Measuring the performance of Organ Procurement Organizations in the United States

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Background

- US: >104,000 people are currently on hospital waiting lists for an organ transplant (kidney, pancreas, liver, intestine, heart, lungs)
- 2022: 42,888 transplants performed from both living and deceased donors
- National Organ Transplant Act (1984) set up a system to recover organs from the deceased, implemented by non-profit government contractors
- **Research questions**: How effective are OPOs at producing transplants? How can I measure their unobserved effort/productivity?
- **Why is this important?** Failure to produce more organ transplants at current resource levels imply huge welfare losses that can be avoided

What are Organ Procurement Organizations?

- There are 57 OPOs in the US. Each OPO is exclusively responsible for recovering deceased donor organs from their Donation Service Area Map Statistics

- OPOs have to (a) identify eligible organ donors, (b) obtain consent for organ donation, (c) recover organs, (d) ensure that organs are viable, and (e) transport organs to transplant center hospitals

- In a recent report, Centers for Medicare & Medicaid Services (CMS) assessed more than half of all OPOs as failing or underperforming, and estimated that up to 28,000 organs available from deceased donors go unprocured each year

- Data show huge variation in OPO performance

Data from brain-deaths show large variation in OPOs' donor recovery rate

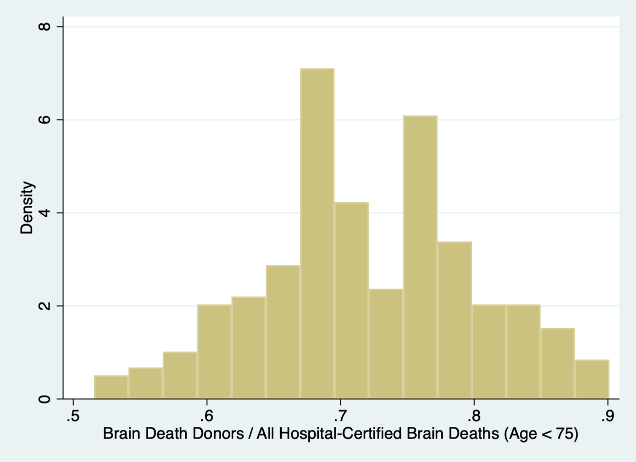

Figure 1: OPO Brain Death Donors (230 OPO-year obs.) Details

There is also variation in successful transplantation after organ recovery

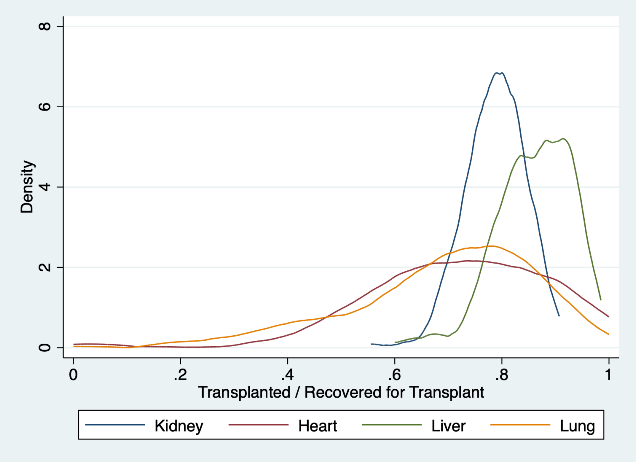

Figure 2: OPO Transplantation Rates (230 OPO-year obs.) Statistics

OPO employment and wages show a weak relationship with transplants per million people; so what explains the differences in OPO performance?

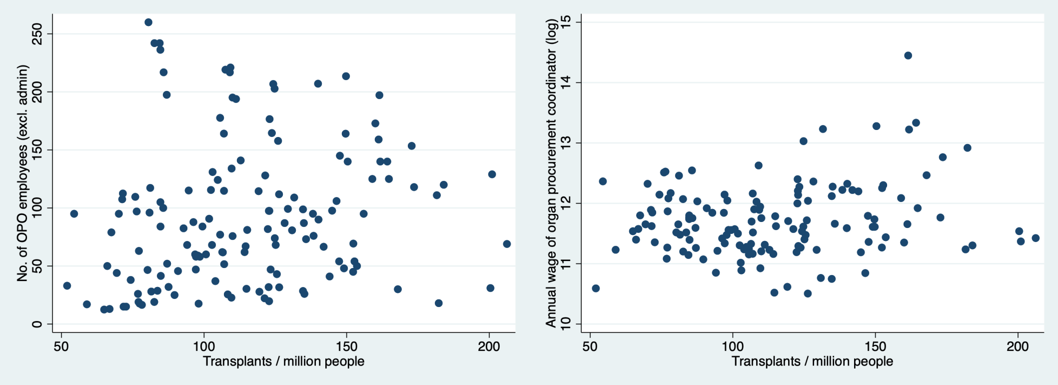

Figure 3: OPO Employment and Wages (∼147 OPO-year obs.) Statistics

Sources for OPO-level data

1. **OPO-specific reports by SRTR[1], 2018-2021:** Example
   Population and land area of each OPO region; No. of organs recovered/transplanted; No. of deceased donors; No. of brain deaths[2]; and more...

2. **OPO annual cost reports to CMS (Form 216-94), 2019-2021:** CMS Form
   OPO organ acquisition costs; operating revenue and expenses, employment; salaries; Medicare claims; assets and liabilities; viable and non-viable organs recovered; and more...

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[1] Scientific Registry of Transplant Recipients (`http://www.srtr.org`) is a research institute that specializes in statistics on OPOs and organ transplants

[2] Brain deaths are counted by SRTR as patients who have been declared brain dead in accordance with state and local laws, are age ≤ 75, and have no exclusionary medical conditions

What are the potential sources of OPO inefficiency?

- In order to produce a transplant, OPOs have to (i) go to deceased donors first, and (ii) recover their organs. A lack of OPO effort could look like:

  (i) OPO fails to follow-up when a potential-donor dies[3]
  $\rightarrow$ OPO performance for producing donors is not accurately measured; hospitals lack incentives to report OPOs

  (ii) OPO fails to recover organs in a timely manner/ does not keep the organ viable/ does not get the organ to the transplant hospital
  $\rightarrow$ OPO performance for producing transplants is accurately measured; every attempted organ recovery is observed

[3] The cause of death may or may not be brain death.

I use the structure of the organ recovery process to write a 2-stage model

- In the 2nd stage, OPOs produce *Transplants* with a single input *Donors*

$$\textit{Transplants} = \exp(\omega) \cdot \exp(\varepsilon) \cdot \textit{Donors}^{\alpha}$$

- α captures returns to scale
- ε is unobserved medical shocks (e.g. transplant doctor decides to reject viable organ; patient passes away before organ reaches them)
- ω is unobserved OPO effort – this is the parameter of interest
- Assume $\varepsilon \perp \omega$: random medical shocks are independent of OPO effort at producing transplants

With limited data, I have to make strong assumptions in the 1st stage

- In the 1st stage, *Donors* is determined by OPO labor, unobserved effort ω and other covariates; in reality, OPO inputs and effort are always required to produce a donor from a potential-donor death
- Assume that *Donors* follows the data generating process

$$Donors = f(X) + \omega + \nu$$

- Assume $f(\cdot)$ is an unknown, smooth function
- Assume[4] $\mathbb{E}(\nu|X, \omega) = 0$
- Given the data[5], let $X = (Brain\ Deaths, Area\ Size, OPO\ Employment)$

[4] This is a strong assumption, because I have not yet carefully worked out what is in ν.

[5] There are 144 OPO-year obs. left after merging SRTR data (2018-2021) with CMS cost reports (2019-2021). The CMS report has missing fields and does not have data on 7 OPOs.

I get a control function for ω, which allows me to recover ε

- The assumptions give the conditional expectation function

$$\mathbb{E}(\omega|X) = \mathbb{E}(Donors|X) - f(X)$$

  which allows for a control function for ω in $(Donors, X)$

- The 2nd stage equation can be expressed with an unknown function $\phi(\cdot)$

$$\log Transplants = \phi(Donors, X) + \varepsilon$$

- $\phi(\cdot)$ can be approximated by a non-parametric estimator $\hat{\phi}(\cdot)$; I use a kernel density estimator for $\hat{\phi}(\cdot)$ to recover $\hat{\varepsilon}$ under the assumption of $\varepsilon \perp \omega$ Results

The final step is to estimate the 2nd stage using an IV

- The last step is to estimate α, and get ω from the same reduced-form equation:

$$\log \textit{Transplants} = \hat{\alpha}_0 + \hat{\alpha}_1 \log \textit{Donors} + \hat{\varepsilon} + \omega$$

- $\mathbb{E}(\omega|\textit{Donors}) \neq 0$, so I need an instrument for *Donors*
    - Any data from CMS or SRTR will fail the exclusion restriction due to selection
    - I construct a population-weighted measure of *Household Income* from US Census data for each OPO-region-year; and show that higher-income regions are associated with more donors Graph
    - I instrument *Donors* with *Household Income* and include year effects; my identification assumption is that OPOs do not respond differently to produce donors and transplants based on the income of their region IV regression

I find that ω could provide a measure for unobserved OPO effort

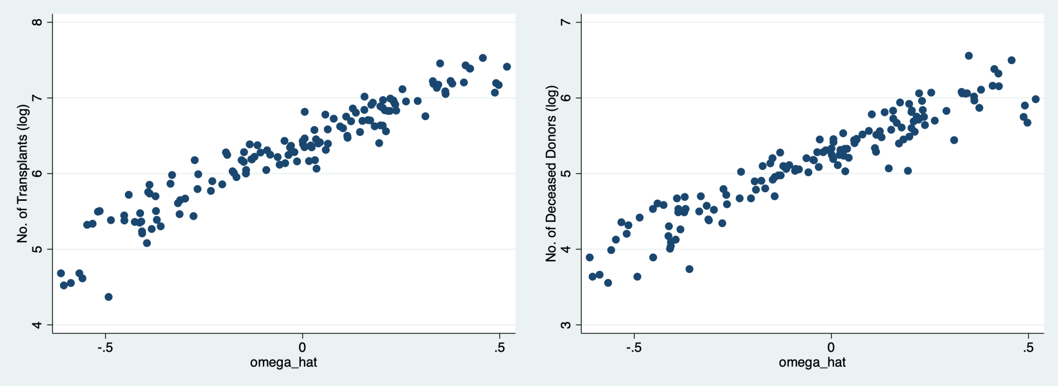


Figure 4: log(*Transplants*) and log(*Donors*) are increasing in $\hat{\omega}$ More Results

Recap

- I show that there is huge variation in OPO performance, both in terms of (i) producing donors and (ii) producing transplants
- I posit that unobserved OPO effort ω can be linked between (i) and (ii); I formulate simple structural equations that describe the organ recovery and transplant process, and derive a method to estimate ω
- To estimate my model, I used OPO-level data from CMS (2019-21), SRTR (2018-21) and aggregated county-level US Census estimates (2019-21) — my final sample only has 144 OPO-year observations and lacks statistical power
- I can compare my estimates of ω with SRTR and CMS performance measures of OPOs; CMS recently published a *Revisions to Outcome Measures for OPOs*

Next Steps

- The central challenge of this project is that potential-donor numbers are not known, so how do we find out if OPOs are doing enough work to recover donors?

- Failure to produce more organ transplants at current resource levels imply huge welfare losses — there are currently no good estimates of this, with most studies focusing on kidney transplants

- One direction to go would be to develop a more sophisticated model, potentially with hospital/patient-level data to estimate the base of potential donors, and/or transplant-level data from SRTR

Next Steps

- CMS cost reports from earlier years (2013-2018) can be obtained via a Freedom of Information Act request
- It should be possible to request OPO-level data from earlier years (2013-2018) from SRTR
- *SRTR standard analysis files*[6] include data on all solid organ transplant candidates, donors, and recipients in the United States since 1987
- *National (Nationwide) Inpatient Sample* (NIS) is the largest publicly available all-payer inpatient care database in the United States, containing data on more than seven million hospital stays

[6] For qualifying students, the cost of a standard analysis file is $200.

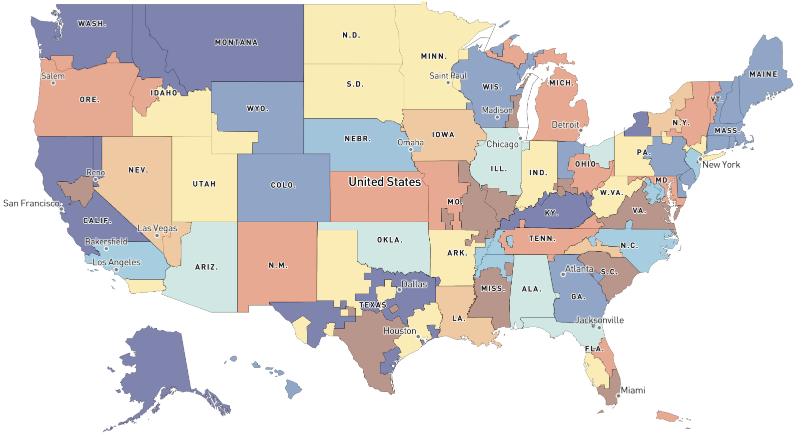


Figure A1: Map of OPO Donation Service Areas (Source: SRTR) Back

	Obs.	Mean	SD	Min	P50	Max
Population (mil)	230	5.76	3.78	1.41	4.72	20.13
Land Area (sq miles)	230	61,571	110,147	3,557	39,589	808,360
By total population:						
All Deaths[7]	230	50,369	29,581	12,303	46,089	150,246
Deceased Donors[8]	230	201.3	125.4	35.0	172.5	705.0
Organ Transplants	230	622.6	374.7	79.0	541.0	1862.0
Per million people:						
All Deaths	230	9,083	1,390	5,670	9,111	13,025
Deceased Donors	230	36.4	11.1	16.4	34.5	79.7
Organ Transplants	230	112.0	31.8	49.8	109.0	206.2

Table A1: Summary Statistics from OPO-Year Observations (2018-2021) Back

[7] US Census Bureau projections

[8] A deceased donor is a donor from whom at least one organ was recovered for the purpose of transplant

There is no clear measure of potential-donors in the data

	Obs.	Mean	SD	Min	P50	Max
Deceased Donors	230	201.3	125.4	35	172.5	705
Deceased Donors ∩ Brain Deaths	230	144.1	91.0	21	124	493
Brain Deaths	230	202.8	130.8	33	178.5	618
Ratio Histogram	230	0.720	0.079	0.516	0.7	0.901

Table A2: Ratio = (Deceased Donors ∩ Brain Deaths) / Brain Deaths

- A deceased donor is a donor from whom at least one organ was recovered for the purpose of transplant; measure includes brain death and non-brain death
- Brain deaths are counted by SRTR as patients who have been declared brain dead in accordance with state and local laws, are age ≤ 75 at death, and have no exclusionary medical conditions

	Obs.	Mean	SD	Min	P50	Max
Kidney	230	0.787	0.056	0.556	0.792	0.907
Heart	230	0.719	0.177	0.000	0.732	1.000
Liver	230	0.861	0.071	0.600	0.862	0.985
Lung	230	0.692	0.175	0.000	0.726	1.000

Table A3: Statistics for $\frac{Transplanted}{Recovered for Transplant}$ (230 OPO-year obs.) Back

	Obs.	Mean	SD	Min	P50	Max
Overall OPO:						
Total Employment	147	172	188	20	126	1168
Average Wage	147	90,211	25,600	26,051	87,739	187,242
Procurement Coordinators	142	47	39	5	36	162
Average Wage	139	156,627	180,115	36,521	111,497	1,884,220
Per Transplant:						
Total Employment	147	0.323	0.445	0.085	0.220	2.707
Average Wage	147	212	201	21	159	1373
Procurement Coordinators	142	0.074	0.057	0.003	0.064	0.418
Average Wage	139	333	290	41	224	1384

Table A4: Summary Statistics on OPO Employment and Wages from CMS Back

Higher-income regions have more deceased donors

Figure A2: Deceased Donors and Household Income of OPO Region Back

Model	(1)	(2)	(1)	(2)	(1)	(2)
	IV 1st Stage	IV 1st Stage	OLS	OLS	IV 2nd Stage	IV 2nd Stage
VARIABLES	log_donors	log_donors	log_transplants	log_transplants	log_transplants	log_transplants
log_hh_income	0.817***	0.750***				
	(0.244)	(0.248)				
log_donors			0.998***	1.030***	0.929***	0.593***
			(0.0154)	(0.0107)	(0.0721)	(0.106)
Constant	-3.939	-3.227	1.139***	0.969***	1.499***	3.222***
	(2.704)	(2.734)	(0.0792)	(0.0553)	(0.370)	(0.546)
Year Effects	No	Yes	No	Yes	No	Yes
Observations	224	224	230	230	224	224
R-squared	0.048	0.084	0.949	0.977	0.946	0.796

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure A3: Regression results for OLS and 2SLS. Model (1) excludes year effects and Model (2) includes year effects. Predicted residuals from model (2) are used to calculate $\hat{\omega}$ Back

	N	Mean	SD	Min	Max
$\hat{\varepsilon}$	143	0.041	0.153	-0.516	0.388

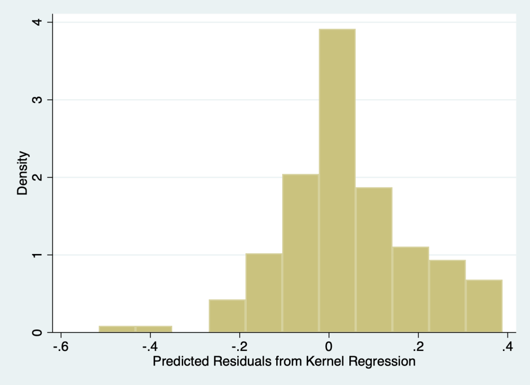
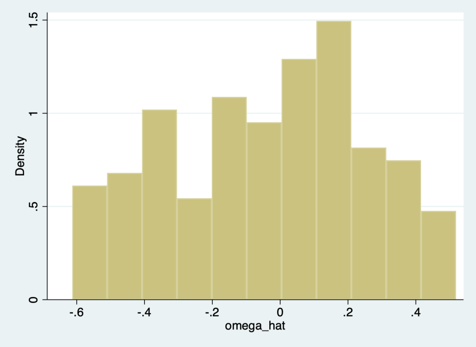


Figure A4: Estimates of $\hat{\varepsilon}$ from control function approach Back

	log_transplants	log_donors
omega_hat	2.270***	2.185***
	(0.0606)	(0.0641)
Constant	6.367***	5.239***
	(0.0176)	(0.0186)
Observations	143	143
R-squared	0.909	0.892

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

(a) OLS Regression for Graphs



(b) Distribution of $\hat{\omega}$

	N	Mean	SD	Min	Max
$\hat{\omega}$	143	-0.037	0.290	-0.613	0.518

Figure A5: Results for $\hat{\omega}$