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Opioids and Organs: How Overdoses Affect the Supply and Demand for Organ Transplants

As the incidence of fatal drug overdose quadrupled in the U.S. over the past two decades, patients awaiting organ transplants may be unintended beneficiaries. We use Vital Statistics mortality data, merged with the universe of transplant candidates in the U.S. from the Scientific Registry of Transplant Recipients, to study the extent to which the growth in opioid-related deaths affects the supply of deceased organ donors and transplants. Using two separate identification strategies, we find that opioid-related deaths led to more than 26,000 organ transplants in the U.S. between 2000 and 2018. We find that transplant centers are increasingly recovering organs from overdose victims for transplant, with the association between opioid-related deaths and organ donors more than doubling between 2000 and 2018. We also present evidence that transplant candidates are more willing to use organs from those who died of opioid-related causes when organ shortages are relatively severe.

Key Words: Organ donation; Organ transplant; Opioid Epidemic

JEL: I11, I18

I. Introduction

According to the Organ Procurement and Transplantation Network (OPTN), organ donation from deceased donors in the US reached an all-time high in 2021 for the eleventh consecutive year.[1] As the supply of organ donors has grown, the composition of the donor pool has dramatically shifted, with the fraction of all deceased donors who died via drug overdose rising from less than 1 percent in 1995 to 13.1 percent in 2018. The share of donors dying via overdose is now as large as the share killed in motor vehicle accidents, a sobering reflection of the opioid epidemic that produced a fourfold increase in annual overdose deaths between 1999 and 2019 (Centers for Disease Control and Prevention, 2020).

While ending the opioid epidemic is a first-order priority, the epidemic's potential effects on the supply of organ donors allow insights into a market that involves massive shortages. As of January 2023, more than 104,000 people are on the national transplant waiting list, and more than 6,000 transplant candidates die each year awaiting a transplant (https://unos.org/data/). Understanding the evolution of donors who died from opioid overdoses provides insights into ways that the shortage of organs can be addressed. In the current system, donated organs from deceased donors are typically allocated first to waitlisted transplant candidates in the geographic region where the organ was recovered (OPTN, 2017). Given the heterogeneity in the geographic concentration of the opioid epidemic in the United States – between 2010 and 2018, opioid overdose deaths rose by nearly 250 percent in Massachusetts, compared to 40 percent in Iowa – the effects of the epidemic on organ donation potentially highlight inefficiencies in the process

[1] https://optn.transplant.hrsa.gov/news/all-time-records-again-set-in-2021-for-organ-transplants-organ-donation-from-deceased-donors/

for matching donated organs to those with the greatest need.[2] Further, physicians and transplant candidates have differing incentives to convert potential donors to organ transplants, depending on the severity of shortages in their geographic region.[3] Mechanical and behavioral responses to the supply shock arising from the tragic opioid epidemic have the potential to shed light on the efficacy of policies specifically designed to address the shortages of human organs in a system without prices.

We use mortality data from the National Vital Statistics System (NVSS) and restricted-use data on transplant candidates and recipients from the Scientific Registry of Transplant Recipients (SRTR) to study the extent to which the growth in fatal drug overdoses affects the supply of deceased organ donors. Our central estimates, based on specifications that use within-geographic area variation in overdoses over time, imply that 100 opioid-related deaths lead to roughly six additional organ transplants from donors who died via drug intoxication. These estimates imply that the opioid crisis resulted in more than 26,000 organ transplants in the US between 2000 and 2018, all else equal, accounting for seven percent of all transplants during that period.

We find evidence that the link between opioid-related deaths and organ transplants is not merely mechanical. Specifically, that link is stronger in areas with greater excess demand for transplants, suggesting that transplant candidates and their doctors are more willing to accept organs from overdose victims when the alternatives are less abundant. We also find that the association between opioid-related deaths and organ transplants increased sharply over time. As

[2] Data on donations and transplants comes from the authors' calculations from the Scientific Registry of Transplant Recipients, described below.
[3] Howard and Kaplan (2006) and Stith and Hirth (2016) show that physicians and candidates in individual transplant centers also have incentive to accept certain organs in response to the Centers for Medicare and Medicaid Services transplant center evaluation system.

the opioid epidemic worsened, candidates and doctors were increasingly willing to accept overdose victims' organs, possibly reflecting increasingly accurate information about the quality of organs from these donors.

Existing research (Choi, 2019; Dickert-Conlin et al., 2019; Fernandez et al., 2013; Lemont, 2019) shows that transplant candidates respond dramatically to shocks to the supply of deceased-donor organs by joining transplant waiting lists and, in the case of kidneys, by increasingly opting for transplants from deceased donors instead of living donors. In contrast, we find little evidence that the surge in organs due to drug intoxication deaths crowded out living donors, and only modest evidence that transplant candidates systematically joined waitlists in areas with the largest opioid-related supply shocks. We speculate that the gradual increase in organ supply due to the opioid epidemic, rather than the discrete shocks studied in previous research, may not be salient to most transplant candidates. Additionally, candidates may (largely incorrectly) perceive that the quality of organs donated due to drug-related deaths is lower than the quality of organs obtained through other circumstances of death.

Finally, we use an alternate identification strategy based on Alpert et al. (2022), who find that Purdue Pharma marketed OxyContin less aggressively in states that required triplicate prescription forms for opioids. As a result, states with these "triplicate" requirements experienced relatively few opioid overdose deaths through the first two decades of the 21st century. Using triplicate requirements as a plausibly exogenous source of variation in opioid-related deaths, we estimate that there were 3.462 fewer monthly opioid-related deaths per million population in triplicate areas relative to non-triplicate areas, along with 0.0748 fewer organ donors who died via drug intoxication and 0.214 fewer transplants. The corresponding instrumental variables estimates imply that each opioid-related death leads to 0.0216 additional organ donors and 0.0618 additional transplants, slightly larger than our central estimates based on intertemporal variation within geographic areas. We again find that the association between opioid-related deaths and donors grew sharply over time, with each opioid-related death leading to nearly three times as many transplants in 2018 compared to 2000.

In Section II, we provide details on the opioid epidemic and how it relates to organ transplants. We present our estimates of how drug overdoses affect the supply of organ donors and transplants in Section III, and Section IV considers how shocks to organ supply influence transplant candidates' behaviors. We present instrumental variables estimates based on "triplicate status" laws in Section V, and we conclude in Section VI.

II. Institutional Background and Descriptive Evidence on the Opioid Epidemic

A. THE OPIOID EPIDEMIC

To measure opioid overdose deaths, we use data from the National Vital Statistics System (NVSS) Multiple Cause of Death mortality files.[4] These data include information from the death certificate for every reported death of a resident in the US. Column (1) of Table 1 shows that the annual number of drug overdose deaths, which include deaths due to opioid, anesthetic, sedative, and stimulant intoxication, nearly quadrupled from 17,322 in 2000 to 67,553 in 2018.[5] Opioids represent a major contributor to the dramatic increase in drug overdose deaths. Column (5) shows that 70 percent of drug overdose deaths in the U.S. in 2018 (= 46,882 / 67,553) involved an opioid, compared to fewer than half of all drug overdose deaths at the turn of the century. A

[4] We use the Multiple Cause of Death Files with County Identifiers, 2000-2018, as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program. We include all ICD-10 codes that list drug overdose as the underlying cause of death: (X40-44, X60-64, X85, Y10-14).

[5] Powell and Pacula (2021) argue that a reformulation of OxyContin in 2010, intended to reduce the ability to abuse the drug, spurred the growth in overall overdoses as people turned to illicit markets as a substitute for OxyContin.

broader measure of the fatality consequences from the opioid epidemic includes all *opioid-related deaths*, not just those listing drug overdose as the underlying cause of death; column (9) shows that these deaths increased by more than a factor of five between 2000 and 2018, from 8,986 to 48,150.[6]

Table 1 also highlights that overdose and opioid-related deaths are concentrated among young adults and men. Those aged 18-49 represented almost 70 percent (= 33,298 / 48,150) of all opioid-related deaths in 2018, as shown in Column (10). Likewise, almost 70 percent (= 32,918 / 48,150) of those who died of opioid-related deaths in 2018 were men.

Opioid overdose death rates also vary considerably across states (Ruhm, 2017). In 2018, the states with the highest rates of opioid-related deaths were West Virginia, Delaware, and Maryland (428, 375, and 362 per million population, respectively), while South Dakota, Nebraska, and Hawaii had the lowest rates of opioid-related deaths (32, 35, and 42 per million population, respectively). Similarly, growth rates of opioid-related deaths varied dramatically by state, with deaths in New Jersey, Pennsylvania, and Connecticut growing by 588 percent, 350 percent, and 345 percent, respectively, between 2010 and 2018. In contrast, opioid-related deaths in the same period declined in Oklahoma, Hawaii and South Dakota by 44 percent, 31 percent, and 27 percent, respectively.

[6] Deaths that are opioid-related deaths but not overdoses are those in which overdose is not listed as the underlying cause of death, but where opioids are coded as one of the multiple causes of death. Specifically, we use the Multiple Cause of Death files and include deaths in which one of the multiple causes of death is coded as opioid-related (ICD-10 codes T40.0, T40.1, T40.2, T40.3, T40.4, and T40.6). As an example of the kinds of mechanisms through which the opioid epidemic can lead to non-overdose deaths, Betz and Jones (2022) use US data to provide evidence that the epidemic has led to a substantial increase in motor vehicle accidents. They find that increases in local opioid prescribing intensities are associated with increases in the number of driver deaths in motor vehicle accidents.

B. THE LINK BETWEEN THE OPIOID EPIDEMIC AND ORGAN DONATION AND TRANSPLANTATION

By 2016, several academic and media publications acknowledged the link between the opioid epidemic and the market for organ transplants. The April 2016 issue of *Journal of Transplantation* reprinted a report (Rudd et al., 2016) that suggested that the epidemic "…may have an impact on the organ donor pool." Similarly, Goldberg et al. (2016) documented the increases in the number of donors whose deaths were due to drug intoxication between 2003 and 2014, showing that the increases varied markedly by organ and geographic area. Hickman et al. (2018) documented the substantial cross-country variation in the share of drug overdose deaths that convert to organ donors.

At the same time, numerous newspaper articles highlighted the link between drug overdoses and organ donors while addressing the viability of organs from donors who died via drug overdoses. The *Washington Post* (Izadi, 2016) quoted David Klassen, the chief medical officer for the United Network for Organ Sharing: "[T]ruthfully, people who are dying of drug overdoses are young and tend to be otherwise healthy. In many ways, they are ... potentially excellent donors, from an organ quality standpoint." Seelye (2016) and Wenner (2016) reported that victims of drug overdose might be high-risk donors because they practice other risky behaviors that are associated with HIV and hepatitis C, but even these diseases can be treated or cured in the unlikely case that the transplant recipient contracts the disease.

To put more structure on the link between the opioid epidemic and organ donation and transplantation, Figure 1 depicts a stylized process from an opioid-related death to an organ transplant. The process broadly has two stages – the supply side, where a death from an opioid-related cause converts to a donor, and the demand side, where transplant candidates receive the donor's organs via transplant.

B.1. SUPPLY SIDE: THE OPIOID EPIDEMIC AND ORGAN DONATION

Almost all deceased organ donors are brain dead at the time of organ recovery, meaning that brain function has irreversibly stopped. Because the heart continues to beat for some time after brain death occurs, current medical technology allows for respiration via a ventilator, so the internal organs receive oxygenated blood and remain viable for transplantation.[7] When a person experiences an opioid overdose, their breathing often slows or stops, causing hypoxia (reduced oxygen to the brain) that potentially leads to brain death.

If a person receives mechanical ventilation after an opioid-related death, the next step in the process is an evaluation of the organ quality by the attending physician. Passing the quality screening to donate an organ is not sufficient to become an organ donor; the individual or their family must also consent to the donation. Individuals can do so by indicating their preference on their driver's license or by registering on a state registry. First-person consent laws and the Revised Uniform Anatomical Gift Act (UAGA), which covers most states, require health care professionals to abide by the potential donor's consent to recover organs. Without first person consent, health care professionals will seek permission from the potential donor's next-of-kin.[8] According to Wenner (2016), 83 percent of potential donors who died of drug overdose ultimately become donors, compared to only 63 percent of the general population of potential donors. This difference appears to stem from relatively high donor registration rates among overdose victims: 46 percent of overdose victims are registered donors, compared to 29 percent of the overall population of potential donors.

[7] In contrast, organs deteriorate rapidly following cardiac deaths and are therefore unsuitable for transplantation, except in extraordinary circumstances in which patients with non-survivable brain injuries who are not brain dead (because they retain some minimal brain stem function) become donors. See http://www.organtransplants.org/understanding/death/ for more details.

[8] Howard (2007) estimates that donation rates among all potential donors range from 51 to 60 percent, primarily due to low consent rates.

Once consent is obtained, the donor enters the organ allocation process in the donation service area (DSA) where they died. The 58 DSAs in the United States broadly follow state boundaries, although large states have multiple DSAs, while some DSAs include multiple states or portions of states. An Organ Procurement Organization (OPO) evaluates potential donors in each DSA, arranges for surgical removal of organs, and coordinates the distribution of donated organs to waitlisted candidates.[9]

Upon identification of an organ donor, physicians consider each transplantable organ (kidneys, liver, heart, lungs, pancreas, and intestines) for recovery. Most donors have at least one organ recovered for transplant, but few have all eight organs recovered.[10] Six percent of organs are not recovered because authorization is not requested, usually because of donor age. Another three percent are not recovered because authorization from the family is not granted, usually because of emotional, cultural, or family-conflict reasons. Another 40 percent of organs are not recovered because of poor organ quality, a donor's medical history, or because the OPO could not locate a transplant candidate who wanted the organ in time.

In summary, Figure 1 highlights the roles of mechanical and behavioral mechanisms for converting opioid-related deaths to organ donations. The behavioral roles include decisions of whether to ventilate a patient, how to evaluate organ quality, and whether to pursue consent for the person to become an organ donor. These decisions potentially depend on many factors, including information about the quality of organs from drug intoxication donors, the demand for

[9] Online Appendix Table A1 shows the complete list of OPOs and the states in which they are headquartered. Each OPO reviews a candidate's application based on its own criteria, which generally include medical and mental health conditions, the quality of the candidate's support system, the probability of surviving the transplant surgery, and the ability to follow up with post-transplant medical care (https://unos.org/transplantation/faqs/).
[10] These numbers are authors' calculations from the Scientific Registry of Transplant Recipients.

organs from drug intoxication donors, and the availability of outside options, such as living donors or deceased donors who died due to other causes.

B.2. DEMAND SIDE: THE OPIOID EPIDEMIC AND ORGAN TRANSPLANTATION

Transplant candidates seeking a deceased-donor transplant must first register with one of more than 200 transplant centers in one or more of the 58 DSAs.[11] About six percent of all transplant candidates register on multiple waiting lists in different DSAs, a process known as "multilisting".

During our study period, when a deceased-donor organ becomes available in a DSA, the DonorNet computer system generates a pool of eligible recipients from the waitlist based on blood type, other compatibility measures, and candidates' willingness to accept the quality of the organ offered (OPTN, 2015).[12] Within the pool of potential candidate matches, the system generates a ranking of candidates, typically based on geographic distance from the donor organ, time on the waitlist, quality of the match, and medical urgency status of the candidate.[13] The weight given to and measurement of these characteristics varies by organ and over time, but geographic distance from the donor organ is usually one of the most influential characteristics due to the need to transplant an organ quickly after the donor's death occurs.

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[11] According to https://optn.transplant.hrsa.gov/about/search-membership/, there are 233 active transplant centers in the US for kidneys, 146 for hearts, 141 for livers, 72 for lungs, 121 for pancreases, and 20 for intestines. To list at multiple centers, a candidate needs to be accepted at each center, which requires being able to arrive in time to the center to receive a transplant if an organ were to become available. See http://optn.transplant.hrsa.gov/learn/about-transplantation/transplant-process/ for more details.

[12] In the last 4 years, OPTN policy eliminated the arbitrary DSA boundaries for first-round matches and moved to concentric circles based on nautical miles from the donor hospital for first-round matches.

[13] There are exceptions to this geographic allocation process. Sharing arrangements exist between OPOs inter- or intra-regionally, although OPTN's Board of Directors must approve such arrangements. Some organs have unusual policies; for example, liver donations are offered first to the most medically needy within regions that contain multiple DSAs.

The OPO offers the deceased donor's organ to the candidate with the best match in the DSA's pool of matches, making the geographic unit defined by the DSA a critical factor in the process. If the candidate accepts the organ, the transplant occurs; otherwise, the OPO offers the organ to the next person on the list. The next offer may be made within the DSA or, if no match is found within the DSA, outside the DSA.[14] If no match is found for the organ, it may not be recovered at all, as described above, or it may be discarded after being recovered. Roughly 51 percent of donated organs are not recovered for transplant, 6 percent are recovered but subsequently discarded due to poor organ quality or the inability to find a match, and 4 percent are recovered for purposes other than transplant, primarily for research. Approximately 39 percent of all donated organs are ultimately transplanted, represented by the final box in Figure 1.

A candidate and their transplant surgeon's decision process to accept an organ adds another layer of discretion in the process from an opioid-related death to a transplant.[15] For some context, Agarwal et al. (2020) show that between 2000 and 2010, the median number of biologically compatible offers for a single kidney before an offer is accepted is 51. The opioid epidemic might influence these decisions on multiple dimensions. First, a higher supply of organs may induce candidates to be more selective, increasing the likelihood of refusing an organ to wait for a higher quality one (Agarwal et al., 2020). Second, because the increased supply of organs in the opioid epidemic comes from donors who likely engaged in risky behaviors, there may be concerns, either substantiated or exaggerated, about organ quality.

[14] In the SRTR data, we estimate that about 2/3 of all organs are transplanted in the same DSA in which they are procured. This share has grown over time, with the highest share for kidneys and combined kidney/pancreas transplants.

[15] Genie et al. (2020) show heterogeneity in transplant candidates' willingness to wait for kidneys based on patient characteristics and the design of the allocation system.

Several recent editorials argue that misperceptions about the quality of organs from drug overdose donors led to underutilization of organs generated by the opioid epidemic. Goldberg et al. (2016) urged the medical community to maximize the utilization of potential donors labeled as "increased risk". In a Special Article for the journal *Transplantation*, Weiner et al. (2017) made the same plea, suggesting that "due to concerns over disease transmission (HIV, hepatitis B, and hepatitis C virus), these donors are underused by the transplant community." Maghen et al. (2019), in a letter to the editor in the *New England Journal of Medicine*, suggested that the views on the acceptability of organs from drug users is changing:

> "Rather than discarding organs obtained from drug users because of the risk of human immunodeficiency virus infection or hepatitis C virus infection, diligent and specific screening methods now permit some organs that were previously considered to be unacceptable to be acceptable for transplantation, with a lower risk for recipients than the risk of turning down the donated organ altogether."

The changing views on the acceptability of organs from drug users stem in large part from research about safety and transplant outcomes. Numerous studies of heart, lung (Durand, 2018, Mehra et al. 2018, Phillips et al, 2019), liver (Gonzalez and Trotter, 2018), and kidney (Chute et al., 2018, Tullius and Rabb, 2018) transplantation find that donors from opioid-related deaths are younger and healthier along many dimensions than donors from other mechanisms of death.[16] While these same studies show that drug overdose donors are more likely to have other health conditions, such as higher rates of hepatitis C, they generally conclude that outcomes of transplants from donors who died from drug-related causes are favorable compared to transplants from donors who died due to other mechanisms.

[16] For example, the medical director of the Heart Transplant Program at the University of Utah Health reports that data from the Program shows "no significant difference in survival between recipients of organs from donors who died of drug overdose and recipients from donors who died of blunt head injury for heart transplantation." See https://www.healio.com/hepatology/transplantation/news/online/%7Bc95305eb-691c-409c-9cad-d184ed02ade9%7D/organs-donated-after-drug-overdose-safe-for-transplantation (accessed May 23, 2021).

While not shown in Figure 1, the option of a living donation, primarily for kidneys but occasionally for livers and lungs, may affect the path from an opioid-related death to an organ transplant. The decision to choose a living donor depends on the availability of a compatible, willing donor and, among other things, the probability of receiving an offer from a deceased donor. Thus, an increase in the supply of deceased organ donors because of the opioid epidemic may reduce transplant candidates' incentives to pursue living-donor transplants. Alternatively, deceased donors who die via drug intoxication may be viewed as "closer" substitutes to deceased donors who die via other mechanisms than to living donors. If so, the extent of crowd-out of living-donor transplants might be negligible.

B.3. DATA ON ORGAN DONATIONS AND TRANSPLANTS

This study uses data from the Scientific Registry of Transplant Recipients (SRTR). The SRTR data system includes data on all donors, wait-listed candidates, and transplant recipients in the US, submitted by the members of the Organ Procurement and Transplantation Network (OPTN). The Health Resources and Services Administration (HRSA), U.S. Department of Health and Human Services, provides oversight to the activities of the OPTN and SRTR contractors. The SRTR data, which come from hospitals and immunology laboratories, include detailed donor-level information such as the cause, circumstance, and mechanism of death; which organs were recovered, discarded, and transplanted; and demographics, such as age, gender, and the geographic location of the donor. SRTR data also include candidate-level information such as time spent on the waitlist, transplant center registrations, health markers, demographics such as zip code of residence, reason for leaving the waitlist, and follow-up health data for those who receive a transplant. Donors can be matched with the transplant recipient if a transplant takes place.

We use the variable *mechanism of death* to identify donors who died from a "drug intoxication" (DI), which we view as roughly corresponding to the drug-related overdoses in NVSS. The other categories of *mechanism of death* include gunshot / stab wounds, asphyxiation, blunt injury, cardiovascular, drowning, electrical, intracranial hemorrhage / stroke, natural causes, seizure, SIDS, "none of the above", and "not reported". SRTR also codes a *cause of death* for each donor. Approximately 93 percent of all donors whose mechanism of death is "drug intoxication" receive "anoxia", defined as injury to the brain due to lack of oxygen, as their cause of death; "cerebrovascular/stroke" and "other" make up the remainder.

Table 2 and Figure 2 show the dramatic rise in the number of deceased organ donors whose mechanism of death is listed as DI. While the number of donors from all other mechanisms rose by roughly 57 percent between 2000 and 2018 (from 5,924 to 9,322), the analogous number from DI rose by more than 2,000 percent (from 66 to 1,401). Men represent about 70 percent of all opioid-related deaths in the NVSS data, but they are only about 55 percent (= 834 / 1,401 in 2018) of all DI organ donors. Table 2 also shows that the concentration of fatalities due to drug overdoses among young adults in the NVSS data mirrors the share of donors whose death mechanism is DI. Between 80 and 90 percent (= 1,256 / 1,401 in 2018) of all DI donors are 18 to 49 years old, while just over 50 percent (= 4,851 / 9,822 in 2018) of donors from a mechanism other than DI are 18 to 49.

Although donors from drug intoxications are substantially younger and, presumably, in better health than donors from most other mechanisms, Table 3 shows that the number of organs transplanted per deceased donor is low relative to some other mechanisms of death. For example, 3.14 organs are transplanted per donor who died due to drug intoxication, compared to 4.34 and 3.69 organs per donor among those who died from gunshot wounds and blunt injuries, respectively. These findings are surprising considering the relatively high donor consent rates among victims of drug overdoses (Wenner, 2016).

C. HYPOTHESES AND GRAPHICAL EVIDENCE OF THE LINK BETWEEN OPIOID-RELATED DEATHS AND ORGAN DONATION

Given the existing allocation process and the link between opioid overdose and brain death, we hypothesize that the supply of DI organ donors and transplants from those donors will be positively correlated with the number of drug overdose fatalities. While this relationship is likely to be primarily mechanical as more brain deaths result in more donors, the potential for behavioral responses leads to two related hypotheses: first, the association between the number of transplants from DI donors and the number of drug overdose fatalities will increase over time. We speculate that organs may be more likely to be recovered and / or accepted by transplant candidates as medical procedures for treating conditions associated with drug use (such as Hepatitis C or HIV) improve, understanding of organ quality from DI deaths increases, or stigma about organs recovered from DI deaths change over time.

Second, we hypothesize that the link between DI-donor transplants and drug overdose fatalities will be high in DSAs with relatively high levels of excess demand for organs. High levels of excess demand may induce increased efforts to convert potential transplants to actual transplants because transplant candidates are less likely to receive an organ in time from a donor who did not die of drug-related causes.

On the demand side, we hypothesize that an increase in the supply of DI organ donors will affect the waitlist for deceased-donor organs by increasing the number of organ transplant candidates who register on the waitlist. We also hypothesize that a positive deceased-donor supply shock will crowd out living-donor transplants.

To illustrate the correlation between drug-related deaths and DI organ donors, we aggregate the mortality and organ donation data to the DSA level, using a county crosswalk provided by the SRTR. We normalize our measures of deaths and donations by population data from the National Cancer Institute (2018) to generate measures per million DSA residents.

The top panel of Figure 3 provides graphical evidence of the dramatic increase in opioid-related deaths per capita and the variation across the DSAs. We divide 57 DSAs into quintiles based on their 2018 opioid-related deaths per million residents as calculated in the Vital Statistics Data.[17] The variation across quintiles began to increase dramatically in 2012. For example, the top quintile had 79 opioid-related deaths per million in 2008, compared to 48 in the lowest quintile. By 2018, the top quintile had more than six times as many opioid-related deaths per million as the bottom quintile, 307 versus 51.

The bottom panel of Figure 3 shows changes over time in DI organ donations per capita. We again categorize the 57 DSAs into quintiles based on 2018 opioid-related deaths per capita. Similarly to the top panel, the DSAs in the top quintile of opioid-related deaths per capita have the highest level of DI organ donors in 2018 (8.24 per million, compared to 5.05, 4.48, 2.95 and 1.59 per million in the fourth through first quintiles, respectively). Moreover, the variation across the quintiles increased dramatically since 2010, with the ratio of the top quintile to the bottom exceeding five in recent years.

[17] There are 58 DSAs in the United States; however, we exclude Puerto Rico's DSA because we do not have mortality data for all years in our sample. The 1st quintile contains the following OPOs in DSAs: AROR, CADN, CAGS, CAOP, HIOP, IAOP, MSOP, MWOB, NEOR, TXGC, TXSA, and TXSB. The 2nd quintile contains the following DSAs: ALOB, AZOB, CASD, CORS, GALL, INOP, LAOP, MNOP, OKOP, ORUO, and WALC. The 3rd quintile contains the following DSAs: DCTC, FLFH, NCCM, NCNC, NYAP, NYRT, PADV, SCOP, TNMS, UTOP, VATB, and WIUW. The 4th quintile contains the following DSAs: FLMP, FLUF, FLWC, ILIP, MIOP, MOMA, NJTO, NMOP, NVLV, NYFL, and TNDS. The 5th quintile contains the following DSAs: KYDA, MAOB, MDPC, NYWN, OHLB, OHLC, OHLP, OHOV, PATF, CTOP, and WIDN.

III. Opioid-Related Deaths and the Supply of Organ Donors and Transplants

To further investigate the links between opioid-related deaths and organ transplants, we estimate DSA- and month-specific organ donation and transplantation rates as a function of the number of opioid-related deaths in that DSA and month. We begin by estimating the following model via OLS:

(1) $$Y_{st} = \alpha_s + \delta_t + \gamma Deaths_{st} + \beta' X_{st} + \varepsilon_{st} ,$$

where Y_{st} is either the number of deceased organ donors or transplants per million population, *s* indexes the DSA, *t* indexes the month-year, and $Deaths_{st}$ is either the number of opioid-related deaths, opioid overdose deaths, or drug overdose deaths per million population. All specifications include a full set of DSA (α_s) and month-year (δ_t) indicators to capture unobservable DSA characteristics that are constant within a DSA over time and time characteristics that are fixed within a month-year across DSAs, respectively.

The vector X_{st} includes time-varying DSA-level unemployment rates, along with measures of several policies that might be correlated with opioid-related deaths and organ donation. For example, one such policy is motorcycle helmet laws, which Dickert-Conlin et al. (2019) show are strongly associated with the number of organ donors who died in motor vehicle accidents. We include the share of a DSA's population covered by a universal motorcycle helmet law in each year. We also include the share of the DSA covered by the Revised UAGA, which mandates that the wishes of registered organ donors do not need to be confirmed by the family, based on Anderson's (2015) estimates that the UAGA revisions increased kidney donations by five to seven percent.

The covariates also include the share of the DSA covered by a Naloxone Access Law that allows lay responders to administer the drug naloxone, which can reverse an opioid overdose.

Rees et al. (2019) find that these laws reduce opioid-related deaths by 9 to 11 percent. We also include the share of the DSA covered by Prescription Drug Monitoring Programs (PDMPs) and Mandatory PDMPs (MPDMPs), which collect data on opioid prescriptions and act as a data-sharing network between institutions and providers.[18] Studies such as Buchmueller and Carey (2018), Meinhofer (2018), Neumark and Savych (forthcoming), Ukert and Polsky (forthcoming), and Wen et al. (2017) find that MPDMP programs reduce opioid misuse.[19] Additionally we include the share of the DSA covered by a Good Samaritan overdose laws (GSL), which offer some legal protection for bystanders who witness an overdose but might be afraid to call for medical help due to any perceived association with the substance use. Rees et al. (2019) and McClellan et al. (2018) find that GSLs may reduce opioid-related deaths. Finally, we include measures of the share of the DSA that has dispensary access to recreational marijuana, given recent findings that access to legal marijuana legalization reduces opioid mortality (Chan et al., 2020 and Powell et al., 2018).[20] We weight all observations by the population in that DSA and year.

The first three columns of Panel A in Table 4 present estimates of γ from specification (1) based on models in which the dependent variable is the number of DI donors per million DSA residents. Because we also measure $Deaths_{st}$ per million DSA residents, the estimates measure the effect of one additional death on the supply of DI organ donors. In column (1), we use the number of opioid-related deaths as our measure of $Deaths_{st}$, estimating that each opioid-related

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[18] See, for example, http://www.pdaps.org/datasets/pdmp-implementation-dates, http://www.pdaps.org/datasets/prescription-monitoring-program-laws-1408223416-1502818373, and https://www.pdmpassist.org/State.

[19] Grecu et al. (2018) do not find evidence that PDMP affect mortality related to prescription drugs, but they do find that prescription drug abuse is responsive to PDMP.

[20] We thank Serena Phillips and Mike Pesko for sharing data they received from Rosalie Pacula as part of the OPTIC Vetted Policy Data Warehouse. Smart and Pacula (2019) describe these data in more detail. Note that the estimates throughout are essentially identical when we exclude the full set of organ donation and drug law control variables – see Online Appendix Table A2.

death increases the supply of DI organ donors by 0.0189 (with a standard error of 0.0017), which is approximately 15 percent of the sample mean of 0.1266 DI donors per million DSA residents. In columns (2) and (3), we use opioid overdoses and all drug overdoses, respectively, as the measure of $Deaths_{st}$. In each case, the point estimates and standard errors are nearly identical to those in column (1). Columns (4)-(6) show the estimated effects of $Deaths_{st}$ on the number of transplants from DI donors.[21] The estimate in column (4) implies that each additional opioid-related death leads to 0.0581 transplanted organs from DI donors, again a 15 percent increase over the mean transplants per capita. Note that this estimate is roughly three times as large as that in column (1), consistent with the descriptive statistics presented in Table 3 showing that each DI donor donates roughly three organs for transplant. The estimates in columns (4)-(6) are again insensitive to the measure of $Deaths_{st}$ we use, so we focus on opioid-related deaths in all specifications hereafter.[22]

In Panel B of Table 4, we present estimates from models in which the dependent variable is all organ donors (columns (1)-(3)) and all transplants (columns (4)-(6)), rather than only DI donors and transplants as in Panel A. We note that the estimates are slightly smaller than the analogous estimates from Panel A, suggesting that transplants from DI donors might crowd out transplants from non-DI deceased donors. We consider this possibility in Appendix Table A3 by estimating the relationship between opioid-related deaths and each of five mechanisms of death

[21] In most cases, each organ transplant maps one-to-one to a transplant candidate. In some rare cases, two organs, such as two lungs, go to one recipient; alternatively, a single liver can be split into two segments and transplanted into two recipients. There are also some dual-organ transplants (heart-lung and kidney-pancreas) that are coded as two transplants, even though a single recipient receives both organs.

[22] We consider the possibility that the opioid epidemic affects the organ allocation system in other, less direct ways. We find no evidence that that the opioid epidemic causes transplant candidates to leave the waitlist, as measured by the correlation between opioid-related deaths and waitlist exits due to candidate deaths or sickness. This is a crude measure of whether the opioid epidemic affects the waitlist. If opioid usage leads to disqualification among transplant candidates and no other candidate received the transplant, this would induce a negative relationship between the extent of the opioid epidemic and the number of transplants, biasing our estimates toward zero. Given the extreme shortage of organs, this situation is arguably unlikely.

other than DI: seizure / stroke, drowning / asphyxiation, violent injury, cardiovascular / natural causes, and SIDS (along with DI, these mechanisms comprise over 95 percent of all deceased donors). We find little clear evidence of crowd-out, as the estimates are small in magnitude and varying in sign; the estimates are negative for seizure / stroke, drowning / asphyxiation, and violent injury, and positive for cardiovascular / natural causes and SIDS.

To put these estimates in context, recall from Table 1 that more than 450,000 people died of opioid related deaths between 2000 and 2018. The estimates in Table 4 imply that this staggering number of opioid-related deaths resulted in more than 8,600 organ donors and more than 26,000 organ transplants over this period.

IV. Behavioral Responses to Opioid-Related Deaths

A. EFFECTS OF SUPPLY SHOCKS ON ORGAN UTILIZATION

To test the hypothesis that transplant candidates and medical professionals are increasingly willing to use organs from opioid-related deaths in transplants over time, we estimate the following specification:

(2) $$Y_{st} = \alpha_s + \delta_t + \gamma_{Year} Deaths_{st} + \beta' X_{st} + \varepsilon_{st},$$

which is identical to specification (1) except that we now allow the association between deaths and DI donors to vary across years, as captured by the γ_{Year} term. We again use month-year data and include a set of month-year indicators δ_t.

We display the estimates of γ_{Year} from (2), separately for DI donors and DI-donor transplants, in Figure 4. For both donors and transplants, the estimates grow markedly over time, particularly after 2010 (we present the full set of estimates of γ_{Year} in Appendix Table A6).[23]

[23] Online Appendix Figure A5 and Online Appendix Table A8 show that these patterns hold for kidney, liver, heart, and lung transplants. The data are noisy for pancreas and intestines because there are so few transplants.

Consider the estimates for DI-donor transplants; we estimate that an additional opioid related death results in 0.0186 additional DI-donor transplants in 2000, compared to 0.0777 in 2018. Those two estimates are statistically distinguishable from each other, and not surprisingly, we also reject the null that the estimates are constant across all 19 years ($F = 6.78$; $p < 0.001$). For DI donors, the analogous F-statistic is 6.63 ($p < 0.001$).[24] To provide some context, our central estimates above implied that the 48,150 opioid-related deaths in 2018 resulted in 3,707 (= 48,150 × 0.0777) additional transplants, all else equal. If the "conversion rate" from opioid-related deaths to transplants had instead remained constant at its 2000 level, the 48,150 opioid-related deaths in 2018 would have yielded only 895 (= 48,150 × 0.0186) additional transplants.[25]

Our hypothesis is that this increasing conversion rate from deaths to donors and transplants arises from an increasing willingness to use organs from opioid-related deaths in transplants. As further evidence that this is a response specific to the shock in the supply of opioid-related deaths and *not* an overall increase in conversion rates for all donors, we estimate the conversion rate for other mechanisms of death in the Vital Statistics on the number of donors for those mechanisms of death. For example, we estimate the relationship between an additional seizure / stroke death on organ donors who died of a seizure / stroke. We find no evidence of an

[24] There could be competing effects over time in the relationship between donors and transplants. Specifically, a higher donor supply means that candidates can be more selective; all else equal, this would reduce the conversion rate from DI donors to transplants.

[25] In Appendix Figure A1, we present figures analogous to Figure 4, but rather than focusing on DI donors and transplants, we show the effects of opioid-related deaths on *all* donors and transplants (top panel) and non-DI donors and transplants (bottom panel). The estimates in the top panel are sufficiently noisy that it is difficult to draw firm conclusions. The bottom panel shows that opioid-related deaths do not appear to influence non-DI donors and transplants, as the estimates are flat and insignificantly different from zero throughout the dramatic increase in opioid-related deaths during the 2010s. In fact, none of the other mechanisms of death for organ donors show statistically or economically significant responses to the rise in opioid-related deaths beginning in 2010 (see Appendix Figure A2). Taken together, the figures suggest that as the opioid epidemic worsened in the 2010s, each opioid-related death led to increasingly more transplants from DI donors, but that there was no corresponding decrease in the number of non-DI donors or non-DI-donor transplants.

increasing conversion rate over time between deaths by any mechanism and donors, except for drug intoxication and opioid-related deaths (see Appendix Figure A3).

At least one other contemporaneous change occurred in the environment of opioid use that may account for higher conversion rates: although prescription opioids accounted for most drug overdose deaths in 2000, by 2016 synthetic opioids and heroin accounted for most drug overdose deaths (CDC, 2018). This shift resulted in a compositional change in drug overdose victims because synthetic opioid or heroin overdose deaths occur in younger individuals compared to prescription opioid overdose deaths (CDC, 2018). Table 2 supports a discrete shift toward younger donors around 2011: until 2010, roughly 84 percent of DI donors were between ages 18 and 49, but between 2011 and 2018, 87 to 91 percent of DI donors were between 18 and 49. However, in this latter period, where we observe large increases in the conversion of an opioid-related deaths to DI donors and transplants, there is no contemporaneous increasing trend in the share of DI donors who are young.[26]

To attempt to isolate changes in willingness to accept DI organs from the shift in the demographics of opioid users, we consider whether the DSAs with larger organ shortages have higher conversion rates than DSAs with smaller shortages. For each DSA, we generate a measure of excess organ demand in the 2000-2007 period, before, but chronologically close to, the dramatic rise in opioid-related deaths. We calculate the average number of transplant candidates who join organ waitlists each month – which measures waitlist inflows – and then divide by the average number of monthly transplants, which measures waitlist outflows. We use

[26] While younger donors may also be "higher quality" donors because of their youth, this trend may be countered by a higher incidence of infectious diseases or stigma attached to potential donors who engaged in risky behaviors associated with IV drug use. We find no evidence that the number of opioid-related deaths in a DSA-month-year is associated with the share of donors with the organ-specific definitions of expanded criteria (older and/or having significant medical history and histories of high-risk social behaviors) and risky (increased risk of HIV, hepatitis B or C infection) donors; see Appendix Figure A4.

this net-inflow measure to capture excess demand for transplants, defining DSAs with above-median values as "high excess demand" and those with below-median values as "low excess demand". We then estimate equations (1) and (2) for the two groups in the period 2008 to 2018, when the trend in opioid related deaths increased dramatically. We present the results in Table 5.

Comparing columns (1) and (2) of Table 5, we estimate that an additional opioid-related death leads to 0.0228 additional DI organ donors in high excess demand DSAs and 0.0144 additional DI organ donors in low excess demand DSAs. This differential is consistent with medical professionals in areas with larger shortages acting more aggressively in converting deaths to donations. Consistent with the increases in donations, Columns (3) and (4) show that DI-donor transplants increase proportionally more in DSAs with high excess demand (0.0715 additional transplants for an additional opioid related death), relative to DSAs with low excess demand (0.045 additional transplants for an additional opioid related death). We reject that the set of high and low excess demand DSA estimates are identical for both donors (F =11.38; p=0.0014) and transplants (F =8.05; p=0.0063). These differences are substantively meaningful: again, considering the 48,150 opioid-related deaths in 2018, the conversion rate in high excess demand DSAs would yield more than 1,200 more transplants in that year than the conversion rate in low excess demand DSAs (48,150 × 0.0715 = 3,442, versus 48,150 × 0.045 = 2,193).

We further consider whether DSAs with high excess demand respond differentially to increases in opioid-related deaths by estimating the likelihood of retaining an organ that was recovered within the DSA. Estimates in columns (5) and (7) in Table 5 show that in high excess demand DSAs, each opioid-related death leads to 0.0451 transplants at hospitals in the recovering DSA and 0.0263 transplants outside of that DSA. In other words, 37 percent (= 0.0263 / (0.0263 + 0.0451)) of the additional DI organs recovered in a DSA are "exported" out of that DSA. In comparison, the estimates in columns (6) and (8) show that more than 50 percent (= 0.0227 / (0.0227 + 0.0222)) of organs recovered in low excess demand DSAs are exported out of the DSA.[27] The difference in DI-donor organs used for transplants within the DSA (0.0451 vs. 0.0222) is statistically significant at the 95% confidence level ($F = 7.04$; $p = 0.0103$), although the difference in DI-donor organs exported is not statistically significant at standard levels ($F = 0.55$; $p = 0.4625$). Again, these results suggest that transplant surgeons in high excess demand DSAs retain and use more organs from DI donors than transplant surgeons in low excess demand DSAs.

In Figure 5 we show the intertemporal variation across low and high excess demand DSAs in the conversion rate from opioid-related deaths to DI-donor transplants from 2008 to 2018 (See Table A7 for full results). The point estimates for high excess demand DSAs are larger than those for low excess demand DSAs in every year beginning in 2010, and for both sets of DSAs the estimates appear to be growing over time.

Our findings suggest that behavioral responses play important roles in the conversion of potential donors who died of opioid-related causes to actual donors and transplants. Transplant candidates and medical professionals appear to be more willing to use organs from those who died of opioid-related causes when organ shortages are more severe and as the opioid epidemic deepened. In addition, available organs from DI donors were less likely to be exported out of DSAs where organs were scarce.

[27] "Export rates" are lower among *high excess demand* (30 percent) and *low excess demand* (43 percent) DSAs for all mechanisms of death. Note that overall, DI organs are more likely to be exported.

B. EFFECTS OF SUPPLY SHOCKS ON WAITLIST ADDITIONS

Given the extreme shortage of organs for transplants and the geographic-based allocation system for deceased organs, a positive organ supply shock might also induce additional transplant candidates to join that DSA's waitlist. Dickert-Conlin et al. (2019) show that repeals of state-level motorcycle helmet laws generate large and lasting increases in waitlist inflows. They find that these demand-side responses are driven almost entirely by kidney transplant candidates, who are on average more sensitive to expected waiting time than other candidates because they have dialysis as a substitute for a transplant. Additionally, those who multilist and live outside the DSA that experienced the shock – both indications of candidates who have more resources and / or knowledge of the system – are especially likely to join waitlists in DSAs experiencing supply shocks.

In the context of the opioid epidemic, we ask whether transplant candidates are more likely to join transplant waitlists in DSAs that are most affected by the opioid epidemic. We estimate the following model:

(3) $$Additions_{st} = \alpha_s + \delta_t + \gamma(Deaths)_{st} + \beta' X_{st} + \varepsilon_{st} ,$$

where $Additions_{st}$ measures DSA waitlist additions per million DSA residents, s indexes the DSA, t indexes the month, and $Deaths_{st}$ is the number of opioid-related deaths per capita in that DSA and month. All specifications again include a full set of DSA (α_s) and month-year indicators (δ_t), and the vector X_{st} represents the same set of DSA-time varying variables as in equation (1). We weight each observation by the DSA's population in that year.

Column (1) of Table 6 presents the estimates of the effect of opioid-related deaths on total waitlist additions in total and by organ. The estimate in the top row indicates that each additional opioid overdose death results in an average of 0.0279 (standard error of 0.0416) more waitlist additions per million DSA residents, which is statistically insignificant and small compared to the baseline level of waitlist additions of 14.76 per million DSA residents. The organ-specific estimates show that increases in opioid-related deaths statistically significantly increase waitlist inflows only in the case of livers: 0.0419 (standard error of 0.0172) additions in response to one additional opioid-related death in a DSA. The coefficients on opioid-related deaths are small and not uniformly positive for the other organs; notably, the estimate for kidneys is negative, in contrast to the findings of Dickert-Conlin et al. (2019).[28]

Columns (2) through (4) provide insight about which, if any, candidates might respond to the organ supply shocks induced by the opioid epidemic. Using zip code data for candidates and transplant centers, we generate separate counts of waitlist additions for those who live inside and outside of the DSA's boundaries. Liver waitlist inflows induced by opioid-related deaths are concentrated among candidates who live in the DSA, and there is no indication that multilisted candidates respond to the increase in the number of available organs. In sum, we find very little evidence that any transplant candidates respond to the supply shocks induced by opioid-related deaths.

C. LIVING DONOR CROWD-OUT

Previous research documents substantial substitution away from living-donor transplants in response to deceased-donor supply shocks, especially among kidney candidates, who account for nearly all living-donor transplants (Choi, 2019; Dickert-Conlin et al., 2019; Fernandez et al., 2013; Lemont, 2019; Sweeney, 2010). Table 7 presents estimates from models analogous to

[28] We also acknowledge the possibility that opioid use leads to chronic conditions that require transplants, such as analgesic nephropathy (https://www.hopkinsmedicine.org/health/conditions-and-diseases/analgesic-nephropathy), chronic kidney disease (Novic et al., 2016 and Mallapallil et al., 2017), or worsening conditions among dialysis patients (Kimmel et al., 2019). The finding that waitlists do not largely respond to increases in opioid-related deaths, which are obviously correlated with opioid use, is consistent with the opioid-epidemic not having a measurable effect on the demand for organs.

specification (1) above, except that the dependent variable measures the number of living-donor organ transplants in a DSA in each month. The estimate in column (1) suggests that for each additional opioid-related death, the number of living-donor transplants decreases by 0.0017. This estimate is statistically insignificant and small in comparison to the estimated effect on deceased-donor transplants of 0.0581 from column (4) of Table 4, suggesting that if there is any crowd out of living donors from opioid-driven supply shocks, it is small relative to the direct effect on deceased-donor transplants.[29]

The lack of evidence that transplant candidates respond to increases in the supply of DI-donated organs may stem from misperceptions that organs from DI donors are of relatively low quality in comparison to other donated organs. Moreover, unlike a discrete, salient change such as the repeal of a motorcycle helmet law, geographic variation in the intensity of the opioid epidemic may not be easily observable to transplant candidates and their doctors.

V. Estimates Based on State-Level "Triplicate Status" Laws

The estimates shown thus far are based on specifications that leverage variation over time within DSAs for identification. Although there is no obvious reason to suspect that such variation in opioid-related deaths is related to unobservable determinants of the supply of organ donors and transplants, we cannot test this possibility. In this section, we present estimates based on an alternative source of variation: the "triplicate status" of the states where DSAs are headquartered.

[29] A potential reason for the lack of crowd-out among living donors is that DI donors might instead crowd out other deceased donors. That is, transplant candidates view donations from DI donors as close substitutes to donations from deceased donors who died from other mechanisms of death besides DI. However, we find no evidence that opioid-related deaths crowded out organ donations from other mechanisms of death (see Appendix Table A3 and Appendix Figure A2).

As Alpert et al. (2022) describe, triplicate laws mandate that doctors "use state-issued triplicate prescription forms when prescribing Schedule II controlled substances (which includes many opioids)." The prescriber keeps one copy of the prescription, the pharmacist keeps the second, and the pharmacist files the third with a state agency. Like Alpert et al. (2022), we define a state-level "triplicate status" indicator that captures whether such a program was in place at the time of OxyContin's launch in 1996, as OxyContin played a crucial role in the early years of the opioid epidemic. Alpert et al. (2022) show that in the five states that had triplicate laws in place in 1996 – California, Idaho, Illinois, New York, and Texas – Purdue Pharma did not market OxyContin as aggressively as they did in other states. As a result, drug overdose death rates were persistently lower in triplicate states than in non-triplicate states throughout the first two decades of the 21st century.

In the spirit of Alpert et al.'s (2022) identification strategy, we expand our sample to include NVSS and SRTR data from 1994 to 2018. Data prior to OxyContin's 1996 launch leverages within-state variation in OxyContin exposure. The five states that had triplicate laws in place in 1996 essentially serve as the "control" states, while the remaining states were exposed to the full impact of OxyContin distribution starting in 1996 (Alpert et al., 2022).

To leverage triplicate status to identify the effects of opioid deaths on the market for organ transplants, we first estimate a set of OLS specifications:

(4) $$Y_{st} = \alpha_s + \delta_t + \gamma(Triplicate\_Binding)_{st} + \beta' X_{st} + \varepsilon_{st} ,$$

where Y_{st} includes opioid-related deaths, donors, or transplants. $Triplicate\_Binding_{st}$ is an indicator that equals one if a DSA's OPO is headquartered in a triplicate state and the year is 1996 or later (so that this variable is an interaction between a state's triplicate status and an indicator for whether Oxycontin is on the market), δ_t is a set of month-year fixed effects, and X_{st} include the same DSA-level time-varying controls described above.

Column (1) of Table 8 shows estimates of γ using opioid-related deaths as the dependent variable. We estimate that in each month there were 3.462 (standard error of 0.7951) fewer opioid-related deaths per million DSA residents in triplicate DSAs relative to non-triplicate DSAs.[30] In columns (2) and (3), we present the reduced-form effect of triplicate status on DI donors and transplants from these DI donors, respectively. The estimates imply that there were 0.0748 fewer DI donors per million residents, and 0.214 fewer DI-donor transplants, in triplicate DSAs than in non-triplicate DSAs.

Columns (4) and (5) present the instrumental variables estimates of the effect of opioid-related deaths on DI organ donors and DI-donor transplants, respectively, using $Triplicate\_Binding_{st}$ as an instrument for opioid-related deaths. The estimate in column (4), 0.0216, is equivalent to the ratio of the estimates in columns (2) and (1), and it is slightly larger than our analogous OLS estimate of 0.0189 shown in Table 4, although the two are not statistically distinguishable at conventional significance levels. The estimate in column (5) implies that each opioid-related death leads to 0.0618 additional DI-donor transplants, which is again slightly larger but statistically indistinguishable from the corresponding OLS estimate in Table 4 (0.0581).

We next leverage triplicate status to assess whether organ recovery surgeons are increasingly willing to use organs from opioid-related deaths in transplants. To do so, we first

[30] Alpert et al. (2022) find that non-triplicate states would have experienced 4.49 fewer annual drug overdose deaths from 1996-2017 per 100,000 residents if they had been triplicate states. Converting this estimate to monthly deaths per million residents yields 3.74 (= 4.49 × 10 /12), similar to our estimate of 3.462.

estimate models that allow the reduced-form associations between triplicate status and opioid-related deaths, DI donors, and DI-donor transplants to vary by year:

(5) $$Y_{st} = \alpha_s + \delta_t + \gamma_{Year}(Triplicate\_Binding)_{st} + \beta' X_{st} + \varepsilon_{st}\ .$$

Figure 6 displays the estimates of γ_{Year} from equation (5), with the full set of estimates of γ_{Year} shown in Online Appendix Table A9. Panel A displays results for opioid-related deaths from 1994 to 2018, with γ_{1995} fixed at zero, the year before OxyContin's launch. As Alpert et al. (2022) note, triplicate status had a strikingly large effect on the opioid epidemic: the estimates grow steadily over time, and especially from 2012 onward. In 2016 and 2017, there were roughly seven fewer monthly opioid-related deaths per million residents in triplicate DSAs compared to non-triplicate DSAs (recall that the time-invariant estimate from Table 8 was -3.462).

In Panel B, we show the analogous reduced-form estimates for DI donors. As in Panel A, the role of triplicate laws grew steadily over time, again suggesting that the time-invariant estimate from Table 8 (-0.075) understates the laws' effects from 2012 onward; the year-specific estimates range from -0.133 to -0.178 between 2014 and 2018.[31]

Finally, Panel C shows the year-specific ratios of the estimates in Panel B to those in Panel A, representing annual IV estimates of the effect of opioid-related deaths on DI donors. This panel shows a dramatic increase over time in the "conversion rate" from an opioid-related death to a DI donor, ranging from roughly 0.01 in 2000 to 0.03 in 2018 (we exclude years prior to 2000 because, as shown in Panel A, there was no statistically significant first stage before 2000). Notably, this pattern parallels that in Figure 4 based on the OLS estimates, although the year-specific IV estimates are slightly larger than the OLS estimates in most cases.

[31] The results for transplants are available in Online Appendix Figure A2 and Table A7.

In sum, the use of triplicate status as an instrumental variable yields nearly identical conclusions to those from the OLS estimates presented above in Section III, despite being based on markedly different identifying assumptions. Together, these approaches strongly suggest that the conversion rate from opioid-related deaths to DI donors and transplants grew sharply over time as the opioid epidemic worsened.

VI. Conclusions

We investigate whether those awaiting organ transplants may be unexpected beneficiaries of the opioid crisis. Organ donations due to drug intoxication (DI) increased more than tenfold since 2000, and the rate of increase accelerated in recent years as the opioid crisis deepened. Our central estimates suggest that between 2000 and 2018, opioid-related deaths in the US resulted in more than 8,500 organ donors and more than 26,000 organ transplants.

While some of this increase over time in DI donors is a mechanical relationship between opioid-related deaths and DI donors, we also find that transplant centers increasingly recover DI-donor organs for transplant. The conversion rate from an opioid-related death to an organ donor roughly tripled from 2000 to 2018, while the conversion rate from other mechanisms of death to an organ donor remained largely unchanged. Additionally, we find that transplant candidates appear to be more willing to use organs from those who died of opioid-related causes when organ shortages are more severe. The conversion rate from an opioid-related death to an organ donor is about 50 percent higher in DSAs with high excess demand for transplantable organs than in DSAs with relatively low excess demand. DSAs with high excess demand are also relatively more likely to transplant organs within their DSA, rather than export them to other DSAs for transplant. These patterns suggests that organs recovered from an opioid-related death may be viewed as “acceptable” but inferior to organs from other donors and that behavioral choices by physicians and transplant candidates play a significant role in the allocation of scarce organs.

A recent report by the National Academies of Sciences, Engineering and Medicine (2022) charged with examining "the fairness, equity, transparency, and cost-effectiveness of the deceased donor organ procurement, allocation, and distribution system" concludes that one of two key areas with "great room for improvement" is "transplant centers accepting and using more of the deceased donor organs offered to individuals on the waiting list." Our finding that the conversion of opioid-related deaths to DI donors increased over time, tripling from 2000 to 2018, and especially in areas where there is excess demand for organs, provides evidence that this margin may be fruitful for increasing organ transplants and decreasing the organ shortage.

We find little evidence that transplant candidates respond strongly to supply shocks, either by joining waitlists or, in the case of kidneys, by substituting away from living donors to deceased donors. The modest increases in waitlist registrations that we do find are concentrated among liver candidates, who face low survival rates without a transplant. If organs from opioid-related deaths are perceived as lower quality, such a perception could explain why we only see a response among liver candidates, who do not have the luxury to be selective.

Our results suggest that transplant candidates respond differently to donor supply shocks due to the opioid epidemic than to other donor supply shocks, such as those caused by motorcycle helmet law repeals. These patterns may shed light on the efficacy of policies explicitly designed to increase the supply of organs. Unlike the gradual increases caused by the opioid epidemic, helmet law repeals generate an immediate and sustained shock to the organ supply. Whether because of the gradual versus immediate nature of the shocks, the perceived quality of organ donors, or some other mechanism, the demand-side effects induced by motorcycle helmet law repeals – including crowd-out of living donors and large increases in waitlist additions among candidates with relatively high resources – are not evident in the context of the opioid epidemic. Such differential responses among transplant candidates to the nature of donor supply shocks raise the question of whether proposed policy solutions to the shortage of organs – which include the "pursuit and procurement of donation after circulatory determination of death (DCDD)" as opposed to brain death (National Academies of Sciences, Engineering, and Medicine, 2022), financial incentives for donation (Bilgel and Galle, 2015, and Lacetera et al., 2014), presumed consent rather than informed consent of organ donation (Abadie and Gay, 2006; Costa-Font et al., 2021; and Ugur, 2015), nudges (Sun et al., 2016), management of organ transplant lists (Kessler and Roth, 2012), and increasing living donation through exchange (Roth et al., 2004; and Teltser, 2019) – can be designed to be more effective at raising the overall supply of organs from tragic deaths and promoting equity in access.

Finally, because organs are allocated based on geographical location due to the medical necessity of transplanting organs quickly after they are recovered, our results suggest that candidates in areas with high levels of opioid-related deaths have more opportunities for transplants than those in areas less affected by the opioid epidemic. As technology evolves for maintaining the viability of organs for longer time periods (Mayo Clinic, 2021; National Institutes of Health, 2019; Clavien et al., 2022), the importance of geography may diminish in the future, but in the meantime, the practical considerations related to geographic proximity must be balanced against medical need.

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Table 1: Drug Overdose Deaths, Opioid-related Deaths, and Opioid Overdose Deaths by Year, Age, and Gender

	Drug Overdoses				Opioid Overdoses				Opioid-related Deaths			
Year	All (1)	Young (18-49) (2)	Male (3)	Female (4)	All (5)	Young (18-49) (6)	Male (7)	Female (8)	All (9)	Young (18-49) (10)	Male (11)	Female (12)
2000	17322	13666	11502	5820	8347	7036	6097	2250	8986	7523	6536	2450
2001	19277	15051	12585	6692	9422	7720	6682	2740	10062	8215	7143	2919
2002	23410	18048	14952	8458	11840	9533	8102	3738	12579	10052	8584	3995
2003	25710	19551	16358	9352	12897	10248	8783	4114	13665	10771	9294	4371
2004	27385	20465	17103	10282	13725	10692	9094	4631	14555	11241	9628	4927
2005	29832	21765	18752	11080	14925	11326	9773	5152	15757	11895	10351	5406
2006	34412	24806	21900	12512	17535	13139	11602	5933	18448	13729	12176	6272
2007	36038	25094	22325	13713	18535	13547	11955	6580	19307	13965	12454	6853
2008	36499	24947	22504	13995	19612	14047	12784	6828	20379	14474	13231	7148
2009	37076	24843	22647	14429	20465	14409	13172	7293	21357	14892	13733	7624
2010	38319	25297	23007	15312	21099	14727	13360	7739	22067	15250	14003	8064
2011	41363	27166	25025	16338	22794	15934	14473	8321	23768	16451	15084	8684
2012	41533	26712	25142	16391	23181	15909	14751	8430	24126	16388	15341	8785
2013	43995	27541	26824	17171	25056	16815	16003	9053	26031	17276	16609	9422
2014	47076	29648	28829	18247	28641	19318	18415	10226	29645	19823	19033	10612
2015	52479	33701	33034	19445	33092	22755	21685	11407	34166	23262	22359	11807
2016	63635	41990	41556	22079	42203	29716	28466	13737	43444	30347	29234	14210
2017	70347	46613	46684	23663	47610	33480	32371	15239	48874	34107	33125	15749
2018	67553	43758	45090	22463	46882	32663	32142	14740	48150	33298	32918	15232

Source: Authors calculations from the NVSS multiple-cause-of-death mortality files.

Table 2: Deceased Organ Donors by Mechanism of Death (Drug Intoxication or Other), Year, Age, and Gender

	Drug Intoxication Death				All Other Mechanisms of Death			
Year	All	Young (18-49)	Male	Female	All	Young (18-49)	Male	Female
2000	66	58	35	31	5924	3047	3451	2472
2001	84	70	47	37	5999	3113	3531	2468
2002	107	96	57	50	6089	3224	3640	2449
2003	138	113	75	63	6324	3282	3721	2603
2004	188	145	91	97	6964	3556	4019	2945
2005	158	135	79	79	7437	3800	4345	3092
2006	230	194	135	95	7793	3998	4649	3144
2007	268	227	148	120	7826	4027	4734	3092
2008	285	240	153	132	7708	3929	4583	3125
2009	322	272	168	154	7701	3836	4560	3141
2010	342	299	179	163	7604	3942	4506	3098
2011	473	412	238	235	7657	3998	4528	3129
2012	441	394	231	210	7707	4075	4592	3115
2013	560	496	309	251	7714	3984	4601	3113
2014	625	554	374	251	7977	4216	4793	3184
2015	848	770	501	347	8236	4313	4987	3249
2016	1262	1149	763	499	8717	4606	5197	3520
2017	1384	1225	798	586	8907	4683	5403	3504
2018	1401	1256	834	567	9322	4851	5662	3660

Notes: Authors' calculations from the SRTR data. "All Other Mechanisms of Death" include Gunshot / Stab wound, Blunt Injury, Seizure, Stroke, SIDS, Asphyxiation, Cardiovascular, Drowning, Electrical, Natural Causes, and "None of the above."

Table 3: Average Number of Organs Transplanted per Donor, by Mechanism of Death

Mechanism of Death:	Total	Kidney	Liver	Heart	Lung	Pancreas	Intestine
Drowning	3.23	1.77	0.75	0.41	0.12	0.13	0.06
Seizure	3.25	1.58	0.71	0.36	0.42	0.15	0.04
Drug Intoxication	**3.14**	**1.53**	**0.78**	**0.36**	**0.36**	**0.10**	**0.01**
Asphyxiation	3.39	1.70	0.76	0.38	0.33	0.20	0.03
Cardiovascular	2.34	1.29	0.66	0.15	0.17	0.06	0.01
Electrical	3.20	1.76	0.71	0.36	0.21	0.14	0.02
Gunshot Wound	4.34	1.77	0.89	0.58	0.71	0.35	0.02
Stab	3.52	1.74	0.77	0.39	0.40	0.22	0.00
Blunt Injury	3.69	1.74	0.81	0.46	0.39	0.26	0.03
SIDS	2.41	0.70	0.60	0.73	0.04	0.12	0.21
Intracranial Hemorrhage/Stroke	2.62	1.28	0.75	0.18	0.32	0.08	0.01
Death from Natural Causes	2.67	1.42	0.67	0.24	0.25	0.08	0.01
None of the Above	3.02	1.50	0.71	0.34	0.29	0.14	0.04
Unknown	1.40	0.24	0.30	0.48	0.32	0.04	0.02

Source: Authors' calculations using 2000-2018 SRTR data.

Table 4: Estimates of the Effect of Drug-Related Deaths on Organ Donors and Transplants

Panel A: DI Donors and Transplants

	Donors			Transplants		
Independent Variable	(1)	(2)	(3)	(4)	(5)	(6)
Opioid-Related Deaths	0.0189			0.0581		
	(0.0017)			(0.0064)		
Opioid Overdoses		0.0193			0.0594	
		(0.0017)			(0.0064)	
Drug Overdoses			0.0183			0.0568
			(0.0019)			(0.0069)
Mean of dependent variable:		0.1266			0.3931	

Panel B: All Donors and Transplants

	Donors			Transplants		
Opioid-Related Deaths	0.0143			0.0387		
	(0.0054)			(0.0161)		
Opioid Overdoses		0.0149			0.0406	
		(0.0055)			(0.0163)	
Drug Overdoses			0.0184			0.0479
			(0.0044)			(0.0122)
Mean of dependent variable:		2.0434			6.3006	

Notes: Cell entries represent estimates from twelve different regressions. All estimation samples consist of 57 DSAs from 2000 to 2018 (N=12,996). The unit of observation is a DSA-month. All models include indicators for month-years and DSAs, DSA unemployment rates and a set of policies related to donation and drug overdose outcomes. Standard errors, listed in parentheses, are robust to clustering within DSA over time. Sample means are measured per million DSA residents.

Table 5: Estimates of the Effect of Opioid-Related Deaths on Organ Donations Due to Drug Intoxication and Transplants from Drug Intoxication Donors, by Excess Demand for Organs

	Dependent variables:							
	Drug Intoxication Donors		Transplants from DI Donors		In-DSA Transplants from DI Donors		Out-of-DSA Transplants from DI Donors	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Opioid-Related Deaths	0.0228	0.0144	0.0715	0.0450	0.0451	0.0222	0.0263	0.0227
	(0.0018)	(0.0018)	(0.0070)	(0.0063)	(0.0069)	(0.0054)	(0.0031)	(0.0038)
Mean of dependent variable	0.1895	0.1737	0.5953	0.5380	0.4099	0.3054	0.1850	0.2317
DSAs	29	28	29	28	29	28	29	28
DSAs with high excess organ demand	x		x		x		x	
DSAs with low excess organ demand		x		x		x		x

Notes: Cell entries represent estimates from 8 different regressions. All estimation samples consist of DSAs from 2008 to 2018. The unit of observation is a DSA-month. All models include indicators for DSAs and month-years and a set of DSA-month variables described in the text. We define DSAs with excess demand (the average number of transplant candidates who join organ waitlists each month divided by the average number of monthly transplants) in the 2000-2007 period above the median as *high excess demand* and those below the median as *low excess demand*. Standard errors, listed in parentheses, are robust to clustering with DSA over time. Sample means for relevant dependent variables are measured per million DSA residents.

Table 6: Estimates of the Effect of Opioid-Related Deaths on Waitlist Additions by Organ, Location, and Multilisting Status

	All	In-DSA	Out-of-DSA	Multilisters
	(1)	(2)	(3)	(4)
All organs	0.0279	0.0053	0.0226	0.0071
	(0.0416)	(0.0270)	(0.0199)	(0.0155)
	[14.7615]	[11.4479]	[3.3137]	[3.8567]
Kidneys	-0.0109	-0.0231	0.0122	0.0046
	(0.0267)	(0.0188)	(0.0140)	(0.0136)
	[8.9536]	[7.2132]	[1.7404]	[2.6619]
Liver	0.0419	0.0313	0.0106	0.0031
	(0.0172)	(0.0106)	(0.0074)	(0.0024)
	[3.1101]	[2.2988]	[0.8113]	[0.5211]
Heart	-0.0026	-0.0022	-0.0003	-0.0014
	(0.0034)	(0.0026)	(0.0016)	(0.0006)
	[0.9783]	[0.7555]	[0.2228]	[0.1081]
Lungs	0.0024	0.0011	0.0013	-0.0002
	(0.0060)	(0.0027)	(0.0039)	(0.0014)
	[0.6216]	[0.3909]	[0.2308]	[0.0819]
Pancreas	-0.0018	-0.0013	-0.0004	-0.0008
	(0.0037)	(0.0019)	(0.0021)	(0.0013)
	[0.1779]	[0.1203]	[0.0576]	[0.0657]
Intestines	-0.0008	0.0001	-0.0009	-0.0003
	(0.0025)	(0.0003)	(0.0022)	(0.0006)
	[0.0572]	[0.0207]	[0.0365]	[0.0107]

Notes: The table represents 28 different regressions where the dependent variable in columns 1-4 is the number of wait list additions by category. All estimation samples consist of 57 DSAs from 2000 to 2018. The unit of observation is a DSA-month. All models include indicators for DSAs and month-years and a set of DSA-month variables described in the text. Standard errors, listed in parentheses, are robust to clustering with DSA over time. Sample means for relevant dependent variables are listed in brackets, with all variables measured per million DSA residents.

Table 7: Estimates of the Effect of Opioid-Related Deaths on Living-Donor Transplants

	All Organs	Kidneys	All Except Kidneys
Independent variable:	(1)	(2)	(3)
Opioid Deaths	-0.0017	-0.0047	0.0030
	(0.0057)	(0.0065)	(0.0019)
	[1.7374]	[1.5690]	[0.0713]

Notes: Cell entries represent 3 separate regressions, where the dependent variable is the number of living-donor transplants: overall, kidneys only, and all organs except kidneys. All estimation samples consist of 57 DSAs from 2000 to 2018. The unit of observation is a DSA-month. All models include indicators for DSAs and month-years and the DSA-month controls described in the text. Standard errors, listed in parentheses, are robust to clustering with DSA over time. Sample means for relevant dependent variables are listed in brackets, with all variables measured per million DSA residents.

Table 8: Instrumental Variables Estimates of the Effect of Opioid-Related Deaths on DI Organ Donations Using DSA Triplicate Status as an Instrument

	Reduced-form estimates of the effects of *Triplicate Status* on			Instrumental Variables Estimates of the Effect of *Opioid-Related Deaths* on	
	Opioid-Related Deaths	*DI Donors*	*Transplants from DI Donors*	*DI Donors*	*Transplants from DI Donors*
	(1)	(2)	(3)	(4)	(5)
All years	-3.4615	-0.0748	-0.2140	0.0216	0.0618
	(0.7951)	(0.0237)	(0.0703)	(0.0041)	(0.0121)
Sample Means of Dependent Variable:	5.7922	0.1002	0.3089	0.1002	0.3089

Notes: The table represents three different first stage and reduced form regressions, plus the corresponding two instrumental variables regressions. All estimation samples consist of states from 1994 to 2018. The unit of observation is a state-month. All models include month-year indicators and a set of state-month variables described in the text. Standard errors, listed in parentheses, are robust to clustering with state over time. Dependent variables are measured per million state residents.

Figure 1: Stylized Representation of the Path from Opioid-Related Death to Organ Transplant

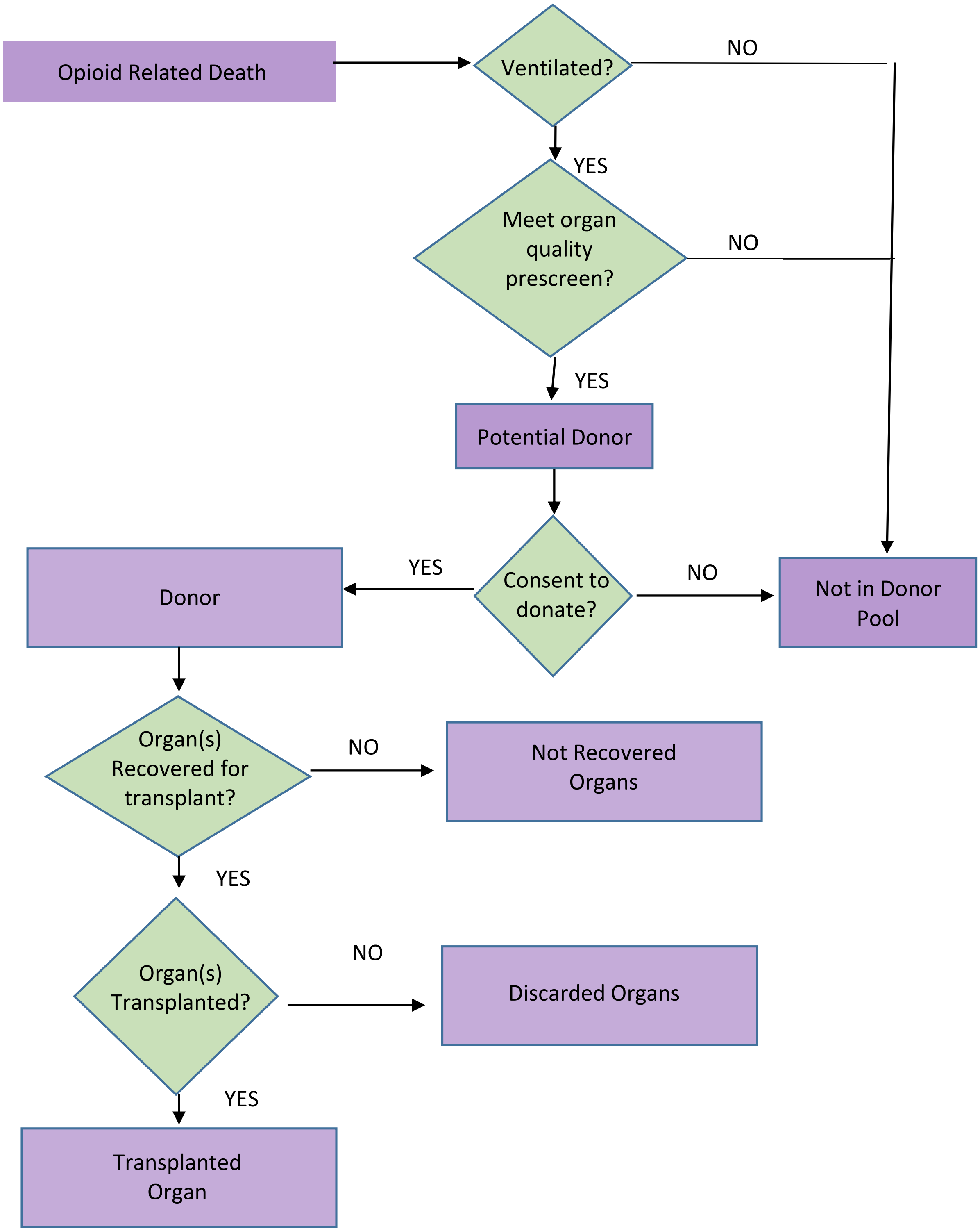
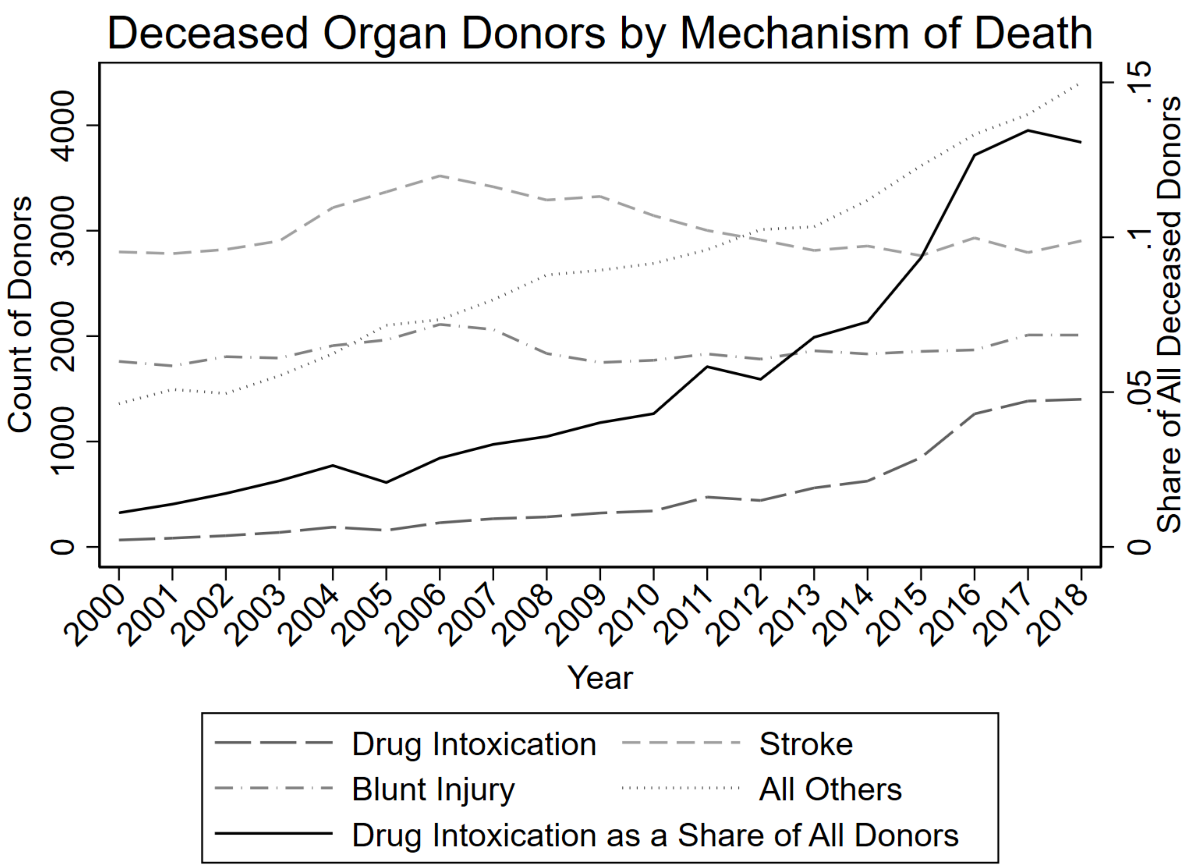
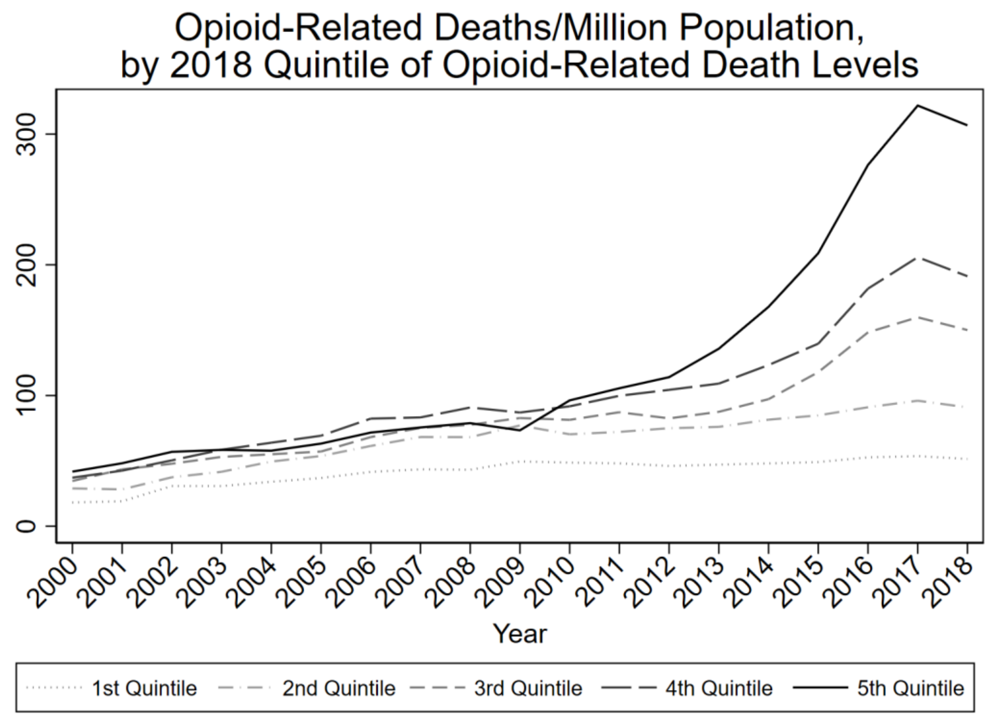


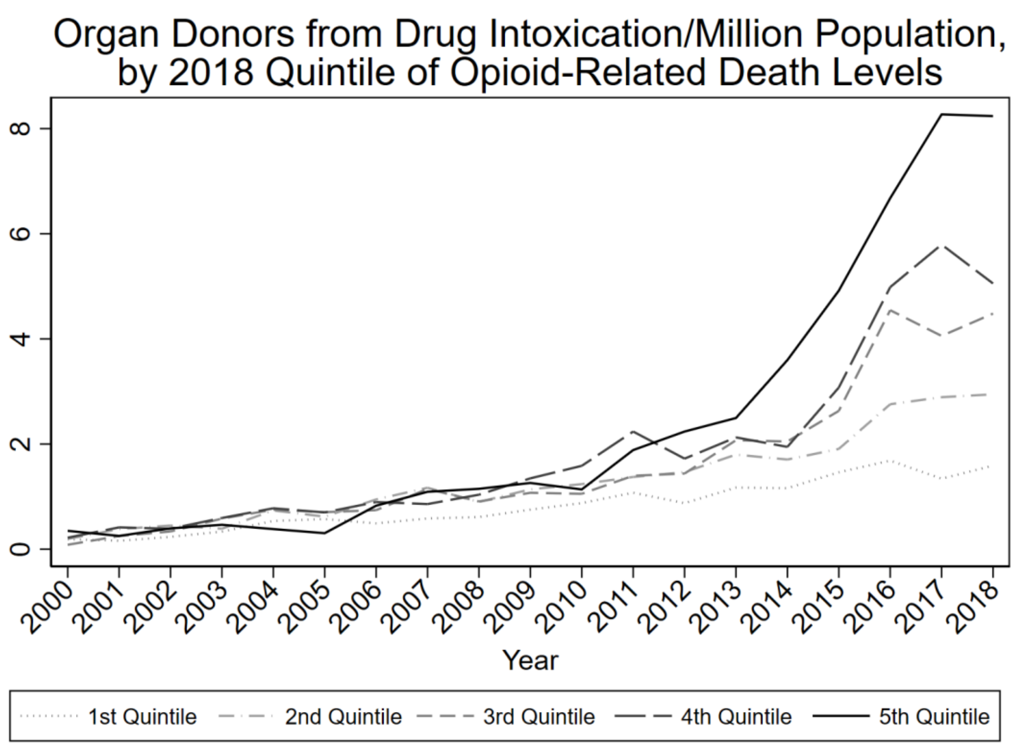
Figure 2



Notes: Authors' calculations from the SRTR data. The figure shows the annual number of deceased organ donors by mechanism of death, where "All others" includes Gunshot / Stab wound, Seizure, SIDS, Asphyxiation, Cardiovascular, Drowning, Electrical, Natural Causes, and "None of the above."

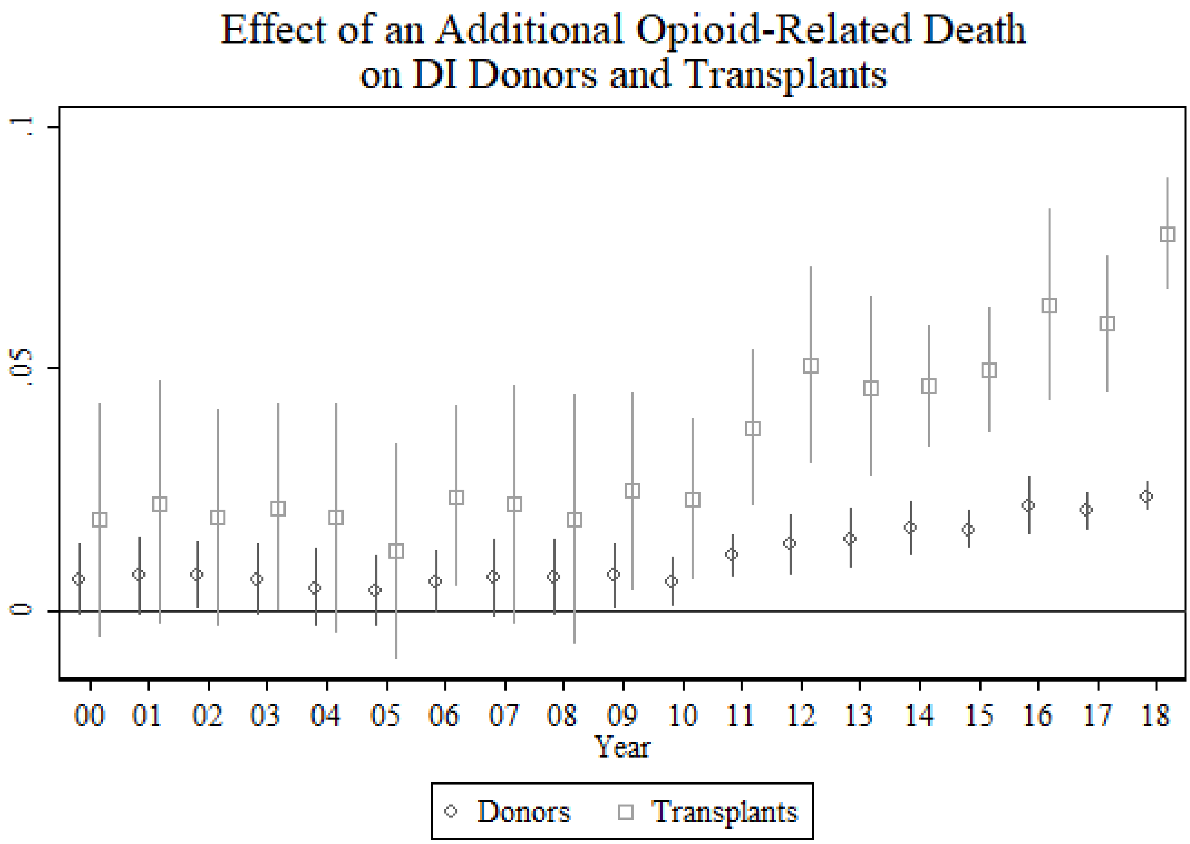
Figure 3


Opioid-Related Deaths/Million Population,
by 2018 Quintile of Opioid-Related Death Levels
0
100
200
300
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Year
1st Quintile
2nd Quintile
3rd Quintile
4th Quintile
5th Quintile


Organ Donors from Drug Intoxication/Million Population,
by 2018 Quintile of Opioid-Related Death Levels
0
2
4
6
8
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Year
1st Quintile
2nd Quintile
3rd Quintile
4th Quintile
5th Quintile

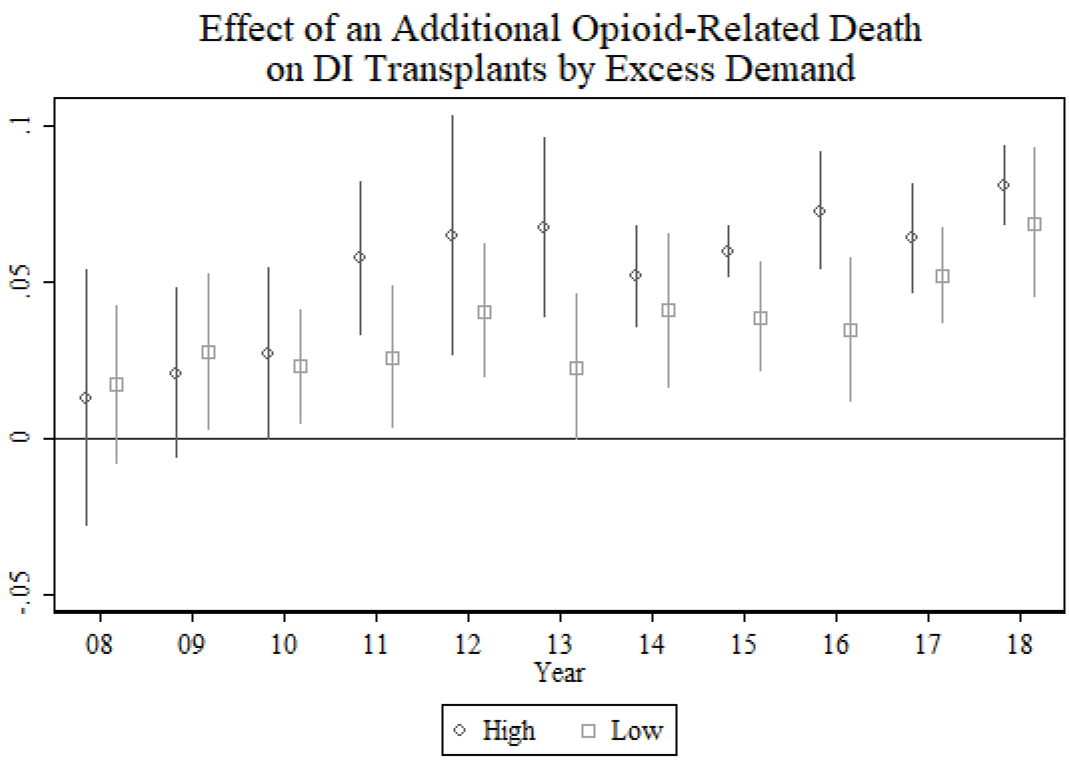
Notes: Authors' calculations from the Vital Statistics Mortality Data and SRTR data. The figure shows the annual number of opioid-related deaths (top panel) and DI organ donors (bottom panel) by million population by quintile. The 1st quintile contains the following DSAs: CADN, CAGS, CAOP, HIOP, IAOP, MNOP, MSOP, MWOB, NEOR, TXGC, TXSA, and TXSB. The 2nd quintile contains the following DSAs: ALOB, AROR, CASD, CORS, GALL, LAOP, OKOP, ORUO, TNMS, WALC, and WIUW. The 3rd quintile contains the following DSAs: AZOB, DCTC, FLMP, FLWC, INOP, NVLV, NYAP, NYRT, NYWN, SCOP, UTOP, and VATB. The 4th quintile contains the following DSAs: FLFH, FLUF, ILIP, MIOP, NCCM, NCNC, NMOP, NYFL, PATF, TNDS, and WIDN. The 5th quintile contains the following DSAs: CTOP, KYDA, MAOB, MDPC, MOMA, NJTO, OHLB, OHLC, OHLP, OHOV, and PADV. See Appendix Table A1 for the full names of the OPOs that oversee the DSAs and the states in which their OPOs are headquartered.

Figure 4



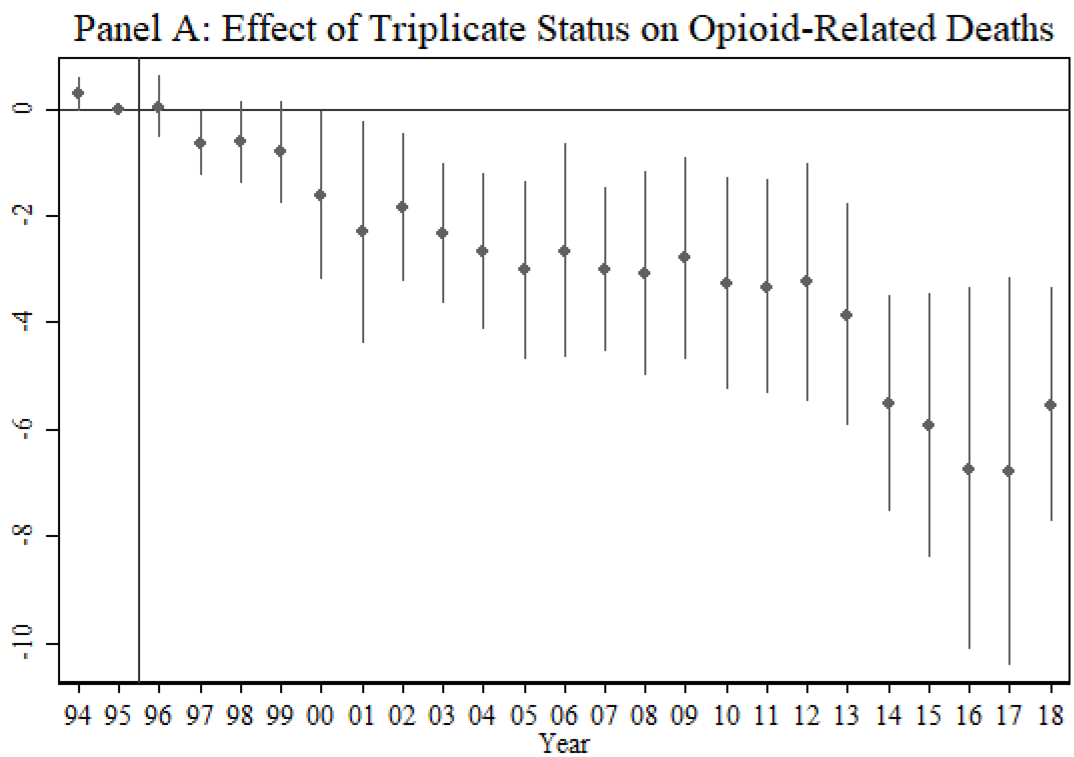
Notes: The figure presents estimates of γ_{YEAR} from equation (2) in the text. Each point represents the estimated effect of an opioid-related death on DI donors (or the number of transplants from those donors) for a given year from 2000-2018. Authors' calculations from the Vital Statistics Mortality Data and SRTR data. The vertical lines in the figure represent 95 percent confidence intervals.

Figure 5



Notes: The figure presents estimates of γ_{YEAR} from equation (2) in the text, separately by whether the DSA was included in the "high excess demand" or "low excess demand" category. Each point represents the estimated effect of an opioid-related death on DI-donor transplants for a given year from 2008-2018. Authors' calculations from the Vital Statistics Mortality Data and SRTR data. Vertical lines represent 95 percent confidence intervals.

Figure 6


Panel A: Effect of Triplicate Status on Opioid-Related Deaths
0
-2
-4
-6
-8
-10
94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18
Year

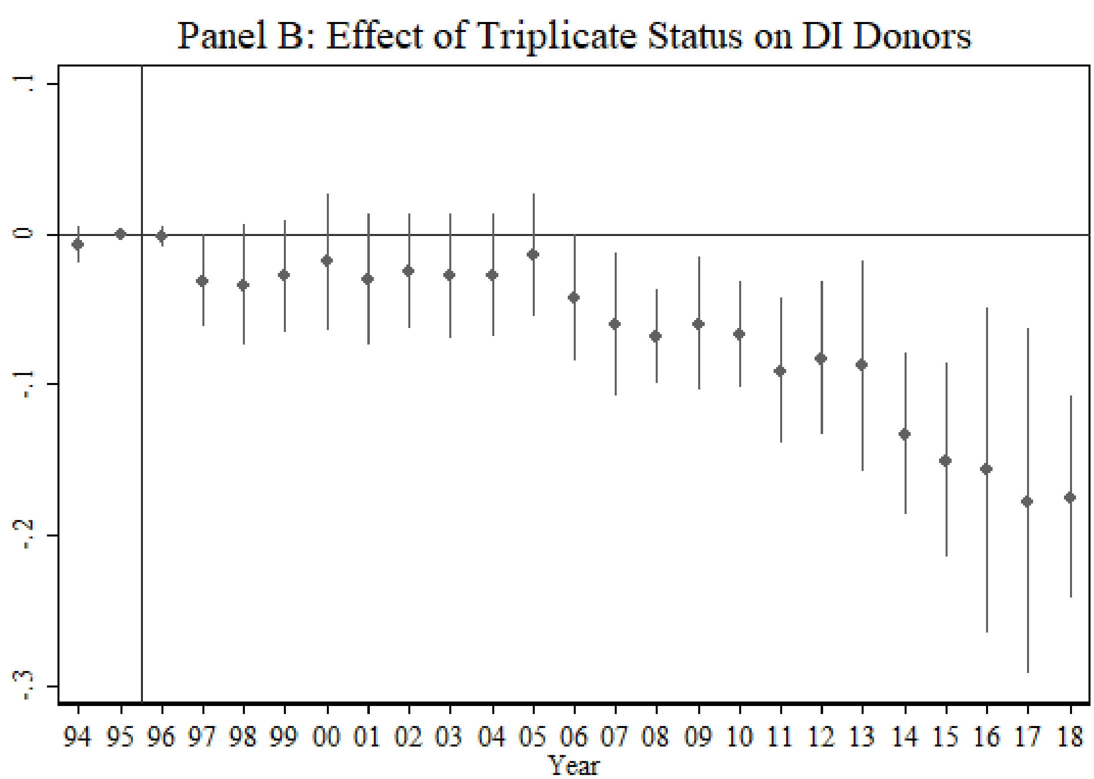
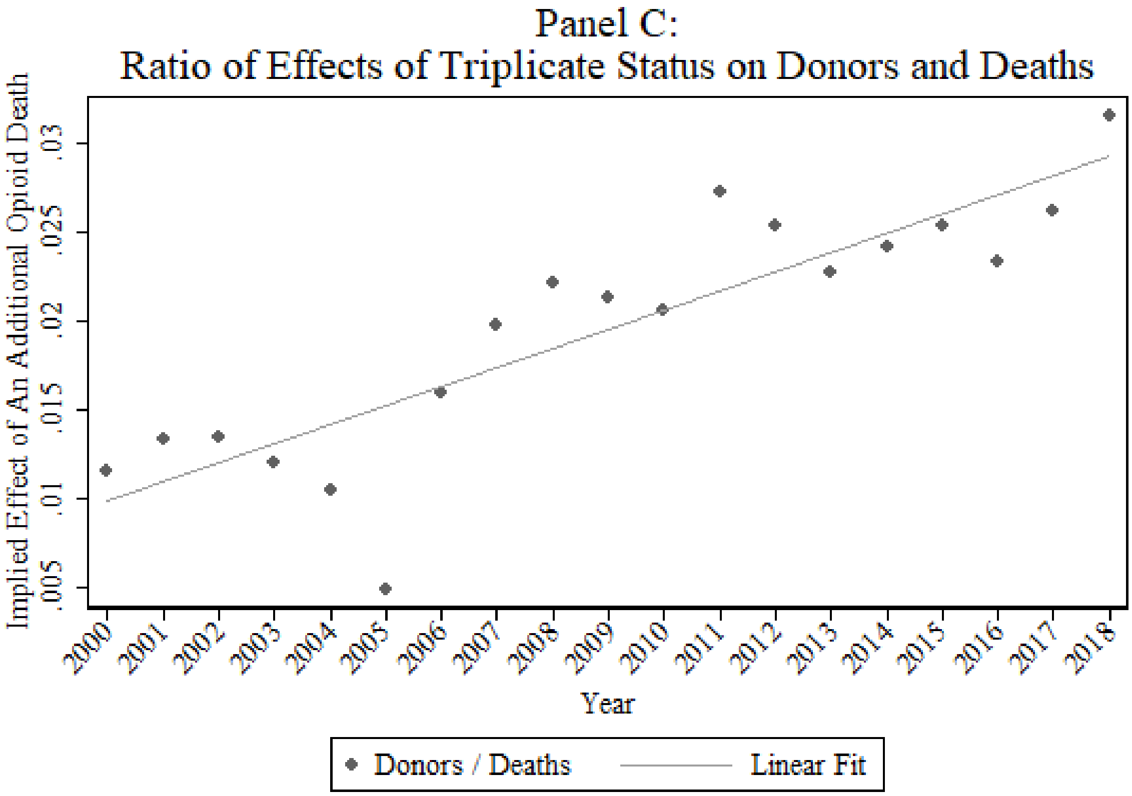

Panel B: Effect of Triplicate Status on DI Donors
.1
0
-.1
-.2
-.3
94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18
Year

Figure 6 (cont'd)



Notes: Authors' calculations from the Vital Statistics Mortality Data. Panel A represents estimates from equation (5) in the text, using opioid-related deaths per million residents as the dependent variable. Panel B uses DI donors per million residents as the dependent variable, and Panel C presents the year-specific ratios of the estimates in Panel B and Panel A, representing year-specific instrumental variables estimates. Triplicate states are California, Idaho, Illinois, New York, and Texas.

Figure 1

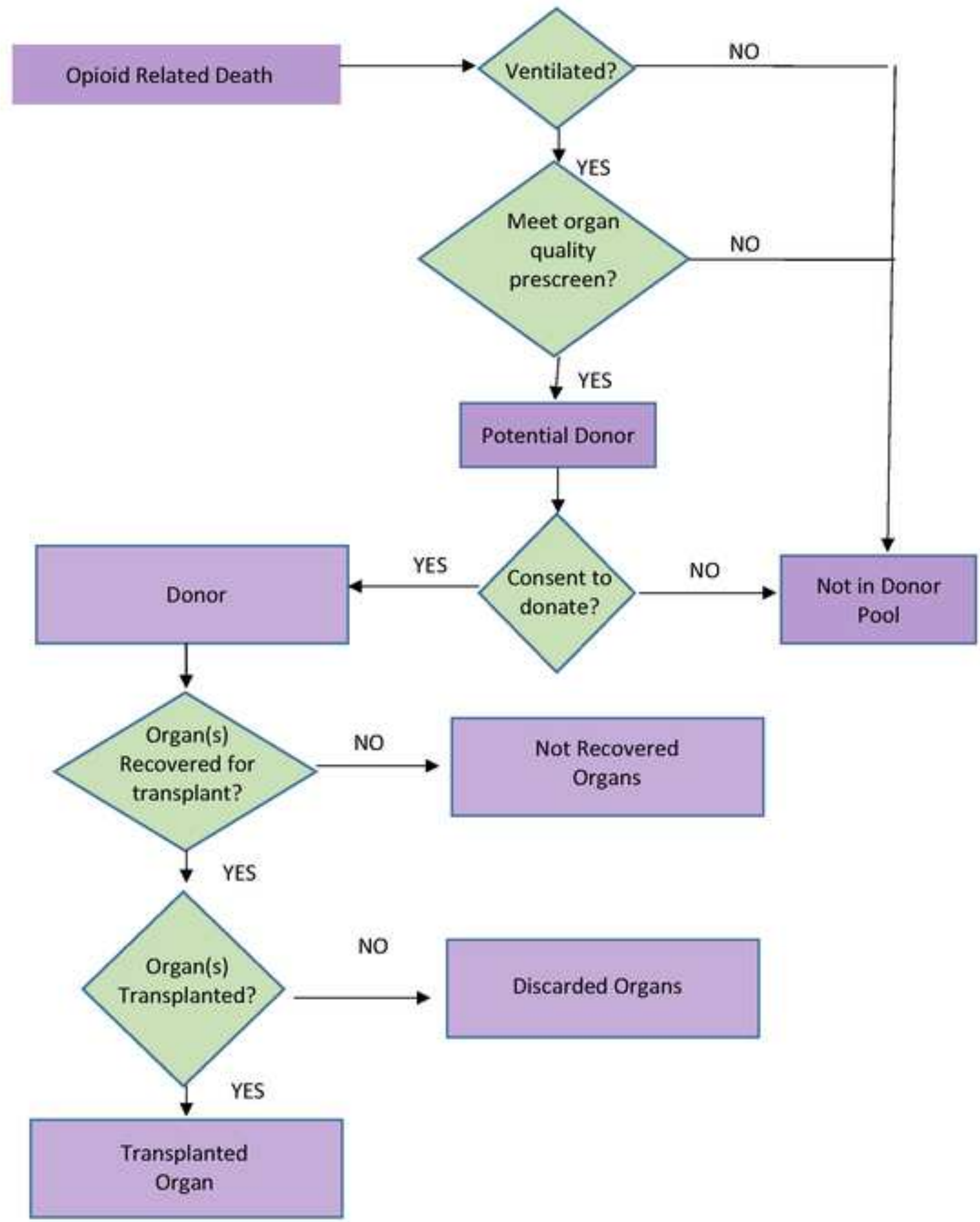

Opioid Related Death
Ventilated?
NO
YES
Meet organ quality prescreen?
NO
YES
Potential Donor
Consent to donate?
YES
NO
Donor
Not in Donor Pool
Organ(s) Recovered for transplant?
NO
Not Recovered Organs
YES
Organ(s) Transplanted?
NO
Discarded Organs
YES
Transplanted Organ

Figure 2

Click here to access/download;Figure;fig2.eps

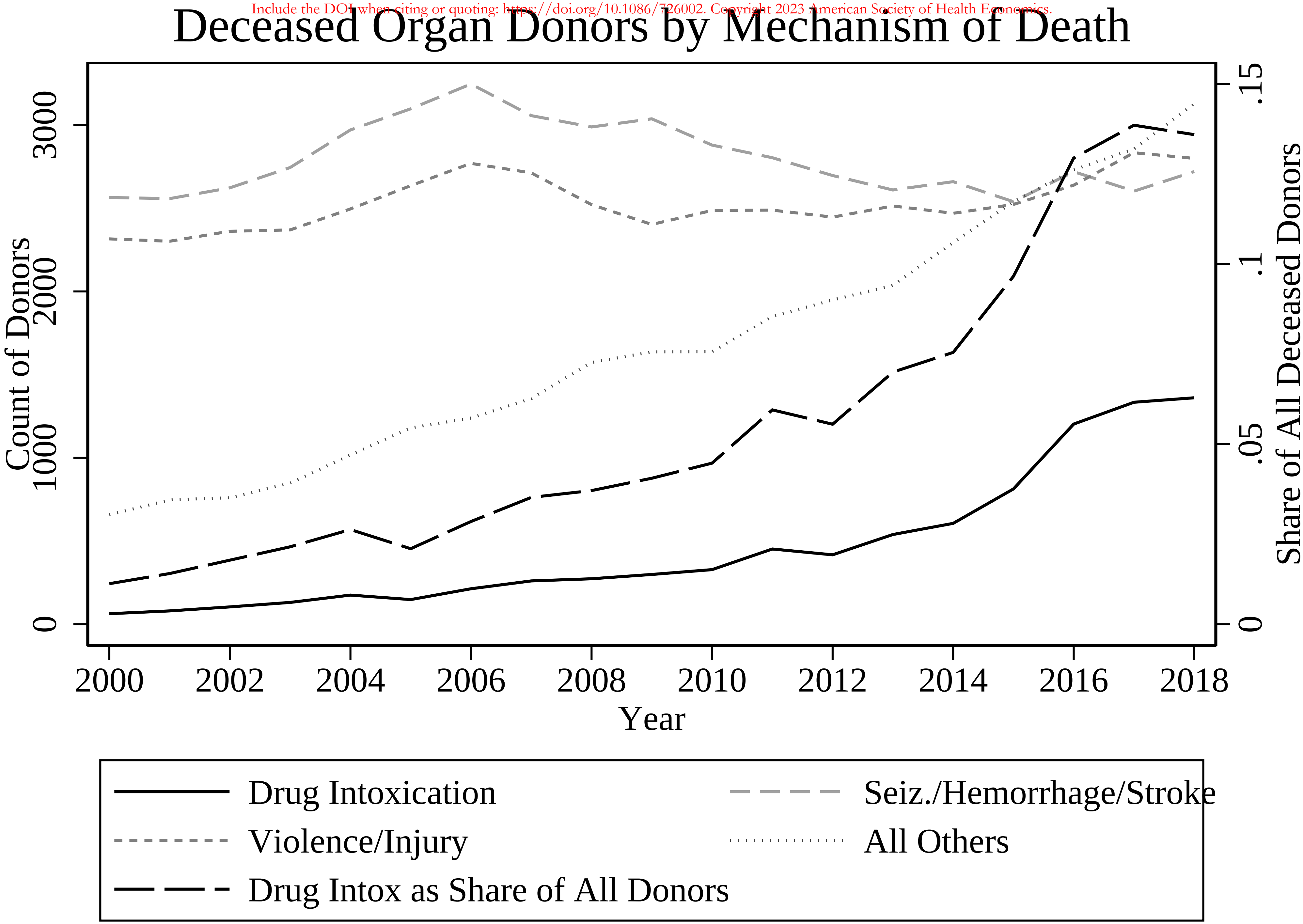


Figure 3a

Click here to access/download;Figure;fig3a.eps

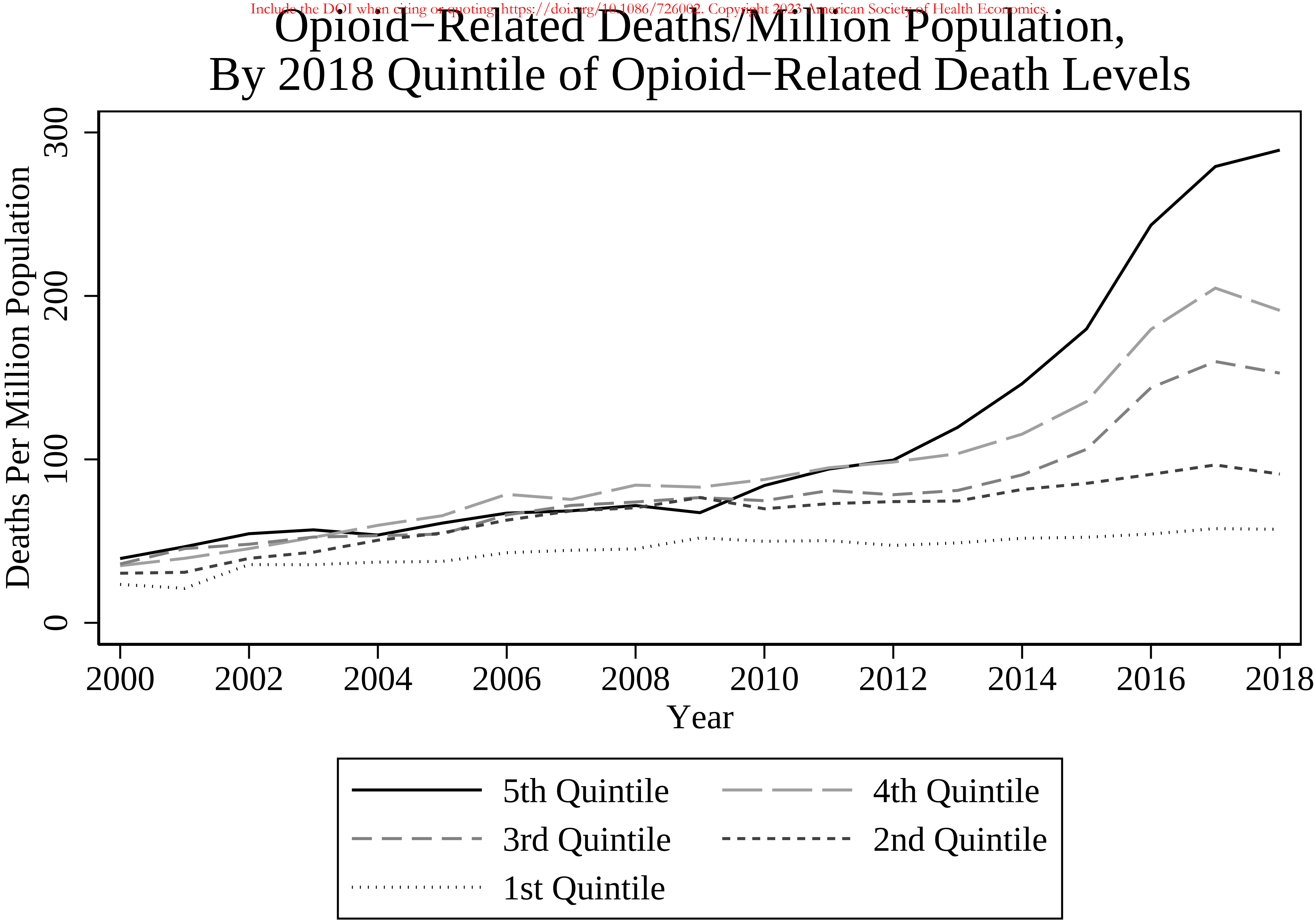


Figure 3b

Click here to access/download;Figure;fig3b.eps

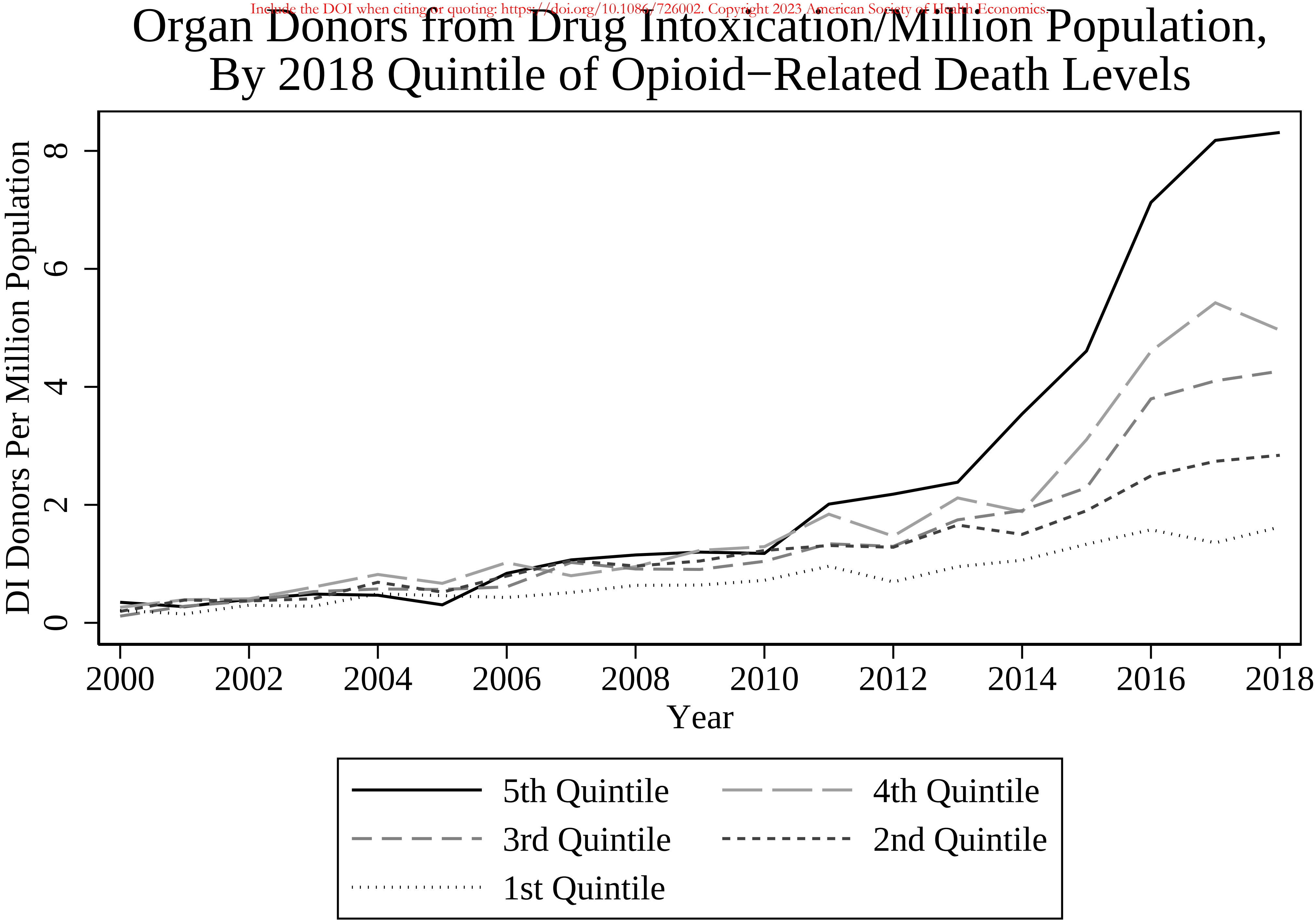


Figure 4

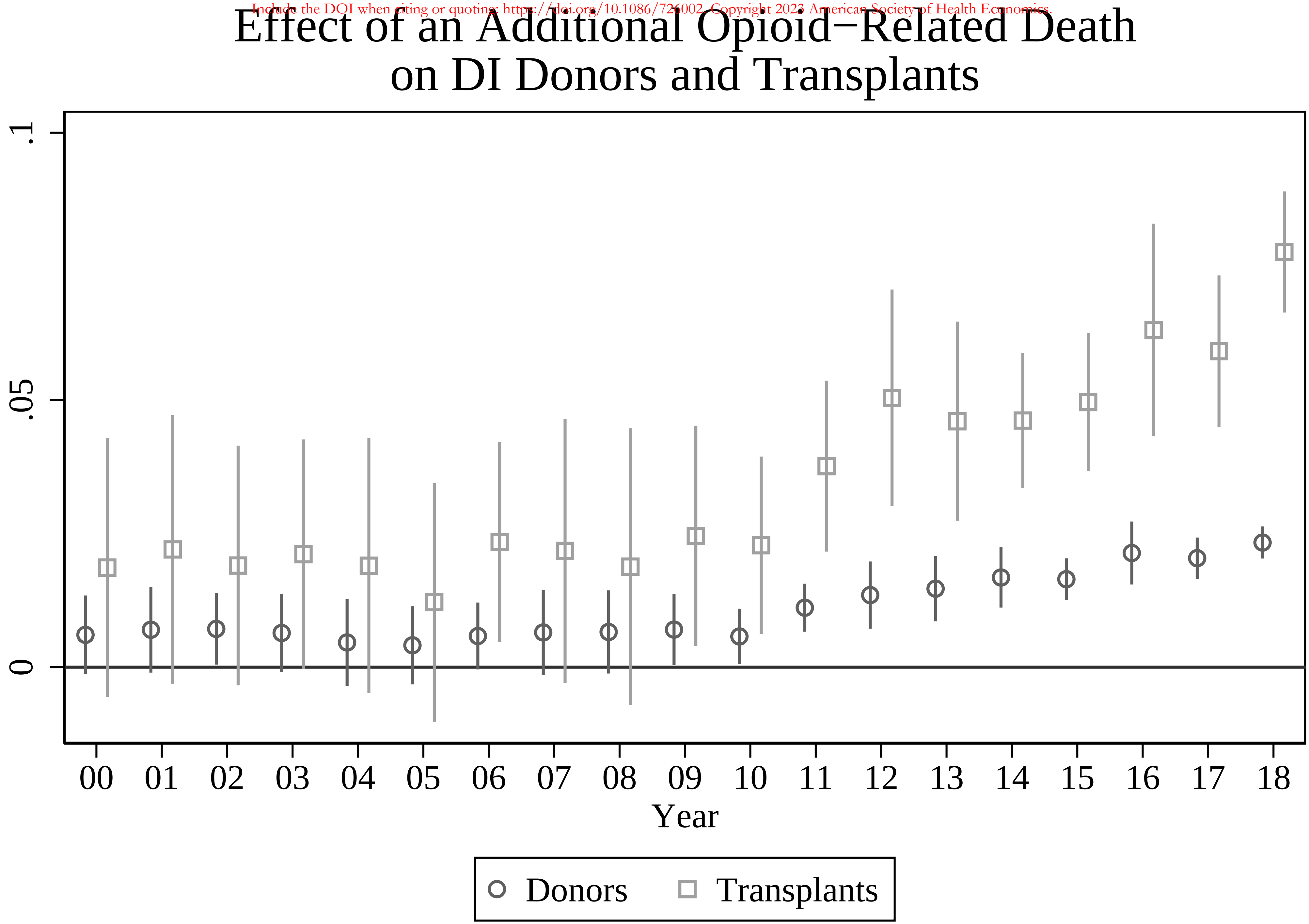

Effect of an Additional Opioid−Related Death
on DI Donors and Transplants
.1
.05
0
00
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
Year
Donors
Transplants

Figure 5

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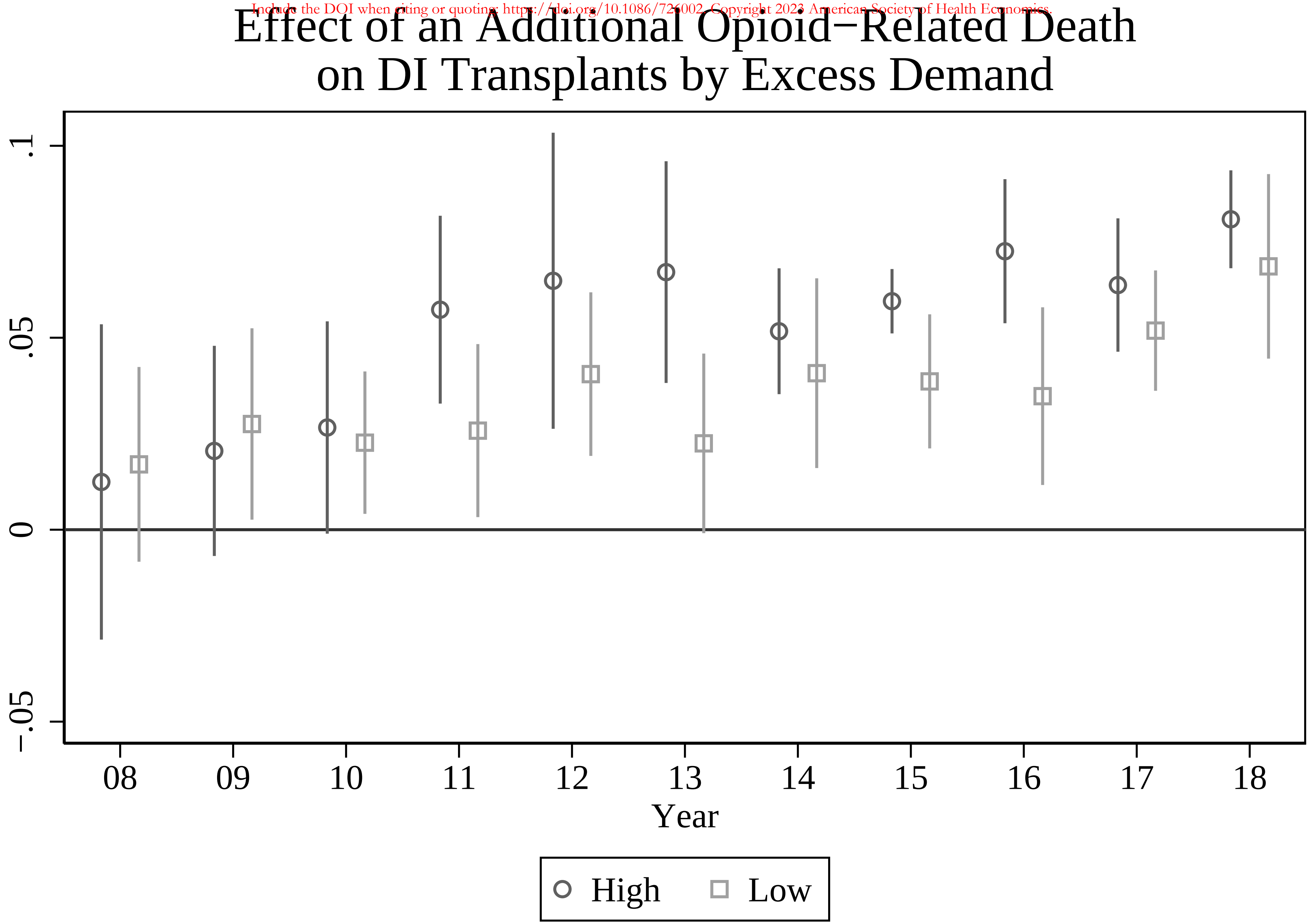


Figure 6a

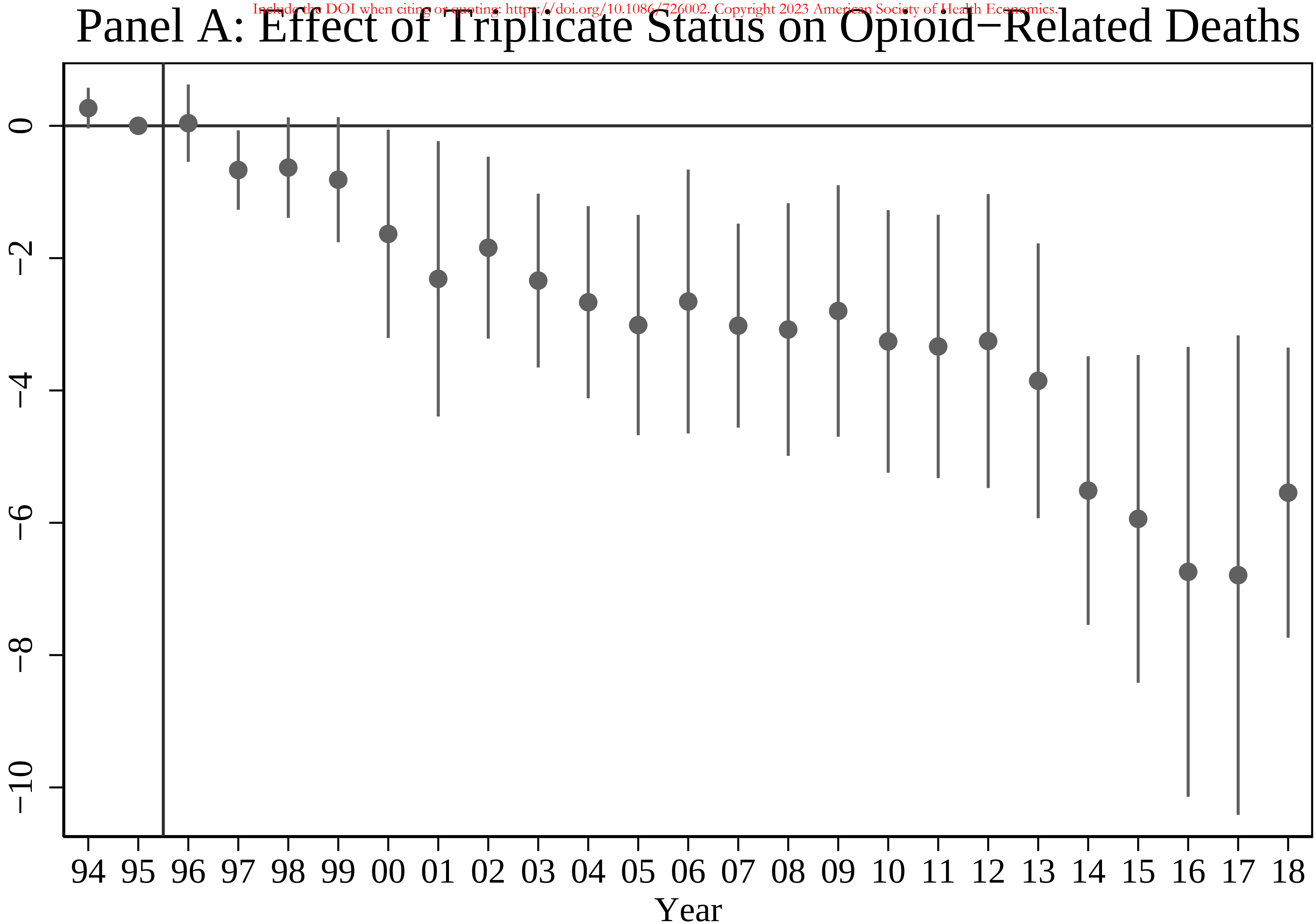
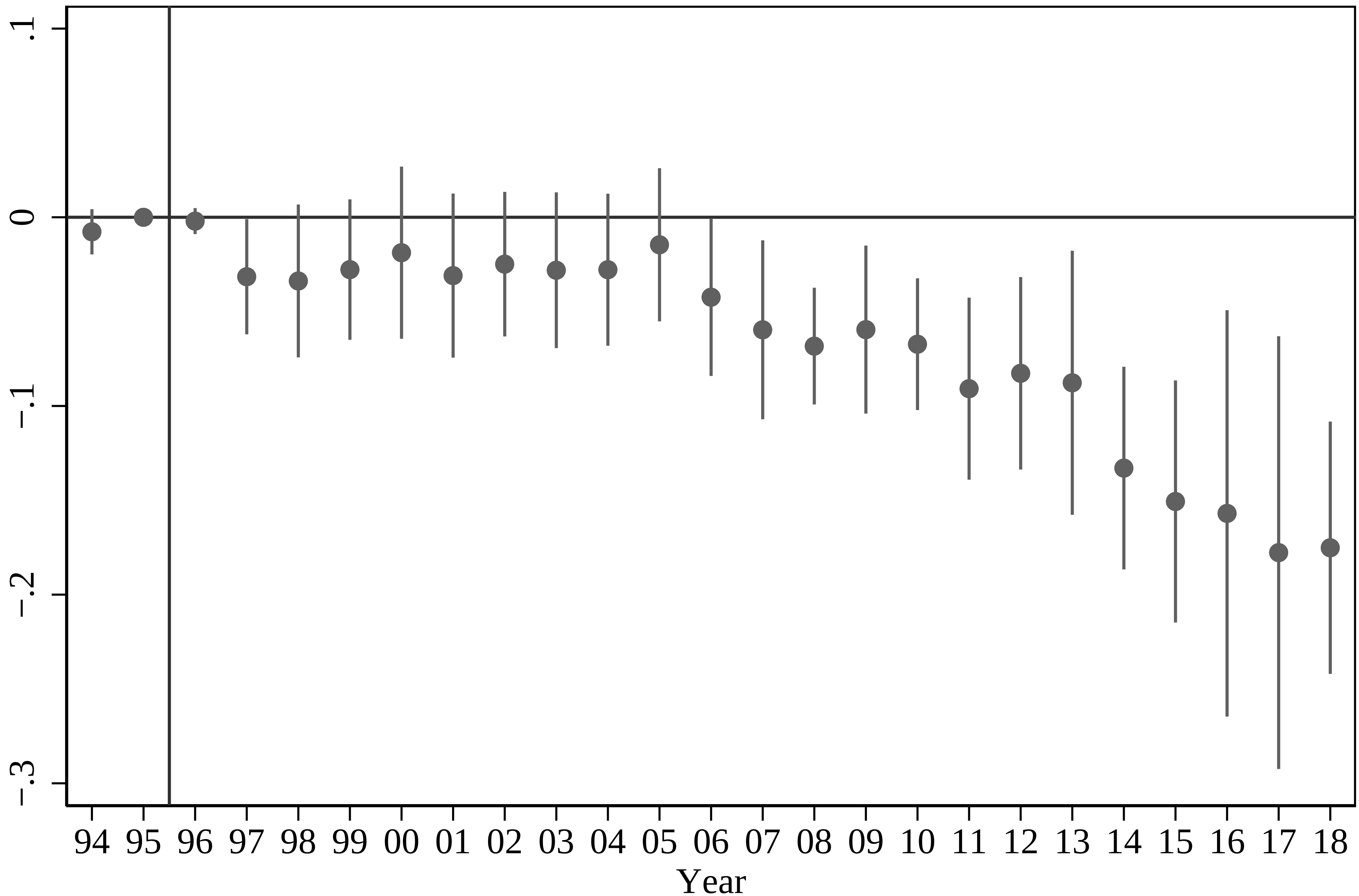

Panel A: Effect of Triplicate Status on Opioid−Related Deaths
0
−2
−4
−6
−8
−10
94
95
96
97
98
99
00
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
Year

Figure 6b

Click here to access/download;Figure;fig6b.eps

Panel B: Effect of Triplicate Status on DI Donors



Panel C:
Ratio of Effects of Triplicate Status on Donors and Deaths

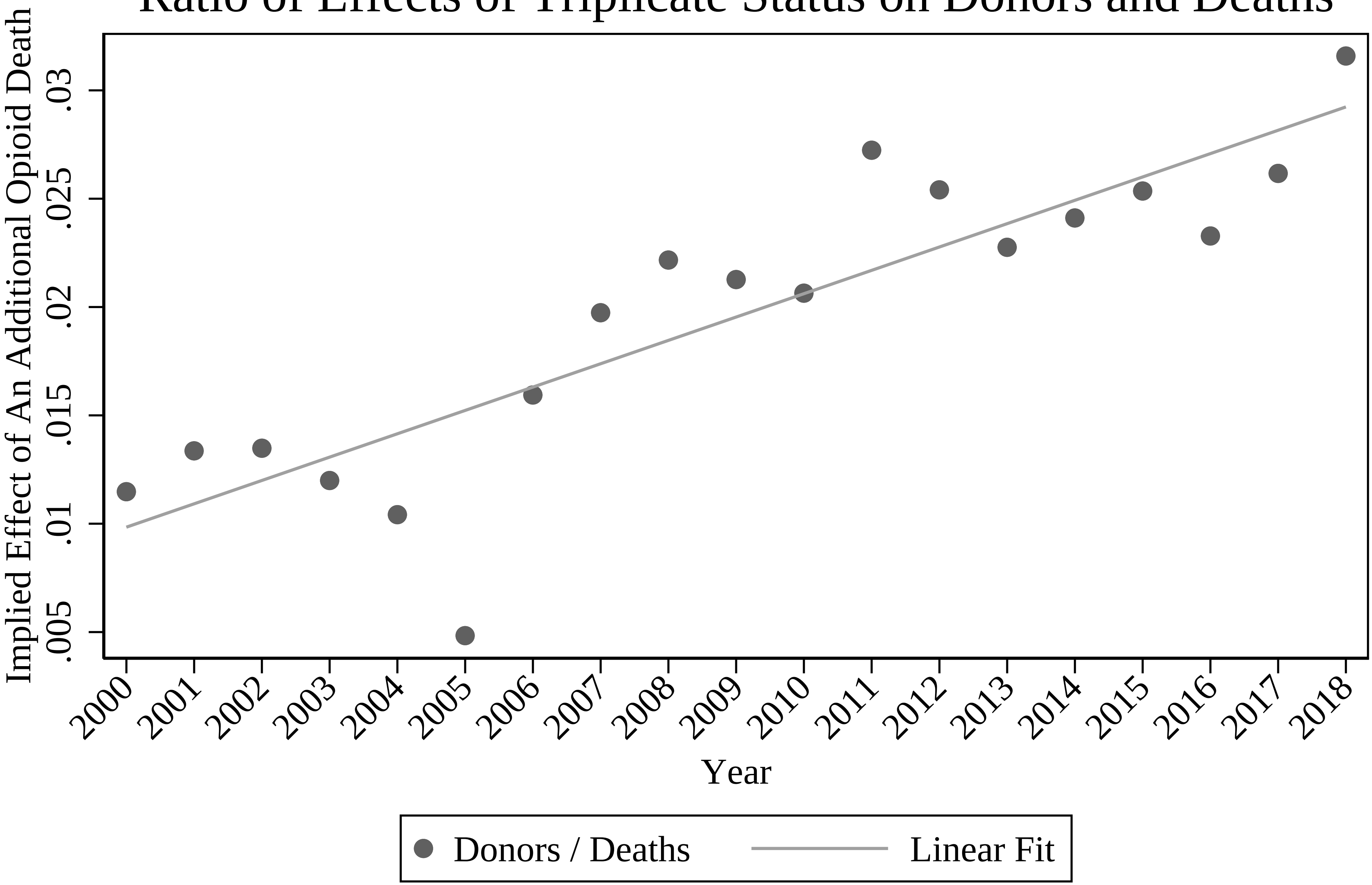


Table 1: Drug Overdose Deaths, Opioid-related Deaths, and Opioid Overdose Deaths by Year, Age, and Gender

	Drug Overdoses				Opioid Overdoses				Opioid-related Deaths			
Year	All (1)	Young (18-49) (2)	Male (3)	Female (4)	All (5)	Young (18-49) (6)	Male (7)	Female (8)	All (9)	Young (18-49) (10)	Male (11)	Female (12)
2000	17322	13666	11502	5820	8347	7036	6097	2250	8986	7523	6536	2450
2001	19277	15051	12585	6692	9422	7720	6682	2740	10062	8215	7143	2919
2002	23410	18048	14952	8458	11840	9533	8102	3738	12579	10052	8584	3995
2003	25710	19551	16358	9352	12897	10248	8783	4114	13665	10771	9294	4371
2004	27385	20465	17103	10282	13725	10692	9094	4631	14555	11241	9628	4927
2005	29832	21765	18752	11080	14925	11326	9773	5152	15757	11895	10351	5406
2006	34412	24806	21900	12512	17535	13139	11602	5933	18448	13729	12176	6272
2007	36038	25094	22325	13713	18535	13547	11955	6580	19307	13965	12454	6853
2008	36499	24947	22504	13995	19612	14047	12784	6828	20379	14474	13231	7148
2009	37076	24843	22647	14429	20465	14409	13172	7293	21357	14892	13733	7624
2010	38319	25297	23007	15312	21099	14727	13360	7739	22067	15250	14003	8064
2011	41363	27166	25025	16338	22794	15934	14473	8321	23768	16451	15084	8684
2012	41533	26712	25142	16391	23181	15909	14751	8430	24126	16388	15341	8785
2013	43995	27541	26824	17171	25056	16815	16003	9053	26031	17276	16609	9422
2014	47076	29648	28829	18247	28641	19318	18415	10226	29645	19823	19033	10612
2015	52479	33701	33034	19445	33092	22755	21685	11407	34166	23262	22359	11807
2016	63635	41990	41556	22079	42203	29716	28466	13737	43444	30347	29234	14210
2017	70347	46613	46684	23663	47610	33480	32371	15239	48874	34107	33125	15749
2018	67553	43758	45090	22463	46882	32663	32142	14740	48150	33298	32918	15232

Source: Authors calculations from the NVSS multiple-cause-of-death mortality files.

Table 2: Deceased Organ Donors by Mechanism of Death (Drug Intoxication or Other), Year, Age, and Gender

	Drug Intoxication Death				All Other Mechanisms of Death			
Year	All	Young (18-49)	Male	Female	All	Young (18-49)	Male	Female
2000	66	58	35	31	5924	3047	3451	2472
2001	84	70	47	37	5999	3113	3531	2468
2002	107	96	57	50	6089	3224	3640	2449
2003	138	113	75	63	6324	3282	3721	2603
2004	188	145	91	97	6964	3556	4019	2945
2005	158	135	79	79	7437	3800	4345	3092
2006	230	194	135	95	7793	3998	4649	3144
2007	268	227	148	120	7826	4027	4734	3092
2008	285	240	153	132	7708	3929	4583	3125
2009	322	272	168	154	7701	3836	4560	3141
2010	342	299	179	163	7604	3942	4506	3098
2011	473	412	238	235	7657	3998	4528	3129
2012	441	394	231	210	7707	4075	4592	3115
2013	560	496	309	251	7714	3984	4601	3113
2014	625	554	374	251	7977	4216	4793	3184
2015	848	770	501	347	8236	4313	4987	3249
2016	1262	1149	763	499	8717	4606	5197	3520
2017	1384	1225	798	586	8907	4683	5403	3504
2018	1401	1256	834	567	9322	4851	5662	3660

Notes: Authors' calculations from the SRTR data. "All Other Mechanisms of Death" include Gunshot / Stab wound, Blunt Injury, Seizure, Stroke, SIDS, Asphyxiation, Cardiovascular, Drowning, Electrical, Natural Causes, and "None of the above."

Table 3: Average Number of Organs Transplanted per Donor, by Mechanism of Death

Mechanism of Death:	Total	Kidney	Liver	Heart	Lung	Pancreas	Intestine
Drowning	3.23	1.77	0.75	0.41	0.12	0.13	0.06
Seizure	3.25	1.58	0.71	0.36	0.42	0.15	0.04
Drug Intoxication	**3.14**	**1.53**	**0.78**	**0.36**	**0.36**	**0.10**	**0.01**
Asphyxiation	3.39	1.70	0.76	0.38	0.33	0.20	0.03
Cardiovascular	2.34	1.29	0.66	0.15	0.17	0.06	0.01
Electrical	3.20	1.76	0.71	0.36	0.21	0.14	0.02
Gunshot Wound	4.34	1.77	0.89	0.58	0.71	0.35	0.02
Stab	3.52	1.74	0.77	0.39	0.40	0.22	0.00
Blunt Injury	3.69	1.74	0.81	0.46	0.39	0.26	0.03
SIDS	2.41	0.70	0.60	0.73	0.04	0.12	0.21
Intracranial Hemorrhage/Stroke	2.62	1.28	0.75	0.18	0.32	0.08	0.01
Death from Natural Causes	2.67	1.42	0.67	0.24	0.25	0.08	0.01
None of the Above	3.02	1.50	0.71	0.34	0.29	0.14	0.04
Unknown	1.40	0.24	0.30	0.48	0.32	0.04	0.02

Source: Authors' calculations using 2000-2018 SRTR data.

Table 4: Estimates of the Effect of Drug-Related Deaths on Organ Donors and Transplants

Panel A: DI Donors and Transplants

	Donors			Transplants		
Independent Variable	(1)	(2)	(3)	(4)	(5)	(6)
Opioid-Related Deaths	0.0189			0.0581		
	(0.0017)			(0.0064)		
Opioid Overdoses		0.0193			0.0594	
		(0.0017)			(0.0064)	
Drug Overdoses			0.0183			0.0568
			(0.0019)			(0.0069)
Mean of dependent variable:		0.1266			0.3931	

Panel B: All Donors and Transplants

	Donors			Transplants		
Opioid-Related Deaths	0.0143			0.0387		
	(0.0054)			(0.0161)		
Opioid Overdoses		0.0149			0.0406	
		(0.0055)			(0.0163)	
Drug Overdoses			0.0184			0.0479
			(0.0044)			(0.0122)
Mean of dependent variable:		2.0434			6.3006	

Notes: Cell entries represent estimates from twelve different regressions. All estimation samples consist of 57 DSAs from 2000 to 2018 (N=12,996). The unit of observation is a DSA-month. All models include indicators for month-years and DSAs, DSA unemployment rates and a set of policies related to donation and drug overdose outcomes. Standard errors, listed in parentheses, are robust to clustering within DSA over time. Sample means are measured per million DSA residents.

Table 5: Estimates of the Effect of Opioid-Related Deaths on Organ Donations Due to Drug Intoxication and Transplants from Drug Intoxication Donors, by Excess Demand for Organs

	Dependent variables:							
	Drug Intoxication Donors		Transplants from DI Donors		In-DSA Transplants from DI Donors		Out-of-DSA Transplants from DI Donors	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Opioid-Related Deaths	0.0228	0.0144	0.0715	0.0450	0.0451	0.0222	0.0263	0.0227
	(0.0018)	(0.0018)	(0.0070)	(0.0063)	(0.0069)	(0.0054)	(0.0031)	(0.0038)
Mean of dependent variable	0.1895	0.1737	0.5953	0.5380	0.4099	0.3054	0.1850	0.2317
DSAs	29	28	29	28	29	28	29	28
DSAs with high excess organ demand	x		x		x		x	
DSAs with low excess organ demand		x		x		x		x

Notes: Cell entries represent estimates from 8 different regressions. All estimation samples consist of DSAs from 2008 to 2018. The unit of observation is a DSA-month. All models include indicators for DSAs and month-years and a set of DSA-month variables described in the text. We define DSAs with excess demand (the average number of transplant candidates who join organ waitlists each month divided by the average number of monthly transplants) in the 2000-2007 period above the median as *high excess demand* and those below the median as *low excess demand*. Standard errors, listed in parentheses, are robust to clustering with DSA over time. Sample means for relevant dependent variables are measured per million DSA residents.

Table 6: Estimates of the Effect of Opioid-Related Deaths on Waitlist Additions by Organ, Location, and Multilisting Status

	All	In-DSA	Out-of-DSA	Multilisters
	(1)	(2)	(3)	(4)
All organs	0.0279	0.0053	0.0226	0.0071
	(0.0416)	(0.0270)	(0.0199)	(0.0155)
	[14.7615]	[11.4479]	[3.3137]	[3.8567]
Kidneys	-0.0109	-0.0231	0.0122	0.0046
	(0.0267)	(0.0188)	(0.0140)	(0.0136)
	[8.9536]	[7.2132]	[1.7404]	[2.6619]
Liver	0.0419	0.0313	0.0106	0.0031
	(0.0172)	(0.0106)	(0.0074)	(0.0024)
	[3.1101]	[2.2988]	[0.8113]	[0.5211]
Heart	-0.0026	-0.0022	-0.0003	-0.0014
	(0.0034)	(0.0026)	(0.0016)	(0.0006)
	[0.9783]	[0.7555]	[0.2228]	[0.1081]
Lungs	0.0024	0.0011	0.0013	-0.0002
	(0.0060)	(0.0027)	(0.0039)	(0.0014)
	[0.6216]	[0.3909]	[0.2308]	[0.0819]
Pancreas	-0.0018	-0.0013	-0.0004	-0.0008
	(0.0037)	(0.0019)	(0.0021)	(0.0013)
	[0.1779]	[0.1203]	[0.0576]	[0.0657]
Intestines	-0.0008	0.0001	-0.0009	-0.0003
	(0.0025)	(0.0003)	(0.0022)	(0.0006)
	[0.0572]	[0.0207]	[0.0365]	[0.0107]

Notes: The table represents 28 different regressions where the dependent variable in columns 1-4 is the number of wait list additions by category. All estimation samples consist of 57 DSAs from 2000 to 2018. The unit of observation is a DSA-month. All models include indicators for DSAs and month-years and a set of DSA-month variables described in the text. Standard errors, listed in parentheses, are robust to clustering with DSA over time. Sample means for relevant dependent variables are listed in brackets, with all variables measured per million DSA residents.

Table 7: Estimates of the Effect of Opioid-Related Deaths on Living-Donor Transplants

	All Organs	Kidneys	All Except Kidneys
Independent variable:	(1)	(2)	(3)
Opioid Deaths	-0.0017	-0.0047	0.0030
	(0.0057)	(0.0065)	(0.0019)
	[1.7374]	[1.5690]	[0.0713]

Notes: Cell entries represent 3 separate regressions, where the dependent variable is the number of living-donor transplants: overall, kidneys only, and all organs except kidneys. All estimation samples consist of 57 DSAs from 2000 to 2018. The unit of observation is a DSA-month. All models include indicators for DSAs and month-years and the DSA-month controls described in the text. Standard errors, listed in parentheses, are robust to clustering with DSA over time. Sample means for relevant dependent variables are listed in brackets, with all variables measured per million DSA residents.

Table 8: Instrumental Variables Estimates of the Effect of Opioid-Related Deaths on DI Organ Donations Using DSA Triplicate Status as an Instrument

	Reduced-form estimates of the effects of *Triplicate Status* on			Instrumental Variables Estimates of the Effect of *Opioid-Related Deaths* on	
	Opioid-Related Deaths	*DI Donors*	*Transplants from DI Donors*	*DI Donors*	*Transplants from DI Donors*
	(1)	(2)	(3)	(4)	(5)
All years	-3.4615	-0.0748	-0.2140	0.0216	0.0618
	(0.7951)	(0.0237)	(0.0703)	(0.0041)	(0.0121)
Sample Means of Dependent Variable:	5.7922	0.1002	0.3089	0.1002	0.3089

Notes: The table represents three different first stage and reduced form regressions, plus the corresponding two instrumental variables regressions. All estimation samples consist of states from 1994 to 2018. The unit of observation is a state-month. All models include month-year indicators and a set of state-month variables described in the text. Standard errors, listed in parentheses, are robust to clustering with state over time. Dependent variables are measured per million state residents.

March 2023

Opioids and Organs: How Overdoses Affect the Supply and Demand for Organ Transplants

ONLINE APPENDIX

Table A1
Crosswalk of Organ Procurement Organizations and Abbreviations

OPO Abbreviation	OPO	OPO State
ALOB	Legacy of Hope	AL
AROR	Arkansas Regional Organ Recovery Agency	AR
AZOB	Donor Network of Arizona	AZ
CADN	Donor Network West	CA
CAGS	Sierra Donor Services	CA
CAOP	OneLegacy	CA
CASD	Lifesharing - A Donate Life Organization	CA
CORS	Donor Alliance	CO
DCTC	Washington Regional Transplant Community	VA
FLFH	TransLife	FL
FLMP	Life Alliance Organ Recovery Agency	FL
FLUF	LifeQuest Organ Recovery Services	FL
FLWC	LifeLink of Florida	FL
GALL	LifeLink of Georgia	GA
HIOP	Legacy of Life Hawaii	HI
IAOP	Iowa Donor Network	IA
ILIP	Gift of Hope Organ & Tissue Donor Network	IL
INOP	Indiana Donor Network	IN
KYDA	Kentucky Organ Donor Affiliates	KY
LAOP	Louisiana Organ Procurement Agency	LA
MAOB	New England Organ Bank	MA
MDPC	The Living Legacy Foundation of Maryland	MD
MIOP	Gift of Life Michigan	MI
MNOP	LifeSource Upper Midwest Organ Procurement Organization	MN
MOMA	Mid-America Transplant Services	MO
MSOP	Mississippi Organ Recovery Agency	MS
MWOB	Midwest Transplant Network	KS
NCCM	LifeShare Carolinas	NC
NCNC	Carolina Donor Services	NC
NEOR	Live On Nebraska	NE
NJTO	New Jersey Organ and Tissue Sharing Network OPO	NJ
NMOP	New Mexico Donor Services	NM
NVLV	Nevada Donor Network	NV
NYAP	Center for Donation and Transplant	NY
NYFL	Finger Lakes Donor Recovery Network	NY
NYRT	LiveOnNY	NY
NYWN	Upstate New York Transplant Services Inc	NY
OHLB	Lifebanc	OH
OHLC	Life Connection of Ohio	OH

OPO Abbreviation	OPO	OPO State
OHLP	Lifeline of Ohio	OH
OHOV	LifeCenter Organ Donor Network	OH
OKOP	LifeShare Transplant Donor Services of Oklahoma	OK
ORUO	Pacific Northwest Transplant Bank	OR
PADV	Gift of Life Donor Program	PA
PATF	Center for Organ Recovery and Education	PA
PRLL	LifeLink of Puerto Rico	PR
SCOP	We Are Sharing Hope SC	SC
TNDS	Tennessee Donor Services	TN
TNMS	Mid-South Transplant Foundation	TN
TXGC	LifeGift Organ Donation Center	TX
TXSA	Texas Organ Sharing Alliance	TX
TXSB	Southwest Transplant Alliance	TX
UTOP	DonorConnect	UT
VATB	LifeNet Health	VA
WALC	LifeCenter Northwest	WA
WIUW	UW Health Organ and Tissue Donation	WI
CTOP	LIfeChoice Donor Services	MA
WIDN	Versiti Wisconsin, Inc.	WI

Table A2: Estimates of the Effect of Drug-Related Deaths on Organ Donors and Transplants - Excluding Covariates capturing policies related to donation and drug overdose outcomes

Panel A: DI Donors and Transplants

	Donors			Transplants		
Independent Variable	(1)	(2)	(3)	(4)	(5)	(6)
Opioid-Related Deaths	0.0210			0.0643		
	(0.0017)			(0.0061)		
Opioid Overdoses		0.0214			0.0657	
		(0.0017)			(0.0061)	
Drug Overdoses			0.0202			0.0624
			(0.0022)			(0.0076)
Mean of dependent variable:		0.1266			0.3931	

Panel B: All Donors and Transplants

	Donors			Transplants		
Opioid-Related Deaths	0.0146			0.0404		
	(0.0053)			(0.0161)		
Opioid Overdoses		0.0151			0.0419	
		(0.0054)			(0.0164)	
Drug Overdoses			0.0178			0.0472
			(0.0043)			(0.0126)
Mean of dependent variable:		2.0434			6.3006	

Notes: Cell entries represent estimates from twelve different regressions. All estimation samples consist of 57 DSAs from 2000 to 2018 (N=12,996). The unit of observation is a DSA-month. All models include indicators for month-years and DSAs and DSA unemployment rates. Standard errors, listed in parentheses, are robust to clustering within DSA over time. Sample means are measured per million DSA residents.

Table A3: Estimates of the Effect of Opioid-Related Deaths on Organ Donors and Transplants by Mechanism of Death other than DI

	(1) Seizure/Stroke	(2) Drowning/Asphyxiation	(3) Cardiovascular/Natural Causes	(4) Violent Injury	(5) SIDS
Independent Variable:					
Panel A: Donors					
Opioid-Related Deaths	-0.0037	-0.0010	0.0044	-0.0029	0.0001
	(0.0021)	(0.0009)	(0.0024)	(0.0014)	(0.0001)
Mean of dependent variable:	0.7642	0.1036	0.3016	0.6918	0.0023
Panel B: Transplants					
Opioid-Related Deaths	-0.0138	-0.0038	0.0110	-0.0088	0.0001
	(0.0060)	(0.0029)	(0.0056)	(0.0062)	(0.0001)
Mean of dependent variable:	2.0637	0.3356	0.7558	2.5866	0.0050

Notes: Cell entries represent estimates from ten different regressions. All estimation samples consist of 57 DSAs from 2000 to 2018 (N=12,996). The unit of observation is a DSA-month. All models include indicators for month-years and DSAs, DSA unemployment rates and a set of policies related to donation and drug overdose outcomes. Standard errors, listed in parentheses, are robust to clustering within DSA over time. Sample means are measured per million DSA residents.

Table A4: Estimates of the Effect of Other (Non-DI) Mechanisms of Death on Organ Donors and Transplants from those with the same (Non-DI) Mechanism of Death

Panel A: Donors

	(1) Seizure/Stroke	(2) Drowning/Asphyxiation	(3) Cardiovascular/Natural Causes	(4) Violent Injury	(5) SIDS
Independent Variable:					
Deaths from Mechanism Y	0.0056	0.0024	0.0004	0.0161	0.0017
	(0.0012)	(0.0006)	(0.0003)	(0.0018	(0.0007)
Mean of dependent variable:	0.7642	0.1036	0.3016	0.6918	0.0023

Panel B: Transplants

	(1) Seizure/Stroke	(2) Drowning/Asphyxiation	(3) Cardiovascular/Natural Causes	(4) Violent Injury	(5) SIDS
Deaths from Mechanism Y	0.0171	0.0073	0.0012	0.0589	0.0035
	(0.0035)	0.0020	(0.0007)	(0.0047)	(0.0020)
Mean of dependent variable:	2.0637	0.3356	0.7558	2.5866	0.0050

Notes: Cell entries represent estimates from ten different regressions. All estimation samples consist of 57 DSAs from 2000 to 2018 (N=12,996). The unit of observation is a DSA-month. All models include indicators for month-years and DSAs, DSA unemployment rates and a set of policies related to donation and drug overdose outcomes. Standard errors, listed in parentheses, are robust to clustering within DSA over time. Sample means are measured per million DSA residents.

Table A5: Estimates of the Effect of Opioid-Related Deaths on Organ Donations Due to Drug Intoxication, by Gender and Age

	Pooled	Men	Women
	(1)	(2)	(3)
Overall	0.0189	0.0105	0.0084
	(0.0017)	(0.0013)	(0.0008)
	[0.1266]	[0.0720]	[0.0546]
Age Categories:			
<18	0.0003	0.0001	0.0002
	(0.0001)	(0.0001)	(0.0001)
	[0.0039]	[0.0021]	[0.0018]
18-34	0.0102	0.0048	0.0054
	(0.0011)	(0.0005)	(0.0007)
	[0.0740]	[0.0454]	[0.0286]
35-49	0.0068	0.0026	0.0041
	(0.0008)	(0.0004)	(0.0006)
	[0.0385]	[0.0203]	[0.0182]
50-64	0.0015	0.0008	0.0007
	(0.0002)	(0.0001)	(0.0002)
	[0.0099]	[0.0041]	[0.0057]
65+	0.0002	0.0001	0.0001
	(0.0001)	(0.0000)	(0.0001)
	[0.0003]	[0.0001]	[0.0002]

Notes: Cell entries represent estimates from 18 separate regressions with organ donors by age and gender category as the dependent variable and opioid-related deaths as the independent variable. All estimation samples consist of 57 DSAs from 2000 to 2018. The unit of observation is a DSA-month. All models include indicators for DSAs and month-years and a set of DSA-month variables described in the text. Standard errors, listed in parentheses, are robust to clustering with DSA over time. Sample means for relevant dependent variables are listed in brackets, with all variables measured per million DSA residents.

Table A6: Estimates of the Effect of Opioid-Related Deaths on Organ Donations Due to Drug Intoxication

Independent variables:	Donors	Transplants
opioid_deaths×2000	0.0061	0.0186
	(0.0037)	(0.0121)
opioid_deaths×2001	0.0070	0.0220
	(0.0040)	(0.0125)
opioid_deaths×2002	0.0072	0.0190
	(0.0033)	(0.0112)
opioid_deaths×2003	0.0064	0.0211
	(0.0036)	(0.0107)
opioid_deaths×2004	0.0046	0.0190
	(0.0040)	(0.0119)
opioid_deaths×2005	0.0041	0.0122
	(0.0036)	(0.0112)
opioid_deaths×2006	0.0058	0.0234
	(0.0031)	(0.0093)
opioid_deaths×2007	0.0065	0.0218
	(0.0040)	(0.0123)
opioid_deaths×2008	0.0066	0.0188
	(0.0039)	(0.0129)
opioid_deaths×2009	0.0070	0.0246
	(0.0033)	(0.0103)
opioid_deaths×2010	0.0058	0.0228
	(0.0026)	(0.0083)
opioid_deaths×2011	0.0111	0.0376
	(0.0022)	(0.0080)
opioid_deaths×2012	0.0135	0.0504
	(0.0031)	(0.0101)
opioid_deaths×2013	0.0147	0.0460
	(0.0030)	(0.0093)
opioid_deaths×2014	0.0168	0.0462
	(0.0028)	(0.0063)
opioid_deaths×2015	0.0165	0.0496
	(0.0019)	(0.0065)
opioid_deaths×2016	0.0214	0.0631
	(0.0029)	(0.0099)
opioid_deaths×2017	0.0204	0.0591
	(0.0019)	(0.0071)
opioid_deaths×2018	0.0233	0.0777
	(0.0015)	(0.0057)
Mean of Dependent Variable	0.1266	0.3931

Notes: The table presents estimates of γ_{YEAR} from equation (2) in the text. The dependent variables are DI donors and DI-donor transplants in columns 1 and 2, respectively, both measured per million DSA residents. The unit of observation is a DSA-month. All models include indicators for DSAs and month-years and a set of DSA-month variables described in the text. Standard errors, listed in parentheses, are robust to clustering with DSA over time.

Table A7: Estimates of the Effect of Opioid-Related Deaths on Organ Transplants Due to Drug Intoxication by Excess Demand

Independent variables:	DI Transplants in High Excess Demand DSAs	DI Transplants in Low Excess Demand DSAs
opioid_deaths×2008	0.0124	0.0170
	(0.0200)	(0.0124)
opioid_deaths×2009	0.0205	0.0275
	(0.0134)	(0.0121)
opioid_deaths×2010	0.0266	0.0227
	(0.0135)	(0.0090)
opioid_deaths×2011	0.0573	0.0258
	(0.0119)	(0.0110)
opioid_deaths×2012	0.0648	0.0405
	(0.0188)	(0.0104)
opioid_deaths×2013	0.0671	0.0225
	(0.0141)	(0.0114)
opioid_deaths×2014	0.0517	0.0408
	(0.0080)	(0.0120)
opioid_deaths×2015	0.0595	0.0386
	(0.0041)	(0.0085)
opioid_deaths×2016	0.0725	0.0348
	(0.0092)	(0.0113)
opioid_deaths×2017	0.0637	0.0519
	(0.0085)	(0.0076)
opioid_deaths×2018	0.0809	0.0686
	(0.0062)	(0.0117)
Mean of Dependent Variable	0.5953	0.5380

Note: The estimates correspond to estimates presented graphically in Figure 5.

Table A8: Estimates of the Effect of Drug-Related Deaths on Organ Donors and Transplants by Organ

	DI Donors	DI Transplants	All Donors	All Transplants
	(1)	(2)	(3)	(4)
All organs	0.0189	0.0581	0.0143	0.0387
	(0.0017)	(0.0064)	(0.0054)	(0.0161)
	[0.1266]	[0.3931]	[2.0434]	[6.3006]
Kidneys		0.0287		0.0169
		(0.0026)		(0.0082)
		[0.2005]		[3.1415]
Liver		0.0166		0.0174
		(0.0017)		(0.0044)
		[0.1034]		[1.6622]
Heart		0.0062		0.0027
		(0.0010)		(0.0021)
		[0.0475]		[0.6748]
Lungs		0.0045		0.0011
		(0.0010)		(0.0027)
		[0.0274]		[0.4572]
Pancreas		0.0019		-0.0003
		(0.0005)		(0.0016)
		[0.0134]		[0.3280]
Intestines		0.0002		0.0009
		(0.0001)		(0.0003)
		[0.0008]		[0.0368]

Notes: The table represents 28 different regressions where the dependent variable is the number of donors or transplants. All estimation samples consist of 57 DSAs from 2000 to 2018. The unit of observation is a DSA-month. All models include indicators for DSAs and month-years and a set of DSA-month variables described in the text. Standard errors, listed in parentheses, are robust to clustering with DSA over time. Sample means for relevant dependent variables are listed in brackets, with all variables measured per million DSA residents.

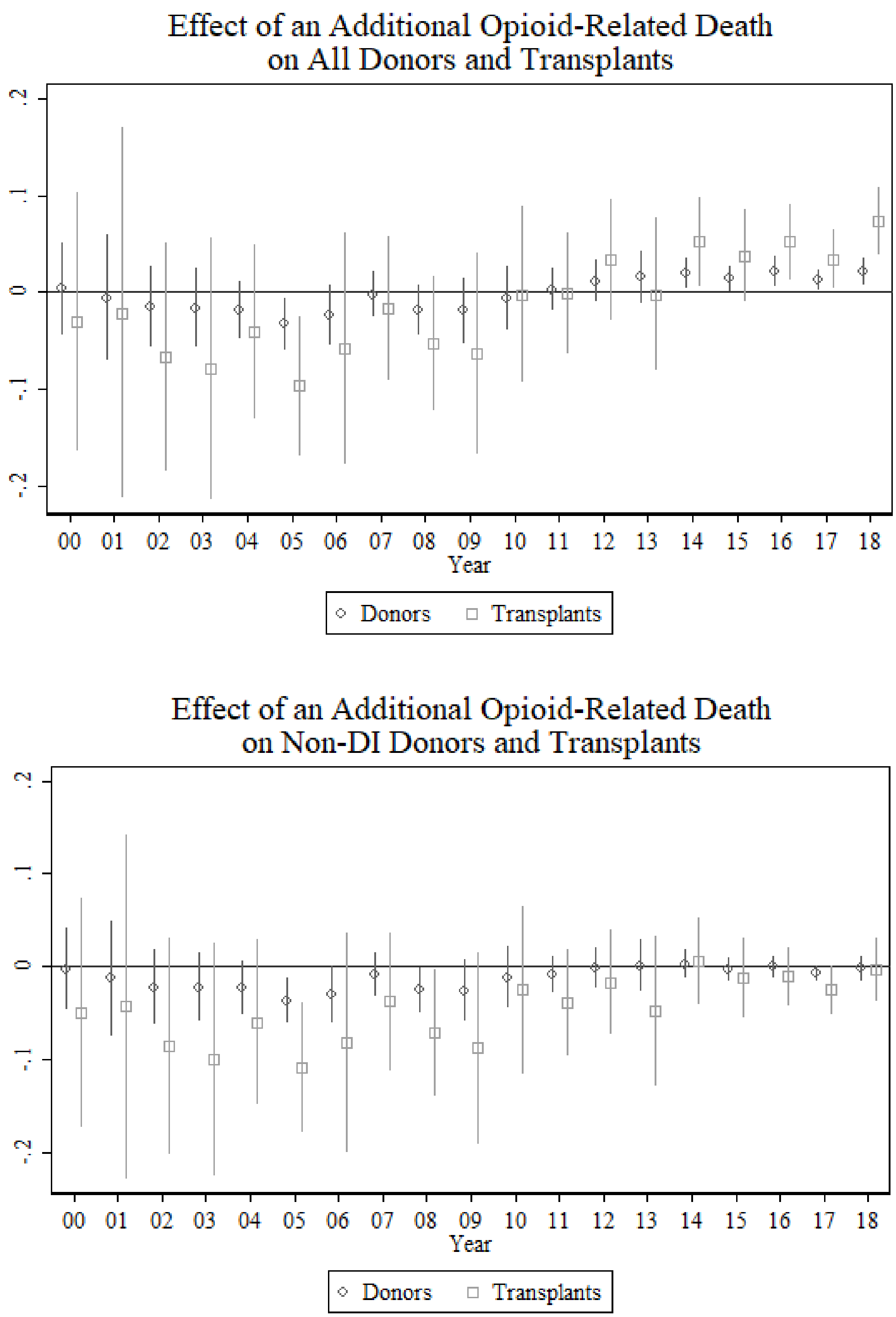
Table A9: Reduced-Form Estimates of the Effect of Triplicate Status on Organ Donations and Transplants Due to Drug Intoxication

Independent variables:	Opioid-related Deaths (1)	Donors (2)	Transplants (3)
Triplicate Binding×1994	0.2673	-0.0077	-0.0351
	(0.1532)	(0.0060)	(0.0154)
Triplicate Binding×1996	0.0400	-0.0020	-0.0128
	(0.2912)	(0.0034)	(0.0105)
Triplicate Binding×1997	-0.6687	-0.0315	-0.0983
	(0.2984)	(0.0152)	(0.0436)
Triplicate Binding×1998	-0.6313	-0.0338	-0.0938
	(0.3784)	(0.0202)	(0.0529)
Triplicate Binding×1999	-0.8146	-0.0277	-0.0783
	(0.4708)	(0.0185)	(0.0578)
Triplicate Binding×2000	-1.6337	-0.0188	-0.0468
	(0.7839)	(0.0227)	(0.0666)
Triplicate Binding×2001	-2.3135	-0.0309	-0.0794
	(1.0360)	(0.0217)	(0.0620)
Triplicate Binding×2002	-1.8427	-0.0248	-0.0589
	(0.6845)	(0.0191)	(0.0570)
Triplicate Binding×2003	-2.3396	-0.0281	-0.0691
	(0.6539)	(0.0206)	(0.0574)
Triplicate Binding×2004	-2.6671	-0.0278	-0.0964
	(0.7230)	(0.0201)	(0.0579)
Triplicate Binding×2005	-3.0115	-0.0146	-0.0228
	(0.8292)	(0.0202)	(0.0621)
Triplicate Binding×2006	-2.6562	-0.0423	-0.1186
	(0.9930)	(0.0208)	(0.0620)
Triplicate Binding×2007	-3.0209	-0.0596	-0.1879
	(0.7677)	(0.0236)	(0.0656)
Triplicate Binding×2008	-3.0796	-0.0683	-0.1818
	(0.9505)	(0.0154)	(0.0479)
Triplicate Binding×2009	-2.7986	-0.0595	-0.1501
	(0.9462)	(0.0222)	(0.0746)
Triplicate Binding×2010	-3.2590	-0.0673	-0.2172
	(0.9883)	(0.0174)	(0.0547)
Triplicate Binding×2011	-3.3347	-0.0908	-0.2693
	(0.9910)	(0.0240)	(0.0833)
Triplicate Binding×2012	-3.2538	-0.0827	-0.2456
	(1.1064)	(0.0254)	(0.0713)
Triplicate Binding×2013	-3.8543	-0.0877	-0.2867
	(1.0341)	(0.0348)	(0.1111)
Triplicate Binding×2014	-5.5136	-0.1329	-0.3607
	(1.0114)	(0.0267)	(0.0845)
Triplicate Binding×2015	-5.9412	-0.1506	-0.4461
	(1.2334)	(0.0319)	(0.1053)
Triplicate Binding×2016	-6.7418	-0.1569	-0.4446
	(1.6928)	(0.0536)	(0.1691)

Triplicate Binding×2017	-6.7917	-0.1777	-0.4907
	(1.8045)	(0.0571)	(0.1644)
Triplicate Binding×2018	-5.5451	-0.1751	-0.5764
	(1.0917)	(0.0333)	(0.1117)
Mean of Dependent Variable	5.7922	0.1002	0.3089

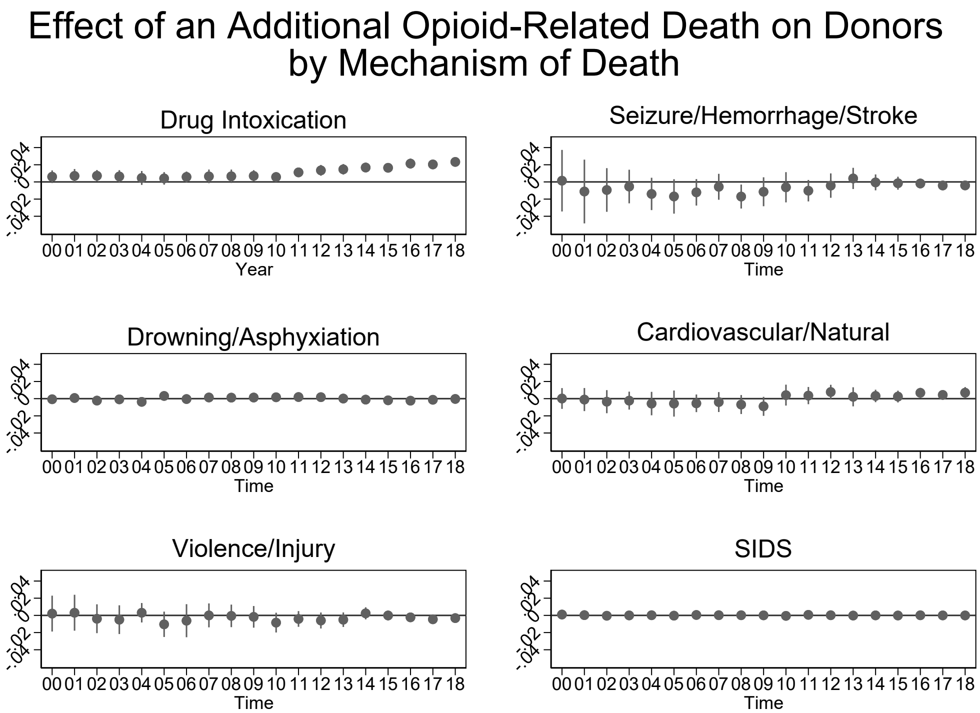
Notes: The table presents estimates of γ_{YEAR} from equation (5) in the text. The dependent variable in column 1 is organ donors and the dependent variable in column 2 is organ transplants, both measured per million DSA residents. All estimation samples consist of 50 states from 1994 to 2018. The unit of observation is a DSA-month. All models include indicators for DSAs and month-years and a set of DSA-month variables described in the text. Standard errors, listed in parentheses, are robust to clustering with DSA over time.

Figure A1



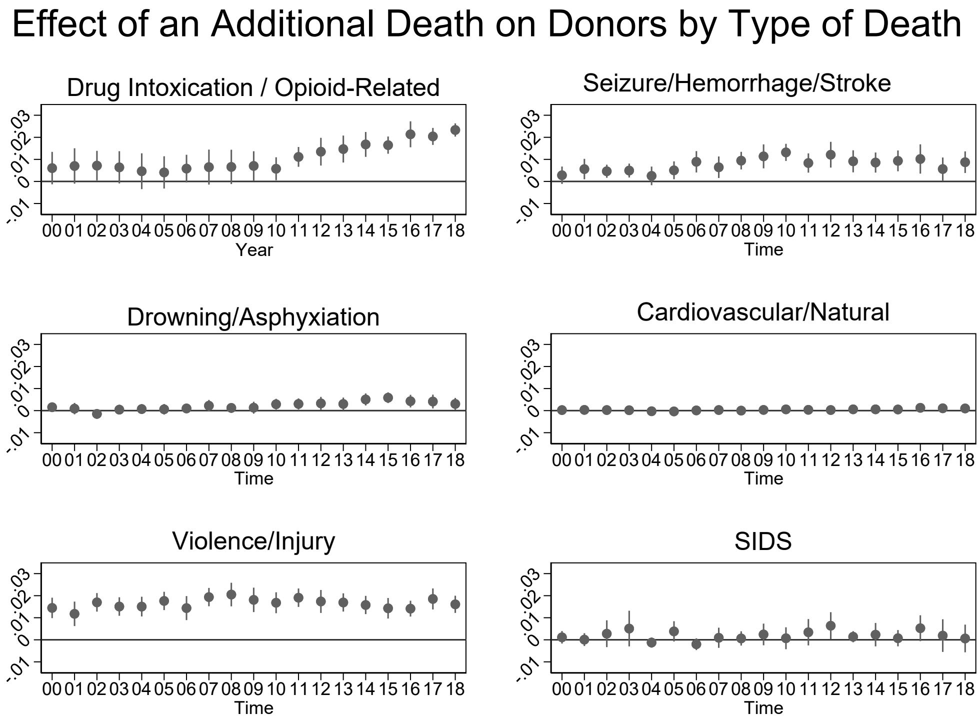
Notes: The figures present estimates of γ_{YEAR} from equation (2) in the text. Each point in Panels A and B represent the estimated effect of an opioid-related death on non-DI donors (or the number of transplants from those donors) and all donors, respectively, for a given year from 2000-2018. Authors' calculations from the Vital Statistics Mortality Data and SRTR data. The vertical lines in the figure represent 95 percent confidence intervals.

Figure A2



Notes: The figures present estimates of γ_{YEAR} from equation (2) in the text. Each point represents the estimated effect of an opioid-related death on donors by mechanism of death, respectively, for a given year from 2000-2018. Authors' calculations from the Vital Statistics Mortality Data and SRTR data. The vertical lines in the figure represent 95 percent confidence intervals.

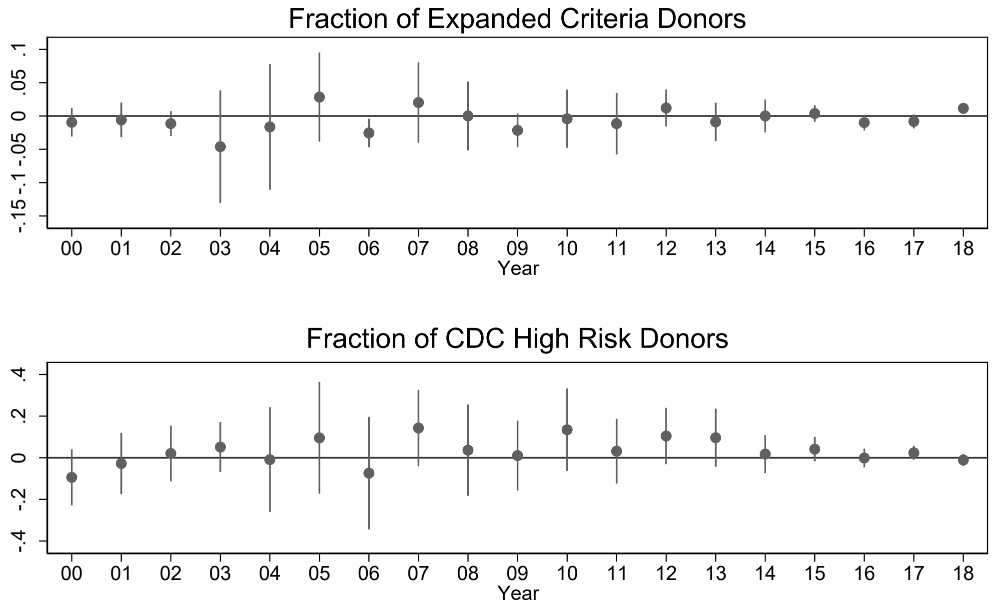
Figure A3



Notes: The figures present estimates of γ_{YEAR} from equation (2) in the text. Each point represents the estimated effect of a death on donors by mechanism of death for a given year from 2000-2018. For example, the top right panel estimates the relationship between an additional seizure/hemorrhage/stroke death on organ donors who died of a seizure/hemorrhage/stroke. Authors' calculations from the Vital Statistics Mortality Data and SRTR data. The vertical lines in the figure represent 95 percent confidence intervals.

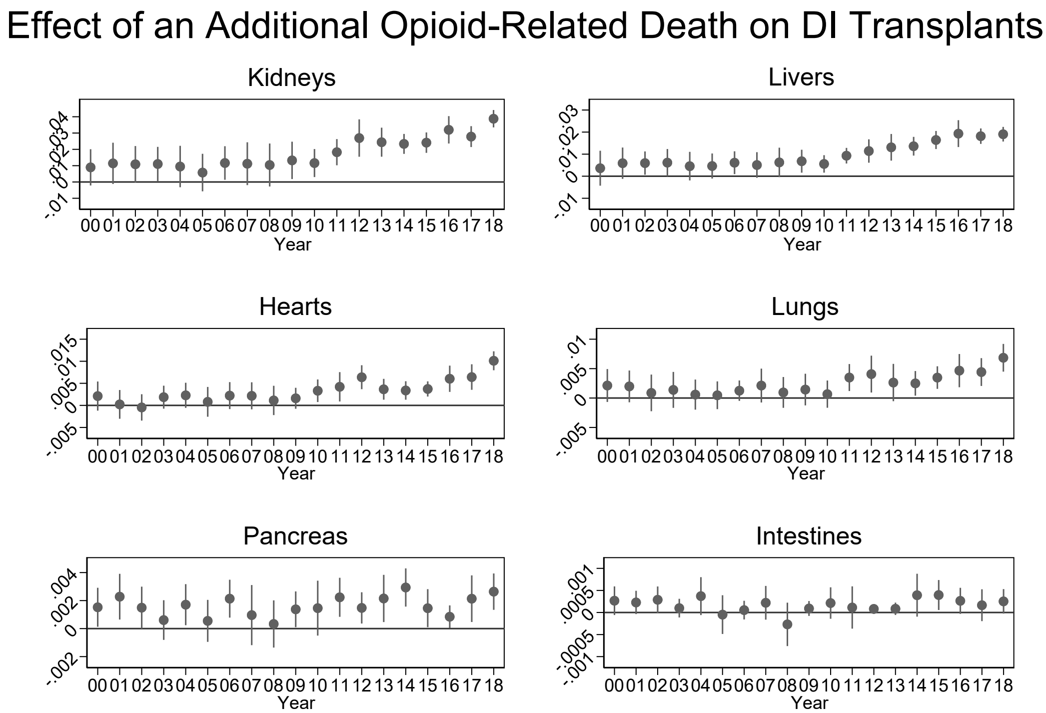
Figure A4

Effect of an Additional Opioid-Related Death on Donor Composition



Notes: The figures present estimates of γ_{YEAR} from equation (2) in the text. Each point represents the estimated effect of an opioid-related death on the fraction of expanded criteria donors (donors with higher age, and/or combinations of the following: significant medical histories, death resulting from stroke, or history of high-risk social behaviors; see, e.g., *https://stanfordhealthcare.org/medical-treatments/l/liver-transplant/types/expanded-criteria-donor.html*) and the fraction of high risk donors (which includes donors that meet certain criteria thought to increase the risk of undetected human immunodeficiency virus (HIV), hepatitis B virus infection, or hepatitis C virus (HCV) infection; see, e.g., https://www.jtcvs.org/article/S0022-5223(18)32285-2/pdf) in each year from 2000-2018. The vertical lines in the figure represent 95 percent confidence intervals.

Figure A5



Notes: The figure presents estimates of γ_{YEAR} from equation (2) in the text. Each point represents the estimated effect of an opioid-related death on the number of specific organ transplants from DI donors for a given year from 2000-2018. Authors' calculations from the Vital Statistics Mortality Data and SRTR data. The vertical lines in the figure represent 95 percent confidence intervals.