Do Kidney Exchanges Improve Patient Outcomes?
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Online Appendices

Appendix A Proofs

A.1 Proof for Proposition 1

Proposition 1. *If the introduction of exchange does not affect the costs nor the benefits to L of direct donation, i.e. $C^E(Direct) = C^N(Direct)$ and $B_k(Q^E(Direct)) = B_k(Q^N(Direct))$, then L is less likely to choose direct donation over no donation after the introduction of exchange.*

Proof. This result holds because patient k's outcome does not improve with exchange introduction under direct donation, while k's expected outcome does improve when k's prospective donor, L, does not donate. L will donate directly when $U_L(Direct) \geq U_L(None)$, or

$$U_L(Direct) = B_k(Q(Direct)) - C(Direct) \geq B_k(Q(None)) = U_L(None). \tag{1}$$

If $U_L(None)$ increases more than $U_L(Direct)$ when exchange is introduced, then the probability that $U_L(Direct) \geq U_L(None)$ will decrease.

Given that exchange introduction has no effect on the cost of donating directly, nor the benefit that L derives from donating to patient k, the effect of exchange introduction on the utility derived from each choice is given by the following:

$$\Delta U_L(Direct) = [B_k(Q^E(Direct)) - C^E(Direct)] - [B_k(Q^N(Direct)) - C^N(Direct)] = 0 \tag{2}$$

and

$$\Delta U_L(None) = \Delta B_k(Q(None)). \tag{3}$$

If patient k's expected outcome improves with the introduction of exchange when L does not donate, such that

$$\Delta U_L(None) = \Delta B_k(Q(None)) \geq 0 = \Delta U_L(Direct), \tag{4}$$

then L is less likely to donate directly, relative to not donating at all, after the introduction of exchange. □

A.2 Proof for Proposition 2

Proposition 2. *Suppose again that the introduction of exchange does not affect the costs nor the benefits to L of direct donation, i.e.* $C^E(Direct) = C^N(Direct)$ *and* $B_k(Q^E(Direct)) = B_k(Q^N(Direct))$. *Then a representative prospective donor L is more likely to become a living kidney donor if the introduction of exchange increases the net utility of donating via exchange, relative to not donating, by a larger magnitude than it increases L's reservation utility, i.e.* $[U_L^E(Exch) - U_L^E(None)] - [U_L^N(Exch) - U_L^N(None)] > U_L^E(None) - U_L^N(None)$.

Proof. L is more likely to become a living kidney donor — that is, the increased likelihood of donating via exchange outweighs the decreased likelihood of donating directly — if

$$\Delta U_L(Exch) - \Delta U_L(None) > -[\Delta U_L(Direct) - \Delta U_L(None)]. \tag{5}$$

This becomes:

$$\begin{aligned}[U_L^E(Exch) - U_L^N(Exch)] - [U_L^E(None) - U_L^N(None)] &> \\ - \{[U_L^E(Direct) - U_L^N(Direct)] &- [U_L^E(None) - U_L^N(None)]\}. \end{aligned} \tag{6}$$

Recall the following relationship from equation (2):

$$\Delta U_L(Direct) = B_k(Q^E(Direct)) - B_k(Q^N(Direct)) - C^E(Direct) + C^N(Direct) = 0. \quad (7)$$

This implies that equation (6) reduces to:

$$[U_L^E(Exch) - U_L^N(Exch)] - [U_L^E(None) - U_L^N(None)] > [U_L^E(None) - U_L^N(None)]. \quad (8)$$

The last step is a simple rearrangement of terms for interpretation purposes:

$$[U_L^E(Exch) - U_L^E(None)] - [U_L^N(Exch) - U_L^N(None)] > [U_L^E(None) - U_L^N(None)]. \quad (9)$$

Alternatively, for interpretation purposes, we can substitute in the terms for each utility and rearrange. We then obtain:

$$MB_L^E + MS_L^E - MB_L^N - MS_L^N - \Delta C(Exch) > \Delta B_k(Q(None)) \quad (10)$$

or

$$\Delta MB_L + \Delta MS_L - \Delta C(Exch) > \Delta B_k(Q(None)). \quad (11)$$

MB (MS) represents marginal benefit (marginal surplus) of donating via exchange over not donating at all, $\Delta C(Exch)$ represents the change in cost of donating via exchange before and after introduction, and $\Delta B_k(Q(None))$ is the change in benefit L derives from k's well-being following exchange introduction. $\square$

A.3 Proof for Proposition 3

Proposition 3. *If the cost of donating anonymously is unaffected by the introduction of exchange, i.e. $C^E(Anon) = C^A(Anon)$, then individuals without a loved one in need of a kidney will be more likely to donate anonymously to start a (sufficiently long) donor chain and* *less likely to donate anonymously to a single patient following the introduction of exchange.*

Proof. Potential donor A will donate anonymously when

$$U_A(Anon) = S_i(Q(Anon)) - C(Anon) \geq 0 = U_A(Anon). \tag{12}$$

If $U_A(Anon)$ increases when exchange is introduced, then $\text{Prob}[U_L(Anon) \geq 0]$ will increase.

The effect of exchange introduction on the utility derived from donating anonymously is given by the following:

$$\Delta U_A(Anon) = U_A^E(Anon) - U_A^N(Anon) =$$
$$S_i(Q^E(Anon)) - S_i(Q^N(Anon)) + S_{-i}(Q^E(Anon)) - [C^E(Anon) - C^N(Anon)] \tag{13}$$

or

$$\Delta U_A(Anon) = \Delta S_i(Q(Anon)) + S_{-i}(Q^E(Anon)) - \Delta C(Anon). \tag{14}$$

If the cost of donating anonymously is the same whether or not exchange has been introduced (i.e. $\Delta C(Anon) = 0$), then $\Delta C(Anon)$ drops out implying that A will be at least as likely to donate anonymously following the introduction of exchange if

$$\Delta S_i(Q(Anon)) + S_{-i}(Q^E(Anon)) \geq 0. \tag{15}$$

This condition says that A will be more likely to donate anonymously if the introduction of exchange increases the total surplus that A's donation generates for patients in need of transplants. Now, since the introduction of exchange improves patients' outside options, it is likely that $\Delta S_i(Q(Anon)) < 0$. If, after the introduction of exchange, anonymous donations are not shifted toward the use of starting exchanges via donor chains, then we would expect a reduction in anonymous donations. However, if A's donation facilitates at least one transplant beyond i's (the direct recipient), then the additional surplus is very likely to outweigh the small negative effect of exchange on the surplus generated by A's donation to i. $\square$

Appendix B Supplementary Tables

Table B1: Sensitivity and Age (2000 - July 2014)

Observed Outcome	Most Recent PRA (Class I)*	Most Recent PRA (Class II)*	Ending C-PRA**	Age at Listing***	Donor Age
Exchange	15.02	14.50	22.10	46.56	43.05
SD	(27.64)	(28.02)	(34.29)	(14.47)	(11.56)
N	3,636	3,481	3,516	4,103	4,103
Anonymous	8.57	8.66	16.68	44.56	43.67
SD	(20.69)	(22.28)	(30.22)	(15.29)	(11.82)
N	1,193	1,106	1,017	1,528	1,528
Direct Living	5.71	5.28	8.98	44.15	40.68
SD	(16.85)	(16.98)	(22.33)	(16.05)	(11.23)
N	52,167	46,053	30,048	82,844	82,843
Deceased	10.93	9.63	19.66	47.82	37.49
SD	(24.54)	(23.68)	(33.23)	(15.25)	(16.71)
N	99,787	89,321	72,104	145,407	145,408
Died on WL	-	-	23.32	52.85	-
SD	-	-	(37.35)	(12.25)	-
N	0	0	32,208	64,825	0
Total	9.27	8.31	18.24	47.86	38.76
SD	(22.48)	(21.94)	(32.67)	(15.19)	(14.98)
N	156,783	139,961	138,893	298,707	233,882

Source: OPTN STAR Data as of 12/31/2014.
*These values are missing for those who were not transplanted. Due to changes in data collection, values only reported from 2004 onward.
**Due to changes in data collection, values only reported from late 2007 onward
***For those transplanted without ever having listed, this is the age at time of transplant.

Table B2: Survival, Match Quality, Waiting Time (2000 - July 2014)

Observed Outcome	Graft Survival >1 year*	Graft Survival >2 years*	# of HLA Mismatches	Registration Duration (Days)**
Exchange	0.97	0.94	4.31	467.68
SD	(0.18)	(0.23)	(1.25)	(523.69)
N	2,995	2,300	4,030	4,099
Anonymous	0.96	0.93	4.31	654.10
SD	(0.20)	(0.26)	(1.26)	(606.73)
N	1,261	1,097	1,497	1,528
Direct Living	0.96	0.93	3.16	237.47
SD	(0.20)	(0.26)	(1.66)	(346.70)
N	75,348	70,610	82,097	82,698
Deceased	0.90	0.86	3.88	813.43
SD	(0.29)	(0.35)	(1.75)	(717.70)
N	127,580	116,714	144,482	145,153
Total	0.93	0.88	3.64	602.31
SD	(0.26)	(0.32)	(1.74)	(667.25)
N	207,184	190,721	232,106	233,478

Source: OPTN STAR Data as of 12/31/2014. Note that survival, HLA mismatches, and registration duration are only defined for transplant recipients. One-year graft survival excludes 2013-14 data, two years excludes 2012-14. Duration is 0 for living donor kidney recipients who did not register on the waiting list.

Table B3: Unconditional Effects of Exchange on Transplant Candidate Health Outcomes

	Representative First Stage		Reduced Form and 2SLS, Outcome Within X Years					
	Ever Received an Exchange TX		Transplanted		Died		Still Needs Kidney	
	2000 - 7/2012	2000 - 7/2010	2 Years	4 Years	2 Years	4 Years	2 Years	4 Years
VARIABLES	(X = 2 years)	(X = 4 years)						
Mean of DV	[0.0083]	[0.0065]	[0.34]	[0.51]	[0.089]	[0.18]	[0.65]	[0.44]
Panel A: Exchanges Within 50 Miles in First Month of Registration								
Total Exchanges Nearby	0.00041	0.00037	0.00068	0.002	0.00035	-0.00048	-0.00054	-0.0018
(Month of Registration)	(0.00028)	(0.00039)	(0.00084)	(0.0015)	(0.00055)	(0.0011)	(0.00089)	(0.0016)
Wald IV Estimates	-	-	1.69	5.35	0.88	-1.29	-1.17	-5.85
(Exchange = First Stage)	-	-	(2.22)	(6.44)	(1.54)	(3.20)	(1.95)	(9.68)
Panel B: Exchanges Within 50 Miles in First Year of Registration								
Total Exchanges Nearby	0.00016**	0.00018**	0.00039*	0.00056*	-0.0000091	-0.000023	-0.00038*	-0.00063*
(First Year of Registration)	(0.000067)	(0.000083)	(0.00020)	(0.00033)	(0.00012)	(0.00026)	(0.00021)	(0.00036)
Wald IV Estimates	-	-	2.38	3.14	-0.056	-0.13	-2.14	-3.69
(Exchange = First Stage)	-	-	(1.45)	(2.17)	(0.76)	(1.46)	(1.37)	(2.81)
Observations	279,349	226,544	279,349	226,544	279,349	226,544	253,810	183,447
Number of Zip Codes	19,112	17,746	19,112	17,746	19,112	17,746	18,446	16,360

This table presents the results from estimating the effect of exchange activity on the probability that a patient receives a transplant within 2 and 4 years, dies within 2 and 4 years, or still needs a kidney (conditional on being alive) after 2 and 4 years (which includes those who had one or more transplants that failed within 2 and 4 years, respectively) of initially registering on a deceased donor waiting list. Using initial registration is the most consistent/reliable way to measure start of transplant candidacy, though it does omit living donor transplant recipients who never register. In Panel A, *Activity* is defined as the number of exchange transplants performed within 50 miles of the patient's zip code of residence in the month of registration, while it is defined as the total number of exchange transplants within 50 miles in the first year following registration in Panel B. All of the outcome variables are binary. Interpretation of Wald IV estimates: a one percentage point increase in probability of ever receiving an exchange increases outcome of interest by β percentage points. Clustered standard errors in parentheses (at zip code level). Significance indicated by: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Appendix C Robustness

In this appendix, I discuss several tests to address the primary concerns raised in Section IV.A about the validity of *Activity*. I also show that, while the estimates vary within reasonable ranges, the preferred specifications yield results that are robust to using activity within 30 and 75 miles rather than 50, using a lagged measure of local exchange activity, using a linear probability model to estimate substitution patterns, dropping zip codes with no exchange activity across the sample period, and excluding the location-by-time controls.

First, I test whether current outcome measures appear to affect future levels of local exchange activity, conditional on controls for patient characteristics, zip code fixed effects, month-year fixed effects, location-specific linear time trends, and state-year fixed effects. Tables C1 and C2, as well as Figures C1 and C2, present the results from estimating the reduced form substitution and quality specifications modified by adding in 12 months of leads and lags of *Activity*. I perform joint F-tests of the statistical significance of all of the leads in each specification. Death while waiting is the only outcome for which I find statistically significant evidence of an outcome variable affecting future values of *Activity*. The result suggests that positive shocks to waiting list deaths are correlated with future increases in local exchange activity. However, this result is primarily driven by a positive coefficient on the 3- and 4-month lead, while the 5- and 6-month lead has a statistically significant negative coefficient. While the joint F-test does provide some support for the concern that centers adopt and promote kidney exchanges in response to worsening outcomes, this finding is not corroborated by similar pre-trends in any of the other outcomes of interest.

Next, I test whether patients endogenously move or change zip code of residence in order to pursue exchange transplants. I observe patients' zip codes of residence at the time of registration on the deceased donor waiting list and again when they receive a transplant. However, I cannot perfectly observe whether patients engage in such behavior because (1) not all patients receiving living donor transplants register on the deceased donor waiting list and (2) I do not observe an updated zip code for patients who died while waiting. With these limitations in mind, I analyze whether exchange activity near patients' current zip code at time of transplant predicts a change in zip code, whether exchange activity near patients' original (listing) zip code at the time of transplant predicts a change in zip code, and whether, conditional on observing a change in zip code, the *Activity* differential between patients' current and original zip code is correlated with the type of transplant received. I find that patients receiving a direct living donor transplant are the least likely to change zip codes (9.1 percent), while patients receiving a deceased donor transplant are the most likely to change zip codes (16.3 percent). Exchange and anonymous donor recipients are in the middle at 11.8 percent and 14.3 percent, respectively. Despite these differences, however, there appears to be no relationship between exchange activity and moving behavior. Column 1 of Table C3 suggests that patients living in more exchange-active zip codes at the time of transplant are no more likely to have changed zip codes than patients living in less exchange-active zip codes. Similarly, column 2 suggests that the level of exchange activity at time of transplant in a patient's original (listing) zip code is not correlated with whether that patient changed zip codes. Finally, columns 3 through 6 suggest that, among patients who changed zip codes, the differential in exchange activity between their current and original zip codes is not correlated with the type of transplant received. In an additional set of analyses, I show that the main results are robust to the possibility of endogenous moving. To do this, I estimate the substitution and quality effects using restricted estimation samples that exclude patients whose associated deceased donor waiting list registration is in a different donor service area (DSA) than the one in which they live. The results, presented in Table C4, are virtually identical to the central results presented in Tables 3 and 4 of the main text.

I turn now to the question of whether the estimates identified using *Activity* are sensitive to the use of different mileage radii in determining the level of local exchange activity. Panel A of Table C5 presents the substitution results when using a 30 mile radius instead of 50 miles. The results show a small reduction in estimated substitution away from direct living transplants and larger increase in anonymous donations, implying that 74 percent

$(1 - 0.39 + 0.13 = 0.74)$ of exchange transplants represent new living donor transplants. Panel A in Table C7 presents the effects on graft survival, HLA mismatches, and registration duration when using a 30 mile radius. The graft survival results are slightly attenuated by 10 to 20 percent, and the two-year graft survival effect is no longer statistically significant. The estimated effect on HLA mismatches moves from -0.02 to 0.20, but is still statistically indistinguishable from zero. The estimated effect on registration duration is attenuated by roughly 50 percent compared to the 50-mile result, still negative, and still statistically insignificant. Panel B of Table C5 presents the substitution results when using a 75-mile radius instead of 50. These estimates are very similar to the original 50-mile results as well as the 30-mile results. The estimates for the effect of exchange activity on direct living and anonymous donor transplants are almost identical to the 50-mile results, implying that 66 percent of exchange transplants represent new living donor transplants. Panel B of Table C7 presents the effects of exchange on quality when using a 75 mile radius. The graft survival results are still positive, but attenuated by roughly 40 percent and now statistically insignificant. The HLA mismatch estimate moves from -0.02 to 0.22 but is still statistically indistinguishable from zero. The registration duration estimate is still negative, attenuated by roughly 10 percent, and still marginally statistically insignificant.

Next, we may worry about reverse causality in the first stage and anonymous donation regressions. Because exchange transplants jointly facilitate one another, and anonymous donations can facilitate donor chains, an additional exchange transplant or anonymous donation may cause an increase in the level of nearby exchanges performed in the same period. To address this concern, I re-estimate the main specifications using a one month lagged measure of *Activity*. Anonymous donations and exchange transplants can only facilitate current or future transplants via exchange, hence the use of a lag to avoid the possible reverse causality issue. However, lags also reduce the precision of the estimates of interest as the lag is likely to be worse at capturing network externalities generated by the nearby occurrence of exchange transplants. Panel C of Table C5 presents the results. First, we see that the first stage result decreases in magnitude from 0.00087 to 0.00019, representing only a 21 percent increase in exchange transplants resulting from an additional nearby exchange transplant. The Wald IV direct living substitution estimate is larger in this specification, implying that 75 percent of exchange transplant recipients would have received a direct living donor transplant in the absence of exchange, though it is imprecise and not statistically distinguishable from the original result of 43 percent. The Wald IV estimate of increased anonymous donation yields an estimated 0.11 additional anonymous donors for each additional exchange transplant, which is larger but less precise than the original estimate.

I also test the robustness of the preferred results by estimating the substitution patterns using a linear probability model analogous to the approach used for the quality analyses. Panel D of Table C5 presents the results of this approach. Here, each observation represents either a transplant or death of a patient while waiting for a kidney. Each binary registration outcome variable is regressed on *Activity*, and the Wald IV estimates are obtained directly via 2SLS. I include the exact same set of controls as in the quality analyses: zip code fixed effects, month-year fixed effects, county-specific linear time trends, state-year fixed effects, and the set of patient characteristics. We see that this choice of functional form has virtually no impact on the substitution estimates, implying that 66 percent ($1-0.41+0.07$) of exchange transplants represent new living donor transplants.

Due to the inclusion of many zip codes that never experience an exchange transplant or nearby exchange activity in the estimation sample, one may wonder if the results are robust to dropping such areas. Addressing this concern, Panel E in Table C6 and Panel C in Table C7 present the estimation results. The substitution patterns do not differ much from the full sample: 38 percent of exchange recipients substitute away from direct living, while 0.06 additional anonymous donations occur for each additional exchange transplant. This implies 68 percent of exchanges represent new living donor transplants. The quality estimates follow a similar pattern as the full sample, though they are attenuated. A one percentage point increase in the probability of receiving an exchange increases one-year survival by 0.15 percentage points, while the estimate on two-year survival is positive but insignificant. The effect of *Activity* on HLA mismatches is indistinguishable from zero, and the effect on registration duration is negative and statistically insignificant (p=0.14).

Tables C6 and C7 present estimates from alternate specifications that exclude state-year fixed effects, location-specific time trends, or both. In Panel H of Table C6 and Panel F of Table C7, we see that excluding state-year fixed effects has no substantive impact on the substitution and quality results. However, excluding/including zip code-specific linear time trends does affect the substitution estimates (Panels F and G in Table C6). The first-stage estimates are essentially unchanged, but we see larger Wald IV estimates of substitution away from direct living transplants (roughly 80 percent of exchange transplants) and increase in anonymous donations (14 percent). We also see estimated substitution away from deceased donor transplants go to zero when excluding zip code-specific linear time trends. This finding appears to highlight the importance of including location-specific time trends. That said, the exclusion of county-specific linear time trends has less of an impact on the quality results (see Panels D and E of Table C7). Here, the graft survival estimates are slightly attenuated, though still statistically significant, and the estimated reduction in registration duration is magnified by 70 to 90 percent and becomes statistically significant at the 1 percent level.

Table C1: Leads and Lags of *Activity*, Substitution

VARIABLES	Directed Living	Anonymous	Deceased	Died on WL
11 & 12 Month Lag	-0.000021	-0.000019	0.00017*	-0.00013
	(0.000084)	(0.000019)	(0.000098)	(0.000083)
9 & 10 Month Lag	0.000049	-7.2e-06	-5.9e-06	-0.000020
	(0.000081)	(0.000020)	(0.000095)	(0.000081)
7 & 8 Month Lag	0.000097	2.1e-06	-0.000025	-0.000092
	(0.000080)	(0.000021)	(0.000096)	(0.000079)
5 & 6 Month Lag	-3.2e-06	0.000035*	0.000038	-0.000100
	(0.000079)	(0.000019)	(0.000090)	(0.000078)
3 & 4 Month Lag	2.9e-06	3.6e-06	7.4e-07	-0.000029
	(0.000075)	(0.000017)	(0.000088)	(0.000072)
1 & 2 Month Lag	-0.000099	-7.8e-06	-0.000088	0.00015*
	(0.000075)	(0.000016)	(0.000091)	(0.000078)
Total Exchanges Nearby	-0.00030***	0.000065**	-0.00040***	-0.00019*
(Excluding Own if Relevant)	(0.00011)	(0.000029)	(0.00013)	(0.00011)
1 & 2 Month Lead	0.000030	6.3e-06	-0.000047	-4.8e-06
	(0.000073)	(0.000016)	(0.000087)	(0.000073)
3 & 4 Month Lead	-0.000028	6.5e-06	-0.00013	0.00020***
	(0.000075)	(0.000017)	(0.000087)	(0.000073)
5 & 6 Month Lead	-0.000014	0.000033*	0.000023	-0.00012*
	(0.000074)	(0.000017)	(0.000085)	(0.000069)
7 & 8 Month Lead	-8.8e-06	-4.7e-06	-0.00010	0.000058
	(0.000072)	(0.000016)	(0.000085)	(0.000070)
9 & 10 Month Lead	0.000053	-0.000014	-0.00013	0.000091
	(0.000067)	(0.000016)	(0.000082)	(0.000071)
11 & 12 Month Lead	0.000042	0.000021	-0.000086	2.6e-06
	(0.000066)	(0.000015)	(0.000082)	(0.000068)
Joint F-test on Leads	0.25	1.23	1.70	2.06
P-value of Joint F-test	0.96	0.29	0.12	0.05
Observations	3,964,354	3,964,354	3,964,354	3,964,354
R-squared	0.385	0.024	0.555	0.317

Clustered standard errors in parentheses (at zip code level). Regressions include month-year fixed effects, zip code fixed effects, zip code-specific linear time trends, and state-year fixed effects. They also include controls for age at listing, previous transplant status, PRA score, blood type, gender, ethnicity, education. Leads and lags are two-month totals. Significance indicated by: *** p<0.01, ** p<0.05, * p<0.1.

Table C2: Leads and Lags of *Activity*, Quality

VARIABLES	Graft Survival >1 Year	Graft Survival >2 Years	HLA Mismatches	Registration Duration (Days)
11 & 12 Month Lag	-0.00014	0.00047	-0.0021	-1.49
	(0.00051)	(0.00077)	(0.0029)	(1.30)
9 & 10 Month Lag	0.00040	0.0012*	0.0023	2.63**
	(0.00049)	(0.00069)	(0.0028)	(1.26)
7 & 8 Month Lag	0.00013	0.00084	-0.0015	-2.29**
	(0.00048)	(0.00069)	(0.0028)	(1.17)
5 & 6 Month Lag	0.00060	-0.00015	-0.00069	-0.71
	(0.00048)	(0.00071)	(0.0028)	(1.21)
3 & 4 Month Lag	-0.00040	0.00072	-0.0041	0.55
	(0.00045)	(0.00064)	(0.0027)	(1.16)
1 & 2 Month Lag	-0.00013	-0.00048	-0.00087	-1.07
	(0.00045)	(0.00071)	(0.0026)	(1.13)
Total Exchanges Nearby	0.0014**	0.0016*	-0.0017	-2.58
(Excluding Own if Relevant)	(0.00058)	(0.00086)	(0.0038)	(1.71)
1 & 2 Month Lead	0.000061	0.00035	0.0048*	-0.070
	(0.00041)	(0.00061)	(0.0025)	(1.14)
3 & 4 Month Lead	-0.00038	-0.00024	0.0026	1.11
	(0.00042)	(0.00062)	(0.0026)	(1.05)
5 & 6 Month Lead	0.00030	-0.000056	-0.0015	-0.59
	(0.00041)	(0.00059)	(0.0026)	(1.07)
7 & 8 Month Lead	-0.00031	-0.00045	-0.00052	1.94*
	(0.00041)	(0.00057)	(0.0024)	(1.09)
9 & 10 Month Lead	0.000055	0.00011	-0.00046	0.35
	(0.00040)	(0.00053)	(0.0024)	(1.03)
11 & 12 Month Lead	-0.00017	-0.00067	-0.00012	1.23
	(0.00038)	(0.00051)	(0.0023)	(1.06)
Joint F-test on Leads	0.32	0.47	0.96	1.12
P-value of Joint F-test	0.93	0.83	0.45	0.35
Observations	185,305	168,915	193,492	194,664
R-squared	0.120	0.131	0.186	0.273

Clustered standard errors in parentheses (at zip code level). Regressions include month-year fixed effects, zip code fixed effects, county-specific linear time trends, and state-year fixed effects. They also include controls for age at listing, previous transplant status, PRA score, blood type, gender, ethnicity, education. The non-death-censored graft survival variables assume transplant survival for those whose last known status is alive with a functioning kidney transplant. Excludes patients who experienced a non-transplant outcome. One-year graft survival excludes 2013-14 data, two years excludes 2012-14. Waiting list registration duration is set to 0 for the living donor transplant recipients who do not register on the deceased donor waiting list. Leads and lags are two-month totals. Significance indicated by: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table C3: Tests of Endogenous Patient Relocation

	Moved	Moved		Only Movers		
	(Binary)	(Binary)	Exchange	Direct Living	Anonymous	Deceased
Mean of Dep. Var.	[0.14]	[0.14]	[0.019]	[0.21]	[0.0076]	[0.76]
Exchanges Near Current	-0.0011					
Zip at Time of TX	(0.00073)					
Exchanges Near Original		0.000047				
Zip at Time of TX		(0.00080)				
Activity Differential Between			-0.0012	0.0035	-0.00023	-0.0021
New and Old Zip			(0.0027)	(0.0046)	(0.0013)	(0.0053)
Observations	163,920	163,920	18,479	18,479	18,479	18,479
R-squared	0.164	0.164	0.378	0.44	0.361	0.439
Number of Zip Codes	16,306	16,306	4,901	4,901	4,901	4,901

Clustered standard errors in parentheses (at zip code level). Regressions include month-year fixed effects, zip code fixed effects, county-specific linear time trends, and state-year fixed effects. They also include controls for age at listing, previous transplant status, PRA score, blood type, gender, ethnicity, education. Significance indicated by: *** p<0.01, ** p<0.05, * p<0.1.

Table C4: Substitution and Quality Estimates, Omitting Out-of-DSA Patients

	Exchange	Direct			Died on
	(First Stage)	Living	Anonymous	Deceased	Wait List
Mean of Dep. Var.	[0.00075]	[0.013]	[0.00031]	[0.030]	[0.013]
Panel A: Substitution Estimates					
Nearby Exchanges	0.00082***	-0.00031***	0.000059**	-0.00030**	-0.00026**
(Excluding Own)	(0.000058)	(0.000094)	(0.000025)	(0.00012)	(0.00010)
Wald IV Estimates	-	-0.39***	0.073**	-0.37***	-0.32***
	-	(0.11)	(0.031)	(0.14)	(0.12)
Observations	4,035,325	4,035,325	4,035,325	4,035,325	4,035,325
Panel B: Quality Estimates					
		Graft	Graft		Registration
	Exchange	Survival	Survival	HLA	Duration
	(First Stage)	>1 year	>2 years	Mismatches	(Days)
Mean of DV	[0.017]	[0.92]	[0.88]	[3.71]	[691]
Nearby Exchanges	0.0065***	0.0014**	0.0017*	0.00086	-2.54
(Excluding Own)	(0.00058)	(0.00063)	(0.00095)	(0.0037)	(1.75)
Wald IV Estimates	-	0.22**	0.24*	0.13	-389
	-	(0.10)	(0.14)	(0.58)	(267)
Observations	169,552	148,266	135,283	168,369	169,231

Excludes patients whose associated deceased donor waiting list registration is in a different DSA than the one in which they live, those whose zip code is not observed at the time of registration, and those who did not register before receiving a transplant. Otherwise, the notes for Panel A are the same as in Table 3 and the notes for Panel B are the same as in Table 4.

Table C5: Substitution Robustness Checks, Part I

Mean of Dep. Var.	Exchange (First Stage) [0.00089]	Direct Living [0.018]	Anonymous [0.00033]	Deceased [0.031]	Died on Wait List [0.013]
			Panel A: Using 30 Mile Radius		
Nearby Exchanges	0.0011***	-0.00043***	0.00014***	-0.00053***	-0.00027*
(Excluding Own)	(0.000087)	(0.00014)	(0.000040)	(0.00017)	(0.00015)
Wald IV Estimates	-	-0.39***	0.13***	-0.49***	-0.25*
	-	(0.12)	(0.038)	(0.15)	(0.13)
			Panel B: Using 75 Mile Radius		
Nearby Exchanges	0.00063***	-0.00026***	0.000047***	-0.00031***	-0.00011
(Excluding Own)	(0.000042)	(0.000071)	(0.000018)	(0.000087)	(0.000074)
Wald IV Estimates	-	-0.41***	0.074***	-0.49***	-0.17
	-	(0.11)	(0.029)	(0.13)	(0.12)
			Panel C: Lagged Activity Measure		
Nearby Exchanges	0.00019***	-0.00014	0.000022	-0.00019	0.00012
(Excluding Own)	(0.000045)	(0.000096)	(0.000020)	(0.00012)	(0.00010)
Wald IV Estimates	-	-0.75	0.11	-1.01	0.64
	-	(0.51)	(0.11)	(0.62)	(0.57)
			Panel D: Linear Probability Model		
Nearby Exchanges	0.0050***	-0.0020***	0.00034*	-0.0019**	-0.0014*
(Excluding Own)	(0.00041)	(0.00074)	(0.00019)	(0.00088)	(0.00076)
	[0.014]	[0.28]	[0.0052]	[0.49]	[0.21]
Wald IV Estimates		-0.41***	0.068*	-0.37**	-0.29*
		(0.15)	(0.038)	(0.17)	(0.15)
Observations	286,541	286,541	286,541	286,541	286,541

Clustered standard errors in parentheses (at zip code level). Regressions include month-year fixed effects, zip code fixed effects, zip code-specific linear time trends (unless stated otherwise), and state-year fixed effects (unless stated otherwise). They also include controls for age at listing, previous transplant status, PRA score, blood type, gender, ethnicity, education. Significance indicated by: *** p<0.01, ** p<0.05, * p<0.1.

Table C6: Substitution Robustness Checks, Part II

Mean of Dep. Var.	Exchange (First Stage) [0.00089]	Direct Living [0.018]	Anonymous [0.00033]	Deceased [0.031]	Died on Wait List [0.013]
Panel E: Dropping Zip Codes with No Exchange Activity Across Sample					
Nearby Exchanges	0.0026***	-0.00100***	0.00015**	-0.0013***	-0.00051*
(Excluding Own)	(0.00020)	(0.00027)	(0.000066)	(0.00031)	(0.00027)
	[0.0075]	[0.050]	[0.00096]	[0.084]	[0.039]
Wald IV Estimates	-	-0.38***	0.057**	-0.48***	-0.19*
	-	(0.097)	(0.026)	(0.11)	(0.10)
Observations	429,975	429,975	429,975	429,975	429,975
Panel F: Including only Zip Code and Month-Year FEs					
Nearby Exchanges	0.0010***	-0.00078***	0.00014***	-0.000064	-0.00031***
(Excluding Own)	(0.000050)	(0.000084)	(0.000023)	(0.00010)	(0.000086)
Wald IV Estimates		-0.77***	0.14***	-0.063	-0.31***
		(0.083)	(0.023)	(0.10)	(0.084)
Panel G: Including only Zip Code FEs, Month-Year FEs, and State-Year FEs					
Nearby Exchanges	0.00092***	-0.00075***	0.00013***	-0.000090	-0.00020**
(Excluding Own)	(0.000054)	(0.000088)	(0.000024)	(0.00011)	(0.000092)
Wald IV Estimates		-0.82***	0.14***	-0.098	-0.22**
		(0.098)	(0.027)	(0.12)	(0.099)
Panel H: Including only Zip Code FEs, Month-Year FEs, and Zip-Specific Linear Time Trends					
Nearby Exchanges	0.00096***	-0.00040***	0.000069***	-0.00043***	-0.00020**
(Excluding Own)	(0.000058)	(0.000095)	(0.000024)	(0.00012)	(0.000100)
Wald IV Estimates		-0.42***	0.072***	-0.45***	-0.21**
		(0.097)	(0.026)	(0.12)	(0.10)

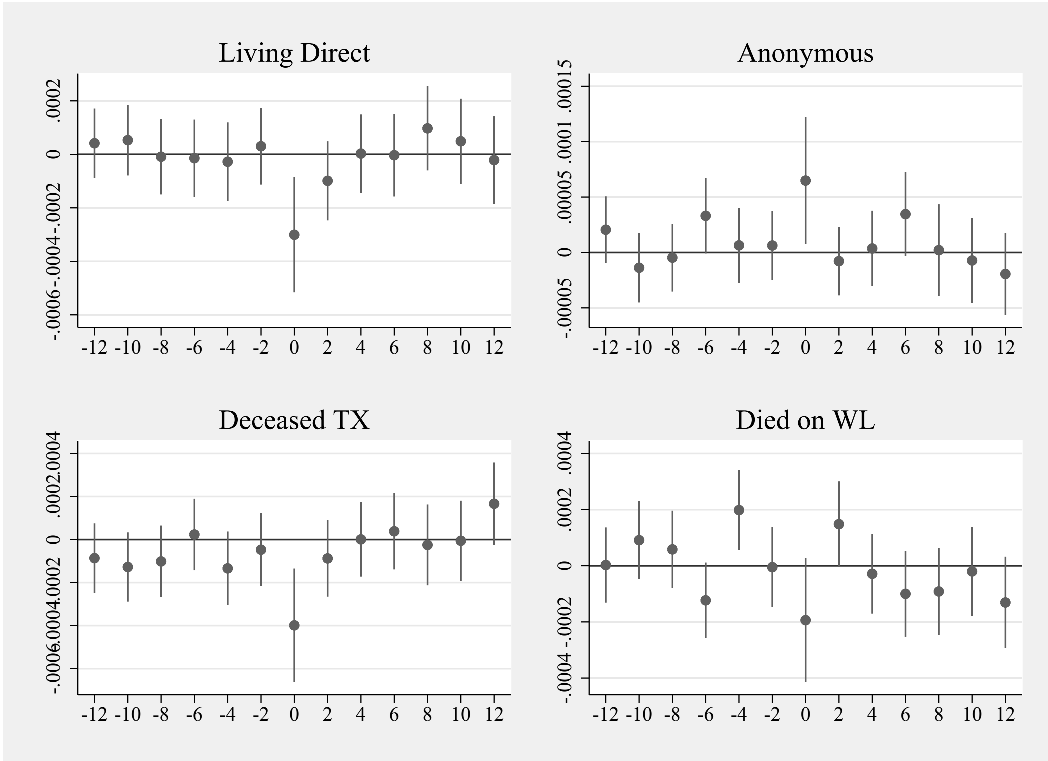
Clustered standard errors in parentheses (at zip code level). Regressions include month-year fixed effects, zip code fixed effects, zip code-specific linear time trends (unless stated otherwise), and state-year fixed effects (unless stated otherwise). They also include controls for age at listing, previous transplant status, PRA score, blood type, gender, ethnicity, education. Significance indicated by: *** p<0.01, ** p<0.05, * p<0.1.

Table C7: Quality Robustness Checks

Mean of Dep. Var.	Exchange (First Stage) [0.018]	Graft Survival >1 year [0.93]	Graft Survival >2 years [0.88]	HLA Mismatches [3.64]	Registration Duration (Days) [604]
Panel A: Using 30 Mile Radius					
Nearby Exchanges	0.0064***	0.0013*	0.0013	0.0012	-1.09
(Excluding Own)	(0.00063)	(0.00066)	(0.00097)	(0.0039)	(1.75)
Wald IV Estimates	-	0.19*	0.19	0.20	-170
	-	(0.100)	(0.14)	(0.61)	(272)
Panel B: Using 75 Mile Radius					
Nearby Exchanges	0.0058***	0.00067	0.00070	0.0013	-2.03
(Excluding Own)	(0.00045)	(0.00052)	(0.00078)	(0.0030)	(1.33)
Wald IV Estimates		0.12	0.13	0.22	-352
		(0.092)	(0.14)	(0.53)	(230)
Panel C: Dropping Zip Codes with No Exchange Activity Across Sample					
Nearby Exchanges	0.011***	0.0016**	0.0012	0.0014	-3.23
(Excluding Own)	(0.00097)	(0.00078)	(0.0012)	(0.0047)	(2.23)
	[0.052]	[0.92]	[0.88]	[3.72]	[638]
Wald IV Estimates	-	0.15**	0.11	0.12	-287
	-	(0.075)	(0.12)	(0.43)	(196)
Observations	61,171	53,691	49,140	60,573	61,038
Panel D: Including only Zip Code and Month-Year FEs					
Nearby Exchanges	0.0072***	0.0014***	0.0012*	0.0032	-5.18***
(Excluding Own)	(0.00044)	(0.00047)	(0.00070)	(0.0027)	(1.25)
Wald IV Estimates		0.19***	0.17*	0.45	-720***
		(0.066)	(0.097)	(0.38)	(177)
Panel E: Including only Zip Code FEs, Month-Year FEs, and State-Year FEs					
Nearby Exchanges	0.0058***	0.0010**	0.0012	0.000065	-3.83***
(Excluding Own)	(0.00049)	(0.00052)	(0.00078)	(0.0031)	(1.41)
Wald IV Estimates		0.17**	0.18	0.011	-655***
		(0.086)	(0.12)	(0.54)	(244)
Panel F: Including only Zip FEs, Month-Year FEs, and County-Specific Linear Trends					
Nearby Exchanges	0.0077***	0.0017***	0.0018**	0.00076	-3.09**
(Excluding Own)	(0.00050)	(0.00055)	(0.00081)	(0.0032)	(1.46)
Wald IV Estimates		0.23***	0.24**	0.100	-402**
		(0.075)	(0.11)	(0.42)	(189)

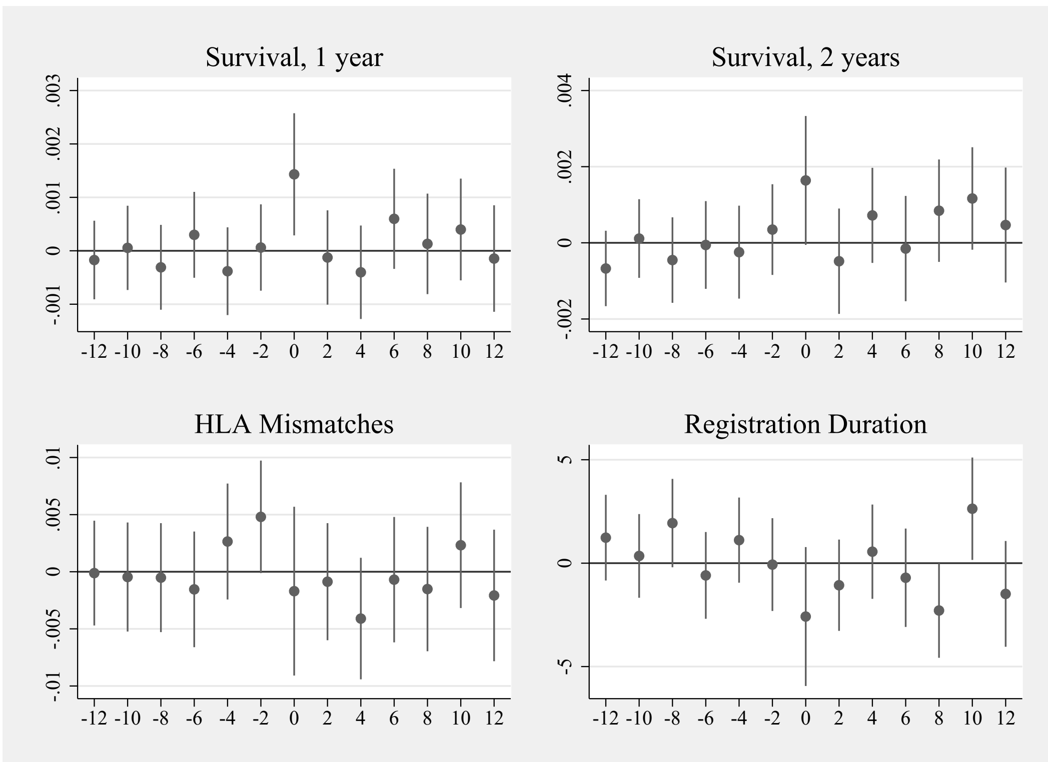
Clustered standard errors in parentheses (at zip code level). Regressions include month-year fixed effects, zip code fixed effects, county-specific linear time trends (unless stated otherwise), and state-year fixed effects (unless stated otherwise). They also include controls for age at listing, previous transplant status, PRA score, blood type, gender, ethnicity, education. The non-death-censored graft survival variables assume transplant survival for those whose last known status is alive with a functioning kidney transplant. Excludes patients who experienced a non-transplant outcome. One-year graft survival excludes 2013-14 data, two years excludes 2012-14. Waiting list registration duration is set to 0 for the living donor transplant recipients who do not register on the deceased donor waiting list. Significance indicated by: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Figure C1: Leads and Lags of *Activity*, Substitution



Estimates from Table C1. Joint F-test on Leads: 0.25 (Direct Living), 1.23 (Anonymous), 1.70 (Deceased), 2.06* (Died on WL)

Figure C2: Leads and Lags of *Activity*, Quality



Estimates from Table C2. Joint F-test on Leads: 0.32 (1-year Survival), 0.47 (2-year Survival), 0.96 (HLA Mismatches), 1.12 (Registration Duration)