Donorcycles: Motorcycle Helmet Laws and the Supply of Organ Donors*

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Abstract:

Traffic safety mandates are typically designed to reduce the harmful externalities of risky behaviors. We consider whether motorcycle helmet laws also reduce a beneficial externality by decreasing organ donation rates. Our central estimates show that state-level counts of organ donors killed in motor vehicle accidents increase by 10 percent following helmet law repeals. In contrast, organ donations due to circumstances other than motor vehicle accidents do not respond to variation in helmet mandates. The estimates imply that every death of a helmetless motorcyclist prevents or delays as many as 0.33 deaths among individuals on organ transplant waiting lists.

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I. Introduction

Empirical evidence consistently shows that motorcyclist deaths are disproportionately concentrated among those riding without a helmet. Based in part on this evidence, helmetless motorcyclists are perceived as a major source of transplantable organs, particularly within the medical trauma community.[1] The perceived link between helmet usage and organ donation has even motivated two recently proposed laws: in 2003, California Assembly Bill 1200 and New Mexico Senate Bill 239 would have made consent for organ donation *presumed* for all helmetless motorcyclists involved in fatal accidents.[2] Both bills ultimately failed, so organ donation in all 50 states still requires *informed* consent in the form of explicit written authorization from either the potential donor or surviving family members.

Despite the perception that helmet usage reduces organ donation rates, no previous research investigates whether such a link exists. Estimates of the magnitude of this relationship are essential to cost-benefit analyses of government regulation of motorcycle helmet use. Currently, cost-benefit arguments are largely based on weighing personal freedoms against the negative externalities associated with helmetless motorcycling, including costs to public health programs resulting from the high rates of injury and death among those involved in accidents

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[1] According to an anonymous transplant surgeon quoted on *New York Times'* online "Wheels" blog in 2008, "[m]otorcycle fatalities are not only our No. 1 source of organs, they are also the highest-quality source of organs, because donors are usually young, healthy people with no other traumatic injuries to the body, except to the head…" http://wheels.blogs.nytimes.com/2008/07/07/brain-dead-why-are-there-no-mandatory-helmet-laws/ (accessed August 3, 2009). Similarly, Trauma.org, an organization of professionals in trauma and critical care, published a discussion about helmet laws that included several mentions of the word "donorcycle" and claims by physicians such as "[w]asn't there a study a couple of years ago which showed organ donations went down by a third when motorcycle helmet laws were strickly (sic) enforced?" http://www.trauma.org/archive/archives/helmet.html (accessed March 9, 2009).

[2] For the specific language of the California and New Mexico bills, see http://info.sen.ca.gov/pub/03-04/bill/asm/ab_1151-1200/ab_1200_cfa_20040109_124839_asm_comm.html and http://www.nmlegis.gov/Sessions/03%20Regular/bills/senate/SB0239.pdf, respectively (accessed March 9, 2009). Under this presumed consent paradigm, motorcyclists could "opt out" of being potential donors only by signing a form explicitly prohibiting their organs for use in transplants. Several European nations currently operate under a presumed consent paradigm; see Abadie and Gay (2006) for more details.

(GAO 1991). We intend to measure an additional, unintended cost of government helmet regulation. More broadly, quantifying the effect of helmet laws on organ donation rates provides insight into how these laws contribute to the severe shortage of organs in the United States.

Using state- and year-specific data on organ donation and variation across states and time in helmet laws, we present evidence that helmet laws reduce organ donation rates. Our estimates suggest that statewide helmet mandates are associated with nearly 10 percent reductions in the number of organ donors who die in motor vehicle accidents (MVAs). In contrast, helmet laws are unrelated to the number of organ donors who die due to non-MVA circumstances such as homicide or natural causes. As further evidence that the estimates identify a causal mechanism, we find large effects of helmet laws on MVA donation rates among men but not among women, which is compelling because men account for more than 90 percent of annual motorcyclist fatalities. Combined with estimates of the effect of helmet laws on motorcycle fatalities, the central results suggest that every death prevented by motorcycle helmet laws shrinks the supply of organ donors by 0.124. Although this is a large effect within the population of motorcycle riders, it is small in relation to the excess demand for organs – eliminating helmet laws nationwide would only negligibly reduce the current shortage of organ donors in the United States.

In the following section, we review the history of helmet laws and describe the mechanism by which helmet laws could influence the supply of organ donors. Section 3 describes the organ donation data from the Organ Procurement and Transplantation Network and how they relate to publicly available traffic fatality data. Section 4 presents the empirical specifications and results, and Section 5 concludes.

II. Institutional Details of Helmet Laws and Their Link to Organ Donation

Between 1966 and 1995, the federal government twice implemented and retracted acts that set guidelines requiring all motorcycle riders to wear helmets. Although federal legislation has never been a strict mandate to states, which ultimately set helmet usage laws, it has included explicit threats to withhold federal highway funds from noncompliant states, resulting in substantial swings in state-level legislation.[3] No federal helmet legislation currently exists, but state legislatures continue to debate and modify their own helmet laws. Currently, 20 states have universal coverage laws, 27 states have partial coverage laws that typically mandate helmet usage for all riders under age 18, and 3 states do not require any riders to wear a helmet.[4] Since the most recent federal guidelines for helmet mandates were removed in 1995, six states (Arkansas, Texas, Kentucky, Louisiana, Florida, and Pennsylvania) repealed universal helmet laws, with Louisiana reinstituting their universal law in 2004. Appendix Table 1 shows the timing of these seven law changes, which play a key role in the analysis below on the link between helmet laws and organ donation.

The decline in the prevalence of helmet laws since 1995 is perhaps surprising in light of strong evidence that these laws increase helmet use and reduce fatalities. Using data from the

[3] The 1966 Highway Safety Act authorized the Secretary of Transportation to withhold up to 10 percent of federal highway construction funds from any state that did not adopt universal helmet laws. The Act was amended in 1976, eliminating the helmet law mandate and removing the authority to withhold funds. Under the 1991 Intermodal Surface Transportation Efficiency Act, states that enacted both universal helmet laws and seat belt laws would be eligible to receive federal grant money, while states that did not comply would be subject to a 3 percent reallocation of federal highway funds towards highway safety programs. The threat of reallocation was removed with the passage of the National Highway System Designation Act in 1995 (Houston and Richardson, 1995).

[4] For the purposes of this study, partial coverage laws are considered equivalent to having no helmet law due to enforcement difficulties and the high proportion of the riding population facing no restrictions. Although the most common partial coverage law requires helmets for riders under age 18, some states have restrictions for riders under age 15, 19, or 21. A handful of states currently require helmets for operators with instructional permits, less than one year of riding experience, or less than $10,000 of personal injury insurance. All helmet statutes specify maximum punishments for violation; for example, in Georgia, riding without a helmet is punishable by a fine of up to $1,000 and one year in jail, but the typical punishment for a first offense is a fine of $90. See http://www.iihs.org/laws/HelmetUseCurrent.aspx for more information on current state helmet laws.

2006 and 2007 National Occupant Protection Use Survey (NOPUS), a field study conducted by the National Highway Traffic Safety Administration to measure the use of motorcycle helmets and seat belts, we estimate helmet usage rates in states with a universal law to be 97.8%, compared to 54.2% in states with partial or no laws. Although the presence of helmet laws could be correlated with preferences of riders within a state, many studies using single-state data also find that helmet usage decreases from nearly 100 percent to roughly 55 percent following universal law repeals (see Berkowitz 1981, Dare et al. 1978, Gilbert et al. 2008, Kraus et al. 1995, Lund et al. 1991, Preusser et al. 2000, Struckman-Johnson 1980, Ulmer and Northrup 2005, and Ulmer and Preusser 2003).

Several additional studies measure the effectiveness of motorcycle helmets in protecting riders in the event of a crash, with arguably the most convincing approach based on within-vehicle variation in survival and helmet use among rider-passenger pairs. Using this approach, Dee (2009) found that helmets reduce fatality risk by 34 percent. A related literature estimates the effects of helmet laws on state-level fatality rates. Estimates based on within-state variation in fatalities and helmet laws over time suggest that universal helmet laws reduce per capita fatalities by more than 20 percent relative to partial laws and by 27 to 29 percent compared to no laws at all (Dee 2009, Houston and Richardson 2008, Sass and Zimmerman 2000).[5]

The Logistics of Organ Donation

Although brain death is rare, occurring in less than 1 percent of all deaths in the U.S., almost all non-living organ donors are brain dead at the time of organ recovery. In the context of organ donation, the crucial distinction between brain death, which involves the irreversible

[5] A number of additional studies focus on a single state before and after a helmet law change. For examples, see Auman et al. (2002), Bledsoe et al. (2002), Bledsoe and Li (2005), Eberhardt et al. (2008), Hotz et al. (2002), Kraus et al. (1994), Mayrose (2008), Mertz and Weiss (2008), Muller (2004), and Muller (2007).

cessation of all brain function, and the more common classification of death (known as "cardiac death") lies in the fact that the heart continues to beat after brain death occurs. Although lung function ends in both definitions of death, current medical technology allows for essentially indefinite respiration via a ventilator following brain death, so the internal organs receive oxygenated blood and remain fully functional and viable for transplantation. In contrast, organs deteriorate rapidly following cardiac deaths and are therefore unsuitable for transplantation except in extraordinary circumstances.[6] If the brain dead patient is otherwise healthy and provided informed consent for donation, either directly or through family members, surgeons instigate the process of organ recovery.[7]

Head trauma and ischemic stroke are the leading causes of brain death, and both conditions may leave the rest of the body in nearly pristine condition. The perception that helmetless motorcyclists are good candidates for organ donors is based on the notion that they can be killed in low-speed, relatively minor collisions solely as a result of head trauma. In contrast, a deceased helmeted cyclist or automobile occupant is likely to have been in a violent collision that caused widespread internal damage and cardiac death. Although the distinction between brain death and cardiac death is undocumented in the context of helmet laws, the existing evidence on helmet use and deaths implies that the incidence of brain death is likely to be lower when helmet laws are in place.

The final link between helmet laws and the supply of organs for transplantation involves the transition from brain death to consenting organ donor. Although federal law has always

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[6] An example of such a circumstance is the growing but controversial practice of "non-heart beating donation", in which patients with non-survivable brain injuries (who are not brain dead because they retain some minimal brain stem function) become donors. Donation in such cases entails removing the patient from a ventilator, typically in the operating room. Once the patient's heart stops beating, the physician declares the patient dead and organs are removed. See http://www.organtransplants.org/understanding/death/ for more details.

[7] "Otherwise healthy" individuals are defined as less than 70 years of age and lacking contraindications to organ donation defined by the International Classification of Diseases. Table 2 of Guandagnoli et al. (2003) lists these contraindications, which include cancer, HIV, hepatitis, and a number of other blood-borne infections.

maintained that health care professionals only need the potential donor's consent to recover organs, a practice known as *first-person* consent, health care professionals typically also seek permission from the potential donor's next-of-kin. Due primarily to low consent rates, donation rates among all potential donors range from 30 to 42 percent according to Guandagnoli et al. (2003) and Sheehy et al. (2003). Despite this apparent inefficiency in organ procurement, policies such as helmet laws that affect the incidence of brain death will likely affect the supply of organs for transplantation. We turn next to measuring the magnitude of this effect.

III. Data

The U.S. first established a unified transplantation network, the Organ Procurement Transplantation Network (OPTN), under directive from the 1984 National Organ Transplant Act. This act provided the authority to divide the United States into mutually exclusive donation service areas (DSAs), each of which was assigned to an Organ Procurement Organization (OPO). Each OPO is a local monopoly within its DSA, exclusively responsible for coordinating and facilitating donation services. One of OPTN's key initiatives involves collection and management of data from every donation and transplant occurring in the United States.[8]

The organ donation data used in this paper are DSA-level counts of deceased donors, available on the OPTN website (http://www.OPTN.org). There are 57 operational OPOs, and therefore DSAs, in the U.S. that provide data to the OPTN. In most cases, the aggregation from DSA to the state level is straightforward, but some DSAs cover part or all of multiple states. In these cases, we assign the donation statistics for the entire OPO to the state where the OPO is

[8] The National Organ and Transplant Act also outlawed the purchase and sale of organs and established the OPTN with the responsibilities of creating a system for matching organs to individuals. It also established OPOs as clearinghouses for acquiring useable organs, maintaining organ quality standards and allocating donated organs equitably (see http://optn.transplant.hrsa.gov/SharedContentDocuments/NOTA_as_amended_-_Jan_2008.pdf, accessed 5/19/09).

headquartered. Because our identification strategy is based on state variation in helmet laws, this assignment may present problems if deaths from a county in a given state are designated to another state's donor counts. However, as we describe below, our results are insensitive to restricting our analysis to DSAs that include only one state. Aggregating to the state level results in 38 observations per year because 13 states do not contain an OPO headquarters (D.C. contains its own OPO). Appendix Figure 1 shows a map of the geographic area of all DSAs, and a complete listing of OPO locations can be found at http://unos.org/members/directory.asp.

The OPTN website provides donor counts from 1988 onward, originating from the Deceased Donor Registration Worksheet filled out at the time of donation. This document lists data on the demographics, medical history, and certification of consent for each donor.[9] Beginning April 1st, 1994, the Worksheet also recorded the donor's circumstance of death, with separate categories for MVAs, other accidents such as falls, child abuse, suicide, homicide, none of the above, and, beginning in 1999, natural causes.

Table 1 presents the number of organ donors per million persons by circumstance of death and gender of donor from 1994 to 2007, with all circumstances other than MVAs aggregated to a single "All Others" category. Note that because reporting of "circumstance of death" began in April of 1994, all donors from the first three months of 1994 are listed in the "All Others" category, making recorded MVA donation rates artificially low in 1994. From 1995 to 2007, donations resulting from circumstances other than MVAs rose steadily for both males and females, increasing by roughly 43 percent from 15.29 to 21.85 per million persons. In contrast, donations due to MVAs were essentially flat during this period, declining from 5.43 to 5.36 per million from 1995 to 2007.

[9] For a sample Deceased Donor Registration Worksheet, see http://www.unos.org/SharedContentDocuments/Deceased_Donor_Registration.pdf.

Because MVAs as a source of organ donors include all motor vehicle accidents, rather than specifically motorcycle accidents, we also use fatality data from the National Highway Traffic Safety Administration's Fatality Analysis Reporting System (FARS) to refine our analysis.[10] Table 2 summarizes motor vehicle fatalities by vehicle type and gender from 1994 to 2007. Note that overall fatality rates declined 13 percent, from 156.3 per million persons in 1994 to 135.3 in 2007, and declined roughly 20 percent (from 147.4 to 118.3 per million) among those in vehicles other than motorcycles. In contrast, motorcycle fatality rates increased by 90 percent over the same period, from 8.9 to 17.0 per million persons. Taken together, Tables 1 and 2 show that per capita donors due to MVAs were roughly constant between 1994 and 2007 in spite of steady decreases in traffic fatalities among those not riding motorcycles. Based solely on the yearly averages, it is unclear whether MVA donor rates were stable because of the dramatic increase in motorcycle fatalities or because of other factors, such as better technological methods of organ recovery or higher rates of consent.

Tables 1 and 2 also show substantial differences across gender in donation and death rates. In every year, men account for roughly 90 percent of all motorcycle fatalities but only two-thirds of deaths in other types of vehicles. Because motorcycle fatalities dramatically increased as a share of all MVA deaths, the share of men in MVA deaths increased over time. Returning to Table 1, the organ donation data show that the number of male donors rose slightly from 1995 to 2007, from 3.55 to 3.74 per million persons, while female donors fell from 1.89 to 1.71. These trends in fatalities and donation rates by gender are consistent with increased motorcycle deaths being responsible for keeping MVA organ donations roughly constant while

[10] The full FARS file contains detailed information on every person involved in an accident on public roads that leads to at least one death within 30 days. Our analysis uses fatalities of vehicle operators and passengers aggregated to the state level.

non-motorcycle fatalities decreased by 20 percent. More importantly, these dramatic differences across gender contribute to the identification strategy we pursue below.

IV. Do Motorcycle Helmet Laws Reduce Organ Donation Rates?

We next turn to assessing whether helmet laws affect the supply of organ donors. As described above, 38 states headquarter OPOs that collect data on deceased organ donors. Our primary empirical strategy involves estimating state- and year-specific organ donation rates as a function of whether the state had a universal mandatory helmet law in place in that year. We begin by estimating the following model:

$$(1) \qquad Donors_{st} = \alpha_s + \delta_t + \gamma(law)_{st} + X_{st}\beta + \varepsilon_{st} \ ,$$

where $Donors_{st}$ measures the number of deceased donors per capita, t indexes year, s indexes the state in which the OPO is located, and law_{st} is an indicator for whether state s had a universal mandatory helmet law in year t. All specifications include a full set of state and year indicators (α_s and δ_t, respectively), and we indicate below when we also control for time-varying state-level variables X_{st}. The vector X_{st} includes state maximum speed limits; separate indicators for whether the state had primary-enforcement and secondary-enforcement mandatory seat belt laws; climate variables correlated with motorcycle ridership (heating degree days and annual precipitation); and indicators for whether the state had an organ donor registry, whether online registration was available, and whether an OPO in the state enforced a first-person consent paradigm.[11] We weight each observation by the state's population in that year using U.S. Census

[11] Information on helmet and seat belt laws comes from the Insurance Institute for Highway Safety's website: http://www.iihs.org/laws/default.aspx. Primary-enforcement seat belt laws specify that police officers may stop vehicles solely on the suspicion of occupants not wearing seat belts. Under secondary enforcement laws, officers may cite vehicle occupants for not wearing seat belts but cannot stop a vehicle solely for this purpose. Data on first-person consent practices, the existence of state donor registries and the ability to sign up for those registries online

Bureau estimates. Estimates of γ based on (1) capture the association between within-state variation over time in mandated helmet laws and within-state variation in organ donation rates.

Table 3 presents estimates of γ from specification (1) separately for donations due to MVAs and donations due to all other circumstances. The top row presents our central estimates, in which $Donors_{st}$ measures the per-capita number of MVA donors, multiplied by one million for readability. The estimate in column (1) implies that the imposition of a universal motorcycle helmet law decreases the supply of organ donors by 0.491 per million state residents, with a standard error of 0.157 (all standard errors are robust to within-state clustering over time). As shown in column (2), inclusion of the time-varying covariates X_{st} does not markedly change the point estimate. In both cases, mandatory helmet laws are associated with roughly 10 percent reductions in organ donor rates relative to the sample average of 5.148 per million persons. For brevity, we do not report estimates of β, but these results are available upon request.

The principal threat to the internal validity of estimates based on difference-in-difference specifications such as (1) stems from differential unmeasured time trends across states in organ donation rates that may be correlated with the presence of helmet laws. These time trends could reflect hospitals improving their procedures for organ recovery, education campaigns encouraging informed consent, or endogenous law changes in response to declining donation rates. If differential trends drive the negative point estimates in the top row of the table, they would likely also induce a negative association between helmet laws and the number of donors due to circumstances other than MVAs. As shown in the "All others" row of the table, this is not the case – the point estimates of 0.843 and 0.485 are both positive although statistically

came from interviews with OPO employees. Climate data come from the National Oceanic and Atmospheric Administration.

indistinguishable from zero at conventional significance levels.[12] The remaining rows of the table present estimates for the individual circumstances that comprise the aggregate "All others" category. None of these circumstance-specific organ donation rates are significantly related to helmet laws.

As Tables 1 and 2 showed above, motorcycle fatalities and MVA donation rates differ substantially across gender, so in Table 4 we present gender-specific estimates of the effects of helmet laws. The first row of the table shows the effect of helmet laws on motorcycle fatalities, given by estimates of γ based on a specification similar to that in (1):

(2) $$Deaths_{st} = \alpha_s + \delta_t + \gamma(law)_{st} + X_{st}\beta + \varepsilon_{st},$$

where $Deaths_{st}$ denotes the number of annual per-million-capita motorcycle fatalities in a state. Population-weighted average death rates are shown in brackets. Column (1) shows that universal helmet laws decrease motorcycle deaths among men by 3.766 per million persons, a 34 percent decline relative to the overall motorcycle death rate of 11.073. Column (2) shows that the absolute effect is much smaller among women, 0.367 per million persons. This reduction is roughly 28 percent of the baseline death rate of 1.333, similar to the relative effect among men. Column (3) presents estimates of γ based on pooled-gender death rates. The 33 percent reduction (= 4.134 / 12.414) in the pooled sample is consistent with the findings of previous studies; Dee (2009) estimates effect sizes of 27 to 34 percent in specifications using the logarithm of fatalities as a dependent variable. In sum, helmet laws decrease motorcycle deaths among both genders,

[12] If state-specific trends in rates of donations due to MVAs and due to all other causes are identical, then the causal effect of helmet laws on MVA donations can be recovered from the difference between the estimates of (1) for MVAs and non-MVA causes. These "triple difference" estimates are -1.438 (= -0.491 - 0.947) and -0.999 (= -0.514 - 0.485) in columns (1) and (2), respectively, both of which are statistically significant at the 1 percent level. We are wary of interpreting these estimates literally because MVA and non-MVA donation rates are unlikely to follow identical trends within states.

but the absolute size of the effect is much larger among men because men account for over 90 percent of all motorcyclist deaths.[13]

The gender-specific fatality estimates in Table 4 suggest an intuitive test for whether the association between helmet laws and organ donors is causal – because helmet laws can causally affect the number of organ donors only through their effect on fatalities, the absolute effects of helmet laws on donors should be substantially larger among men than among women. We therefore present gender-specific estimates of the effect of helmet laws on MVA organ donors in the second row of Table 4. The results are striking. Helmet laws have large, statistically significant effects on the number of male MVA donors, with the estimate of -0.465 (0.106) being over 12 percent of the baseline male MVA donor rate. In contrast, the estimated effect among women is only about 2.5 percent of the baseline rate (= -0.048 / 1.702) and is not significantly different from zero. Although helmet laws are estimated to reduce motorcycle fatalities among women, the reduction is small relative to the number of female MVA deaths; as Table 2 showed, in 2007 only 4 percent of all female MVA fatalities involved motorcycles, compared to 16 percent among men. As a result, the effect of helmet laws on female MVA organ donors is small and statistically indistinguishable from zero. We view this pattern as compelling evidence of a causal effect of helmet laws on organ donations, because the most likely sources of unmeasured confounding trends would affect organ donation rates among men and women similarly.

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[13] The similarity across gender in relative effect sizes may result from a similarity across gender in the effects of helmet laws on helmet usage. Mayrose (2008) finds that in a sample of fatally injured motorcycle riders and passengers, the effects of statewide helmet mandates on helmet use are roughly constant across gender, with 83.8 percent of males and 85.8 percent of females wearing a helmet in states with a universal helmet law, compared to only 36.4 percent and 34.9 percent in states with a partial law. NOPUS observational data, which are not limited to those who were involved in a fatal accident, unfortunately do not differentiate by gender, but these data do allow for estimates of helmet usage separately for drivers and passengers. In our analyses of these data, available upon request, the relationship between helmet laws and helmet usage does not significantly differ between drivers and passengers, suggesting that it also does not differ across gender.

As another check on the plausibility of the central results listed above, the next row of Table 4 presents gender-specific estimates of the association between state helmet laws and organ donors due to circumstances other than MVAs. As in the pooled-gender estimates shown in Table 3, all estimates are indistinguishable from zero, providing further support for a causal interpretation of the relationship between helmet laws and male MVA donors.[14]

Finally, Figure 1 presents graphical evidence of the effects of helmet laws. Panel A shows yearly motorcycle fatality rates among men in two groups: those in the six states that repealed their universal helmet laws from 1994 to 2007, and those in 44 remaining states and D.C. For the states in the former group, the *X*-axis measures the year relative to the state's law change, with zero denoting the year of the repeal, 1 denoting the following year, and so on. For each state without a law change, year zero was randomly generated to equal either 1997, 1998, 1999, 2000, or 2003 with equal probability, because these years corresponded to actual law changes in the other group of states. As the figure shows, death rates in the two groups are roughly equal in the three years prior to the repeals, but starting in year 1 they begin to steadily diverge. By year 4, the difference in death rates between the two groups is large, with the average in the "law repealed" states being 14.98 compared to 11.80 in the "no law change" states. This monotonic divergence gives a sense of the time pattern of effects that the point estimates in Table 4 do not show.

[14] We assessed the sensitivity of the central results to three functional form and measurement issues. First, we estimated all models using a measure of the fraction of the year in which a state's helmet law was in place as the key regressor; as Appendix Table 1 shows, states enacted or repealed helmet laws in the middle of calendar years. Second, we treated the dependent variable as a count variable, estimating all models by Poisson quasi-maximum likelihood, and alternatively measured it as the log of per capita death and donor rates. Finally, we excluded from the analysis all DSAs which cover multiple states (for example, the Kansas City-based DSA covers parts of both Kansas and Missouri) because in these areas, the state in which a death occurred is ambiguous. None of these alternate specifications yielded substantively different results from the central ones reported in the text. These alternate results are available upon request.

Panel B of the figure shows the same divergence between "law repealed" and "no law change" states in MVA organ donation rates among men. The patterns in Panel B are less striking than those in Panel A because donation rates differ in the two sets of states prior to year zero, but they are consistent with the estimate of γ of -0.465 given in Table 4 – the difference between the groups increases from roughly 0.5 in years minus 1 and zero to over 1.0 in year 4. Note that the horizontal axis begins at minus 2 in Panel B because the earliest law repeal occurred in 1997, and the OPTN data do not allow for a clean distinction between MVA and non-MVA donors until 1995.

Perhaps surprisingly, Panels A and B imply that helmet law repeals lead to gradual increases in both motorcyclist death rates and organ donation rates, rather than discrete jumps in the year of the repeal. Panel C, which shows motorcycle registration rates calculated from data from the U.S. Department of Transportation (various years), illustrates one reason why: motorcycle registrations substantially yet gradually increase following helmet law repeals.[15] Registration rates increased by 40 percent in the four years following repeals, from 12.5 to 17.5 per thousand state residents. Registrations increased more slowly in the comparison states, by roughly 15 percent in the four years following simulated law changes (reflecting increased ridership in the U.S. in the late 1990s and early 2000s). This pattern implies that at least some of the association between helmet laws and deaths results from an effect of helmet laws on motorcycle ridership.

The lack of an immediate effect of helmet law repeals on motorcyclist deaths and organ donations may also reflect a gradual effect of repeals on helmet usage. Ulmer and Preusser (2003) show that observed helmet usage declined from 96 percent to 76 percent immediately following the elimination of Kentucky's universal law in 1998, but usage continued to gradually

[15] See http://www.fhwa.dot.gov/policy/ohpi/hss/index.cfm for data from recent years.

decline to 56 percent in 2001. In contrast, observational studies show that the introduction of helmet laws immediately increases helmet usage to nearly 100 percent (Kraus et al., 1995).

The asymmetric effects of helmet law repeals and introductions on helmet usage imply corresponding asymmetries in the effects on death rates and organ donations. To illustrate the possibility that behavior responds more quickly to the introduction of helmet laws than to their repeal, Figure 2 shows motorcyclist registration and death rates for Florida, Texas, and California, the three most populous states with helmet law changes since 1990. The top panel presents registration rates in the three states, and the bottom panel shows death rates. Each graph includes two series, one labeled “State with law change” based on data from the given state, and one showing the average among the 40 states which have neither repealed nor enacted helmet laws since 1990. Each series is normed to equal 1 in the first full year a new regime was in place, represented by the vertical lines in each graph; for example, Florida’s helmet law was repealed in July of 2000, so each series equals 1 in 2001 in the graphs labeled “Florida”. As the figure shows, the time patterns for Florida and Texas are similar to those shown in Figure 1. Specifically, registrations and death rates rose gradually yet steeply relative to the comparison group following helmet law repeals. California, which introduced a universal helmet law in 1992, exhibits a much different pattern. Death rates dropped immediately in 1992, declining by roughly 35 percent from their 1991 levels. This abrupt decline may reflect the efficacy of helmets in preventing deaths, while the additional 40 percent reduction in death rates from 1992 to 1998 mirrors the 40 percent decline in registered motorcyclists over the same period.

This graphical evidence suggests that changes in helmet laws cause gradual adjustments in ridership and helmet usage, resulting in gradual effects on organ donation rates. Helmet usage responds more quickly to the introduction of a helmet law than to the repeal of such a law.

These patterns have two implications for the interpretation of the results in Tables 3 and 4, which are based on an average of seven years of data following law changes. First, the estimates are likely to understate the long-run effects of both repeals and introductions. Second, because the timeframe of OPTN data availability covers six repeals and only one introduction, the estimates may also understate the short-run impacts of helmet law introductions.

To investigate the dynamic impacts of helmet law repeals, we also estimated variants of specifications (1) and (2) that include a linear trend in the number of years since a state repealed its law, measured by the variable "*years since repeal*":

(3) $$Y_{st} = \alpha_s + \delta_t + \lambda(law)_{st} + \varphi(\textit{years since repeal})_{st} + X_{st}\beta + \varepsilon_{st},$$

where Y_{st} refers to either deaths or donors per capita. For death rates, the pooled-gender estimates of λ and φ are -1.94 (with a standard error of 0.61) and 0.90 (0.11), respectively, implying an effect of 5.09 (0.55) at 3.5 years after a repeal. This number is directly comparable to the pooled-gender estimate of 4.134 in Table 4 because the latter number is based on an average of seven years of post-repeal data per state; the two estimates are statistically indistinguishable. Similarly, for MVA organ donors, the pooled-gender estimates of λ and φ are -0.25 (0.23) and 0.11 (0.05), implying an effect of 0.62 (0.17) at 3.5 years following a repeal. Again, this number is insignificantly different from the estimate of 0.514 from Table 4. We prefer the simpler estimates presented in the tables for brevity of exposition, but full results for all specifications are available upon request. Note that we did not attempt to estimate dynamic effects of the introduction of Louisiana's law in 2004, primarily because we are hesitant to make inferences based on a single law change.

Implied Estimates of the Effect of Motorcyclist Deaths on Organ Donation Rates

Estimates of γ from specifications (1) and (2) capture the reduced-form relationships between helmet laws and organ donors and between helmet laws and motorcyclist deaths, respectively. As a result, the ratio of the two estimates of γ represents an instrumental variables estimate of the effect of motorcyclist death rates on organ donation rates. A causal interpretation of this ratio essentially requires that helmet laws only influence organ donation rates through their effect on motorcyclist deaths. Although this assumption cannot be formally tested, the informal evidence presented above suggests that it holds. Specifically, because helmet laws appear unrelated to non-MVA donation rates and to female MVA donation rates, we interpret the estimated ratio as measuring a causal effect of motorcyclist deaths on organ donation rates.

The implied estimates, shown in the bottom row of Table 4, are 0.123 for men (= 0.465 / 3.766), 0.131 for women (= 0.048 / 0.367), and 0.124 for the pooled-gender sample (= 0.514 / 4.134). These estimates measure local average treatment effects that capture the effect of the excess motorcyclist deaths resulting from state repeals of universal helmet laws on the supply of organ donors.[16] Taken literally, they imply that every motorcyclist death due to the lack of a motorcycle helmet law produces 0.123 to 0.131 additional organ donors.

Based on the estimates of the sensitivity of organ donation rates to motorcyclist death rates, we can calculate the size of the positive externality resulting from each helmetless motorcyclist's death, as measured by possible lives saved. According to OPTN data, 2.7 organs are successfully transplanted per cadaveric donor, on average. Under the upper-bound assumption that each of these organs saves one life, the pooled-gender estimate of 0.124 implies

[16] For instrumental variables estimates to be interpreted as local average treatment effects, Imbens and Angrist (1994) show that a potential instrument must also satisfy the property of monotonicity. Although monotonicity is inherently untestable in the context of a binary instrument, it is likely to hold in this setting – it implies that the presence of a helmet law does not increase death rates in any state.

that every motorcyclist death due to the lack of a helmet law saves the lives of 0.33 (= 0.124 × 2.7) individuals on organ transplant waiting lists.[17] Because this upper-bound estimate is far less than one, helmetless riding is clearly an inefficient means of preserving life in the absence of a basis for making normative judgments about the value of one life relative to another. Nonetheless, helmet laws may have significant impacts on death rates even among persons who never ride a motorcycle.

As a further gauge of the magnitude of these estimates, recall that Tables 1 and 2 showed that 135.3 MVA fatalities resulted in 5.36 organ donors per million persons in 2007, so each MVA death produced 0.040 organ donors. This overall donor rate, D, is a weighted average of the donor rates among helmetless motorcyclists (D_{hm}) and all others involved in MVAs (D_o):

(4) $$D = P \times D_{hm} + (1\text{-}P) \times D_o,$$

where P is the proportion of all MVA fatalities that involve helmetless motorcyclists. Our pooled estimate of 0.124 represents an estimate of D_{hm}. Based on 2007 FARS national data on traffic fatalities, P equals 0.050, implying that D_o equals 0.035 – while 12.4 percent of helmetless motorcyclists killed in MVAs eventually become organ donors, the donor rate is only 3.5 percent among all other MVA fatalities. This discrepancy presumably results from higher rates of brain death among helmetless motorcyclists than among others killed in MVAs. Sheehy et al. (2003) estimate that only 42 percent of brain dead potential donors actually become donors because of low consent rates and hospital errors, so if 12.4 percent of all deceased helmetless motorcyclists become donors, roughly 30 percent (= 0.124 / 0.42) of them are viable organ donors based on the pooled-gender estimate in Table 4. We are wary of interpreting this number literally because it

[17] The 2007 OPTN annual report shows one-year survival rates of 94 percent for kidney recipients, 87 percent for liver recipients, and 88 percent for heart recipients, accounting for the three most transplanted organs (Table 1.13). The same report shows that multiple organ transplants are very rare, accounting for fewer than 2 percent of all transplants (Table 1.08). These numbers, and many others in this section, are taken from OPTN's rich national data available for public use on OPTN's website: http://optn.transplant.hrsa.gov/latestData/step2.asp.

is the ratio of three separate estimates and because it is based on the assumption that donor consent rates among motorcyclists are similar to those in the population of potential donors. Nonetheless, to our knowledge this is the first estimate of the fraction of deceased helmetless motorcycle riders who are viable organ donors.

Helmet Laws and Transplant Waiting Lists

Finally, we consider the magnitude of our results in the context of a broader question: how would eliminating all existing universal helmet laws affect organ donation rates and transplant waiting lists? Based on state-level population estimates from the U.S. Census Bureau, approximately 155 million people lived in states with universal helmet laws in 2007, so our preferred estimates imply that the repeal of all helmet laws would increase the number of deceased motorcyclists by roughly 640 (= 4.134 × 155, from Table 4), a large effect relative to the 5128 motorcyclist deaths in that year. These deaths would produce 80 (= 0.514 × 155) additional organ donors because only 12.4 percent of deceased motorcyclists became donors. Using OPTN's estimate of 2.7 transplanted organs per donor, the end result would be 216 additional organs transplanted, less than one percent of the 22,049 organs recovered from deceased donors in the U.S. in 2007.

These calculations of the magnitudes of helmet laws' effects seemingly reveal a contradiction: while helmet laws decrease MVA-based organ donors by roughly 10 percent, a substantial reduction, the resulting effect on overall organ donation rates is miniscule. This discrepancy arises because those killed in traffic accidents account for only a small fraction of organ donors; as Table 1 showed, fewer than 20 percent of all deceased organ donors' circumstance of death involved MVAs in 2007. Moreover, motorcyclists represented only 12 percent of all MVA fatalities, so the scope for the effects of helmet laws on overall organ donation rates is limited. This limitation becomes even more apparent relative to the current (as of September 4, 2009) and steadily growing U.S. transplant waiting list of nearly 104,000 people.[18]

V. Conclusions

Motorcycle helmet mandates are effective – consistent with a larger literature, our estimates indicate that state-level motorcyclist fatalities increase by approximately thirty percent when universal helmet laws are repealed. Despite helmets' efficacy, estimates of helmet usage in states without universal laws suggest that nearly half of all motorcyclists prefer to ride helmetless. Helmet mandates impose costs on these riders, but these costs may be justified by a reduction in the negative externalities imposed by those injured or killed in accidents.

This study finds evidence that helmet laws also decrease the *positive* externalities of helmetless riding by reducing the supply of organ donors. Our central estimates show that organ donations due to motor vehicle accidents (MVAs) increase by 10 percent when states repeal helmet laws. Nearly all of this effect is concentrated among men, who account for over 90 percent of motorcyclist fatalities. Helmet law repeals are unrelated to changes in the number of organ donors due to reasons other than MVAs, suggesting that the association between the laws and MVA-based organ donation rates is causal. Under the upper-bound assumption that each

[18] The dramatic shortage of organs has generated a large body of research evaluating mechanisms for increasing organ donation rates. In a special issue of the *Journal of Economic Perspectives* addressing the excess demand for organs, Becker and Elias (2007) focus on financial incentives for increasing living donors, Howard (2007) reviews policies for increasing consent rates and the pool of potential donors, and Roth (2007) discusses the compensation of organ donors in light of "repugnance" for the market trading of organs. In a series of papers, Roth, Sonmez, and Unver (2004, 2005) design a matching mechanism for organ recipients and donors that has been implemented in New England. Abadie and Gay (2006) find that countries using presumed consent donation standards have 25 to 30 percent higher donation rates than observationally similar countries using informed consent regimes.

transplanted organ saves one life, the estimates imply that every motorcyclist death due to the lack of a helmet law saves the lives of 0.33 individuals on organ transplant waiting lists.

Understanding and quantifying the unintended consequences of helmet laws allows for more informed policymaking by providing a more complete picture of the associated costs and benefits. Although our estimates point to a sizeable effect of helmet laws on MVA-based organ donations, the repeal of all helmet laws would be only marginally effective in reducing the severe shortage of organs in the U.S., primarily because less than 20 percent of cadaveric organ donors die in motor vehicle accidents. In the current informed consent regime, our preferred estimates imply that nationwide elimination of helmet laws would increase the annual supply of organ donors by less than one percent.

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Table 1: Organ Donors by Year, Gender, and Circumstance, per Million Persons

	Circumstance: Motor Vehicle Accident			Circumstance: All Others		
	All	Female	Male	All	Female	Male
1994*	4.05	1.34	2.71	15.87	6.37	9.50
1995	5.43	1.89	3.55	15.29	6.39	8.90
1996	5.16	1.73	3.44	15.52	6.64	8.88
1997	5.25	1.87	3.39	15.45	6.60	8.84
1998	5.19	1.80	3.40	16.36	7.25	9.11
1999	4.94	1.70	3.24	16.41	7.39	9.02
2000	5.24	1.72	3.52	16.43	7.33	9.10
2001	4.92	1.55	3.37	16.84	7.43	9.41
2002	5.20	1.65	3.55	16.71	7.17	9.54
2003	5.03	1.70	3.33	17.63	7.66	9.97
2004	5.30	1.77	3.54	19.43	8.75	10.68
2005	5.24	1.73	3.50	20.69	9.12	11.57
2006	5.64	1.78	3.86	21.68	9.26	12.41
2007	5.36	1.61	3.74	21.85	9.15	12.68

*Note: OPTN began reporting circumstances of death on April 1, 1994. For the first three months of 1994, all donors are in the "All Others" circumstances. Source: OPTN.

Table 2: Motor Vehicle Fatalities by Gender, per Million Persons

	All MVA			All Motorcycle Fatalities			All Other Vehicles			US Population
Year	All	Male	Female	All	Male	Female	All	Male	Female	
1994	156.3	105.3	51.1	8.9	8.1	0.8	147.4	97.2	50.3	260,327,000
1995	159.0	107.0	52.0	8.5	7.7	0.8	150.5	99.3	51.2	262,804,000
1996	158.5	105.7	52.7	8.1	7.4	0.7	150.3	98.3	52.0	265,228,000
1997	156.8	103.9	52.9	7.9	7.2	0.7	148.9	96.7	52.2	267,784,000
1998	153.4	102.1	51.3	8.5	7.7	0.8	144.9	94.4	50.6	270,248,000
1999	152.8	102.8	50.1	9.1	8.3	0.8	143.7	94.5	49.2	272,691,000
2000	148.4	101.0	47.4	10.2	9.3	1.0	138.1	91.7	46.4	282,194,308
2001	146.5	100.6	45.9	11.1	10.1	1.0	135.4	90.5	44.9	285,112,030
2002	148.9	102.1	46.9	11.3	10.3	1.1	137.6	91.8	45.8	287,888,021
2003	147.1	100.7	46.4	12.7	11.5	1.3	134.4	89.2	45.2	290,447,644
2004	145.8	100.2	45.6	13.7	12.2	1.5	132.1	88.0	44.1	293,191,511
2005	146.8	102.4	44.4	15.4	13.9	1.5	131.3	88.4	42.9	295,895,897
2006	140.7	98.5	42.2	15.9	14.6	1.4	124.8	84.0	40.8	298,754,819
2007	135.3	95.7	39.6	17.0	15.4	1.5	118.3	80.2	38.0	301,621,157

Note: Authors' calculations using Fatality Analysis Reporting System (FARS) data.

Table 3: Estimates of the Effect of Helmet Laws on per Capita Organ Donors

Donor Circumstance	(1)	(2)	Sample Mean
Motor Vehicle Accident	-0.491	-0.514	5.148
	(0.157)	(0.146)	
All others	0.843	0.485	17.668
	(1.283)	(0.769)	
Accidents not involving vehicles	-0.039	0.000	1.931
	(0.233)	(0.193)	
Homicide, suicide, or child abuse	0.421	0.408	3.390
	(0.267)	(0.271)	
Natural Causes	-0.020	-0.037	4.086
	(1.348)	(1.261)	
None of the above	0.466	-0.102	8.261
	(2.229)	(2.210)	
State-year controls?	No	Yes	

Notes:

1) All estimation samples consist of 38 states from 1994 to 2007. The unit of observation is a state-year. All models include indicators for years and states.
2) Models in column (2) add state-level controls for the state maximum speed limit, total population of the state, heating degree days, annual precipitation, and indicators for whether the state has a donor registry, whether the state allows online donor registration, whether organs can be donated without the consent of family members of the prospective donor, and whether the state had primary enforcement of seatbelt laws.
3) Standard errors, in parentheses, are robust to clustering within state over time.

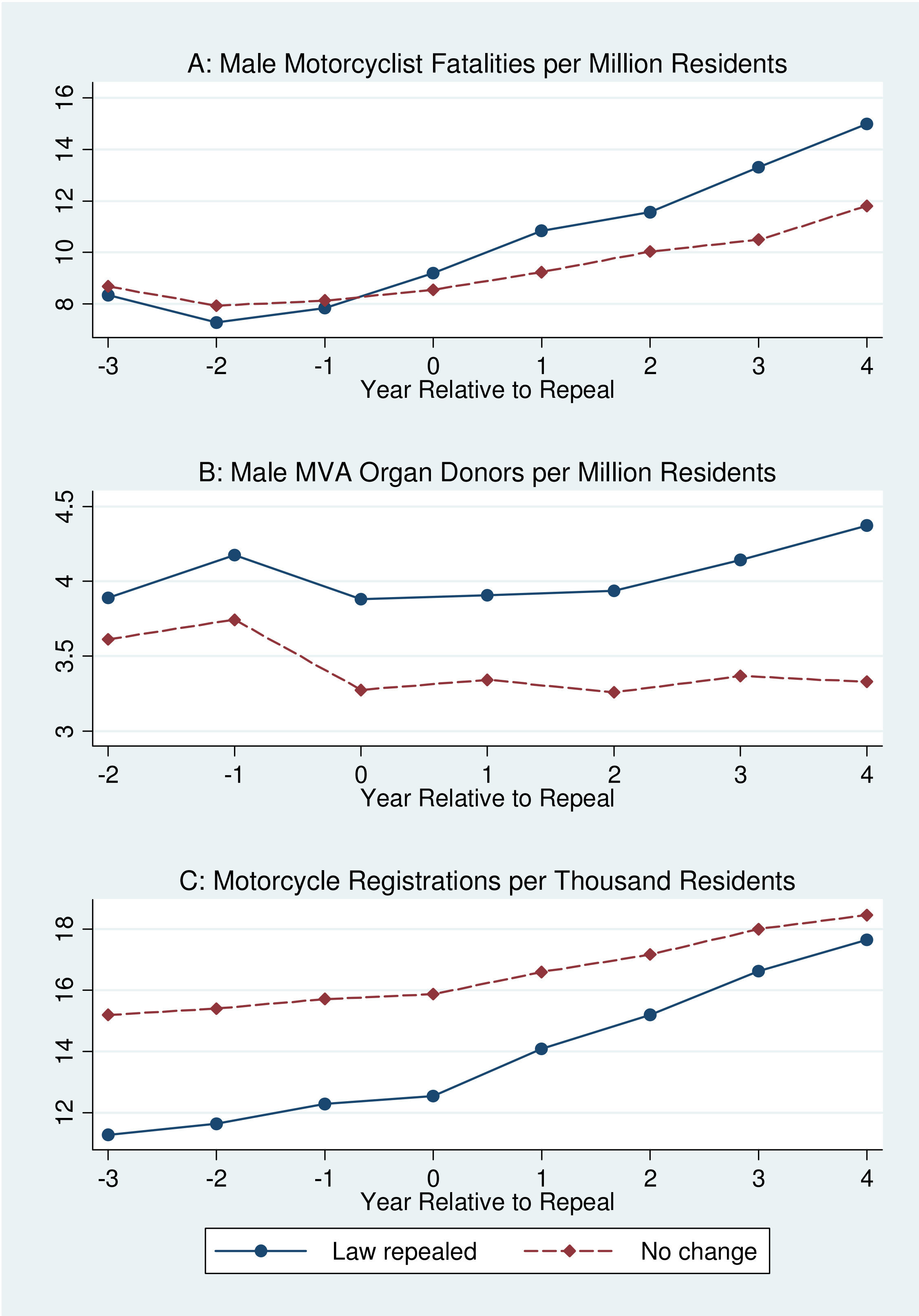
Table 4: Estimates of the Effect of Helmet Laws on per Capita Motorcycle Fatalities and Organ Donors, by Gender

Dependent Variable	(1)	(2)	(3)
	Males	Females	Pooled
Motorcycle Fatalities	-3.766	-0.367	-4.134
	(0.385)	(0.097)	(0.421)
	[11.073]	[1.333]	[12.414]
Organ Donors by Circumstance:			
Motor Vehicle Accident	-0.465	-0.048	-0.514
	(0.106)	(0.075)	(0.146)
	[3.445]	[1.702]	[5.148]
All others	0.649	-0.060	0.485
	(0.721)	(0.609)	(0.769)
	[10.018]	[7.648]	[17.668]
Wald IV estimates:			
Effects of Motorcyclist Death Rates on MVA Donation Rates	0.123	0.131	0.124
	(0.045)	(0.256)	(0.039)

Notes:

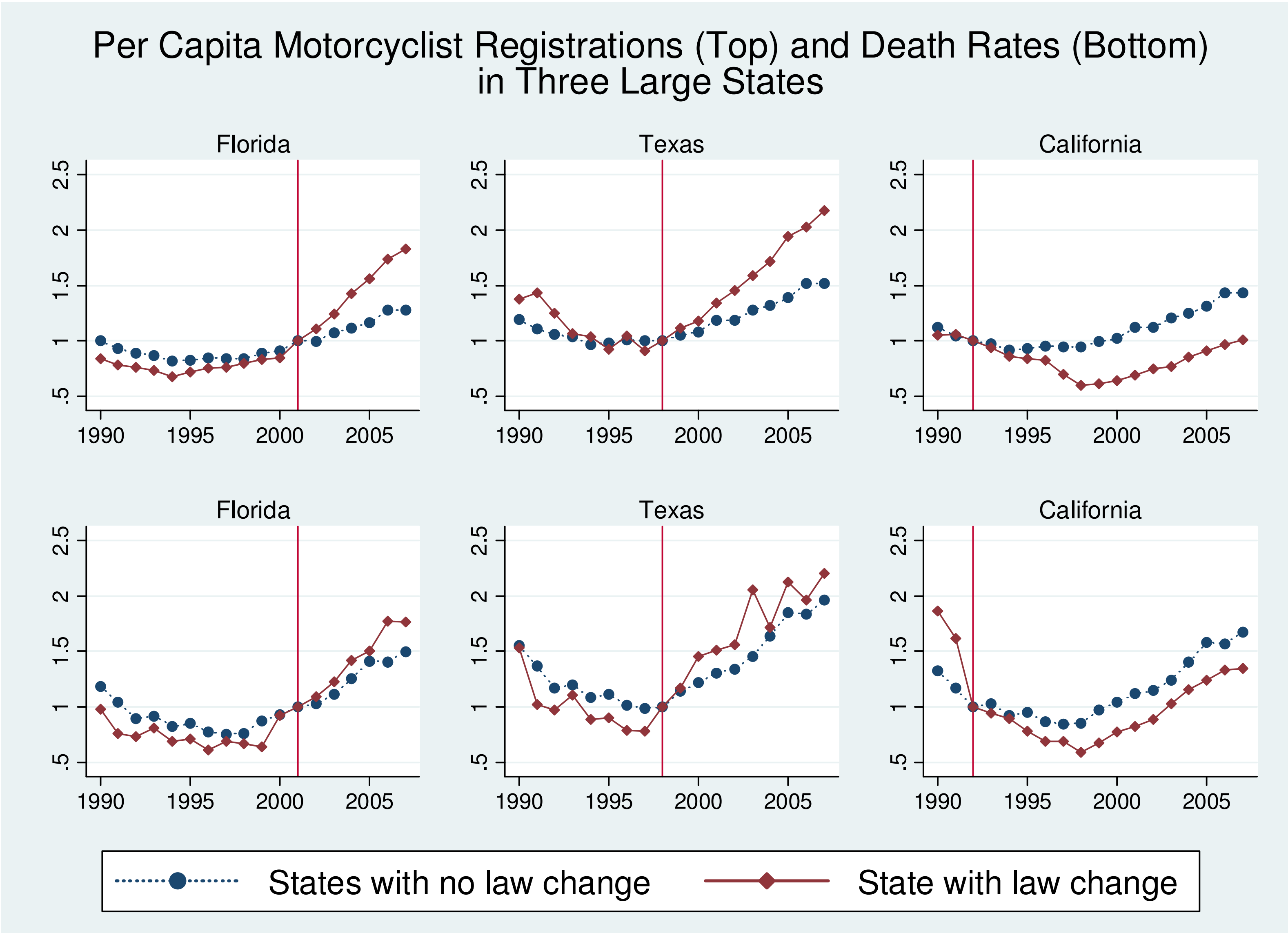
1) All estimation samples consist of 38 states from 1994 to 2007. The unit of observation is a state-year. All models include indicators for years and states.
2) All models include the state-year controls described in the notes to Table 3.
3) Standard errors, in parentheses, are robust to clustering within state over time.
4) Sample means for relevant dependent variables are in brackets.

Figure 1



Note: Authors' calculations from FARS, OPTN and Department of Transportation data, 1994-2007.

Figure 2



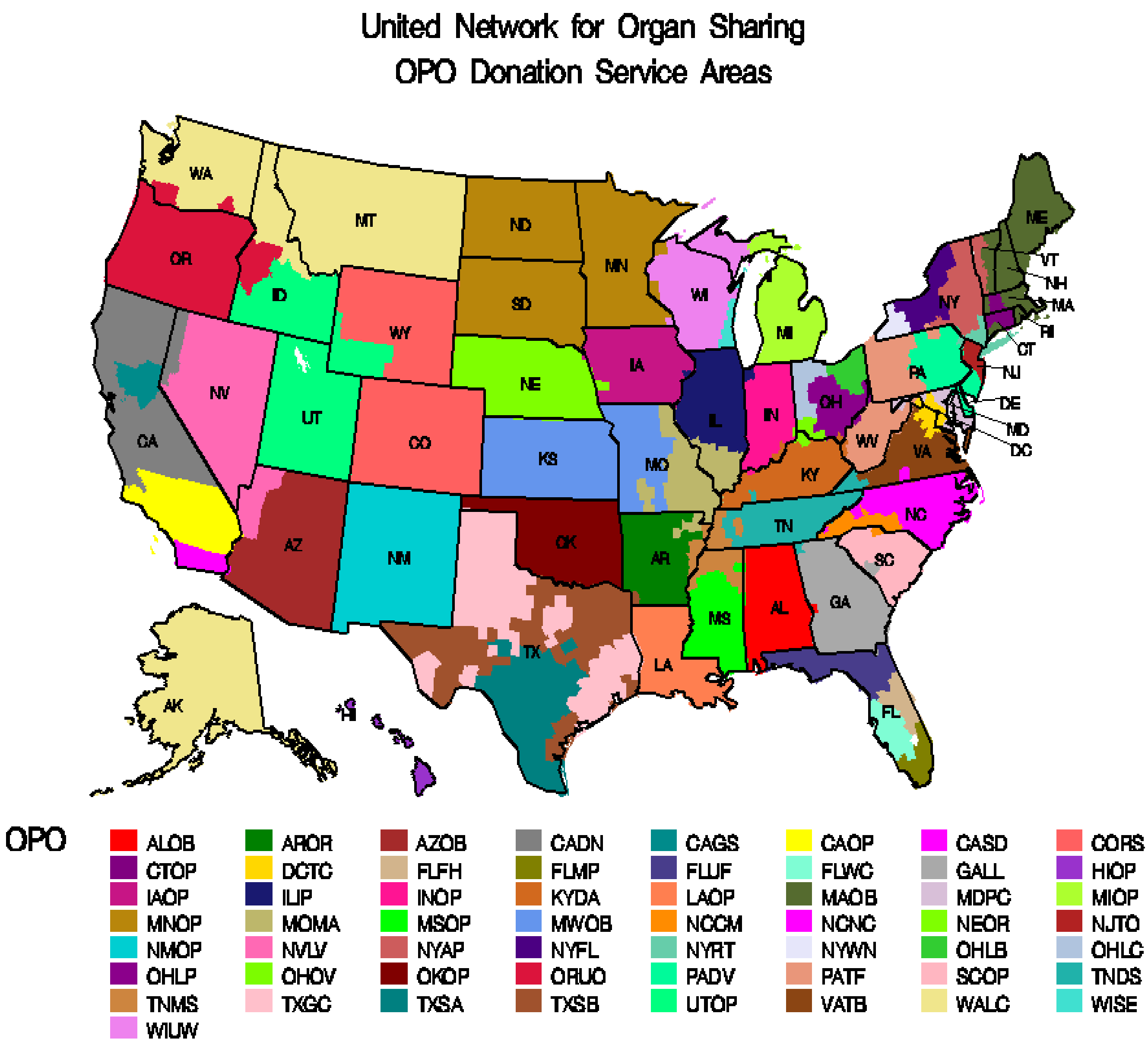
Note: Authors' calculations from FARS and Department of Transportation data. Data are normed to 1 in the first full year of the law change.

Appendix Table 1 – Changes in State Helmet Laws, 1994-2007

Year	None to Partial	Universal to Partial	Partial to Universal	Partial to None
1994				
1995				NH (9)
1996				
1997		AR (8), TX (9)		
1998		KY (7)		
1999		LA (8)		
2000		FL (7)		
2001				
2002				
2003		PA (9)		
2004			LA (8)	
2005				
2006				
2007	CO (7)			

Notes: The month a law changed is in parentheses (where "1" denotes January, "2" denotes February, and so on). Source: Insurance Institute for Highway Safety: http://www.iihs.org/laws/default.aspx

Appendix Figure 1



<u>Note</u>: This map was produced by OneLegacy, an organ procurement organization in Southern California. See http://OneLegacy.org for more details.