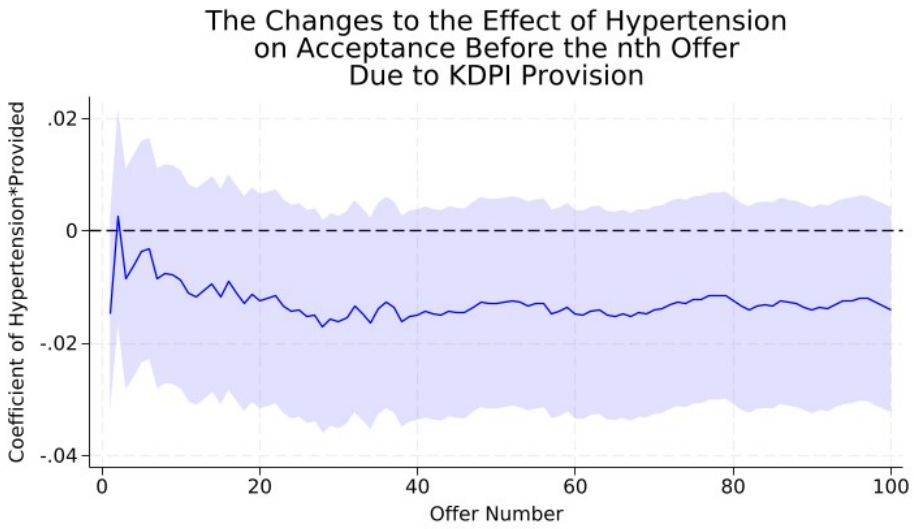


All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

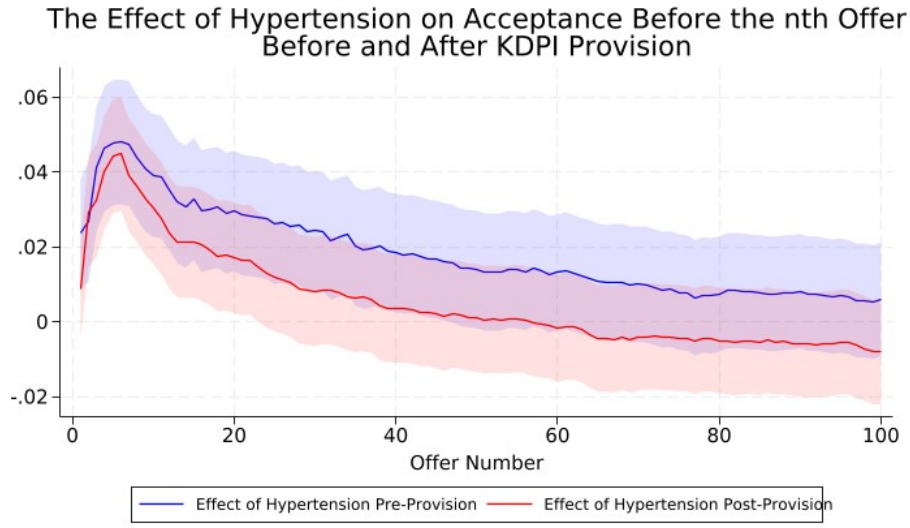


All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

B.4 Hypertension

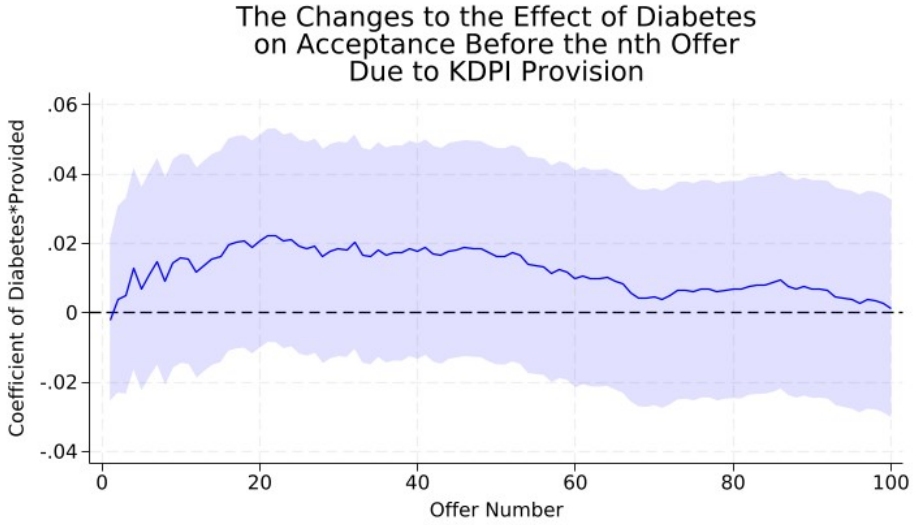


All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

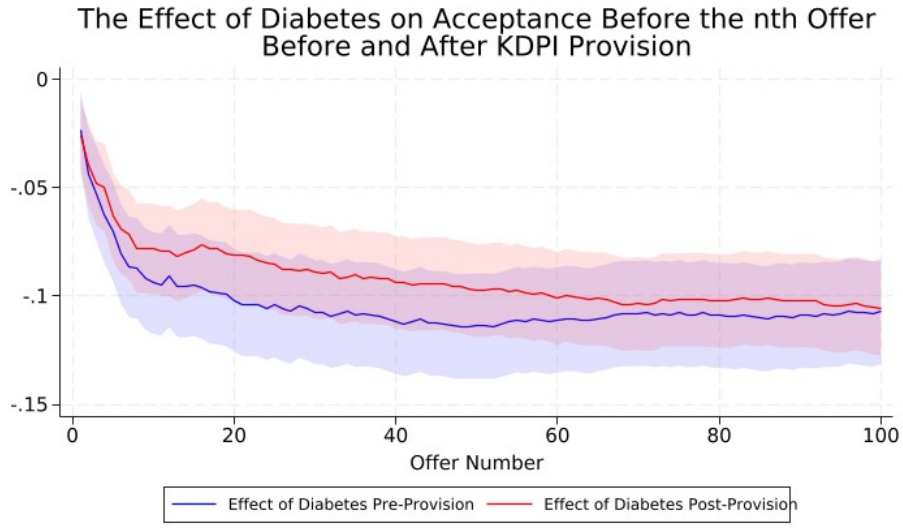


All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

B.5 Diabetes

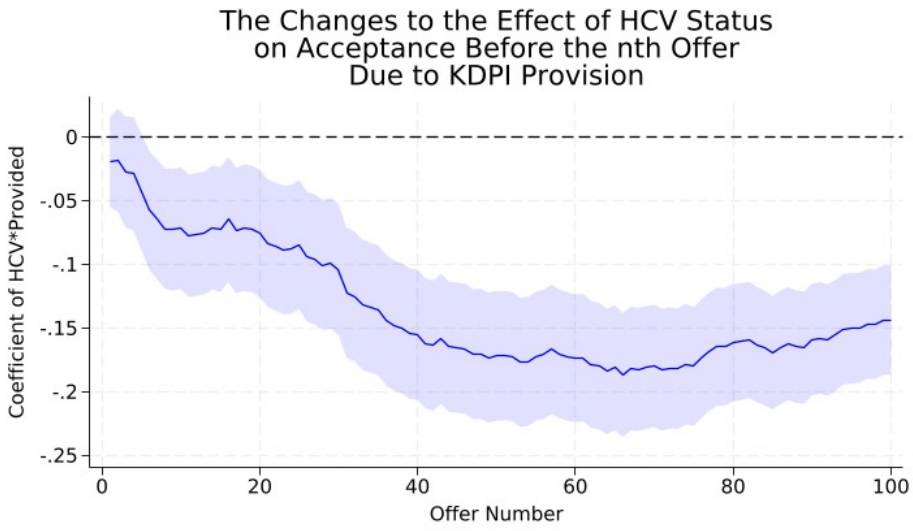


All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

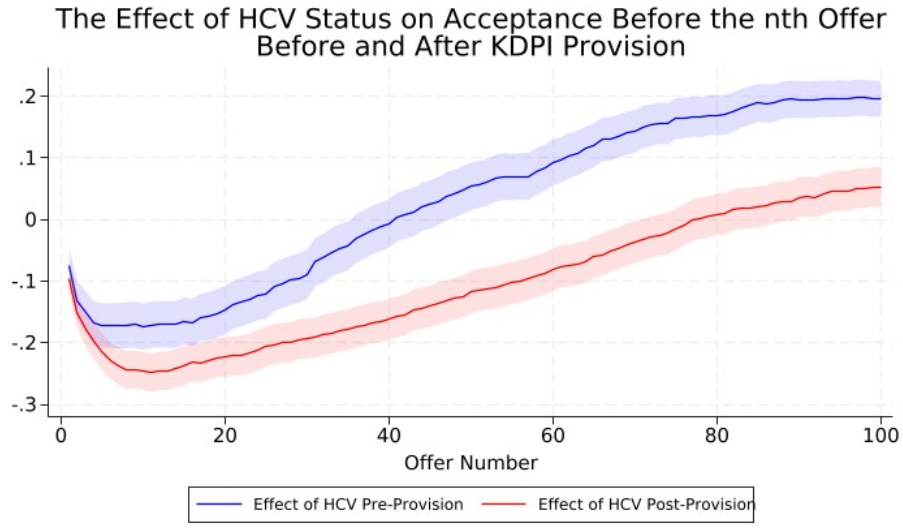


All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

B.6 Hepatitis C Positive

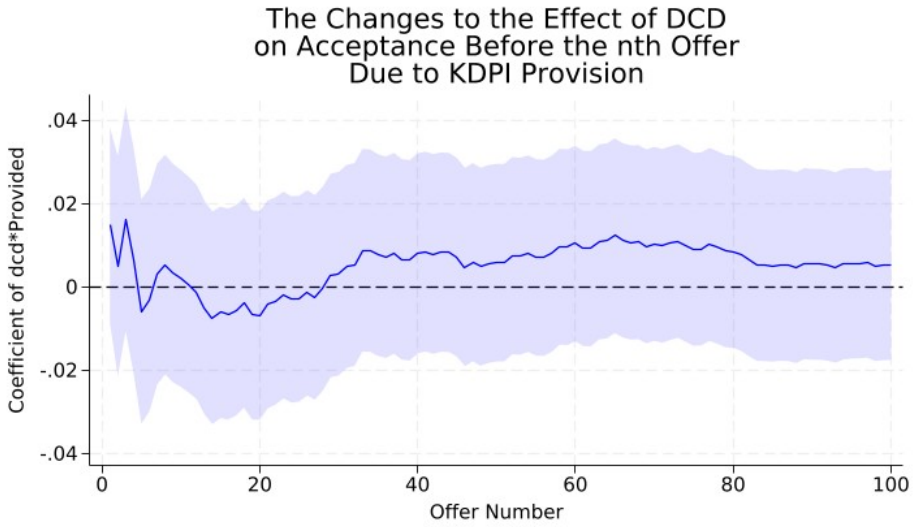


All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

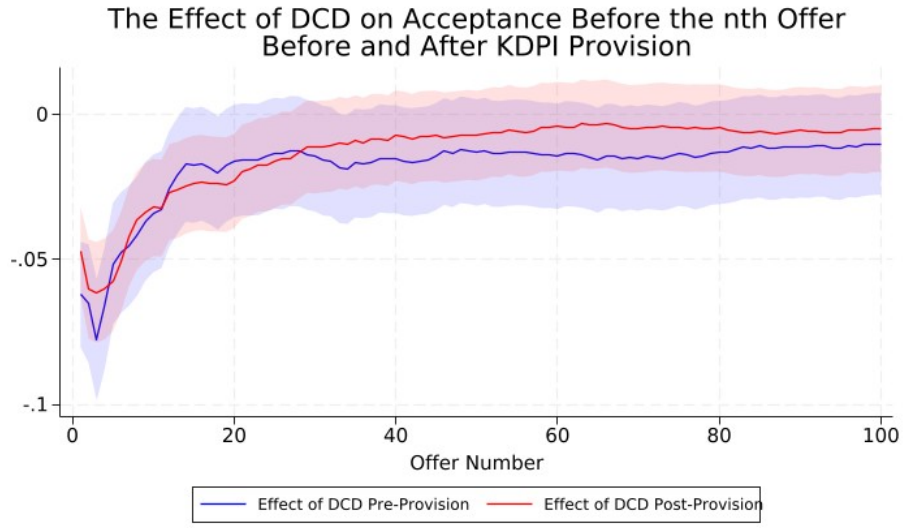


All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

B.7 Deceased Cardiac Death

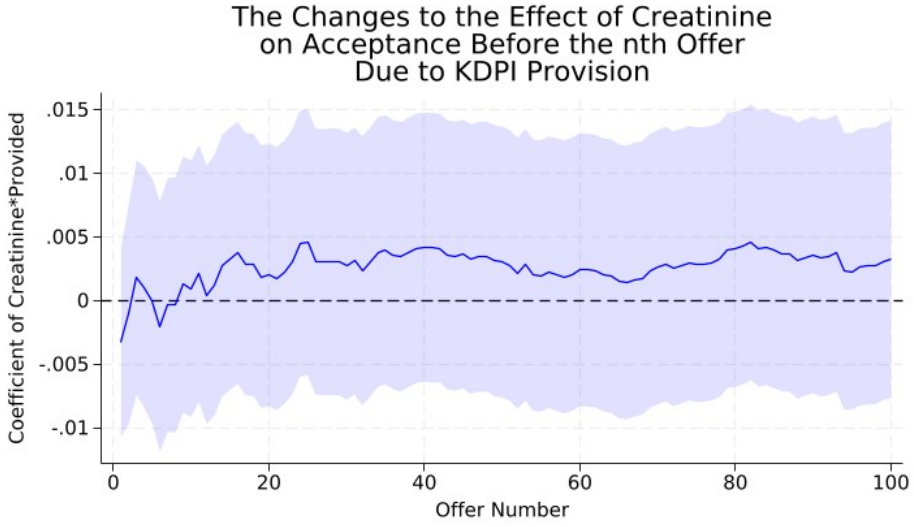


All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

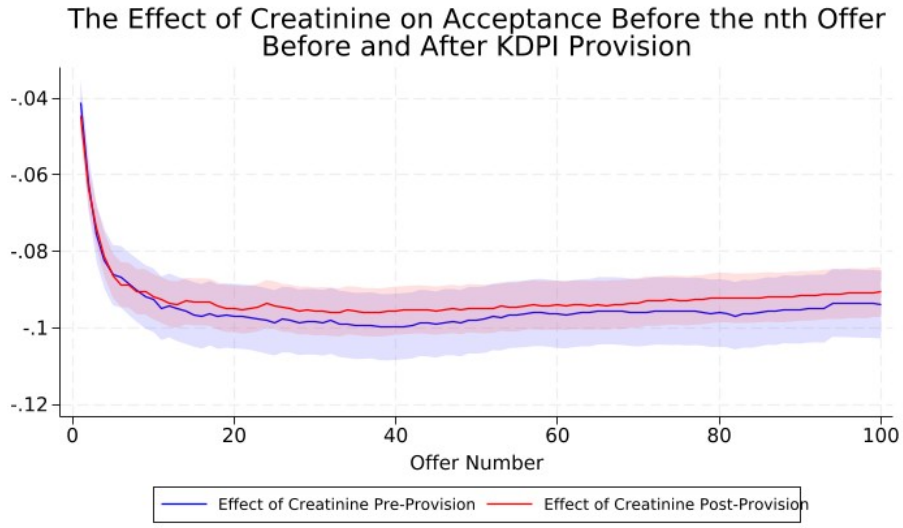


All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

B.8 Serum Creatinine

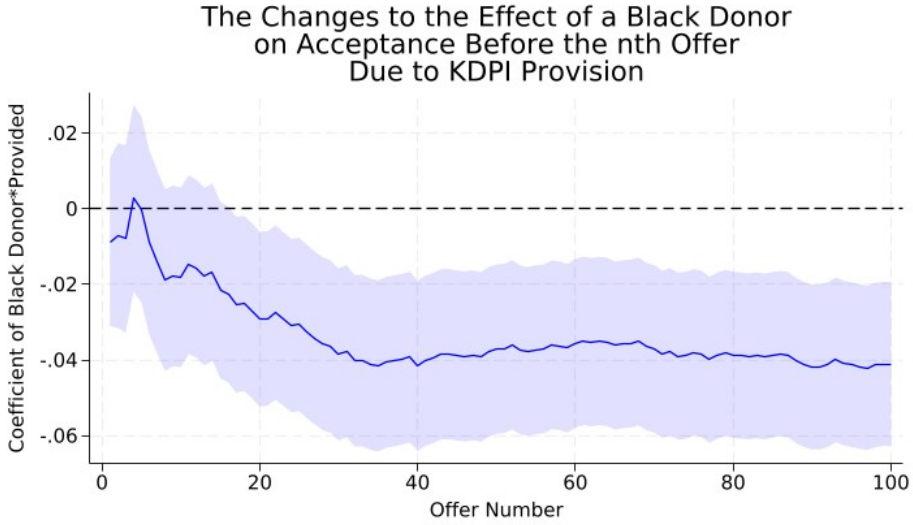


All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

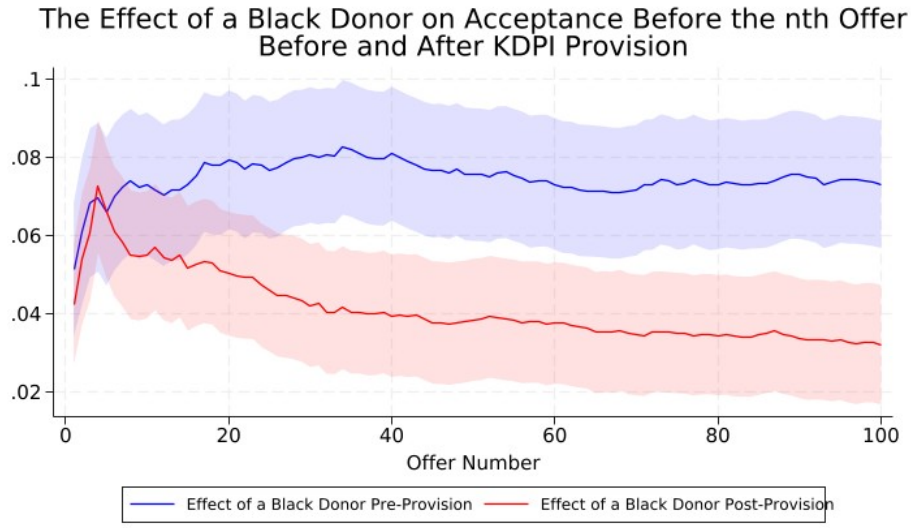


All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

B.9 Black or African American Donor

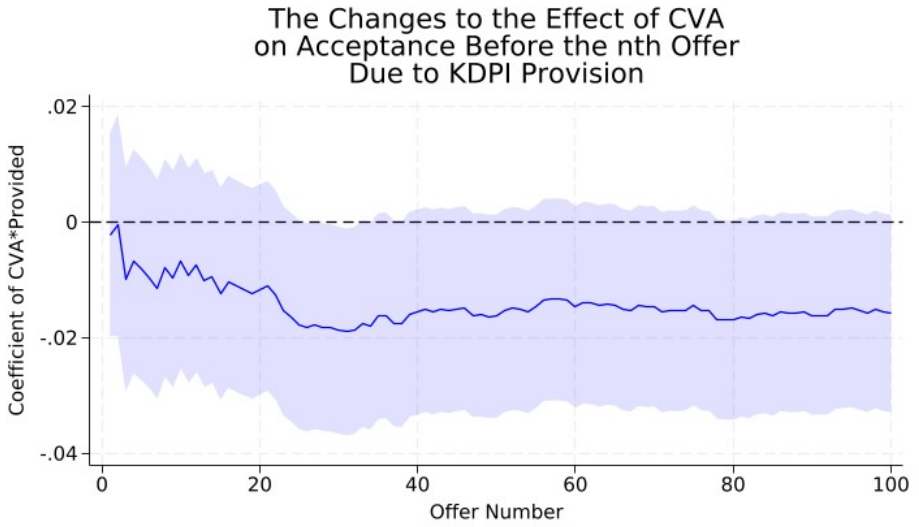


All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

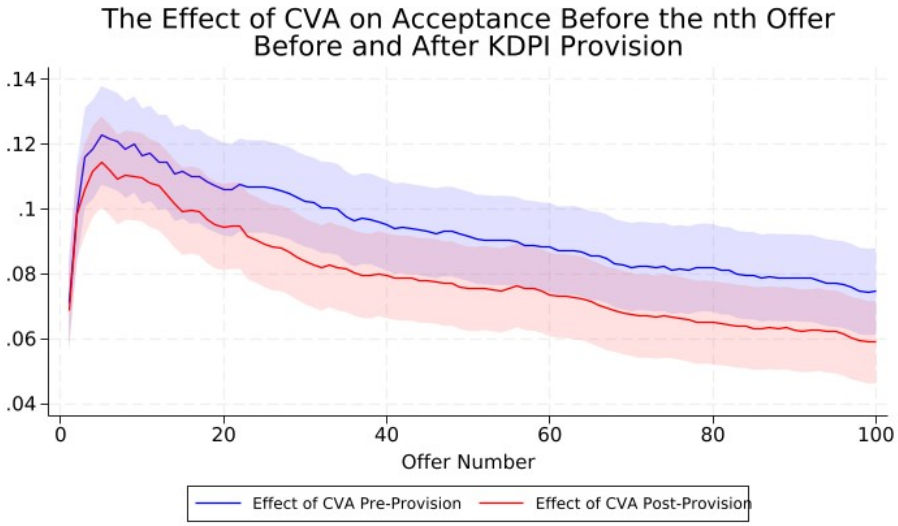


All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients

B.10 Cerebrovascular Accident



All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients



All Deceased-Donor, Adult, Kidney-Only Offers, 2010-2014. Source: Scientific Record of Transplant Recipients