Donorcycles: Do Motorcycle Helmet Laws Reduce Organ Donations?[*]

Stacy Dickert-Conlin, Todd Elder and Brian Moore
Michigan State University

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Abstract:

Government 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 the pool of viable organ donors. Our central estimates show that organ donations due to motor vehicle fatalities increase by 10 percent when states repeal helmet laws. Two characteristics of this association suggest that it is causal: first, nearly all of it is concentrated among men, who account for over 90 percent of all motorcyclist deaths, and second, helmet mandates are unrelated to organ donations due to circumstances other than motor vehicle accidents. Our 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

The justification for governmental regulation of motorcycle helmet use is largely based on the potential externalities associated with motorcycle accidents. A 1991 GAO report argues that the costs associated with helmetless motorcyclists' higher rates of severe injury and death are borne by society at large in the form of lost productivity, higher insurance premiums, and publicly-financed programs to support severely injured riders (GAO (1991), p. 28).[1] Although the net social costs imposed by helmetless motorcyclists are difficult to quantify, helmet mandates are primarily enacted to eliminate these externalities before they occur by reducing fatalities and injuries.[2]

This paper investigates the possibility of an offsetting societal *benefit* of riding without a helmet: do helmetless riders increase organ donation rates? If helmets reduce the number of deaths from severe brain injury, and if these deaths often involve viable organ donors, the repeal of helmet laws may increase the overall number of donors.

The possibility of a link between motorcycle helmets and organ donation is not novel, although the existing supporting evidence appears to be anecdotal.[3] Despite the lack of quantitative evidence, the perceived existence of this link motivated two recently proposed laws. Specifically, organ donation in the United States operates under a paradigm of informed consent,

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[1] In an acknowledgement of the externalities associated with health care costs, Florida and Texas exempt riders from statewide helmet mandates if the rider has personal injury insurance: http://www.iihs.org/laws/helmet_history.html.

[2] In principal, mandatory helmet laws could *increase* the monetary costs of motorcyclists by increasing the probability of severe injuries that require long-term care while reducing the probability of immediate death due to head trauma. Similarly, in the context of cigarette taxation, Viscusci (1995) argues that there are long term societal savings from premature deaths in the form of reduced Social Security and pensions.

[3] For example, Wikipedia's "Organ Donation" entry states that "motorcycle helmet laws…have lowered the number of sudden deaths in vehicle accidents, and therefore lowered the number of otherwise healthy corpses which could have been organ donors" with no citation for this claim: http://en.wikipedia.org/wiki/Organ_donation. Trauma.org, an organization providing resources for professionals in trauma and critical care, published a discussion about helmet laws in which physicians posted claims 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?" and "[m]otorcycle helmet repeal laws are fraught with problems. We have always said if they tried to repeal ours, we would have the organ donors associations lobby in favor of it, and maybe that will get a legislator or two to think about it." http://www.trauma.org/archive/archives/helmet.html (accessed March 9, 2009).

which implies that organ procurement is only possible if persons "opt in" to donating their organs by signing a consent form while alive or if their families give consent in the event of their death. In 2003, two states proposed exceptions to this nationwide rule: California Assembly Bill 1200 and New Mexico Senate Bill 239 would have made organ donation *presumed* for all motorcyclists who were not wearing a helmet and were declared brain dead as a result of an accident.[4] 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. Both proposals seemingly reflect the beliefs that helmetless motorcyclists may generate some positive externalities and that capturing these benefits through presumed consent legislation may partly counteract the associated social costs.

Using state- and year-specific measures of organ donation and variation across states and time in helmet laws, we present evidence that helmet mandates reduce organ donations. Our estimates suggest that the presence of a statewide helmet law is associated with a nearly 10 percent reduction in the number of organ donors who died in motor vehicle accidents (MVA). In contrast, helmet laws are unrelated to the number of organ donors resulting from other circumstances of death, such as homicide or natural causes. As further evidence that the central estimates do not merely reflect spurious unobserved trends, we find large, statistically significant effects of helmet laws on MVA donors among men but not among women, which is plausible because 90 percent of annual motorcycle fatalities occur among men. Combining these results with estimates of the effect of helmet laws on motorcycle fatalities, our preferred point estimates suggest that every death prevented by motorcycle helmet laws results in 0.124 fewer organ

[4] 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). Note that many European nations operate under a "presumed consent" paradigm; see Abadie and Gay (2006) for more details.

donors. Although these are large effects within the population of motorcycle riders, they are small in relation to the severe shortage of organs in the organ transplant population; eliminating helmet laws nationwide would have only a negligible effect on 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 (OPTN) and the patterns in the number of organ donors among MVA and other circumstances of death as they relate to traffic fatality data from the Fatality Analysis Reporting System (FARS). Section 4 presents the empirical specifications and results, and Section 5 concludes.

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

The history of motorcycle helmet laws can be characterized by a series of mandates outlining federal policy followed by highly responsive reactions from state legislatures. Between 1966 and 1995, the federal government implemented and retracted universal helmet legislation twice.[5] Each mandate was accompanied by the threat of withholding federal highway funds from noncompliant states, a threat with enough credibility to elicit substantial swings in state-level helmet laws as federal mandates were passed and repealed. No federal helmet mandates currently exist, although state legislatures continue to debate and modify their own helmet laws. Since 1994, six states (Arkansas, Texas, Kentucky, Louisiana, Florida, and Pennsylvania) have

[5] 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)).

repealed universal helmet mandates that required all riders to wear helmets, with Louisiana reinstituting their universal law in 2004. Appendix Table 1 lists all helmet law changes occurring since 1994. Currently, 20 states and the District of Columbia require all motorcycle riders to wear helmets, and 27 states have partial coverage laws that typically mandate coverage for all riders age 17 and younger.[6] Illinois, Iowa, and New Hampshire do not require any riders to wear a helmet. In states with helmet laws, the statute specifies a maximum punishment. For example, in Georgia, riding without a helmet is punishable by a fine of up to $1000 and one year in jail. However, the punishment for a first offense is typically much smaller, such as a fine of $90.

Establishing a link between helmet laws and organ donations requires establishing the following: (1) helmet laws decrease fatalities, either directly through increased helmet use or through the removal of risk-loving drivers from roads (note that this composition effect could increase fatalities in principle, and the direct effect could be lessened by compensatory behavior in the form of more risk-taking among helmeted drivers), and (2) some of these fatalities would involve viable candidates for donation. Using data from the 2006 and 2007 National Occupant Protection Use Survey (NOPUS), an observational field study conducted by the National Highway Traffic Safety Administration intended to measure the use of motorcycle helmets and seat belts, we estimate helmet usage rates in states with a universal helmet law to be 97.8%, compared to 54.2% in states with partial or no laws. Although this comparison does not isolate a causal role of helmet laws, because the laws could be correlated with preferences of riders within

[6] 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 under no restrictions. Although the most common partial coverage law requires helmets for operators age 17 and younger, some states have restrictions for riders under age 14, 20, 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. Passengers riding with operators covered by helmet laws are also often required to wear helmets.

a state, several papers using single-state data find consistent evidence that the percentage of riders wearing helmets decreases from nearly 100 percent under universal helmet laws to roughly 50 percent when helmet laws are repealed (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 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 within-vehicle approach, Dee (2009) found that helmets reduce fatality risk by 34 percent. Similarly, a recent meta-analysis found that helmets reduce the risk of death by 42 percent and the risk of head injury by 69 percent (Liu et al. 2008). 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 27 to 29 percent relative to states with no laws and by over 20 percent relative to states with partial laws (Dee 2009, Houston and Richardson 2008, Sass and Zimmerman 2000).[7]

Despite the consistent findings that universal helmet laws increase helmet use and reduce fatalities, five fewer states required universal helmet usage in 2009 than in 1994. Before turning to estimates of the link between helmet laws and organ donation, we describe the institutional details that describe the mechanism for a motorcycle fatality to result in organ donation.

[7] A number of 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), Muller (2007), and Stolzenberg and D'Alessio (2003).

The Logistics of Organ Donation

Almost all non-living organ donors are brain dead at the time of organ recovery, meaning that brain function has irreversibly ceased. In the context of organ donation, the crucial distinction between brain death and the more common definition of death (known as "cardiac death") lies in the fact that the heart continues to beat after brain death occurs. Although lung function ends at brain death, current medical technology allows for essentially indefinite respiration via a ventilator, so that the internal organs receive oxygenated blood and remain fully functional. Although brain death is rare, occurring in less than 1 percent of all deaths in the U.S., it may result in useful organs for transplantation. In contrast, organs deteriorate rapidly in cardiac deaths and are therefore unsuitable for transplantation except in extraordinary circumstances.[8] 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.[9]

Head trauma and ischemic stroke are the leading causes of brain death, and both conditions often leave the rest of the body in pristine condition. The conventional wisdom 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

[8] 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.

[9] "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. Although federal law has always maintained that health care professionals only need the donor's consent to recover organs (as established in the Uniform Anatomical Gift Act of 1968), health care professionals have typically required consent from the potential donor's next-of-kin in practice. States have recently enacted stronger laws outlining what methods of consent are required to begin organ recovery, known as *first person consent* or *legally binding consent*. When transitioning to a system of legally binding consent, most states have made an effort to strengthen donor registries to ensure the decedent's wishes are accurate and accessible (Childress and Liverman, 2006).

contrast, a deceased helmeted cyclist or automobile occupant is likely to have been in a violent collision that caused widespread internal damage. Although the distinction between brain death and cardiac death is undocumented in the context of helmet laws, the existing evidence on helmet use and head injury suggests that the incidence of brain death is likely to be lower when helmet laws are in place.

Even if helmetless motorcycling produces large pools of potential donors, the effect on actual donation will be smaller because of low consent-to-donate rates.[10] In the remainder of this paper, we use the seven statewide repeals and enactments of universal helmet laws between 1994 and 2007 to shed light on the link between helmet laws and organ donation.

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 the OPTN's key initiatives involves collection and management of data from every donation and transplant occurring in the United States.[12]

[10] According to Sheehy et al. (2003), requests for donation were made in 84 percent of cases involving potential donors (a patient meeting the medical qualifications for brain death with no absolute contraindication to organ donation), but consent was granted by just 54 percent of families approached about donation. Similarly, Siminoff et al. (2001) found that 80 percent of potential donors' families were asked to consent to donation and 47.5 percent of those asked consented.

[12] 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 (http://optn.transplant.hrsa.gov/SharedContentDocuments/NOTA_as_amended_-_Jan_2008.pdf, accessed 5/19/09).

The organ donation data used in this paper are counts of deceased donors, available on the OPTN website (http://www.OPTN.org). Donor counts are collected from each OPO, meaning that all data are aggregated to the DSA level. There are 57 operational OPOs, and therefore DSAs, in the U.S. that provide data to the OPTN.[13] 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 headquartered. Because our identification is based on state variation in helmet laws, this strategy may present problems if deaths from a county in a given state are designated to another state's donor counts. However, our results below are not sensitive to restricting our analysis to DSAs that include only one state. Aggregating to the state level results in 38 observations per year because thirteen 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 demographics, such as gender and age, medical history, and certification of consent for each donor.[14] Beginning April 1st, 1994, the Worksheet recorded the donor's circumstance of death, with separate categories for motor vehicle accidents (MVA), other accidents such as falls, child abuse, suicide, homicide, none of the above, unreported and, beginning in 1999, natural causes.

Table 1 presents the number of organ donors per capita by circumstance of death and gender of donor from 1994 to 2007, with all circumstances other than MVA aggregated to a

[13] A 58th DSA serves Puerto Rico and the US Virgin Islands.
[14] For a sample Deceased Donor Registration Worksheet, see http://www.unos.org/SharedContentDocuments/Deceased_Donor_Registration.pdf

single "All Others" category. Note that because reporting of "circumstance of death" began April 1st of 1994, MVA donation rates are artificially low in 1994 because all donors from the first three months of 1994 are included in the "All Others" category. 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, donors due to MVAs were essentially flat during this period, declining from 5.43 to 5.36 per million from 1995 to 2007.

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 Fatality Analysis Reporting System (FARS).[15] 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 held 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 held steady 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 donors and death rates. In every year, men account for roughly 90 percent of all motorcycle fatalities but only two-thirds

[15] 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.

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 by gender are consistent with a role for increased motorcycle deaths in holding MVA organ donors roughly constant while non-motorcycle fatalities decreased by 20 percent since 1994. 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 number 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), 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); indicators

for whether the state had an organ donor registry, whether that registry was available online, and whether an OPO in the state enforced a "first person consent" paradigm, in which organs may be recovered from a potential donor if he or she had signed a donor card or registered with the state's donor registry, regardless of whether the potential donor's family provided consent for donation.[16] We weight each observation by the state's population in that year using U.S. Census Bureau estimates. Estimates of γ based on equation (1) capture the association between within-state variation over time in mandated helmet laws and within-state variation in organ donor rates.

Table 3 presents estimates of γ from model (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 organ donors by 0.491 per million state residents, with a standard error of 0.157 (all standard errors are robust to clustering at the state level). 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; 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 legislative endogeneity or, more generally, differential time trends across states in organ donation rates that may be correlated with the presence of helmet

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

laws. If the negative point estimates in the top row of the table are driven solely by these spurious differential trends, one might expect a negative association between helmet laws and the number of donors due to circumstances other than MVAs. This is not the case – the point estimates of γ are 0.947 and 0.485 in columns 1 and 2, respectively, although neither is statistically distinguishable from zero at conventional significance levels. Both are inconsistent with state helmet laws being enacted in response to declines in state-level organ donation rates.[17]

As illustrated in Tables 1 and 2, motorcycle fatalities and MVA donation rates differ substantially across gender, so in Table 4 we present gender-specific estimates. The first row of the table shows the effect of helmet laws on motorcycle fatalities, given by estimates of γ based on this specification:

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

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 death rate of 11.073. As shown in column 2, the absolute effect is much smaller among women, 0.367 per million persons, but this reduction is roughly 28 percent of the baseline death rate of 1.333 per million persons, a similar relative effect to that of men. Column 3 presents estimates of γ based on pooled-gender death rates, closely corresponding to the estimates in Dee (2009). The 33 percent reduction (= 4.134 / 12.414) in the pooled sample is consistent with the findings of previous studies; Dee estimates effect sizes of 27 to 34 percent in

[17] 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 significantly different from zero at the 1 percent significance level. We are wary of interpreting these estimates literally because it is unlikely that MVA and non-MVA donation rates follow identical trends within states.

specifications using the logarithm of fatalities as a dependent variable. In sum, helmet laws decrease motorcycle fatalities roughly proportionately for men and women, but the absolute size of the effect is much larger among men since men account for over 90 percent of all motorcyclist deaths.[18]

The gender-specific fatality estimates in Table 4 suggest an intuitive test for whether the association between helmet laws and organ donors is causal – since helmet laws can only causally affect the number of organ donors 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 insignificantly different from zero. Although helmet laws are estimated to reduce motorcycle fatalities among women, the absolute size of the reduction is small relative to the number of deaths in all MVAs per year – 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 sufficiently small that it is statistically undetectable using OPTN

[18] The similar relative magnitudes by gender may result from similar effects of helmet laws on helmet usage by gender. 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; however, these data do allow for estimates of helmet usage separately for drivers and passengers. In our analyses of these data, available upon request, the effect of helmet laws on helmet usage do not significantly differ between drivers and passengers, suggesting that they also do not differ across gender.

data. We view this pattern as compelling support for the face plausibility of a causal effect of helmet laws on organ donations.

As another check on the plausibility of the central results listed above, the next rows of Table 4 present 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 statistically indistinguishable from zero. We view the lack of a discernable link between helmet laws and donors due to circumstances other than MVAs, combined with the relative magnitudes of the gender-specific MVA effects, as powerful evidence that the relationship between helmet laws and male MVA donors is real.[19]

Finally, Figure 1 presents graphical analogs of the estimates in Tables 3 and 4. The top panel 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 the law was repealed, 1 denoting the following year, and so on. For each state with no law changes, year zero was randomly generated to equal either 1997, 1998, 1999, 2000, or 2003 with equal probability, since these years corresponded to actual law changes in the other group of states. The average numbers of deaths per million capita are roughly equal in years minus 3 through minus 1, but starting in year 1 they begin to diverge, with the differences increasing monotonically each year. By year 4, the differences in death rates

[19] 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.

between the two groups are dramatic, with the average in the "no law change" states being 14.98 compared to 11.80 in the "law repealed" states. We view this steady divergence as compelling evidence that helmet laws reduce motorcycle fatalities, giving a sense of the time pattern of effects that the point estimates in Table 4 do not.

Panel B of the figure shows the same divergence between "law repealed" and "no law change" states in MVA organ donors per capita among men. The patterns in Panel B are not as clean as those in Panel A, since the two sets of states have different donation rates prior to year zero, but they are consistent with the estimate of γ of -0.465 listed in Table 4. The difference in donors between the two groups increases from roughly 0.5 in years minus 1 and zero to over 1.0 in year 4. Note that the *X*-axis begins at minus 2 in Panels B and C because the earliest law repeal occurred in 1997, and the OPTN data does not allow for a clean distinction between MVA and non-MVA donors until 1995. Finally, Panel C of the figure shows the analogous time patterns for non-MVA male organ donors. Reassuringly, the trends among states that repealed helmet laws do not appear to systematically differ from those that had no law change.

Wald Estimates of the Effect of Motorcyclist Deaths on Organ Donors

Estimates of models (1) and (2) capture the reduced-form relationships between helmet laws and organ donors and between helmet laws and motorcyclist deaths, respectively. The ratio of the estimates of γ from the two models therefore represents a Wald estimate of the relationship between motorcycle deaths and organ donors. This estimate measures the causal effect of motorcyclist deaths on organ donations if the association between organ donors and helmet laws arises solely due to the effect of the laws on motorcycle death rates. Although this assumption is

strong, it is supported by the lack of an association between helmet laws and MVA organ donors among women and between helmet laws and non-MVA donors for both genders.

The implied Wald 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 average association between motorcyclist deaths and organ donors among states whose death rates are affected by motorcycle helmet laws. In other words, they measure the effect on organ donor rates of the excess motorcyclist deaths resulting from state repeals of universal helmet laws.[20] Taken literally, the point estimates imply that every motorcyclist death due to the lack of a motorcycle helmet law produces 0.123 to 0.131 additional organ donors.

These point estimates allows us to measure 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.[21] Under the upper-bound assumption that each of these organs saves one life, the pooled Wald estimate implies 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. 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, our estimates suggest that deaths due to helmetless riders may have significant impacts on the death rates of persons who may never ride a motorcycle.

[20] See Imbens and Angrist (1994) for a detailed discussion of local average treatment effects in the context of a binary instrument.

[21] This number 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.

As a further gauge on 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 additional 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):

$$D = P \times D_{hm} + (1\text{-}P) \times D_o, \tag{3}$$

where P is the proportion of all MVA fatalities that involve helmetless motorcyclists. Our pooled Wald estimate of 0.124 represents an estimate of D_{hm}. According to (unreported) FARS national data on traffic fatalities in 2007, 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.

It is also useful to compare the Wald estimates to published estimates of the donor conversion rate, defined as the fraction of viable potential donors who actually become donors. Sheehy et al. (2003) and Guadagnoli et al. (2003) find this rate to be roughly 0.42, so if every motorcycle fatality involved a brain dead victim who was otherwise healthy, the number of organ donors would increase by 0.42 per motorcyclist death. Based on the preferred Wald estimate, the implied proportion of motorcyclists who are viable organ donors is 0.29 (= 0.124 / 0.42). We are obviously wary of interpreting this number literally because it is the ratio of three separate estimates and is based on the assumption that organ conversion rates for motorcyclists are similar to those in the population of potential donors**.** Despite this caveat, 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 place our results in a larger context: how would eliminating all universal helmet laws affect organ donations 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 estimates imply that helmet laws reduced 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. Not all deceased motorcyclists become potential donors and not all potential donors provide informed consent, so the resulting reduction in organ donors was only 80 (= 0.514 * 155). This reduction translated into 216 (2.7 organs/donor *80) fewer organs transplanted. Relative to the 22,049 organs transplanted from deceased donors in the U.S. in 2007, the elimination of all universal helmet laws in the U.S. would increase the annual number of transplants by less than 1 percent.

The interpretation of the magnitudes of the effects of helmet laws seemingly uncovers a contradiction: helmet laws decrease MVA-based organ donors by roughly 10 percent, a dramatic effect, but the resulting increase in overall organ donors is miniscule. This discrepancy arises because those killed in traffic accidents account for only a small fraction of organ donors. As

Table 1 showed, in 2007 fewer than 20 percent of all deceased organ donors' circumstance of death involved MVAs, and motorcyclists represent only 12 percent of all MVA fatalities. As a result, the scope for the effects of helmet laws on organ transplants is limited, a fact that is even more apparent relative to the current (as of 6/8/2009) and steadily-growing U.S. transplant waiting list of nearly 102,000 people.[23]

V. Conclusion

Helmet mandates are effective – our estimates, which are consistent with a larger literature, imply that motorcyclist fatalities decline by thirty percent when universal helmet laws are enacted. Although many riders presumably know the risks of riding without a helmet, the relatively low rate of helmet usage in states without universal mandates suggests that roughly 40 percent of motorcyclists prefer to ride without a helmet in spite of the inherent danger. Helmet mandates increase private costs for these riders, but supporters of the mandates argue that these costs are justified by a reduction in the social costs imposed by those injured or killed in accidents.

This paper finds evidence that helmet laws also decrease the social *benefits* of helmetless riding by reducing the number of organ donors. Our central estimates show that organ donations due to motor vehicle accidents increase by 10 percent when states repeal helmet laws. Nearly all

[23] The dramatic shortage of organs has generated a large number of theoretical and empirical papers evaluating direct mechanisms for increasing the number of organ donations. A 2007 issue of the *Journal of Economic Perspectives* addresses the severe shortage of organs. Becker and Elias (2007) focus on financial incentives for increasing living donors. Howard (2007) reviews the suggested policies for increasing the pool of potential deceased donors and the consent rates among those donors. 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 and is being considered as a national kidney exchange (http://kuznets.fas.harvard.edu/~aroth/alroth.html#KidneyExchange). Abadie and Gay (2006) find that presumed consent countries had 25 to 30 percent higher donation rates than informed consent countries after controlling for other covariates.

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 motor vehicle accidents, suggesting that the association between the laws and organ donations does not merely reflect differences in underlying trends between states with and without universal laws.

Understanding the unintended consequences of helmet laws allows for more informed policymaking by providing a more complete picture of the costs and benefits involved. Although our estimates point to a sizeable effect of helmet laws on motor vehicle accident-based organ donations, the repeal of all helmet laws as a measure to reduce the severe shortage of organs in the U.S. would be ineffective in isolation, primarily because over 80 percent of organ donors die due to circumstances unrelated to motor vehicle accidents. Our preferred estimates imply that nationwide elimination of helmet laws would increase annual organ donations 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

Dependent Variable	(1)	(2)	Sample Mean
Donor circumstance:			
Motor Vehicle Accident	-0.491	-0.514	5.148
	(0.157)	(0.146)	
All others	0.947	0.485	17.668
	(1.283)	(0.769)	
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, 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.
4) The results are robust to limiting the treatment group to states that only receive donors from that state, i.e., Florida, Louisiana, and Texas (the point estimates and standard errors slightly increase in magnitude), and to limiting states in the control group to those that receive no donors from treatment states. The results are also robust to measuring the law as the number of months the helmet law was in place during the year. Finally, treating the dependent variable as a count variable, estimating all models by Poisson quasi-maximum likelihood, or measuring it as the log of per capita donor rates also lead to similar results.

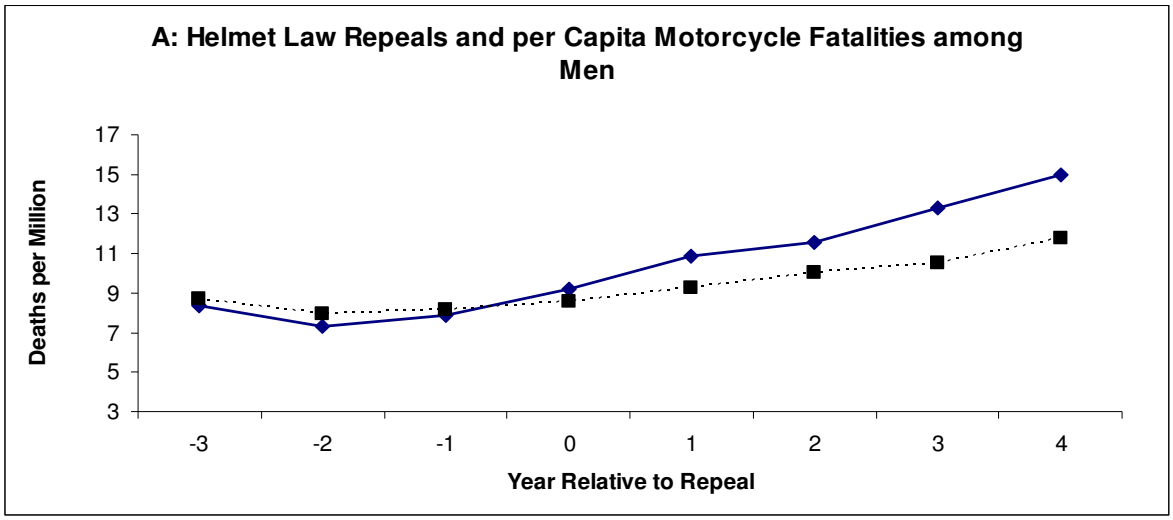
Table 4: Estimates of the Effect of Helmet Laws on per Capita Motorcycle Fatalities and Organ Donors, by Gender

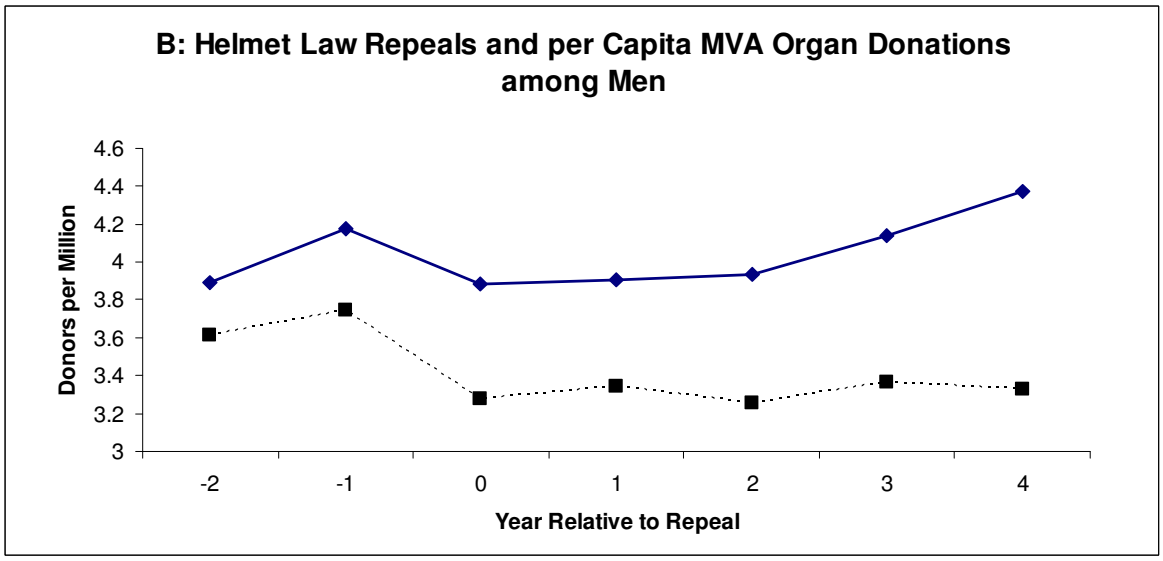
Dependent Variable	(1)	(2)	(3)
	Males	Females	Pooled
Motorcycle Fatalities	-3.766	-0.367	-4.134
	(0.385)	(0.097)	(0.421)
	[11.073]	[1.333]	[12.414]
Organ Donors by Circumstance:			
Motor Vehicle Accident	-0.465	-0.048	-0.514
	(0.106)	(0.075)	(0.146)
	[3.445]	[1.702]	[5.148]
All others	0.649	-0.060	0.485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

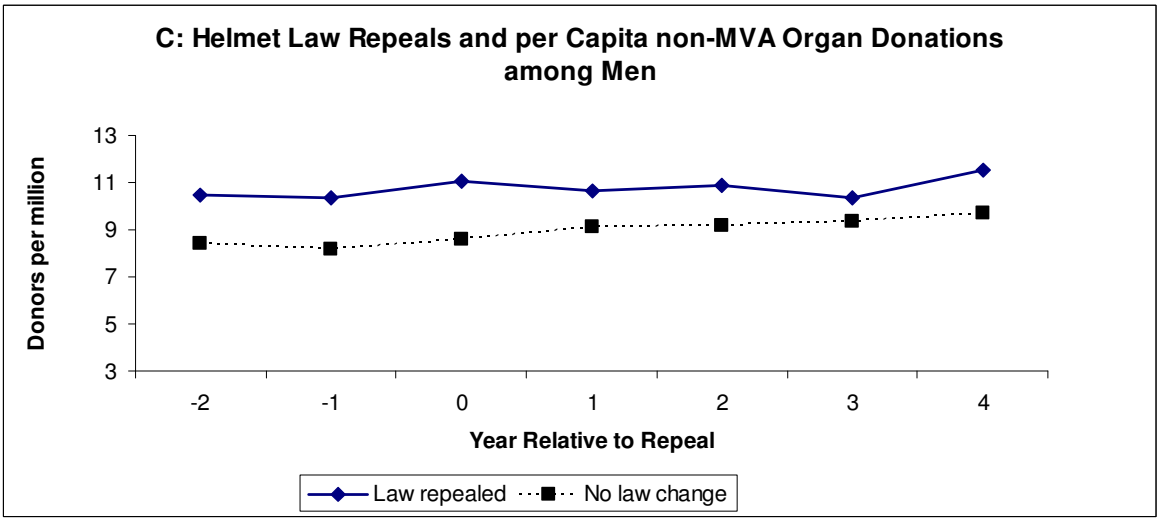
Notes:

1) All estimation samples consist of 38 states from 1994 to 2007. The unit of observation is state*year. All models include indicators for years and states.
2) Controls are as described in 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







Notes: Authors' calculations from FARS and OPTN data.

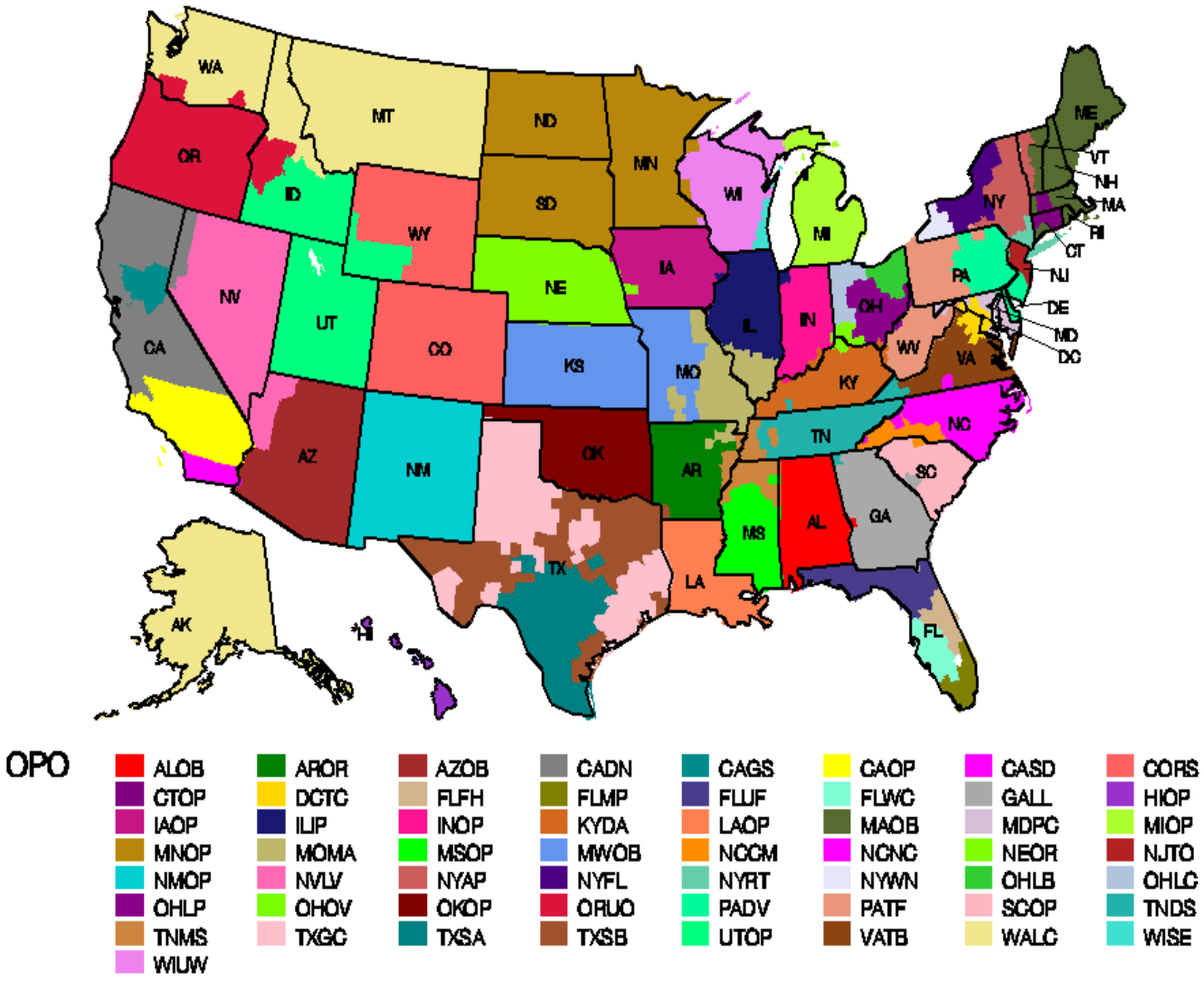
Appendix Table 1 – Changes in State Helmet Laws, 1994-2007

Year	No to Partial	Full to Partial	Partial to Full	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 (that is, 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

United Network for Organ Sharing
OPO Donation Service Areas



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