Incentivized Kidney Exchange

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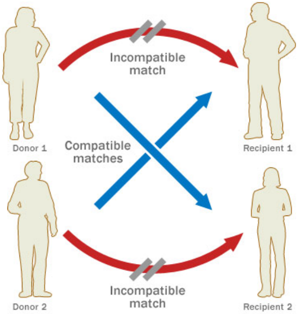
Kidney Exchange

- **Kidney Exchange** became a wide-spread modality of transplantation within the last decade (Roth, Sönmez, & Ünver 2004, 2005, 2007).
- More than 700 patients a year receive kidney transplant in the US along through exchange, more than 12% of all living-donor transplants.

Kidney Exchange



- Human organs cannot received or given in exchange for "valuable consideration" (US, NOTA 1984, WHO)
- However, **living donor kidney exchange** is not considered as "valuable consideration" (US NOTA amendment, 2007)

Outline

- Background and Contribution
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  - Impact of (Non-)Inclusion of Compatible Pairs in Exchange
  - Efficiency and Access Equity As Two Transplantation Goals
  - Contribution of This Paper
- Model and Steady-State Derivations
  - Deceased Donation
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  - Efficiency and Equity Impact on Deceased-Donation Recipients
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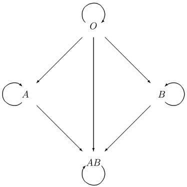
- Numerical Model Calibration Results

BACKGROUND AND CONTRIBUTION

Medicine of Kidney Donation: Compatibility

A donor needs to be pass two compatibility tests before transplantation can go through.

- Blood-type Compatibility: There are four blood types O, A, B, AB. Blood-type compatibility partial order: O $\triangleright$ A,B $\triangleright$ AB.



- Tissue-type Compatibility: Prior to transplantation, the potential recipient is tested for the presence of preformed antibodies against donor tissue type antigens, known as HLA.

  If such antibodies exist above some threshold level, the donor is deemed tissue-type incompatible.

Donation Technologies

- Deceased Donation: Centralized priority allocation based on a points scheme. Waiting time is always prioritized.
  For kidneys ≈ first-in–first-out (FIFO) queue based on geography except for patient with high tissue-type incompatibility chance and younger patients.
- (Directed) Living Donation: Mostly loved ones of the patient come forward.
  If one of them is compatible with the patient, then transplantation is conducted.
- Living-Donor Organ Exchange: If none of the living donors who came forward for their patient are compatible, kidney of one of them is exchanged with the compatible kidney from another incompatible patient-donor pair.

(Non-)Inclusion of Compatible Pairs

- Typically a blood-type compatible pair participates in kidney exchange only when the donor is tissue-type incompatible with the patient.
- In contrast, a blood-type incompatible pair has no option for living donation other than kidney exchange.
- Hence, there are many more blood-type incompatible pairs in kidney exchange programs than blood-type compatible pairs.

Number of O Patients $\gg$ Number of O Donors

- This disparity can be minimized if compatible pairs can also be included in kidney exchange.
- Most gains from kidney exchange will come from inclusion of compatible pairs rather than innovations in exchange formats or platforms.

Goals of Organ Allocation: Efficiency and Access Equity

In the US, the Organ Procurement and Transplantation Network (OPTN) is established to oversee equitable and efficient organ transplantation

> *"With all of our collective efforts focused on patients, the goals of the OPTN are to:*
>
> - ***Increase** the number of transplants*
> - *Provide **equity in access** to transplants*
> - *Improve waitlisted patient, living donor, and transplant recipient outcomes"*

Equity in Organ Transplantation

- Three goals of OPTN for Equity in Access
  - Across blood types
  - Across tissue-type incompatibility levels
  - Across geographic regions
- Certain efficiency improving paradigms are abandoned because of inequity enhancing features
  - Example: ABO-incompatible indirect exchange

Contribution: Proposal

New Proposal

Incentivize compatible pairs to participate in exchange:

*If a compatible pair with a more valuable donor blood type than patient blood type (such as A patient - O donor) participates in exchange, then give **priority** to the patient of this pair on the deceased-donor queue in case the patient's transplant fails in the future.*

- 15% of patients are reentrants for kidneys.
- Insure the patient of the compatible pair's altruism.
- All living donors already get such a **priority** for their altruism.

Contribution: Model

- A new continuous-time continuum arrival (a.k.a. fluid) model that can help us analyze the impact of all donation technologies together:
  - deceased-donor allocation,
  - direct living donation, and
  - living-donor exchange

  for all patient groups participating in different phases of the transplantation process.
- A new test–bed to quantify, predict, and estimate the **efficiency** and **equity** consequences of old and new transplant allocation policies.

Contribution: Summary of Theoretical Results

In a homogeneous population (i.e., with uniform rates of donor arrivals per patient of the same blood type and with uniform tissue-type incompatibility probability), when reentry rates are sufficiently small:

- When only deceased donation is available, all patients wait for the same duration for a transplant.
- When, in addition direct living donation becomes available,
  - every patient group benefits,
  - access inequity to deceased donation arises: $t_O > t_B > t_A > t_{AB}$.
- When, in addition, (regular) exchange becomes available,
  - every patient group benefits,
  - paired AB and O patients benefit the least, and paired B patients benefit the most,
  - access inequity to deceased donation persists for O: $t_O > t_B = t_A > t_{AB}$.
- When, in addition, incentivized exchange becomes available,
  - every patient group benefits,
  - all strictly with the exception of AB patients,
  - O patients benefit the most,
  - access inequity to deceased donation decreases.

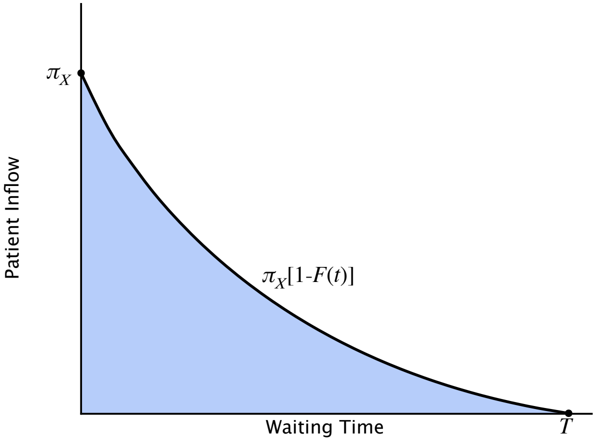
MODEL AND STEADY-STATE DERIVATIONS

Model: Patients with an Organ Failure

- Each patient is represented by his blood type $X \in \mathcal{T} = \{A, B, AB, O\}$.
- Measure π_X of X blood-type new patients arrive every moment.
- $F(t)$: The probability of a patient dying within t weeks after arrival such that $F(T) = 1$ for some T.
- The survival function is $1 - F(\cdot)$: Living X blood-type patients at time t after arrival is

$$\pi_X[1 - F(t)].$$

Patients with an Organ Failure



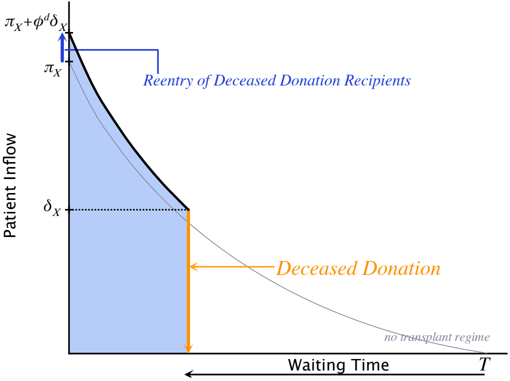
Transplant Technology: Deceased Donation

- Measure δ_X of X blood-type deceased donors arrive every moment with $\delta_X < \pi_X$.
- First-in–first-out (FIFO) deceased-donor allocation protocol.
- $\theta < 1$: The probability of a random donor having tissue-type incompatibility with a random patient
  (Tissue-type incompatibility probability could also be a distribution with mean θ across the patient population, in the paper we consider this case).
- Blood-type allocation policy:
  - ABO-i(dentical): X blood-type deceased-donor kidneys are only transplanted to X blood-type, compatible patients.
  - In the US, the policy is almost ABO-i, with the exception of A kidneys can be also transplanted to AB patients.

Reentry of Patients After Past Transplants

- At steady state, every moment a ϕ^d fraction of the previous flow of deceased-donor transplants fail and those recipients reenter the queue.
- Reentrant survival function is assumed to be the same as that of new patients as $1 - F(\cdot)$.
- Thus, $\phi^d \delta_X$ is the flow of blood-type X reentrants.

Deceased Donation: Steady State



$$\text{Demand} = \text{Supply}$$

$$\left[\pi_X + \phi^d \delta_X\right]\left(1 - F(t_X^{\mathbf{d},dec})\right) = \delta_X$$

$$\Longrightarrow \quad t^{\mathbf{d},dec} = F^{-1}\left(1 - \frac{\delta_X}{\pi_X + \phi^d \delta_X}\right)$$

Deceased Donation: Steady State

- To prove the above result, we need a new large market matching lemma regarding the possibility of **perfectly** matching

  a flow γ of donors with a flow γ of patients,

  who are blood-type compatible with these donors but can possibly be tissue-type incompatible with some.
- We prove such a lemma using a technique that uses Gale's Demand & Supply Theorem, assuming each patient has a donor-tissue-rejection type, and each rejection type's arrival flow goes to zero as the number of rejection types goes to infinity.
- We prove these types of lemmas for all of our results in the paper, i.e. for living-donor exchange as well.

Direct Living Donation

- Fraction λ_X of blood-type X patients have a paired living donor, who is willing to donate to them.
- p_X is the probability that the paired donor is of blood type X.
- We denote a pair type by patient-living donor blood types as $X - Y$.
- $p_Y \lambda_X \pi_X$ is the flow of pairs.
- $\phi^l < \phi^d$ is the reentering fraction of living donation recipients.

Direct Living Donation

- Let p^l_X be the probability of an X patient to be compatible with his living donor:

$$\begin{aligned} p^l_O =& (1-\theta)(p_O) \\ p^l_A =& (1-\theta)(p_O + p_A) \\ p^l_B =& (1-\theta)(p_O + p_B) \\ p^l_{AB} =& (1-\theta)(p_O + p_A + p_B + p_{AB}) = (1-\theta) \end{aligned}$$

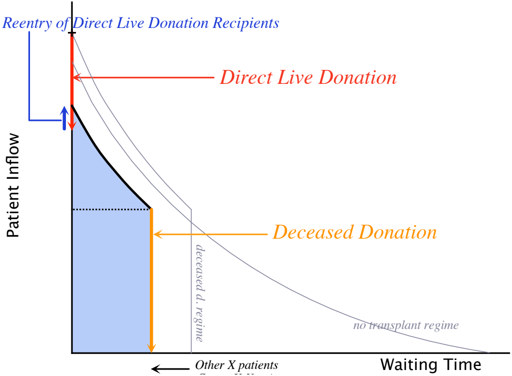
- In reality as $p_B < p_A$, we have

$$p^l_O < p^l_B < p^l_A < p^l_{AB}.$$

- Patient flow benefiting from direct living donation

$$l_X = p^l_X \lambda_X \pi_X$$

Direct Living Donation: Steady State



Demand =Supply

$$\left[\pi_X - \mathbf{l}_X + \phi^d \delta_X + \phi^l \mathbf{l}_X\right]\left(1 - F(t_X^{\mathbf{l},dec})\right) = \delta_X$$

$$\Longrightarrow \quad t^{\mathbf{l},dec} = F^{-1}\left(1 - \frac{\delta_X}{\pi_X - (1-\phi^l)\mathbf{l}_X + \phi^d \delta_X}\right)$$

Regular Living-Donor Exchange

- Only incompatible pairs participate.
- Only two-way exchanges are feasible.
- **Assumption:**
  - if $Y \triangleright X$ then $\theta p_Y \lambda_X \pi_X < p_X \lambda_Y \pi_Y$.
  - $p_B \lambda_A \pi_A \leq p_A \lambda_B \pi_B$
- Categorize the pair types:
  - Overdemanded types: X-Y such that Y $\triangleright$ X and Y $\neq$ X & A-B
  - Underdemanded types: X-Y such that X $\triangleright$ Y and Y $\neq$ X & B-A
  - Self-demanded types: X-X

Living-Donor Exchange

Theorem (Optimal Living-Donor Exchange Rule)

At steady state, a policy that dictates matching the longest-waiting pairs of a type X-Y with their longest-waiting reciprocal type Y-X pairs maximizes the flow of regular exchange transplants.

Living-Donor Exchange and Deceased Donation

- Self-demanded types and overdemanded types never wait in the exchange pool. They get matched immediately.
- Underdemanded types simultaneously wait in the **deceased-donor queue** and **exchange pool**.

Living Donation under Exchange

In addition to flow of patients benefiting direct living donation, $\mathbf{l}_X$ found before, flow of patients benefitting from exchange, $\mathbf{e}_X$:

$$\begin{aligned}
\mathbf{e}_O &= \theta p_O(\lambda_O\pi_O + \lambda_A\pi_A + \lambda_B\pi_B + \lambda_{AB}\pi_{AB}) \\
\mathbf{e}_A &= \theta p_A(\lambda_A\pi_A + \lambda_{AB}\pi_{AB}) + \theta p_O\lambda_A\pi_A + p_B\lambda_A\pi_A, \\
\mathbf{e}_B &= \theta p_B(\lambda_B\pi_B + \lambda_{AB}\pi_{AB}) + \theta p_O\lambda_B\pi_B + p_B\lambda_A\pi_A, \text{ and} \\
\mathbf{e}_{AB} &= \theta(p_{AB} + p_A + p_B + p_O)\lambda_{AB}\pi_{AB} = \theta\lambda_{AB}\pi_{AB}.
\end{aligned}$$

Deceased Donation under Exchange: Pooling

- Introduce a tool for determining waiting times for deceased donation.
- Define a hypothetical r-ratio, a supply-to-demand flow ratio, as

$$r = \frac{\text{Flow of Donors}}{\text{Flow of Patients Who Demand These Donors}}$$

- As if all these donors will exclusively be allocated to these patients, a hypothetical waiting time for a group with supply-to-demand flow ratio r:

$$t = F^{-1}(1 - r).$$

decreasing in r.

Deceased Donation under Exchange: Pooling

Define the following *r*-ratios:

- For underdemanded type X-Y, they can participate in deceased donation or exchange. However, if they only participated in exchange the relevant *r*-ratio would be as follows:
  - If X ▷ Y
    $$r_{X-Y} = \frac{\theta p_X \lambda_Y \pi_Y}{p_Y \lambda_X \pi_X}$$
  - If X-Y=B-A
    $$r_{B-A} = \frac{p_B \lambda_A \pi_A}{p_A \lambda_B \pi_B}$$
- For unpaired X patients, if all deceased donors were available to them because X-Y underdemanded pairs receive exclusively exchange:
  $$r_X = \frac{\delta_X}{\pi_X - \lambda_X \pi_X + \phi^d \delta_X + \phi^l (\mathbf{l}_X + \mathbf{e}_X)} = \frac{\delta_X}{\pi_X^u}$$

Deceased Donation under Exchange: Pooling

- If $t_X > t_{X-Y}$ then X-Y types will receive exclusively exchange transplants from Y-X and never receive deceased donation.

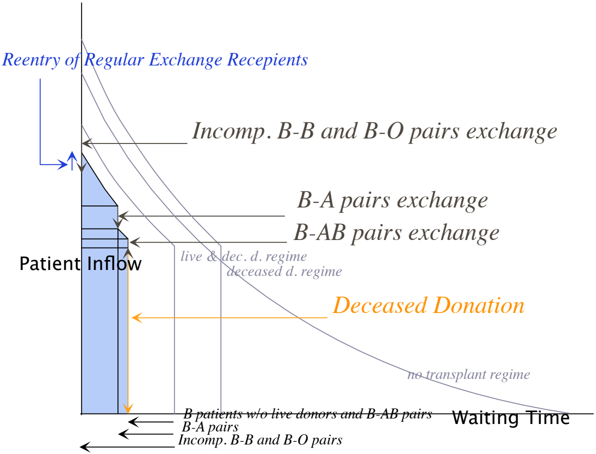
$$\Longrightarrow t_X^{\mathbf{e},dec} = F^{-1}(1 - r_X)$$

- If $t_X < t_{X-Y}$ then Y-X supply for X-Y demand is not enough to serve them all by exchange before a deceased-donor becomes available; thus, by assumption they are pooled:

$$r_{X,X-Y} = \frac{\delta_X + \pi_{Y-X}}{\pi_X^u + \pi_{X-Y}}$$

$$\Longrightarrow t_X^{\mathbf{e},dec} = F^{-1}(1 - r_{X,X-Y})$$

Regular Exchange: Blood-Type B Patients' Example



New Policy: (Balanced) Incentivized Exchange

- A ρ_{X-Y} fraction of compatible pairs with type X-Y such that Y $\triangleright$ X and Y $\neq$ X participate in exchange, in return if their exchange transplant fails in the future, they receive priority in the deceased-donor queue upon reentry.
- Balanced: This measure of deceased donors of Y blood type will be reserved for X reentrants with **priority** for immediate transplantation.
- Waiting time for deceased donation is found similar to the case for regular exchange using the pooling procedure.

Deceased Donation under Incentivized Exchange

- No reentering patient gets a priority in AB deceased-donor queue.
  $\Longrightarrow$ Waiting time for AB deceased donation stays the same
- Reentering X $\in$ {A,B,AB} patients of X-O get priority in O queue. If O-X were pooled for deceased donation under regular exchange in O deceased-donor queue: they begin dropping off of competition for deceased O donors, as incentivized X-O types facilitate more exchanges.
  $\Longrightarrow$ If θ and ϕ^l are low, the waiting time for regular O deceased donation decreases
- Deceased-donor queues of B and A are similar to O's.

WELFARE AND ACCESS EQUITY

Living Donation under Incentivized Exchange

Theorem (Efficiency and Access Equity for Living Donation)

Let $p_A > p_B$. Suppose that all $\lambda_X = \lambda$, $\frac{\pi_X}{\pi_Y} = \frac{p_X}{p_Y}$ for all X and Y, and incentivized exchange participant fraction is uniform at $\rho < 1$. Then:

1. *Direct living donation:*

$$\frac{\mathbf{l}_{AB}}{\pi_{AB}} > \frac{\mathbf{l}_A}{\pi_A} > \frac{\mathbf{l}_B}{\pi_B} > \frac{\mathbf{l}_O}{\pi_O}$$

2. *Kidney exchange:*

$$\frac{\mathbf{e}_B}{\pi_B} > \frac{\mathbf{e}_A}{\pi_A} > \frac{\mathbf{e}_{AB}}{\pi_{AB}} = \frac{\mathbf{e}_O}{\pi_O}$$

With the inclusion of kidney exchange, overall access to living donation is ranked as

$$\frac{\mathbf{l}_O + \mathbf{e}_O}{\pi_O} < \frac{\mathbf{l}_B + \mathbf{e}_B}{\pi_B} = \frac{\mathbf{l}_A + \mathbf{e}_A}{\pi_A} < \frac{\mathbf{l}_{AB} + \mathbf{e}_{AB}}{\pi_{AB}} = \lambda$$

Theorem (continued)

3. *Balanced incentivized exchange:*

$$\frac{\mathbf{i}_O}{\pi_O} > \frac{\mathbf{i}_A}{\pi_A} = \frac{\mathbf{i}_B}{\pi_B} > \frac{\mathbf{i}_{AB}}{\pi_{AB}} = 0$$

and overall access to living donation is ranked as

$$\frac{\mathbf{l}_O + \mathbf{e}_O + \mathbf{i}_O}{\pi_O} < \frac{\mathbf{l}_B + \mathbf{e}_B + \mathbf{i}_B}{\pi_B} = \frac{\mathbf{l}_A + \mathbf{e}_A + \mathbf{i}_B}{\pi_A} < \frac{\mathbf{l}_{AB} + \mathbf{e}_{AB} + \mathbf{i}_{AB}}{\pi_{AB}} = \lambda$$

Deceased Donation under Incentivized Exchange

Theorem (Efficiency and Access Equity for Deceased Donation)

Let $p_A > p_B$. Suppose that all $\lambda_X = \lambda$, $\frac{\pi_X}{\pi_Y} = \frac{p_X}{p_Y} = \frac{\delta_X}{\delta_Y}$ for all X and Y, and incentivized exchange participant fraction is uniform at $\rho < 1$. Then:

1. *With deceased-donor transplantation only, the waiting time at each deceased-donor queue is the same:*

$$t_O^{\mathbf{d},dec} = t_A^{\mathbf{d},dec} = t_B^{\mathbf{d},dec} = t_{AB}^{\mathbf{d},dec}$$

2. *Under direct living-donor transplantation, the waiting time at each deceased-donor queue decreases, and:*

$$(t_{AB}^{\mathbf{d},dec} - t_{AB}^{\mathbf{l},dec}) > (t_A^{\mathbf{d},dec} - t_A^{\mathbf{l},dec}) > (t_B^{\mathbf{d},dec} - t_B^{\mathbf{l},dec}) > (t_O^{\mathbf{d},dec} - t_O^{\mathbf{l},dec})$$

$$t_{max}^{\mathbf{l},dec} = t_O^{\mathbf{l},dec} > t_B^{\mathbf{l},dec} > t_A^{\mathbf{l},dec} > t_{AB}^{\mathbf{l},dec} = t_{min}^{\mathbf{l},dec}$$

Theorem (continued)

Further suppose that θ and ϕ^l are sufficiently small. Then:

3. *Under kidney exchange, the waiting time at each deceased-donor queue decreases, and:*

$$(t^{\mathbf{d},dec}_{AB} - t^{\mathbf{e},dec}_{AB}) > (t^{\mathbf{d},dec}_{A} - t^{\mathbf{e},dec}_{A}) = (t^{\mathbf{d},dec}_{B} - t^{\mathbf{e},dec}_{B}) > (t^{\mathbf{d},dec}_{O} - t^{\mathbf{e},dec}_{O})$$
$$t^{\mathbf{e},dec}_{max} = t^{\mathbf{e},dec}_{O} > t^{\mathbf{e},dec}_{B} = t^{\mathbf{e},dec}_{A} > t^{\mathbf{e},dec}_{AB} = t^{\mathbf{e},dec}_{min}$$

4. *Under balanced incentivized exchange:*

$$t^{\mathbf{b},dec}_{O} < t^{\mathbf{e},dec}_{O}; \quad t^{\mathbf{b},dec}_{A} = t^{\mathbf{b},dec}_{B} < t^{\mathbf{e},dec}_{A} = t^{\mathbf{e},dec}_{B}; \quad t^{\mathbf{b},dec}_{AB} = t^{\mathbf{e},dec}_{AB}$$
$$(\underbrace{t^{\mathbf{b},dec}_{max}}_{=t^{\mathbf{b},dec}_{O}} - \underbrace{t^{\mathbf{b},dec}_{min}}_{=t^{\mathbf{b},dec}_{AB}}) < (\underbrace{t^{\mathbf{e},dec}_{max}}_{=t^{\mathbf{e},dec}_{O}} - \underbrace{t^{\mathbf{e},dec}_{min}}_{=t^{\mathbf{e},dec}_{AB}})$$

NUMERICAL MODEL CALIBRATION RESULTS

Calibration Parameters						
	O	**A**	**B**	**AB**		
ABO-i deceased-donor flows $(\delta_X) =$	4982	3922	1225	314	Tissue-type incompatibility prob. $\theta =$	0.0473
De-facto deceased-donor flows $(\delta'_X) =$	4726	3818	1347	554	Reentry fraction of the recipients $\phi^l = \phi^d =$	25.86%
New patient flows $(\pi_X) =$	14693	9983	4466	1162	Incentivized-exchange particip. frac. $(\rho) =$	25%, 50%, 100%
Paired-donor blood-type prob. $(p_X) =$	0.456	0.378	0.126	0.040	Survival probability function $1 - F(t) =$	$0.9427e^{-0.1667t}$
Paired-donor fractions $(\lambda_X) =$	43.07%	29.32%	31.74%	21.31%		

2009 US OPTN National Data and ESRD Survival Rates

Policy Experiments

Model Outcomes: Patients Receiving Transplant						
		O	**A**	**B**	**AB**	**Overall**
Treatments		*Living-Donor Transplants*				
Living-donor transplantation ($\mathbf{l}_X$)		2749.17 *18.71%*	2325.30 *23.29%*	785.76 *17.59%*	235.93 *20.30%*	6096.17 *20.12%*
Regular exchange ($\mathbf{e}_X + \mathbf{l}_X$)		2984.82 *20.31%*	2813.68 *28.18%*	1194.71 *26.75%*	247.65 *21.31%*	7240.85 *23.89%*
Incentivized	$\rho = 25\%$	3483.52 *23.71%*	2835.97 *28.41%*	1202.14 *26.92%*	247.65 *21.31%*	7769.28 *25.64%*
($\mathbf{e}_X + \mathbf{l}_X + \mathbf{i}_X$)	$\rho = 50\%$	3982.23 *27.10%*	2858.26 *28.63%*	1209.56 *27.08%*	247.65 *21.31%*	8297.71 *27.38%*
	$\rho = 100\%$	4979.65 *33.89%*	2902.85 *29.08%*	1224.42 *27.42%*	247.65 *21.31%*	9354.56 *30.87%*
Treatments	**Dec. Donor A.**	*Deceased-Donor Transplants*				
All except	ABO-i (δ_X)	4981.85 *33.91%*	3921.51 *39.28%*	1224.57 *27.42%*	314.07 *27.03%*	
Balanced inc.	De facto (δ'_X)	4726.00 *32.16%*	3815.00 *38.21%*	1347.00 *30.16%*	554.00 *47.68%*	
Balanced inc.	ABO-i	4852.86 *33.03%*	3997.96 *40.05%*	1262.47 *28.27%*	328.71 *28.29%*	
$\rho = 25\%$	De facto	4597.01 *31.29%*	3891.45 *38.98%*	1384.9 *31.01%*	568.64 *48.94%*	10442.00 *34.46%*
$\rho = 50\%$	ABO-i	4723.87 *32.15%*	4074.41 *40.81%*	1300.36 *29.12%*	343.35 *29.55%*	
	De facto	4468.02 *30.41%*	3967.9 *39.75%*	1422.79 *31.86%*	583.29 *50.20%*	
$\rho = 100\%$	ABO-i	4465.89 *30.39%*	4227.31 *42.35%*	1376.16 *30.81%*	372.64 *32.07%*	
	De facto	4210.05 *28.65%*	4120.79 *41.28%*	1498.58 *33.56%*	612.58 *52.72%*	

Policy Experiments

Model Outcomes: Average Time to Nonprioritized Deceased-Donor Transplant															
Dec.	**O**	**A**	**B**	**AB**	**Overall**	**O**	**A**	**B**	**AB**	**Overall**	**O**	**A**	**B**	**AB**	**Overall**
Donor A.	Deceased-donor transplantation					Incentivized $\rho = 25\%$					Balanced inc. $\rho = 25\%$				
ABO-i	6.64	5.83	7.82	7.90	6.51	5.16	4.70	6.52	7.23	5.20	5.30	4.58	6.33	6.94	5.20
De facto	6.93	5.98	7.28	4.79	6.51	5.41	4.85	5.98	4.04	5.21	5.56	4.72	5.81	3.88	5.19
	Living-donor transplantation					Incentivized $\rho = 50\%$					Balanced inc. $\rho = 50\%$				
ABO-i	5.82	4.81	7.04	6.99	5.62	4.70	4.83	6.73	7.53	5.06	4.97	4.59	6.35	6.94	5.05
De facto	6.11	4.95	6.51	3.92	5.62	4.94	4.91	6.17	4.20	5.05	5.23	4.74	5.82	3.88	5.05
	Regular exchange					Incentivized $\rho = 100\%$					Balanced inc. $\rho = 100\%$				
ABO-i	5.67	4.56	6.32	6.94	5.37	4.37	5.03	7.08	8.18	5.00	5.02	4.54	6.29	6.94	5.05
De facto	5.95	4.71	5.80	3.88	5.37	4.64	5.19	6.48	4.55	5.05	5.34	4.69	5.76	3.88	5.06

Summary

- New policy proposal: Incentivize compatible pair participation through prioritization of their patients in case he reenters the queue.
- To measure the welfare and equity effects formally, we introduce new machinery, a new dynamic entry-reentry model.
- We use the model for measuring, quantifying, estimating various effects of new and old policies on patient groups.