Online Appendix for

Allocating Scarce Organs: How a Change in Supply Affects Transplant Waiting Lists and Transplant Recipients

*B*Y STACY DICKERT-CONLIN, TODD ELDER, AND KEITH TELTSER

Online Appendix A: Identifying transplant candidates who multilist

The SRTR data do not directly identify whether a transplant candidate is multilisted, so we create a multilisting identifier based on a unique patient identification variable. For each patient, we identify all registrations that belong to the same spell for a single-organ transplant by working backwards from the end of a listing spell. A spell ends when the individual receives a transplant, leaves the waitlist when there are no open registrations, dies without receiving a transplant, or is still on a waitlist when the data were extracted in 2014.

For each individual, all registrations in which the listing date is the same date or earlier than the first observed transplant or death are coded as part of the individual's first spell. A subsequent spell begins when a registration occurs following the end of a previous spell from transplant and ends when we observe a transplant or death. All registrations that begin after the date of the 2^{nd} spell and end before or at the same time as the 2^{nd} spell are coded in the 2^{nd} spell and so on. Registrations that occur after the most recent transplant are counted as the final spell. If a patient has never had a transplant, all of their registrations for that given organ are categorized as a single spell. We code all registrations as part of a multiple listing or not. We also code the chronological order of the multilisting registrations within spells.

A special case involved candidates who are listed for multi-organ registrations (kidney-pancreas and heart-lung). We split these into two single-organ observations. For example, kidney-pancreas registrations are split into one kidney and one pancreas listing. Therefore, we follow the kidney spell and the pancreas spell. We do this because some of these multi-organ wait list registrations end when the candidates receives a transplant for one of the two organs.

Online Appendix B: Supplemental Tables

Table OB1: Waiting List Additions (Registrations), by Organ and Year

Listing Year	Kidney	Liver	Heart	Lung	Pancreas	Intestine	Kidney/ Pancreas	Heart/ Lung	Total
1988	12,189	2,182	2,835	121	260			219	17,811
1989	12,764	2,950	2,933	209	540			226	19,632
1990	13,370	3,683	3,608	518	704		48	176	22,107
1991	13,694	4,176	3,855	977	694		177	128	23,702
1992	15,204	4,807	3,967	1,198	379		719	159	26,433
1993	16,075	5,522	3,834	1,357	208	59	1,060	163	28,278
1994	16,530	6,229	3,725	1,569	200	85	1,217	159	29,714
1995	17,884	7,329	4,244	1,752	229	91	1,387	138	33,054
1996	18,327	8,054	3,877	1,837	282	88	1,378	153	33,996
1997	19,049	8,620	3,757	1,939	328	134	1,411	140	35,378
1998	20,171	9,537	3,938	2,084	396	152	1,534	137	37,949
1999	21,000	10,520	3,541	1,990	527	149	1,803	109	39,639
2000	22,285	10,880	3,449	1,974	789	170	2,005	116	41,668
2001	22,334	11,126	3,400	2,032	949	219	1,788	106	41,954
2002	23,483	9,645	3,230	1,887	898	203	1,743	88	41,177
2003	24,409	10,324	2,939	1,953	917	205	1,644	69	42,460
2004	27,123	10,856	2,882	2,000	984	250	1,729	78	45,902
2005	29,139	10,987	2,836	1,564	889	284	1,786	59	47,544
2006	31,500	11,037	3,037	1,775	880	317	1,671	77	50,294
2007	32,860	11,083	3,112	1,959	779	281	1,619	50	51,743
2008	33,051	11,175	3,384	2,005	747	267	1,603	53	52,285
2009	34,089	11,262	3,515	2,280	662	260	1,569	64	53,701
2010	34,895	12,010	3,527	2,469	595	241	1,549	57	55,343
2011	34,245	11,925	3,448	2,464	526	184	1,350	56	54,198
2012	35,605	11,611	3,660	2,346	482	159	1,453	46	55,362
2013	37,353	12,020	3,985	2,530	478	180	1,272	46	57,864
Total	648,278	235,421	93,460	45,924	15,573	4,069	34,107	3,056	1,079,888

Notes:
These numbers are calculated at a single point in time in each year. Source: authors' calculations from SRTR data. Blank cells indicate that the count is below 25.

Table OB2: Waiting List Exits by Year and Reason for Leaving

Year	Deceased Donor Tx	Living Donor Tx	Transferred to another center	Too Sick	Died	Other	Total Waitlist Exits
1988	9,946	314	712		1,580	2,182	15,217
1989	10,626	410	921		1,784	2,390	16,692
1990	12,473	528	1,122		2,056	2,578	19,445
1991	13,033	634	1,165		2,532	2,602	20,775
1992	13,328	798	1,267		2,769	2,437	21,622
1993	14,587	937	1,650		3,140	2,661	24,184
1994	15,098	1,218	1,444		3,343	2,953	25,435
1995	15,834	1,497	1,961	703	3,708	2,960	27,055
1996	15,868	1,723	1,962	1,061	4,288	3,079	27,981
1997	16,170	1,978	2,207	1,149	4,832	2,839	29,176
1998	16,904	2,259	2,319	1,228	5,537	2,930	31,178
1999	16,919	2,692	2,662	1,369	6,835	3,248	33,728
2000	17,240	3,455	3,285	1,473	6,455	3,124	35,039
2001	17,554	4,002	3,385	1,584	7,065	2,972	36,574
2002	18,188	4,159	3,303	1,862	7,202	4,764	39,498
2003	18,561	4,350	3,292	1,646	7,138	4,014	39,019
2004	19,949	4,765	3,702	1,632	7,373	4,046	41,491
2005	21,117	4,952	4,767	1,905	7,373	4,262	44,378
2006	22,135	5,063	4,388	2,119	7,370	4,898	45,974
2007	21,999	4,911	4,462	2,463	7,135	6,155	47,129
2008	21,703	5,121	4,357	2,947	7,170	7,006	48,305
2009	21,815	5,633	4,290	3,427	7,158	6,078	48,403
2010	22,058	5,766	4,494	3,880	7,049	6,316	49,564
2011	22,457	5,425	4,716	4,441	7,301	6,615	50,955
2012	22,141	5,361	5,046	4,739	6,986	6,790	51,063
2013	22,935	5,534	5,173	5,242	6,733	6,863	52,480

Notes:
The “Other” category includes “removed in error”, “changed to kidney/pancreas”, “deceased donor emergency transplant”, “deceased donor multi-organ transplant”, “inactive program”, “died during transplant”, “unable to contract transplant and refused transplant”, “medically unsuitable”, and “health improved; transplant not needed”. The “medically unsuitable” category was split into “health improved; transplant not needed” and “too sick” in 1995.

Table OB3: Registrations on Waitlists, by Organ and Year

Year	Kidney	Liver	Heart	Lung	Pancreas	Intestine	Kidney/ Pancreas	Heart/ Lung
1988	12,446	553	969	87	142			180
1989	14,975	699	1,266	121	282			204
1990	16,705	1,020	1,679	341	394		61	186
1991	18,449	1,443	2,138	655	351		233	145
1992	21,519	2,112	2,625	929	138		737	178
1993	24,226	2,805	2,777	1,201	205	43	862	196
1994	26,761	3,791	2,832	1,570	251	71	1,003	202
1995	30,083	5,288	3,336	1,848	315	78	1,152	200
1996	33,371	6,930	3,519	2,201	358	78	1,366	231
1997	36,665	8,831	3,664	2,533	379	87	1,514	223
1998	39,989	10,936	3,882	2,977	454	93	1,729	244
1999	42,703	13,113	3,728	3,227	517	100	2,111	216
2000	46,095	15,074	3,713	3,380	746	135	2,419	191
2001	48,953	16,615	3,640	3,516	1,043	160	2,448	190
2002	51,469	15,505	3,468	3,519	1,143	173	2,476	176
2003	54,348	15,576	3,208	3,586	1,315	162	2,392	168
2004	58,111	15,405	2,933	3,571	1,387	179	2,367	151
2005	60,994	15,207	2,689	2,900	1,372	176	2,429	118
2006	64,306	14,637	2,516	2,599	1,441	198	2,290	109
2007	67,301	14,106	2,360	2,077	1,322	176	2,184	82
2008	72,087	13,777	2,490	1,888	1,259	168	2,178	69
2009	77,296	13,823	2,763	1,760	1,176	181	2,125	56
2010	82,413	14,262	2,980	1,734	1,094	220	2,142	43
2011	85,819	14,391	2,958	1,631	1,003	231	2,039	42
2012	90,828	14,208	3,203	1,560	919	218	2,052	29
2013	96,520	14,301	3,512	1,562	906	224	1,978	28
Total	1,289,423	264,947	75,500	53,007	19,948	3,153	42,312	4,015

Notes:
These numbers include both active and inactive patients on waitlists and are calculated at a single point in time in each year. Source: authors' calculations from SRTR data. Blank cells indicate that the count is below 25.

Table OB4: Listing of All Current DSAs

DSA ID Number	DSA Name	State of Headquarters	SRTR DSA Code
5	Alabama Organ Center	AL	ALOB
10	Arkansas Regional Organ Recovery Agency	AR	AROR
19	Donor Network of Arizona	AZ	AZOB
34	Donor Network West	CA	CADN
38	Sierra Donor Services	CA	CAGS
52	OneLegacy	CA	CAOP
61	Lifesharing - A Donate Life Organization	CA	CASD
88	Donor Alliance	CO	CORS
92	LifeChoice Donor Services	CT	CTHH
106	Washington Regional Transplant Community	DC	DCTC
115	TransLife	FL	FLFH
124	Life Alliance Organ Recovery Agency	FL	FLMP
134	LifeQuest Organ Recovery Services	FL	FLUF
138	LifeLink of Florida	FL	FLWC
143	LifeLink of Georgia	GA	GALL
157	Organ Donor Center of Hawaii	HI	HIOP
169	Iowa Donor Network	IA	IAOP
176	Gift of Hope Organ & Tissue Donor Network	IL	ILIP
200	Indiana Donor Network	IN	INOP
207	Kentucky Organ Donor Affiliates	KY	KYDA
222	Louisiana Organ Procurement Agency	LA	LAOP
302	New England Organ Bank	MA	MAOB
309	The Living Legacy Foundation of Maryland	MD	MDPC
330	Gift of Life Michigan	MI	MIOP
346	LifeSource Upper Midwest Organ Procurement Organizatior	MN	MNOP
360	Mid-America Transplant Services	MO	MOMA
369	Mississippi Organ Recovery Agency	MS	MSOP
374	Midwest Transplant Network	KS	MWOB
378	Lifeshare of the Carolinas	NC	NCCM
390	Carolina Donor Services	NC	NCNC
399	Nebraska Organ Recovery System	NE	NEOR
411	New Jersey Organ and Tissue Sharing Network OPO	NJ	NJTO
416	New Mexico Donor Services	NM	NMOP
422	Nevada Donor Network	NV	NVLV
427	Center for Donation and Transplant	NY	NYAP
440	Finger Lakes Donor Recovery Network	NY	NYFL
450	LiveOnNY	NY	NYRT
460	Upstate New York Transplant Services Inc	NY	NYWN
470	LifeBanc	OH	OHLB
471	Life Connection of Ohio	OH	OHLC
472	Lifeline of Ohio	OH	OHLP
480	LifeCenter Organ Donor Network	OH	OHOV
494	LifeShare Transplant Donor Services of Oklahoma	OK	OKOP
505	Pacific Northwest Transplant Bank	OR	ORUO
516	Gift of Life Donor Program	PA	PADV
530	Center for Organ Recovery and Education	PA	PATF
589	LifeLink of Puerto Rico	PR	PRLL
596	LifePoint	SC	SCOP
604	Tennessee Donor Services	TN	TNDS
612	Mid-South Transplant Foundation	TN	TNMS
637	LifeGift Organ Donation Center	TX	TXGC
660	Texas Organ Sharing Alliance	TX	TXSA
661	Southwest Transplant Alliance	TX	TXSB
692	Intermountain Donor Services	UT	UTOP
706	LifeNet Health	VA	VATB
730	LifeCenter Northwest Organ Donation Network	WA	WALC
747	UW Health Organ and Tissue Donation	WI	WIUW
832	Wisconsin Donor Network	WI	WIDN

Table OB5: Synthetic Control Estimates of the Effect of Helmet Law Repeals on per Capita Organ Donors, Organ Donations, and Organ Transplants, by Organ

	MVA Organ Transplants (1)	MVA Organ Donors (2)	Non-MVA Organ Transplants (3)	Non-MVA Organ Donors (4)
Overall	3.535	0.842	0.521	0.072
	{0.000}	{0.000}	{0.287}	{0.921}
	[17.001]	[4.851]	[49.668]	[16.844]
By Organ				
Kidney	1.487		-0.293	
	{0.000}		{0.884}	
	[8.345]		[25.152]	
Liver	0.562		0.756	
	{0.000}		{0.161}	
	[3.647]		[12.223]	
Heart	0.688		0.028	
	{0.000}		{0.843}	
	[2.393]		[5.284]	
Lung	0.610		0.329	
	{0.000}		{0.402}	
	[1.292]		[4.417]	
Pancreas	0.290		-0.008	
	{0.000}		{0.972}	
	[1.252]		[2.358]	

Notes:
1) All estimation samples consist of 58 DSAs from 1992 to 2013. The unit of observation is a DSA-year.
2) *p*-values, in braces, are obtained from permutation inference based on 10,000 placebo treatment effects in each case.
3) Sample means for relevant dependent variables are listed in brackets.

Table OB6: Synthetic Control Estimates of the Effect of Helmet Law Repeals on Waiting List Additions by In- Versus Out-of-Area

	All Additions	In-DSA	Out-of-DSA
	(1)	(2)	(3)
Overall	19.726	9.404	9.814
	{0.001}	{0.036}	{0.000}
	[157.909]	[122.910]	[35.000]
By Organ			
Kidney	9.841	4.232	4.979
	{0.001}	{0.378}	{0.000}
	[93.033]	[76.236]	[16.796]
Liver	6.327	3.395	1.729
	{0.000}	{0.000}	{0.423}
	[33.124]	[24.103]	[9.021]
Heart	0.333	0.175	0.437
	{0.365}	{0.428}	{0.210}
	[11.778]	[9.085]	[2.693]
Lung	3.970	2.121	1.931
	{0.000}	{0.000}	{0.000}
	[6.544]	[3.970]	[2.574]
Pancreas	-0.501	-0.282	0.085
	{0.714}	{0.819}	{0.499}
	[2.003]	[1.338]	[0.665]

Notes:
1) All estimation samples consist of 58 DSAs from 1992 to 2013. The unit of observation is a DSA-year.
2) *p*-values, in braces, are obtained from permutation inference based on 10,000 placebo treatment effects in each case.
3) Sample means for relevant dependent variables are listed in brackets.

Table OB7: Synthetic Control Estimates of the Effect of Helmet Law Repeals on Waiting List Additions by In- Versus Out-of-Area and by Multilisting Status

	No Multilistings			Multilistings		
	All Additions	In-DSA	Out-of-DSA	All Additions	In-DSA	Out-of-DSA
	(1)	(2)	(3)	(4)	(5)	(6)
Overall	11.076	5.363	3.159	9.989	5.713	4.141
	{0.002}	{0.198}	{0.341}	{0.032}	{0.000}	{0.002}
	[117.204]	[96.222]	[20.982]	[40.706]	[26.688]	[14.018]
By Organ						
Kidney	2.756	0.227	1.188	6.019	3.744	3.728
	{0.279}	{0.793}	{0.432}	{0.072}	{0.000}	{0.004}
	[67.063]	[58.887]	[8.176]	[25.969]	[17.349]	[8.620]
Liver	3.593	4.387	0.448	3.349	1.577	1.558
	{0.096}	{0.000}	{0.753}	{0.032}	{0.003}	{0.048}
	[27.457]	[20.740]	[6.717]	[5.666]	[3.363]	[2.304]
Heart	1.426	0.451	0.437	0.077	-0.012	0.066
	{0.393}	{0.740}	{0.301}	{0.662}	{0.867}	{0.599}
	[10.594]	[8.272]	[2.322]	[1.184]	[0.813]	[0.371]
Lung	3.682	1.997	1.055	0.535	0.183	0.252
	{0.001}	{0.000}	{0.098}	{0.167}	{0.085}	{0.236}
	[5.489]	[3.470]	[2.019]	[1.055]	[0.500]	[0.555]
Pancreas	0.198	-0.086	0.111	-0.419	-0.160	0.022
	{0.822}	{0.640}	{0.611}	{0.034}	{0.196}	{0.724}
	[1.261]	[0.860]	[0.401]	[0.742]	[0.478]	[0.264]

Notes:
1) All estimation samples consist of 58 DSAs from 1992 to 2013. The unit of observation is a DSA-year.
2) *p*-values, in braces, are obtained from permutation inference based on 10,000 placebo treatment effects in each case.
3) Sample means for relevant dependent variables are listed in brackets.

Table OB8: Synthetic Control Estimates of the Effect of Helmet Law Repeals on per Capita Living Organ Donors, by Relation to the Recipient

	All Organs	Kidneys	All Except Kidneys
Overall	-1.889	-1.630	-0.335
	{0.023}	{0.053}	{0.040}
	[15.564]	[15.027]	[0.537]
By Donor's Relationship to Intended Recipient			
Parent	-0.108	-0.177	0.061
	{0.729}	{0.033}	{0.966}
	[2.279]	[2.141]	[0.137]
Child	-0.589	-0.425	…
	{0.001}	{0.009}	…
	[2.510]	[2.388]	[0.122]
Sibling	-0.199	-0.203	-0.052
	{0.025}	{0.035}	{0.020}
	[4.752]	[4.674]	[0.078]
Other Relative	-0.195	-0.259	0.002
	{0.050}	{0.037}	{0.547}
	[1.066]	[1.009]	[0.057]
Spouse	-0.072	0.000	…
	{0.107}	{0.384}	…
	[1.558]	[1.531]	[0.027]
Other Directed Donations	-0.833	-0.869	0.005
	{0.041}	{0.227}	{0.779}
	[2.428]	[2.337]	[0.092]

Notes:
1) All estimation samples consist of 58 DSAs from 1992 to 2013. The unit of observation is a DSA-year.
2) *p*-values, in braces, are obtained from permutation inference based on 10,000 placebo treatment effects in each case.
3) Sample means for relevant dependent variables are listed in brackets.

Table OB9: Synthetic Control Estimates of the Effect of Helmet Law Repeals on Candidate Outcomes

	Transplants per Million DSA Residents		Graft Survival Rate	
	Within 9 months	Within 18 months	1 year	3 years
	(1)	(2)	(3)	(4)
Overall	2.158	1.628	0.007	0.003
	{0.377}	{0.675}	{0.081}	{0.273}
	[45.582]	[59.933]	[0.888]	[0.797]
By Organ				
Kidney	-1.230	1.330	-0.003	0.001
	{0.452}	{0.496}	{0.845}	{0.914}
	[18.935]	[28.267]	[0.919]	[0.833]
Liver	2.347	3.190	0.024	0.025
	{0.370}	{0.116}	{0.074}	{0.071}
	[14.351]	[16.712]	[0.834]	[0.747]
Heart	1.073	1.017	0.027	0.022
	{0.270}	{0.318}	{0.043}	{0.236}
	[6.232]	[7.123]	[0.866]	[0.788]
Lung	0.938	2.040	0.046	0.045
	{0.462}	{0.081}	{0.073}	{0.063}
	[2.804]	[3.485]	[0.780]	[0.594]
Pancreas	0.225	0.224	0.117	0.061
	{0.345}	{0.364}	{0.047}	{0.265}
	[0.815]	[1.008]	[0.773]	[0.634]

Notes:
1) All estimation samples consist of 58 DSAs from 1992 to 2013. The unit of observation is a DSA-year.
2) *p*-values, in braces, are obtained from permutation inference based on 10,000 placebo treatment effects in each case.
3) Sample means for relevant dependent variables are listed in brackets.

Table OB10: Weights for Synthetic Control Estimates for MVA Organ Transplants

	Treatment DSA ID Number												
Control DSAs	10	115	124	134	138	207	222	330	516	530	637	660	661
5	0.027	0	0.006	0.003	0	0.01	0	0	0	0	0.001	0	0
19	0.009	0	0.014	0.003	0	0.006	0	0	0	0	0	0	0
34	0.01	0	0.009	0.002	0	0.006	0	0	0	0	0	0	0
38	0.014	0	0.006	0.007	0	0.011	0	0	0	0	0.001	0	0
52	0.011	0	0.009	0.003	0	0.007	0	0	0	0	0	0	0
61	0.008	0	0.011	0.007	0	0.011	0	0	0	0	0	0	0
88	0.037	0	0.007	0.004	0	0.008	0	0	0	0	0.001	0.343	0
92	0.06	0	0.326	0.104	0	0.101	0	0	0.339	0.527	0.098	0	0.473
106	0.008	0	0.006	0.002	0	0.005	0	0	0	0	0	0	0
143	0.011	0	0.014	0.005	0	0.009	0	0	0	0	0	0	0
157	0.005	0	0.026	0.002	0	0.004	0	0	0	0	0	0	0
169	0.006	0	0.015	0.319	0	0.078	0.1	0	0	0	0	0	0
176	0.012	0	0.011	0.009	0	0.027	0	0	0.112	0	0	0	0
200	0.01	0	0.009	0.003	0	0.006	0	0	0	0	0	0	0
302	0.01	0	0.011	0.003	0	0.007	0	0.412	0	0	0	0	0
309	0.091	0	0.01	0.002	0	0.006	0	0	0	0.084	0.041	0	0
346	0.013	0	0.01	0.003	0	0.007	0.574	0	0	0	0	0	0
360	0.008	0	0.016	0.002	0	0.005	0	0	0	0	0	0	0
369	0.008	0	0.064	0.001	0	0.003	0	0	0	0	0	0	0
374	0.019	0.197	0.006	0.002	0.059	0.01	0	0	0.084	0	0.001	0	0.408
378	0.016	0	0.006	0.002	0	0.124	0	0	0	0	0.092	0	0
390	0.063	0	0.007	0.003	0	0.007	0	0.456	0	0	0.002	0	0
399	0.006	0.347	0.008	0.001	0.146	0.004	0	0	0	0	0	0	0
411	0.014	0	0.01	0.005	0	0.01	0	0	0	0	0.001	0	0
416	0.011	0.263	0.004	0.004	0	0.005	0	0	0	0	0	0	0
422	0.011	0	0.015	0.025	0	0.122	0	0.132	0.028	0.091	0	0.008	0
427	0.007	0	0.026	0.003	0	0.006	0	0	0	0	0	0	0
440	0.012	0	0.006	0.004	0	0.008	0	0	0	0	0.001	0	0
450	0.008	0	0.015	0.003	0	0.006	0	0	0	0	0	0	0
460	0.218	0	0.005	0.003	0	0.013	0	0	0	0	0.492	0	0
470	0.013	0	0.009	0.004	0	0.009	0	0	0	0	0.001	0	0
471	0.009	0	0.106	0.003	0	0.01	0.077	0	0	0	0	0	0
472	0.008	0.072	0.01	0.002	0	0.005	0	0	0	0	0	0	0
480	0.008	0	0.005	0.003	0	0.006	0	0	0	0	0	0.47	0
494	0.019	0	0.01	0.008	0	0.012	0	0	0	0	0.001	0	0
505	0.008	0	0.019	0.002	0	0.005	0	0	0	0	0	0	0
589	0.008	0	0.008	0.001	0	0.004	0	0	0	0	0.001	0.112	0
596	0.012	0	0.006	0.003	0	0.008	0	0	0	0	0	0	0
604	0.012	0	0.017	0.003	0	0.007	0	0	0.437	0	0	0	0
612	0.014	0	0.047	0.081	0	0.014	0.183	0	0	0	0.001	0	0.02
692	0.015	0.122	0.004	0.269	0	0.21	0	0	0	0	0	0.067	0
706	0.013	0	0.007	0.003	0	0.006	0	0	0	0	0.001	0	0
730	0.008	0	0.006	0.002	0	0.006	0	0	0	0	0	0	0
747	0.014	0	0.046	0.074	0.795	0.059	0.066	0	0	0.298	0	0	0.099
832	0.095	0	0.013	0.003	0	0.007	0	0	0	0	0.258	0	0

Table OB11: Weights for Synthetic Control Estimates for Waitlist Additions

	Treatment DSA ID Number												
Control DSAs	10	115	124	134	138	207	222	330	516	530	637	660	661
5	0	0	0.002	0	0.001	0	0	0.006	0	0	0.006	0.009	0.003
19	0.827	0	0.001	0	0.481	0	0	0.015	0	0	0.006	0.009	0.182
34	0	0	0.004	0	0.002	0	0	0.068	0	0.708	0.002	0.009	0.173
38	0.058	0	0.002	0	0.009	0.181	0.019	0.015	0	0	0.006	0.006	0.003
52	0	0	0.007	0	0.002	0	0	0.009	0.364	0.007	0.007	0.011	0.224
61	0	0	0.014	0	0.004	0	0	0.022	0	0	0.006	0.008	0.011
88	0	0	0.002	0	0.002	0	0	0.005	0	0	0.01	0.01	0.002
92	0	0	0.002	0	0.002	0.207	0	0.273	0	0	0.007	0.01	0.014
106	0	0.114	0.001	0.223	0.153	0.108	0.4	0.005	0	0	0.004	0.009	0.004
143	0	0	0.002	0	0.001	0	0	0.044	0.162	0	0.008	0.009	0.003
157	0	0	0.003	0.196	0.002	0	0	0.005	0	0	0.02	0.007	0.003
169	0	0	0.002	0	0.002	0	0	0.005	0	0	0.005	0.011	0.003
176	0	0	0.005	0	0.002	0	0	0.008	0	0	0.007	0.011	0.002
200	0	0	0.002	0	0.004	0	0	0.005	0	0	0.008	0.01	0.009
302	0	0	0.002	0	0.002	0	0	0.009	0	0	0.006	0.01	0.003
309	0	0	0.015	0.181	0	0	0	0.005	0.226	0.066	0.001	0.038	0
346	0	0	0.002	0.4	0	0	0.362	0.011	0	0	0.002	0.009	0.004
360	0	0	0.002	0	0.002	0	0.079	0.006	0	0	0.003	0.008	0.003
369	0	0.067	0	0	0.004	0	0	0.001	0	0	0.019	0.008	0.002
374	0	0	0.001	0	0.002	0	0	0.009	0	0	0.008	0.014	0.003
378	0	0	0.002	0	0.003	0.029	0	0.003	0	0	0.004	0.003	0.003
390	0	0	0.003	0	0.002	0	0	0.006	0	0	0.007	0.013	0.002
399	0.015	0	0.04	0	0.002	0	0	0.006	0	0	0.002	0.007	0.003
411	0	0	0.002	0	0.005	0	0	0.007	0	0	0.009	0.013	0.004
416	0	0	0.001	0	0.003	0.476	0.14	0.003	0	0	0.003	0.023	0.004
422	0	0	0.115	0	0.01	0	0	0.004	0	0	0.14	0.007	0.105
427	0	0	0.002	0	0.003	0	0	0.003	0	0	0.064	0.009	0.003
440	0	0	0.002	0	0.001	0	0	0.009	0	0	0.003	0.367	0.005
450	0	0	0.213	0	0.002	0	0	0.117	0	0	0.007	0.008	0.022
460	0	0	0.443	0	0.003	0	0	0.006	0	0	0.01	0.011	0.004
470	0	0	0.003	0	0.003	0	0	0.009	0	0	0.003	0.009	0.008
471	0	0	0.002	0	0.001	0	0	0.048	0	0	0.015	0.01	0.004
472	0.1	0	0.014	0	0.003	0	0	0.156	0	0	0.164	0.005	0.002
480	0	0	0.003	0	0.004	0	0	0.022	0.249	0.219	0.009	0.008	0.005
494	0	0	0.002	0	0.002	0	0	0.01	0	0	0.008	0.012	0.003
505	0	0	0.002	0	0.003	0	0	0.006	0	0	0.006	0.023	0.005
589	0	0.677	0.001	0	0.003	0	0	0	0	0	0.138	0.013	0.005
596	0	0	0.001	0	0.001	0	0	0.005	0	0	0.227	0.103	0.002
604	0	0	0.003	0	0.003	0	0	0.007	0	0	0.01	0.009	0.006
612	0	0	0.002	0	0.001	0	0	0.005	0	0	0.005	0.076	0.023
692	0	0.143	0.001	0	0.007	0	0	0.008	0	0	0.006	0.014	0.003
706	0	0	0.003	0	0.003	0	0	0.015	0	0	0.004	0.009	0.003
730	0	0	0.001	0	0.003	0	0	0.007	0	0	0.005	0.016	0.003
747	0	0	0.062	0	0.246	0	0	0.006	0	0	0.004	0.006	0.001
832	0	0	0.004	0	0.002	0	0	0.007	0	0	0.005	0.011	0.119

Table OB12: Estimates of the Effect of Helmet Law Repeals on Candidate Outcomes

	Transplants per Million DSA Residents		Graft Survival Rate	
	Within 9 months	Within 18 months	1 year	3 years
	(1)	(2)	(3)	(4)
	Panel A: OLS Estimates Based on "Nolawshare" Measure			
Overall	2.877	5.212	0.010	0.007
	(3.858)	(3.959)	(0.004)	(0.005)
	[45.582]	[59.933]	[0.889]	[0.799]
By Organ				
Kidney	-2.441	-0.765	0.000	-0.002
	(1.630)	(1.859)	(0.006)	(0.009)
	[18.935]	[28.267]	[0.923]	[0.839]
Liver	3.312	3.579	0.028	0.028
	(2.545)	(2.566)	(0.011)	(0.012)
	[14.351]	[16.712]	[0.836]	[0.749]
Heart	-0.316	-0.266	0.033	0.030
	(0.759)	(0.839)	(0.009)	(0.015)
	[6.232]	[7.123]	[0.867]	[0.789]
Lung	1.938	1.134	0.073	0.033
	(1.249)	(1.181)	(0.023)	(0.022)
	[2.804]	[3.485]	[0.781]	[0.591]
Pancreas	0.129	0.123	0.091	0.071
	(0.226)	(0.287)	(0.046)	(0.040)
	[0.815]	[1.008]	[0.782]	[0.631]
	Panel B: Synthetic Control and OLS Estimates Based on Repeal Indicator			
Overall				
Synthetic Control	2.158	1.628	0.007	0.004
	{0.377}	{0.675}	{0.057}	{0.116}
OLS	1.839	3.788	0.010	0.008
	(3.301)	(3.413)	(0.004)	(0.004)

Notes: All estimation samples consist of 58 DSAs from 1992 to 2013. The unit of observation is a DSA-year. All OLS models include indicators for years and DSAs. Standard errors of OLS estimates, listed in parentheses, are robust to clustering with DSA over time. In panel B, *p*-values, in braces, are obtained from permutation inference based on 10,000 placebo treatment effects in each case. Sample means for relevant dependent variables are listed in brackets.

Table OB13: The Contribution of Changes in The Observable Composition of Donors and Candidates to Graft Survival

All Organs

	Estimated Effects on 1-year Graft Survival × 100	Coefficients on *nolawshare* in Models Using Characteristics as Dependant Variables	Col. (1) × Col. (2)
	(1)	(2)	(3)
Candidate Characteristics:			
On Expanded Donor List	-1.289	0.0185	-0.024
Accept a Post-Cardiac Death Donor?	-0.031	0.0658	-0.002
First Allocation PRA (at listing)	-0.003	-2.008	0.005
Initial Peak PRA	-0.001	-1.984	0.002
Maximum PRA	-0.006	-0.462	0.003
Initial MELD	0.006	-0.629	-0.004
Last MELD	0.015	0.666	0.010
Greater than HS Education	0.019	0.00571	0.000
Candidate Had Previous Transplant	-2.442	-0.00585	0.014
Candidate Had Private Insurance	0.236	-0.0598	-0.014
Candidate Had Medicare Only	-0.063	0.0610	-0.004
Under 18 Years Old	1.244	-0.0107	-0.013
Age at Listing	0.054	0.352	0.019
Blood Type O	0.076	-0.00481	0.000
On Dialysis	-0.557	0.0132	-0.007
White	0.252	-0.00285	-0.001
BMI	-0.057	0.0636	-0.004
Most Recent Absolute Creatinine	-0.001	-0.0109	0.000
Has Diabetes	-0.670	-0.00490	0.003
Functional Status (0 - 100)	-0.059	-0.0513	0.003
6-minute Walking Distance	0.000	-177.3	0.016
In Urgent Need of Tx (Status 1a)	0.154	-0.103	-0.016
Cardiac Output (CO L/min)	0.026	0.211	0.005
Donor Characteristics:			
Donor Age	-0.026	0.121	-0.003
Meets ECD Criteria, post 2003	-1.413	-0.046	0.065
Post-Cardiac Death Donor	-0.326	-0.00267	0.001
Donor BMI	0.068	0.000939	0.000
Total			0.055

Table OB13: The Contribution of Changes in The Observable Composition of Donors and Candidates to Graft Survival (cont.)

Kidney

	Estimated Effects on 1-year Graft Survival × 100 (1)	Coefficients on *nolawshare* in Models Using Characteristics as Dependant Variables (2)	Col. (1) × Col. (2) (3)
Candidate Characteristics:			
On Expanded Donor List	-1.289	0.0187	-0.024
Accept a Post-Cardiac Death Donor?	-0.031		0.000
First Allocation PRA (at listing)	-0.003	-2.031	0.005
Initial Peak PRA	-0.001	-2.013	0.002
Maximum PRA	-0.006	-0.546	0.004
Initial MELD	0.006		0.000
Last MELD	0.015		0.000
Greater than HS Education	0.019	-0.00461	0.000
Candidate Had Previous Transplant	-2.442	-0.00639	0.016
Candidate Had Private Insurance	0.236	-0.0708	-0.017
Candidate Had Medicare Only	-0.063	0.0675	-0.004
Under 18 Years Old	1.244	-0.00694	-0.009
Age at Listing	0.054	0.195	0.011
Blood Type O	0.076	-0.00608	0.000
On Dialysis	-0.557	0.0128	-0.007
White	0.252	-0.0208	-0.005
BMI	-0.057	-0.0211	0.001
Most Recent Absolute Creatinine	-0.001	0.222	0.000
Has Diabetes	-0.670	-9.90e-05	0.000
Functional Status (0 - 100)	-0.059	-0.0409	0.002
6-minute Walking Distance	0.000		0.000
In Urgent Need of Tx (Status 1a)	0.154		0.000
Cardiac Output (CO L/min)	0.026		0.000
Donor Characteristics:			
Donor Age	-0.026	-0.0992	0.003
Meets ECD Criteria, post 2003	-1.413	-0.00449	0.006
Post-Cardiac Death Donor	-0.326	-0.00273	0.001
Donor BMI	0.068	0.00139	0.000
Total			-0.016

Table OB13: The Contribution of Changes in The Observable Composition of Donors and Candidates to Graft Survival (cont.)

Liver

	Estimated Effects on 1-year Graft Survival × 100 (1)	Coefficients on *nolawshare* in Models Using Characteristics as Dependant Variables (2)	Col. (1) × Col. (2) (3)
Candidate Characteristics:			
On Expanded Donor List	-1.289		0.000
Accept a Post-Cardiac Death Donor?	-0.031		0.000
First Allocation PRA (at listing)	-0.003		0.000
Initial Peak PRA	-0.001		0.000
Maximum PRA	-0.006		0.000
Initial MELD	0.006	-0.629	-0.004
Last MELD	0.015	0.666	0.010
Greater than HS Education	0.019	0.0604	0.001
Candidate Had Previous Transplant	-2.442	-0.0109	0.027
Candidate Had Private Insurance	0.236	-0.0546	-0.013
Candidate Had Medicare Only	-0.063	0.0580	-0.004
Under 18 Years Old	1.244	-0.0198	-0.025
Age at Listing	0.054	0.975	0.053
Blood Type O	0.076	-0.00477	0.000
On Dialysis	-0.557		0.000
White	0.252	0.0315	0.008
BMI	-0.057	0.272	-0.016
Most Recent Absolute Creatinine	-0.001	-0.0170	0.000
Has Diabetes	-0.670	-0.00961	0.006
Functional Status (0 - 100)	-0.059	-0.0889	0.005
6-minute Walking Distance	0.000		0.000
In Urgent Need of Tx (Status 1a)	0.154		0.000
Cardiac Output (CO L/min)	0.026		0.000
Donor Characteristics:			
Donor Age	-0.026	-0.0575	0.001
Meets ECD Criteria, post 2003	-1.413	0.00752	-0.011
Post-Cardiac Death Donor	-0.326	-0.00413	0.001
Donor BMI	0.068	0.00207	0.000
Total			0.042

Table OB13: The Contribution of Changes in The Observable Composition of Donors and Candidates to Graft Survival (cont.)

Heart

	Estimated Effects on 1-year Graft Survival × 100 (1)	Coefficients on *nolawshare* in Models Using Characteristics as Dependant Variables (2)	Col. (1) × Col. (2) (3)
Candidate Characteristics:			
On Expanded Donor List	-1.289		0.000
Accept a Post-Cardiac Death Donor?	-0.031	0.0132	0.000
First Allocation PRA (at listing)	-0.003		0.000
Initial Peak PRA	-0.001		0.000
Maximum PRA	-0.006		0.000
Initial MELD	0.006		0.000
Last MELD	0.015		0.000
Greater than HS Education	0.019	-0.0171	0.000
Candidate Had Previous Transplant	-2.442	-9.74e-05	0.000
Candidate Had Private Insurance	0.236	0.00450	0.001
Candidate Had Medicare Only	-0.063	0.0157	-0.001
Under 18 Years Old	1.244	0.00865	0.011
Age at Listing	0.054	-0.564	-0.031
Blood Type O	0.076	0.0105	0.001
On Dialysis	-0.557		0.000
White	0.252	-0.00735	-0.002
BMI	-0.057	0.290	-0.017
Most Recent Absolute Creatinine	-0.001	-0.0390	0.000
Has Diabetes	-0.670	-0.0161	0.011
Functional Status (0 - 100)	-0.059	-0.00953	0.001
6-minute Walking Distance	0.000		0.000
In Urgent Need of Tx (Status 1a)	0.154	-0.103	-0.016
Cardiac Output (CO L/min)	0.026	0.128	0.003
Donor Characteristics:			
Donor Age	-0.026	-0.544	0.014
Meets ECD Criteria, post 2003	-1.413	-0.00390	0.006
Post-Cardiac Death Donor	-0.326	0.000100	0.000
Donor BMI	0.068	0.00141	0.000
Total			-0.019

Table OB13: The Contribution of Changes in The Observable Composition of Donors and Candidates to Graft Survival (cont.)

Lung

	Estimated Effects on 1-year Graft Survival × 100	Coefficients on *nolawshare* in Models Using Characteristics as Dependant Variables	Col. (1) × Col. (2)
	(1)	(2)	(3)
Candidate Characteristics:			
On Expanded Donor List	-1.289		0.000
Accept a Post-Cardiac Death Donor?	-0.031	0.0427	-0.001
First Allocation PRA (at listing)	-0.003		0.000
Initial Peak PRA	-0.001		0.000
Maximum PRA	-0.006		0.000
Initial MELD	0.006		0.000
Last MELD	0.015		0.000
Greater than HS Education	0.019	-0.0625	-0.001
Candidate Had Previous Transplant	-2.442	-0.00202	0.005
Candidate Had Private Insurance	0.236	-0.0607	-0.014
Candidate Had Medicare Only	-0.063	0.0705	-0.004
Under 18 Years Old	1.244	-0.0109	-0.014
Age at Listing	0.054	1.391	0.076
Blood Type O	0.076	-0.0157	-0.001
On Dialysis	-0.557		0.000
White	0.252	0.00351	0.001
BMI	-0.057	0.503	-0.029
Most Recent Absolute Creatinine	-0.001	-0.00464	0.000
Has Diabetes	-0.670	-0.0292	0.020
Functional Status (0 - 100)	-0.059	-0.0872	0.005
6-minute Walking Distance	0.000	-183.9	0.016
In Urgent Need of Tx (Status 1a)	0.154		0.000
Cardiac Output (CO L/min)	0.026	0.290	0.007
Donor Characteristics:			
Donor Age	-0.026	-0.877	0.023
Meets ECD Criteria, post 2003	-1.413	-0.0126	0.018
Post-Cardiac Death Donor	-0.326	-0.000718	0.000
Donor BMI	0.068	0.000854	0.000
Total			0.106

Table OB13: The Contribution of Changes in The Observable Composition of Donors and Candidates to Graft Survival (cont.)

Pancreas

	Estimated Effects on 1-year Graft Survival × 100 (1)	Coefficients on *nolawshare* in Models Using Characteristics as Dependant Variables (2)	Col. (1) × Col. (2) (3)
Candidate Characteristics:			
On Expanded Donor List	-1.289		0.000
Accept a Post-Cardiac Death Donor?	-0.031		0.000
First Allocation PRA (at listing)	-0.003	-3.507	0.009
Initial Peak PRA	-0.001	-3.658	0.004
Maximum PRA	-0.006	-2.478	0.016
Initial MELD	0.006		0.000
Last MELD	0.015		0.000
Greater than HS Education	0.019	0.00825	0.000
Candidate Had Previous Transplant	-2.442	0.0353	-0.086
Candidate Had Private Insurance	0.236	-0.0577	-0.014
Candidate Had Medicare Only	-0.063	0.0157	-0.001
Under 18 Years Old	1.244	0.0175	0.022
Age at Listing	0.054	-2.195	-0.119
Blood Type O	0.076	-0.0251	-0.002
On Dialysis	-0.557	-0.00695	0.004
White	0.252	0.00989	0.002
BMI	-0.057	-0.420	0.024
Most Recent Absolute Creatinine	-0.001	-0.121	0.000
Has Diabetes	-0.670	-0.0331	0.022
Functional Status (0 - 100)	-0.059	-0.0262	0.002
6-minute Walking Distance	0.000		0.000
In Urgent Need of Tx (Status 1a)	0.154		0.000
Cardiac Output (CO L/min)	0.026		0.000
Donor Characteristics:			
Donor Age	-0.026	-0.497	0.013
Meets ECD Criteria, post 2003	-1.413	-0.00116	0.002
Post-Cardiac Death Donor	-0.326	-0.0115	0.004
Donor BMI	0.068	0.00311	0.000
Total			-0.098

Online Appendix C: Designating Counties to Donation Service Areas

Donation Service Areas (DSAs) are the unit of observation throughout our analysis. Currently there are 58 DSAs in operation. According to personal correspondences with Peggye Wilkerson at the Centers for Medicare & Medicaid Services (CMS), the mapping between counties and DSAs that is provided in the SRTR data was effective as of May 31, 2006.

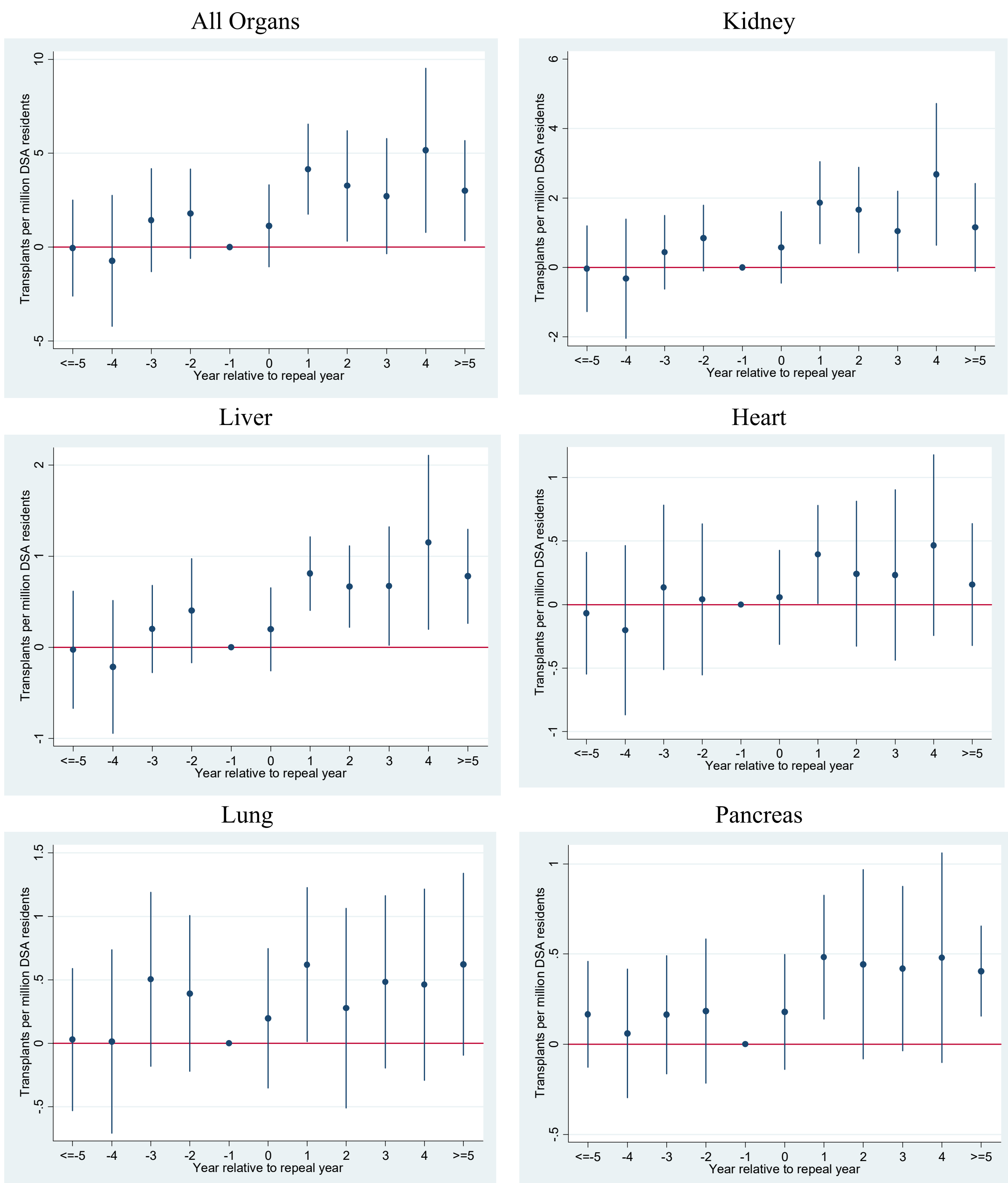
In cases in which a county is split between two DSAs, we use a variable in the county-level data which lists the share of deaths in a county that were handled by a specific OPO. Only 2 percent of the counties are split between two DSAs, and only 1.4 percent of the counties are split between two DSAs for more than one year. When the county is split in only one year, it is because the DSA's boundaries were changing in that year (see below), which occurs infrequently. To account for shifts in DSA boundaries, we assign, for all years, the entire county to the DSA where the larger share of the county referrals was made in 2013. We gratefully thank Bryn Thompson at SRTR for helping us resolve these issues.

A second issue for assigning the counties to DSAs is that the DSAs changed over time and, in some cases, the names of the OPOs that administer the DSAs changed over time. Therefore, in our individual-level data, we have transplant candidates listed in OPOs/DSAs that no longer exist and are not available in the current mapping between counties and DSAs. Mark Paster at the Association of Organ Procurement Organization and Chas MacKenzie at the Life Choice Donor Services provided valuable information on the history of a Wisconsin OPO name change and a Connecticut name discrepancy in our data. A more substantive issue is that many of the original DSAs eventually merged into the current set of DSAs. That is, 30 OPOs/DSAs in the SRTR dataset were in existence at one point but no longer exist. 13 of those were only in existence between 1987 and 1988. We do not have data on which counties were in the DSAs in the early years; we only know that the DSAs existed. Peggye Wilkerson of CMS suggested that the county-DSA concordance from those years is not readily available. The most straightforward solution, we believe, is to assume that the current county to DSA designation was always in place. It seems unlikely that this would substantively affect our results since we are simply treating two DSAs as if they were always one and the DSAs are likely to be affected by the same state laws, except in few cases where DSAs cross state lines. Most of the 30 DSAs that no longer exist are in states where the DSAs are wholly contained in a single state.

Online Appendix D: Supplemental Figures

Figure D1

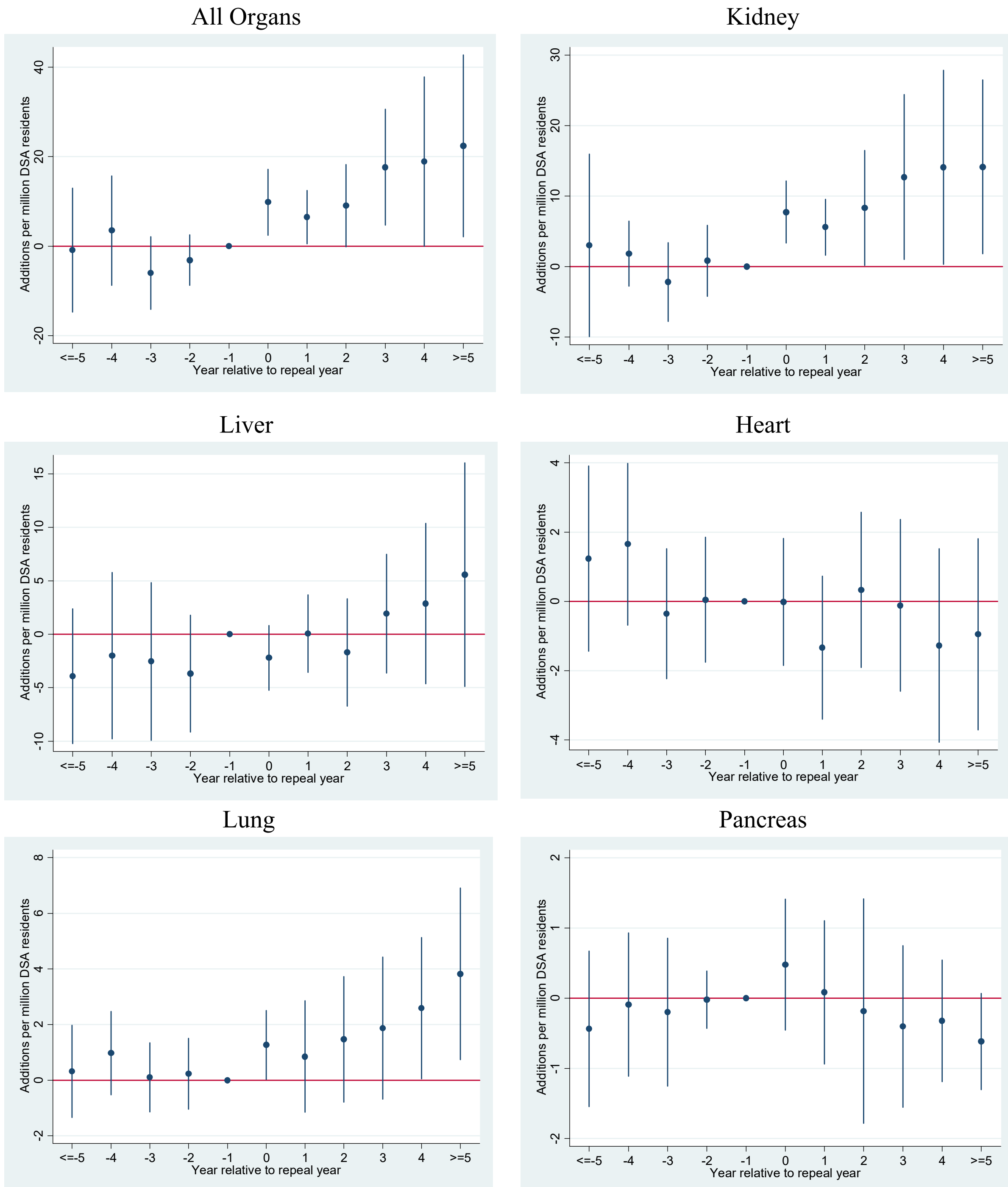
Event-Study Estimates of the Effects of Helmet Law Repeals on MVA Organ Transplants



Notes:

1) All estimation samples consist of 58 DSAs from 1987 to 2013.
2) Each figure plots event-study estimates as described in specification (2) in the text.

Figure D2
Event-Study Estimates of the Effects of Helmet Law Repeals on Waiting List Additions



<u>Notes</u>:
1) All estimation samples consist of 58 DSAs from 1992 to 2013.
2) Each figure plots event-study estimates as described in specification (2) in the text.

Online Appendix E: An Equilibrium Framework of Transplant Candidate Behavior

In this section we present a simple model of transplant candidates' listing decisions that generates predictions for how candidates respond to supply shocks in a local organ market. We begin by assuming that candidates' homes are uniformly spatially distributed on the unit interval [0,1], with the total mass of candidates equal to one. There are two DSAs, denoted X and Y, respectively, each with one transplant center. These transplant centers are located at the endpoints of the [0,1] interval, with X's transplant center located at 0 and Y's center located at 1.

Assume that the only costs facing potential candidates are transportation costs associated with traveling from one's home to the transplant center; there is no monetary cost to sign up on a waitlist or to receive a transplant.[1] Travel costs are quadratic in distance, so if a candidate lives at location m, the cost of travelling to 0 is cm^2 and the cost of travelling to 1 is $c(1-m)^2$, with $c > 0$.

A transplant candidate will sign up for a waitlist if the expected benefit from doing so, B_j, where $j \in \{X, Y\}$, exceeds the travel cost. Let m_j denote the location of the marginal candidate who is indifferent between signing up on waitlist j and not.[2] Figure D1 illustrates a hypothetical pair of marginal candidates, m_x and m_y, along with the set of inframarginal candidates that sign up for each waitlist. As shown in the figure, it is possible to have overlap, so that candidates

[1] Costs might also include insurance costs that differ depending on where transplant centers are located, information costs, health conditions that determine where a person is on a waiting list in a DSA, and the availability of outside options such as living donors. Our comparative statics remain unchanged if we include fixed listing costs in the model in order capture these differences.

[2] There are many dimensions of marginal candidates because once a candidate joins, her place on the list is not well-defined. There is not an actual waiting list, but rather a pool of candidates generated each time a deceased organ becomes available. Depending on health status, transplant compatibility measures, and, in some cases, waiting time a candidate accrued and transferred from another list, a person who is a recent addition on the waitlist may be higher on the list generated for a particular organ than those who registered earlier.

located between m_y and m_x sign up for both waitlists. These multilisting candidates leave both waitlists when they receive a transplant.

The benefit from signing up on a given list depends on the list's expected waiting time as well as expected organ quality.[3] We assume that, all else equal, the expected waiting time increases with the number of candidates on the list, and it decreases with the size of the overlap. A larger overlap decreases waiting time because, for a given number of candidates on a list, the "queue" moves more quickly when there are more candidates that are also signed up on another list – some of those candidates ultimately receive an organ via the other list, thereby exiting both. We impose that the "overlap effect" is smaller than the direct effect of a change in m_j on wait time; for example, if m_x rises so that there are more candidates on list *X* but also more candidates on both lists, expected waiting time in *X* will increase. We view this condition as quite likely to hold in practice.

Expected waiting time is also decreasing in market "thickness" t, the supply of organs in a given DSA. For simplicity, and because our primary interest lies in characterizing comparative statics when t changes exogenously, we only allow thickness to vary in DSA *X*. Thus, expected waiting time in *X* is $w_x(m_x, m_y, t)$, with first derivatives given by $\frac{\partial w_x}{\partial m_x} > 0$, $\frac{\partial w_x}{\partial m_y} > 0$, and $\frac{\partial w_x}{\partial t} < 0$, respectively. Note that $\frac{\partial w_x}{\partial m_y} > 0$ because of the "overlap effect" – when m_y increases, so that the number of candidates registered in *Y* declines, expected waiting times in *X* increase because

[3] Lindsay and Feigenbaum (1984) propose a market-clearing model for waiting lists for medical procedures that also focuses on the role of expected waiting time in the decision to join a list. Their model describes a context involving a single market (the British National Health Service), rather than the multiple markets that characterize the organ allocation system in the U.S.

of reduced overlap. Similarly, expected waiting time in *Y* is given by $w_y(m_y, m_x)$, with $\frac{\partial w_y}{\partial m_y} < 0$ and $\frac{\partial w_y}{\partial m_y} < 0$.

We further assume that organ quality in DSA *X*, $q_x(t)$, also depends positively on the thickness of the market, so that $\frac{\partial q_x}{\partial t} > 0$. Because of the matching process for allocating deceased-donor organs, a larger pool of organs may increase the efficiency of the allocation process and improve match quality, even holding the quality of the overall pool of organs constant (see Roth et al., 2004, for a discussion of the effects of expanding organ pools in living kidney exchanges). In our setting, the source of the supply shift may generate a quality change directly, as DCEM's (2011) results show that the increase in the supply of organs from helmet law repeals is concentrated in men aged 18 to 35, who are likely in better pre-donation health than donors from other circumstances of death.

The following two equations define the marginal candidates m_x and m_y:

(D1) $$H_x(m_x, m_y, t) \equiv B_x\left(w_x(m_x, m_y, t), q_x(t)\right) - cm_x^2 = 0$$

(D2) $$H_y(m_x, m_y) \equiv B_y\left(w_y(m_y, m_x), q_y\right) - c(1 - m_y)^2 = 0,$$

where $B_j(\cdot)$ is the expected benefit of signing up for list $j \in \{X, Y\}$. For a given value of *t*, these two equations in two unknowns (m_x and m_y) define the equilibrium. Under the assumption that the direct effect of a change in the number of candidates on expected waiting time is larger than the "overlap effect", so that $\frac{\partial w_x}{\partial m_x} \geq \frac{\partial w_x}{\partial m_y}$ and $\left|\frac{\partial w_y}{\partial m_y}\right| \geq \left|\frac{\partial w_y}{\partial m_x}\right|$, this equilibrium is unique:

Proposition 1. If $\frac{\partial w_x}{\partial m_x} \geq \frac{\partial w_x}{\partial m_y}$ and $\left|\frac{\partial w_y}{\partial m_y}\right| \geq \left|\frac{\partial w_y}{\partial m_x}\right|$, then the equilibrium defined by the values of m_x and m_y that solve (D1) and (D2) is unique.

Proof of Proposition 1

First, we demonstrate that the two curves defined by (D1) and (D2) are downward-sloping in $\{m_x, m_y\}$ space. We apply the Implicit Function Theorem to derive the slope of equation (D1):

(D3) $$\frac{dm_y}{dm_x}(H_x) = -\frac{\frac{\partial H_x}{\partial m_x}}{\frac{\partial H_x}{\partial m_y}} = -\frac{B_{x1}\frac{\partial w_x}{\partial m_x} - 2cm_x}{B_{x1}\frac{\partial w_x}{\partial m_y}} < 0,$$

where B_{x1}, the derivative of B_x with respect to expected waiting time in market *X*, is negative. Both $\frac{\partial w_x}{\partial m_x}$ and $\frac{\partial w_x}{\partial m_y}$ are positive, implying that both the numerator and denominator of (D1) are negative.

Applying the same logic to equation (D2) yields

(D4) $$\frac{dm_y}{dm_x}\left(H_y\right) = -\frac{\frac{\partial H_y}{\partial m_x}}{\frac{\partial H_y}{\partial m_y}} = -\frac{B_{y1}\frac{\partial w_y}{\partial m_x}}{B_{y1}\frac{\partial w_y}{\partial m_y} + 2c(1 - m_y)} < 0.$$

In this case, both the numerator and denominator are positive because B_{y1}, $\frac{\partial w_y}{\partial m_y}$, and $\frac{\partial w_y}{\partial m_x}$ are all negative. Thus, the two curves defined by (D1) and (D2) are uniformly downward-sloping in $\{m_x, m_y\}$ space.

Next we show that, if $\frac{\partial w_x}{\partial m_x} \geq \frac{\partial w_x}{\partial m_y}$ and $\left|\frac{\partial w_y}{\partial m_y}\right| \geq \left|\frac{\partial w_y}{\partial m_x}\right|$, then the $H_x(\cdot)$ curve defined implicitly by (D1) is uniformly steeper than the $H_y(\cdot)$ curve, i.e., that

(D5) $$\frac{B_{x1}\frac{\partial w_x}{\partial m_x} - 2cm_x}{B_{x1}\frac{\partial w_x}{\partial m_y}} > \frac{B_{y1}\frac{\partial w_y}{\partial m_x}}{B_{y1}\frac{\partial w_y}{\partial m_y} + 2c(1 - m_y)}.$$

Recall that $B_{x1} < 0, B_{y1} < 0, \frac{\partial w_x}{\partial m_x} > 0, \frac{\partial w_y}{\partial m_y} < 0, \frac{\partial w_y}{\partial m_x} < 0$, and $\frac{\partial w_x}{\partial m_y} > 0$. Thus, the numerator and denominator on the left side of the inequality in (D5) are both negative, while the numerator and denominator on the right side are positive. Expression (D5) is then equivalent to

(D6) $\quad (B_{x1}\frac{\partial w_x}{\partial m_x} - 2cm_x)\left(B_{y1}\frac{\partial w_y}{\partial m_y} + 2c\big(1-m_y\big)\right) < (B_{x1}\frac{\partial w_x}{\partial m_y})(B_{y1}\ \frac{\partial w_y}{\partial m_x}),$

where both sides of this inequality are negative. Because $\frac{\partial w_x}{\partial m_x} \geq \frac{\partial w_x}{\partial m_y}$, then $\left|B_{x1}\frac{\partial w_x}{\partial m_x}\right| \geq \left|B_{x1}\frac{\partial w_x}{\partial m_y}\right|$, implying that $\left|B_{x1}\frac{\partial w_x}{\partial m_x} - 2cm_x\right| > \left|B_{x1}\frac{\partial w_x}{\partial m_y}\right|$ (because $B_{x1}\frac{\partial w_x}{\partial m_x} < 0$ and $2cm_x > 0$). Similarly, $\left|\frac{\partial w_y}{\partial m_y}\right| \geq \left|\frac{\partial w_y}{\partial m_x}\right|$ implies $\left(B_{y1}\frac{\partial w_y}{\partial m_y} + 2c\big(1-m_y\big)\right) > B_{y1}\frac{\partial w_y}{\partial m_x}$. Thus, the inequality in (D5) holds, implying that the equilibrium is unique.

Q.E.D.

The assumptions that $\frac{\partial w_x}{\partial m_x} \geq \frac{\partial w_x}{\partial m_y}$ and $\left|\frac{\partial w_y}{\partial m_y}\right| \geq \left|\frac{\partial w_y}{\partial m_x}\right|$ are arguably innocuous. Consider the first assumption, $\frac{\partial w_x}{\partial m_x} \geq \frac{\partial w_x}{\partial m_y}$. Intuitively, this means that the effect on expected waiting time in market *X* of an increase in the number of candidates on market *X*'s waitlist is larger than the effect of an identically-sized decrease in the number of candidates on market *Y*'s waitlist, i.e., an increase in m_y. The first effect operates directly – more candidates in DSA *X* lead to longer waiting times – while the second effect operates only indirectly through the overlap effect – holding constant the number of candidates in *X*, fewer candidates on *Y*'s waitlist reduces overlap, thereby increasing expected waiting time in *X*. The intuition behind the condition that $\left|\frac{\partial w_y}{\partial m_y}\right| \geq \left|\frac{\partial w_y}{\partial m_x}\right|$ is similar. As a result, we view these two conditions as very likely to hold in reality.

Given uniqueness, we can characterize how shocks to the supply of organs in market *X* affect candidate behavior in both markets. Figure D2 shows the functions defined by (D1) and (D2) in $\{m_x, m_y\}$ space. Note that both functions are strictly downward-sloping (this is demonstrated in the proof of Proposition 1). Suppose *t* increases from, say, t_0 to t_1. This positive supply shock increases B_x for two reasons: it decreases expected waiting time and it increases expected organ quality. As B_x increases, more candidates sign up on waitlist *X*; for a given m_y, m_x must increase to restore equality in (D1). These marginal candidates live farther from point 0 and therefore have higher transportation costs than those who listed in *X* before the shock. Thus, the H_x curve shifts to the right, as indicated by the dashed downward-sloping line in the figure. As a result, m_x increases and m_y falls, implying that *both* waitlists get longer and the overlap increases (recall that a reduction in m_y corresponds to more candidates registered in *Y*). To see why m_y falls, note that the increase in m_x – due to the direct effect of the shock – decreases expected waiting time in *Y* by increasing overlap. In response, more candidates register in *Y*.

The formal derivation underlying Figure D2 involves totally differentiating (D1) and (D2) and applying Cramer's Rule. Carrying out the differentiation yields

(D7) $$\begin{bmatrix} B_{x1}\frac{\partial w_x}{\partial m_x} - 2cm_x & B_{x1}\frac{\partial w_x}{\partial m_y} \\ B_{y1}\frac{\partial w_y}{\partial m_x} & B_{y1}\frac{\partial w_y}{\partial m_y} + 2c(1-m_y) \end{bmatrix} \begin{bmatrix} dm_x \\ dm_y \end{bmatrix} = \begin{bmatrix} -B_{x1}\frac{\partial w_x}{\partial t} - B_{x2}\frac{\partial q_x}{\partial t} \\ 0 \end{bmatrix} dt$$

By Cramer's Rule,

(D8) $$\frac{dm_x}{dt} = \frac{-(B_{x1}\frac{\partial w_x}{\partial t} + B_{x2}\frac{\partial q_x}{\partial t})(B_{y1}\frac{\partial w_y}{\partial m_y} + 2c(1-m_y))}{D} > 0$$

(D9) $$\frac{dm_y}{dt} = \frac{(B_{x1}\frac{\partial w_x}{\partial t} + B_{x2}\frac{\partial q_x}{\partial t})B_{y1}\frac{\partial w_y}{\partial m_x}}{D} < 0,$$

where *D* is the determinant of the 2x2 matrix on the left of (D7): $D = (B_{x1}\frac{\partial w_x}{\partial m_x} - 2cm_x)\left(B_{y1}\frac{\partial w_y}{\partial m_y} + 2c(1-m_y)\right) - (B_{x1}\frac{\partial w_x}{\partial m_y})(B_{y1}\frac{\partial w_y}{\partial m_x})$. *D* is negative, as shown in expression (D6) above. The numerator of (D8) is negative because $\left(B_{x1}\frac{\partial w_x}{\partial t} + B_{x2}\frac{\partial q_x}{\partial t}\right)$ is positive (because B_{x1} and $\frac{\partial w_x}{\partial t}$ are negative while B_{x2} and $\frac{\partial q_x}{\partial t}$ are positive), while $\left(B_{y1}\frac{\partial w_y}{\partial m_y} + 2c(1-m_y)\right)$ is trivially positive. The numerator of (D9) is positive for similar reasons. Recalling again that a decline in m_y implies an increase in the number of candidates on list Y, (D8) and (D9) show that a positive supply shock induces more candidates to join both waitlists.

This simple model predicts unambiguously that, following a positive supply shock in DSA *X*, more candidates join the waitlist in *X* (and in *Y*). In addition, the marginal joiners have higher travel costs than those who would join in the absence of the shock – they are disproportionately likely to be those who do not live within the DSA's coverage area. Expected organ quality also increases in the DSA that received the shock. Finally, the effect on expected waiting time is ambiguous because more candidates register for waitlists (in all markets).

Figure E1: Waiting List Participation in the Two-Market Case

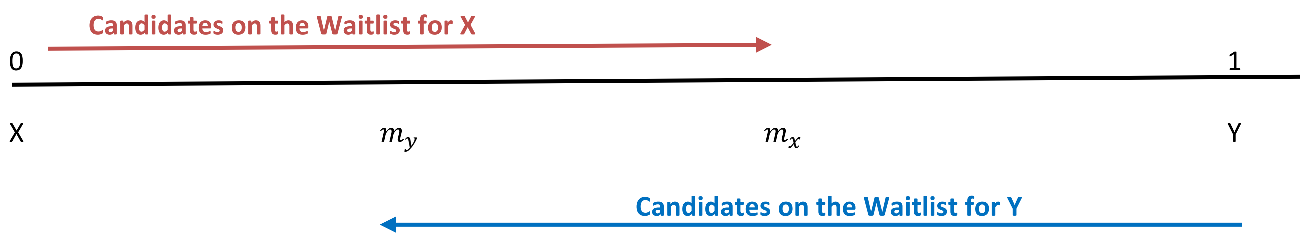


Figure E2: The Effects of a Supply shock in DSA X.

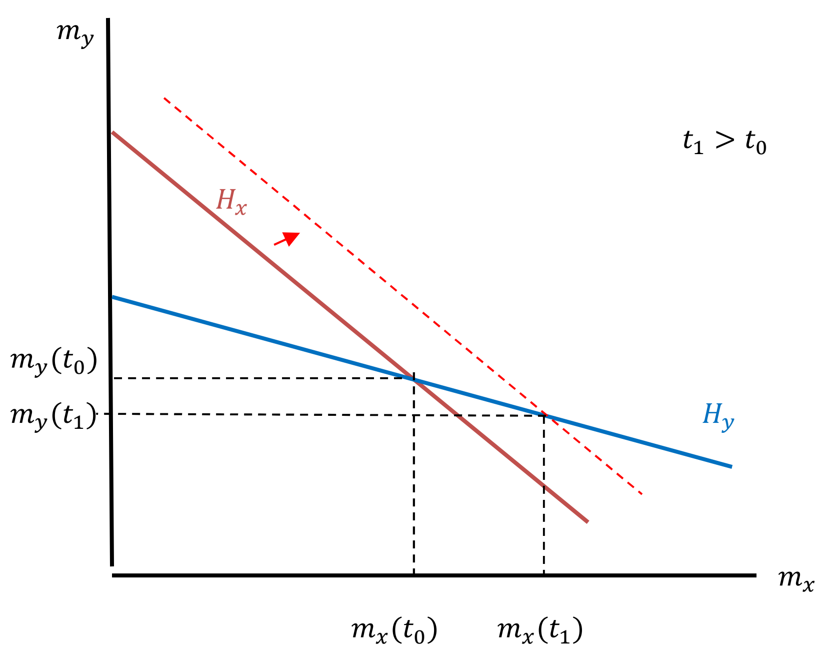
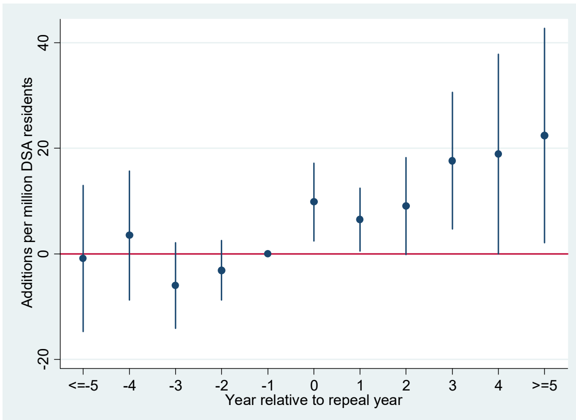
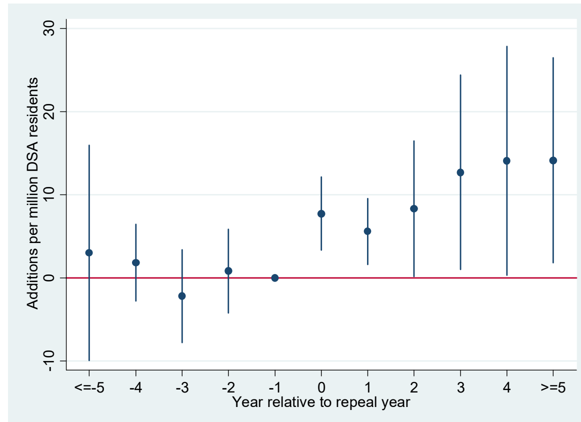


Figure D4
Event-Study Estimates of the Effects of Helmet Law Repeals on Waiting List Additions

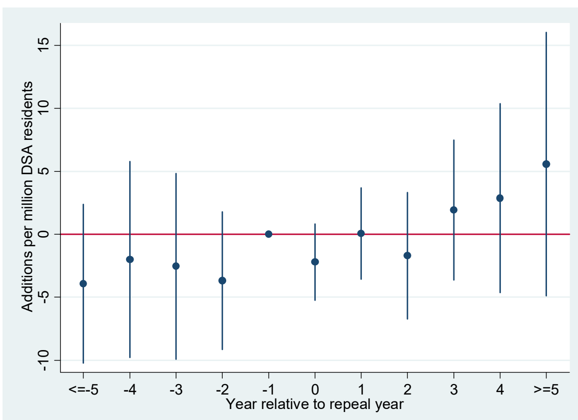
All Organs



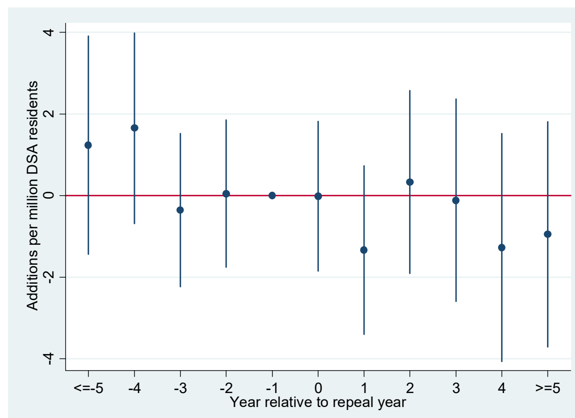
Kidney



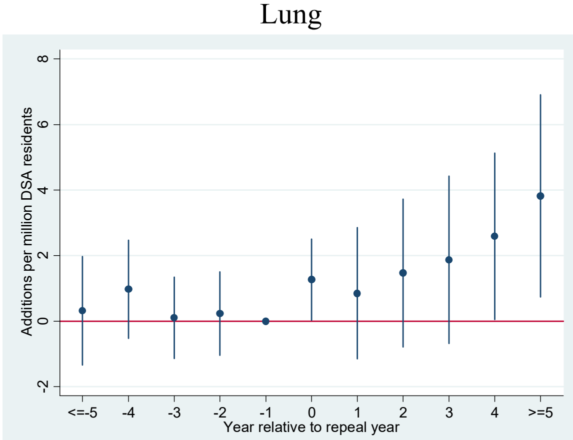
Liver



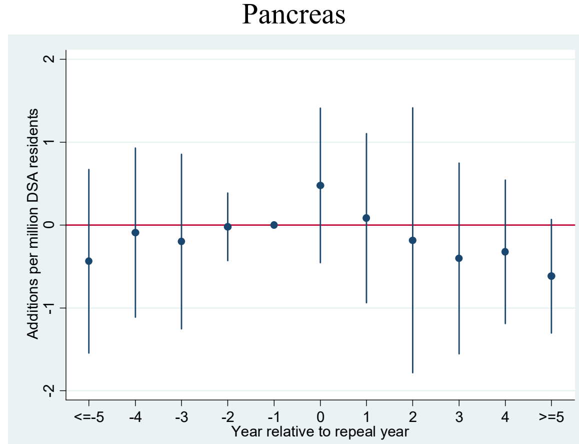
Heart



Lung



Pancreas



Notes:
1) All estimation samples consist of 58 DSAs from 1992 to 2013.
2) Each figure plots event-study estimates as described in specification (2) in the text.