

# Legal Origins, Religion and Health Outcomes: A Cross-Country Comparison of Organ Donation Laws

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## Abstract

This paper investigates what drives countries to legislate presumed consent —making citizens organ donors by default unless they opt out —instead of explicit consent. A wide range of economic, social, political, institutional, and demographic variables is used. Results reveal the following: (i) civil law predicts presumed consent, which uncovers a mechanism by which an institution that long pre-dates transplantation medicine has an impact on current health outcomes; (ii) Protestantism predicts explicit consent; and (iii) higher pro-social behavior decreases the likelihood of presumed consent. The plausible mechanisms and implications are discussed.

Keywords: Organ donation laws, presumed consent, legal origins, religion, altruism, regulation.  
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# 1 Introduction

Across the World Health Organization member states, an estimated 126,670 organs were transplanted in 2015 (Global Observatory on Donation and Transplantation, 2015). This figure pales in comparison to the number of patients with end-stage organ failure: within the US alone, nearly 120,000 patients are on the transplantation waitlist, and an estimated 20 people die each day while waiting for a transplant (US Department of Health and Human Services, 2018). Despite progress in transplantation medicine, there remains a worldwide shortage of organs available.

In the face of a global shortage, countries vary widely in their rates of deceased organ donation (IRODAT, 2017). Cross-country analyses suggest that this may be influenced by the type of legislation implemented—whether a country presumes consent (such that residents are organ donors by default unless they ‘opt out’), or requires explicit consent (where residents actively ‘opt in’ for organ donation) (Johnson and Goldstein, 2003; Abadie and Gay, 2006; Gimbel et al., 2003; Shepherd et al., 2014). Experimental research suggests that the default influences individual decision-makers by communicating a recommendation or by normalizing organ donation (Davidai et al., 2015; McKenzie et al., 2006). Correspondingly, several countries have reported increases in the donor pool after presumed consent laws were passed (Shum and Chern, 2006; Rithalia et al., 2009).

While a causal link has not been established definitively, a systematic review of the literature concluded that “[i]n the four best quality between-country comparisons, presumed consent law or practice was associated with increased organ donation—increases of 25-30%, 21-26%, 2.7 more donors per million population, and 6.14 more donors per million population in the four studies” (Rithalia et al., 2009). Taken together, the extant literature suggests that the introduction of presumed consent would result in an increase of donation rates (Ugur, 2015; Li et al., 2013; Oz et al., 2003).

Although the potential implications of policy types are sizable, to the best of our knowledge, there has been no study that uses data from all continents to explore in a systematic manner what drives countries to choose presumed over explicit consent. This is what this paper does: by identifying mechanisms that have led countries to establish opt-out laws, this paper aims to inform future debates on the suitability of such laws in different contexts.<sup>1</sup>

Our data set includes all countries present in the International Registry on Organ Donation and Transplantation dataset (IRODaT – Gómez et al. (2014)). This leaves us with 93 countries from all five continents, which we categorize as *explicit consent* (if they require individuals to opt in as donors;  $N = 48$ ), *presumed consent* (if consent is assumed, unless indicated otherwise;  $N = 39$ ), and *unclear/mixed policy* (no legislation in this matter, no organs procurement from the deceased, no national organ networks, or unclear policy;  $N = 6$ ). We focus on those variables that the previous literature has considered to be relevant with regards to decisions about deceased organ donations (Abadie and Gay, 2006; Rithalia et al., 2009; Shepherd et al., 2014): religion and system of beliefs, in particular beliefs about the value of preserving the body after death; public preferences for redistribution and for a public health system; economic and technological capacity to carry out transplants; legal traditions; and other-regarding preferences, in particular altruism. Hence, we collect data on economic development, social equality, state religiosity, religion preferences, legal system, urbanization, human development, political preferences, and altruism.

Results reveal a few key predictors. First, countries with civil law regimes are more likely to enact

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<sup>1</sup>While (Shepherd et al., 2014), (Abadie and Gay, 2006) and (Healy, 2005) suggest a few patterns, their studies do not aim to systematically uncover the determinants of presumed consent, and have significantly smaller sample sets for analysis (48, 22, and 17 countries, respectively) than ours (93 countries).

presumed consent policies. Previous research has uncovered the preference of civil law countries for a more centralized and activist government in areas related to economic development (such as labor markets, property rights, or state ownership), which is consistent with our finding. [Anderson \(2018\)](#) and this paper are the first ones to document that the impact of legal origins extends to the sphere of health.

Our finding has also relevant implications for Legal Origins Theory: critics have argued that legal origins are “merely a proxy” for political, historical or social developments that occurred as the legislation was being developed ([La Porta et al., 2008](#); [Spamann, 2015](#)). In clear contrast to this, organ donation laws did not appear until well into the second half of the 20th century —organ transplants were not feasible in a safe and systematic way until the 1970s.<sup>2</sup> That is, *many* decades after the establishment of the legal system. Hence, the only way that legal origins may have affected organ donation laws is via the *modus operandi* inherent to each type of legal system — i.e., a preference for “private market allocations vs. a preference for state-based allocations” ([La Porta et al., 2008](#)). In this sense, organ donation laws are a perfect case in point to illustrate that countries design laws consistently with their legal traditions, which is in essence the core of Legal Origins Theory.

Second, compared to Catholic countries, Protestant countries are considerably more likely to prefer explicit consent laws — we find no significant effects for other religious faiths. Previous research has shown that Protestantism encourages the pursuit of an active, social responsibility among its members, whereas Catholicism has been characterized by more hierarchical structures ([Lam, 2002, 2006](#)). Our findings emphasize how these behavioral and institutional patterns ultimately translate into legal outcomes. Third, whereas the following result is not always robust, we believe it uncovers a pattern that is worth highlighting, especially given the small size of our sample: countries with a larger religious population (including believers of any faith) are more likely to avoid presumed consent policies. Although formally no religion opposes deceased donations ([Bruzzzone, 2008](#)), research has consistently shown a negative correlation between religiosity and organ donations ([Ugur, 2015](#); [Wakefield et al., 2010](#); [Rumsey et al., 2003](#); [Wong, 2010](#); [Ghorbani et al., 2011](#); [van Dalen and Henkens, 2014](#)). Fourth, countries with higher pro-social behavior tend to *avert* presumed consent. This could result from the norm of giving being regarded as an active process in countries where philanthropy is high ([Davidai et al., 2015](#); [Shepherd et al., 2014](#)). Taken together, these results suggest that the legislator is to some extent responsive to the preferences of the public.

In a period when many countries are re-visiting their organ donation laws (only in 2018, Argentina, the Netherlands and Ukraine have updated them), our findings have relevant policy implications. However central the role of legal origins may be, the salience of the religious and social values dimensions highlight the importance of recognizing that adoption of presumed consent does not occur in a vacuum. Previous studies have emphasized the need for parallel measures in order to guarantee the success of opt-out systems ([Shepherd et al., 2014](#); [Li et al., 2013](#); [Bilgel, 2012](#)). Similarly, several countries have debated this possibility in the public space, but concluded that cultural factors rendered an opt-out policy impractical ([Etheredge et al., 2018](#)). As [La Porta et al. \(2008\)](#) note, states may apply the tools characteristic of their legal style to areas of regulation where they are inappropriate. Presumed consent laws are likely to be a good example if the legislator fails to register public preferences that are opposed to such procedures.

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<sup>2</sup>Although the first successful kidney transplant took place in 1954 —between two identical twins—, techniques to prevent rejection of transplanted organs were not discovered until two decades later ([Watson and Dark, 2012](#)). “[Until then,] there were no laws governing the removal of organs for use in living individuals. There was simply no need for such laws.” ([Howard et al. \(2012\)](#), p. 9). See also (<https://www.organdonor.gov/about/facts-terms/history.html>) for details.

## 2 Data and empirical specification

Countries are selected if they are in the International Registry on Organ Donation and Transplantation dataset (IRODAT – Gómez et al. (2014)). This leaves us with 93 countries, which we categorize as follows: explicit consent (countries that require individuals to opt in as donors;  $N = 48$ ), presumed consent (countries where consent is assumed, unless indicated otherwise;  $N = 39$ ), and unclear/mixed policy (countries that do not have legislation in this matter, do not procure organs from the deceased, do not have national organ networks, or cannot be identified clearly as having either explicit or presumed consent;  $N = 6$ ). Table 1 and Table 2 in the Supplementary Materials provide the list of countries, their current legislation status and the sources used.

For each country, we collect information on all factors that could plausibly influence deceased organ donation laws. We use main religion, state religiosity and % of religions population to capture the dominant *credo* and system of beliefs regarding the dead and their bodies — in particular, predominant religion of each country is determined as the largest religious community according to CIA (2018).<sup>3</sup> Size of public sector, size of public health system and maximum tax rates are used to proxy political preferences, in particular preferences for redistribution and for a public health system. GDP per capita, degree of urbanization, life expectancy, literacy rate, formal education levels and OECD membership capture economic development and technological capacity. Legal system captures the preferences and *modus operandi* of the legislator. Democracy index, Gini index and percentage of members of parliament who are women capture the level of equality and social development. Lastly, blood donations per capita and giving index score measure other-regarding preferences. Figure 2 shows a world map with the main variables of interest: donation laws, legal origins, and religious faith. Table 3 in the Supplementary Materials gives further details on the sources of all independent variables, whereas Table 4 (Supplementary Materials) provides the descriptive statistics and further details.

[Figure 1 about here ]

To find the key predictors of presumed consent, we run a linear regression model where each country is an observation:

$$\text{Policy}_i = \alpha + X_i' \beta + \varepsilon_i, \quad (1)$$

$\text{Policy}_i$  is a dummy that captures presumed consent (1=presumed consent; 0=explicit consent),  $i$  denotes country, and  $X$  denotes the vector of independent variables. Given the limited number of observations we have, we have to restrict the number of independent variables in the analysis. Hence, the variables included in  $X$  are legal origins, state religiosity, % who are religious, dominant religion, log of GDP per capita, % who have secondary school degree, size of the public sector, degree of urbanization, democracy index and OECD membership. We include all remaining ones in a series of robustness checks.

## 3 Results

Table 1 provides results. Each column displays the coefficient for all independents variables included in each regression. The base category for civil law is “No civil law”.<sup>4</sup> Results for “both Civil and Common Law” are omitted. The base category for religion in column (4) is Catholicism. Results for “other

<sup>3</sup>We group them into the following categories: Catholicism; Protestantism; Orthodoxy (Christian); Islam; and Other (which includes Judaism, Confucianism, Buddhism, Hinduism, and Shintoism)

<sup>4</sup>20 countries in the dataset have no civil law, of which 17 have common law, and 3 have neither, according to CIA (2018).

religion” are omitted. Column (4) excludes Australia and Germany, since both countries have virtually the same number of Protestants and Catholics according to the official statistics (for instance, whereas the CIA World Factbook specifies that there are 0.7% more Protestants than Catholics in Australia, the Australian Bureau of Statistics recently stated that “Catholicism is the largest Christian grouping in Australia” albeit by a small margin ([Australian Bureau of Statistics, 2017](#)), and the US Freedom Report on Australia does not provide a clear answer on the largest denomination in the country ([US Department of State, 2016](#))).

[Table 1 about here ]

Table 1 reveals that the strongest predictors of presumed consent are legal origins and religion. First, civil law countries are more likely than common law countries to have an opt-out system. The magnitude of the observed effect is large: *caeteris paribus*, civil law countries are five times more likely to enact presumed consent laws than common law countries.

Second, the influence of a country’s predominant religion does not pale in comparison. Namely, countries where Catholicism dominates are around four times more likely to enact presumed consent than countries where Protestantism dominates. We find no significant results for other religions when we compare them to Catholicism. Excluding Australia and Germany does not alter our results: When we include them, the resulting p-values for Protestantism are 0.023, 0.042, 0.008, and 0.004 (for all four possible combinations).

Apart from legal origins and religious faith, we find that countries with a larger proportion of religious population —regardless of faith— tend to prefer explicit consent systems. Everything else held constant, a country where half its residents hold any religious faith will enact presumed consent with a probability close to 75%, whereas that probability drops to around one third for a country where everyone is religious. However, as discussed below, this result is not robust to all specifications (Figure 3c).

Table 5 in the Supplementary Materials replicates Table 1 with the inclusion of countries where the policy is not clear (i.e., where the dependent variable is 1 for presumed consent and 0 for explicit consent/no policy/unclear/mixed). All results hold.

### 3.1 Robustness checks and alternative explanatory variables

Next we check if results hold for alternative specifications that incorporate all remaining controls described above. In order to keep a reasonable number of degrees of freedom, we include these controls one at a time. That is, the robustness checks we carry take the following form:

$$\text{Policy}_i = \alpha + X_i' \beta + \gamma z_i + \varepsilon_i, \quad (2)$$

where  $z$  is the new variable included in each case.

Figure 1 in the Supplementary Materials shows that —with only one exception— no other variables have explanatory power at conventional statistical levels. In other words, economic and social development, preferences for redistribution or size of the public health sector are not correlated to any type of policy. The exception is altruism: when we include measures that capture pro-social behavior, we find that *lower* levels of altruistic behavior are associated with opt-out consent systems. Results are displayed in Figure 2. We proxy altruism with ‘giving index’, a measure constructed by the Charities Aid Foundation by means of a worldwide survey ([Charities Aid Foundation, 2017](#)). Specifically, it is computed based on the proportion of people who report one or more of the following non-health related altruistic

behavior in the month prior to being interviewed: helping a stranger, donating money, and volunteering. We find that countries in which residents report higher levels of giving are more likely to enact explicit consent. To be precise, the predicted probability that a country enacts presumed consent decreases by 1.7 percentage points as the giving index score increases by one percent. This means that the predicted probability of having opt-out for a country with a giving score of 25% is around three times larger than for a country with a score of 50%. As with the percentage of religious adherents, however, this predictor is not robust across all model specifications (Figure 3d).

[Figure 2 about here ]

Figure 3 shows how robust results for the main explanatory variables are to the inclusion of the extra controls. Figure 3a, for instance, shows the 95% confidence intervals of the coefficient on civil law when each of the extra controls is included. We repeat this exercise for dominant religious faith (Figure 3b), size of religious population (Figure 3c), and altruism (Figure 3d).

Figures 3a and 3b show that results for civil law and Protestantism are robust to all specifications (with one exception each). This gives us confidence on the robustness of our findings.<sup>5</sup> On the other hand, Figure 3c shows that results regarding proportion of religious population are not as robust: even though the point estimate and confidence intervals indicate a clear negative correlation, only in one case the 95% confidence interval fails to cut the vertical bar at 0. Whereas we contend results in 3c are clearly suggestive, we cannot make conclusive statements as with the case of legal origins and Protestantism. Finally, Figure 3d shows that results for altruism are robust to most specifications, although they fail to meet conventional significance levels in three cases.

## 4 Discussion and remarks

Having accounted for structural, political, economic, and social variables, we find that the historical origin of a country’s laws is the strongest predictor of organ transplant policies: countries with civil law regimes are more likely to enact presumed consent policies, whereas common law countries are more likely to prefer explicit consent rules. This confirms earlier evidence presented in (Shepherd et al., 2014) and (Abadie and Gay, 2006), who suggested the same pattern with much smaller data sets for analysis (48 and 22 countries, respectively).

Historically, the common law tradition originates from the laws of England, whereas the civil law tradition has its roots in the Roman law, and was adopted and exported by France. These two legal systems operate in very different ways: civil law relies on professional judges, legal codes, and written records; whereas common law focuses on lay judges, broader legal principles, and oral arguments (Glaeser and Shleifer, 2002). Furthermore, common law follows the legal principle of *stare decisis*, — i.e., precedent is binding— while this is not necessarily the case for civil law (Dainow, 1996). Since legal traditions were typically introduced into colonized countries through conquest, persisted after independence, and varied between common and civil law colonizers, they provide a natural experiment for researchers to trace the effects of legal system variation on various outcomes (Anderson, 2018).

Among other findings, civil law regimes are more likely to impose military conscription (Mulligan and Shleifer, 2005), to have government ownership of media (Djankov et al., 2003) and banks La Porta et al. (2002), to strictly regulate labor markets (Botero et al., 2004), to favor a heavier hand of government

<sup>5</sup>The countries that are defined as Protestant in our data set are Denmark, Finland, Latvia, Iceland, New Zealand, Norway, South Africa, South Korea, Sweden, Trinidad and Tobago, United Kingdom, and the United States of America (CIA, 2018). Australia and Germany are excluded from the analysis for the reasons explained above.

ownership and more hierarchical regulation (La Porta et al., 2008; D’Amico and Williamson, 2015), and to be more comfortable with a centralized and activist government than common law regimes (Mahoney, 2001). Adding to this literature, our findings suggest that donation laws also tend to reflect the polity’s default position on broader conceptions of the relationship between the individual and the state (Healy, 2005). Notably, by highlight how the more interventionist approach of civil law countries extends to the area of organ donation laws, our results underscore how legal origins have consequences that extend into the sphere of health: while it has been claimed that ‘default saves lives’ in organ donation (Johnson and Goldstein, 2003), the evidence suggests that a country’s legal origins is what dictates its default in the first place. This complements recent work highlighting the impact of legal origins on the HIV rates of females in Sub-Saharan Africa (Anderson, 2018).

The second key predictor of donor legislation is religion. Countries where the largest religion is Protestantism are more likely to choose explicit consent as compared to countries where Catholicism dominates; the latter are nearly 30 percentage points more likely to legislate presumed consent than Protestant-dominant countries. Notably, this is not driven by religious credo, since formally all religions endorse deceased organ donation (Bruzzzone, 2008). In particular, Protestant and Catholic leaders express equal levels of support to deceased donations (Oliver et al., 2011). We thus contend that our observed findings reflect the institutional and social dynamics induced by these two different religious affiliations.

In previous research, Protestantism has been associated with higher levels of altruism (Mocan and Tekin, 2007; Bekkers and Schuyt, 2008). It has been show to encourage lay members to engage in voluntary activities both inside and outside the church (Lam, 2006; Arruñada, 2010), to encourage the pursuit of social responsibility among its members (relative to other religions) (Lam, 2002), and to rely on more horizontal structures than Catholicism (Rose, 1954; Lipset, 1990). On the other hand, Catholicism has been characterised by more hierarchical structures and a greater reliance on the government to take responsibility, favoring the provision of social services within its own hierarchy and limiting lay involvement (Lam, 2006). Although religious leaders in Catholic and Protestant countries have no direct say on legislation, historically dominant religions are likely to leave a long-lasting imprint on cultures and may shape peoples attitudes — even if they are not religious themselves (Halman and Luijkx, 2006; Kaasa, 2013). Returning to our analyses, religions may have affected the legislator’s policy choices through the political culture they contribute to shape. In this light, the state having limited say regarding organs from the deceased seems to fit within the general lack of hierarchization intrinsic to Protestantism.

Beyond the Protestant-Catholic distinction, countries with a larger religious population (including believers of any faith) are more likely to avoid opt-out policies. Despite the fact that, as stated above, formally no major religion opposes donations (Bruzzzone, 2008), research on organ donations has consistency shown that religiosity is negatively associated with willingness to donate (Ugur, 2015; Wakefield et al., 2010; Rumsey et al., 2003; Wong, 2010; Ghorbani et al., 2011; van Dalen and Henkens, 2014). These two results fit well in any standard model of political economy where policy-makers are responsive to citizens’ demands to some extent. If religious individuals have a stronger hesitation to donate and this translates into lobbying against presumed consent, such political pressure is more likely to be successful in countries where the presence of religious groups (of any kind) is more widespread. Nonetheless, we caution that — unlike dominant religion — the proportion of religious adherents is not robust across all model specifications (Figure 3c). Further, the measure of religiosity that we use (from the CIA World Factbook) is not as precisely estimated as other variables in our data set. For example, some entries are outdated (the information for Cuba is “prior to Castro assuming power”), may require some hand-waving (the French State, by law, cannot collect any information on individuals’ religion beliefs since



1872), or may report large proportions of “unspecified” faith (e.g., 27.4% for Bulgaria, or 26.3% for Finland) (CIA, 2018). Thus, we are circumspect regarding the association between the proportion of a religious population and organ donation laws.

Finally, our results suggest that presumed consent systems are associated with *lower* levels of non-health related philanthropy. This confirms the findings in Shepherd et al. (2014). Although this result may seem surprising, experimental research suggests that opt-in policies portray donation as an active, altruistic act (Davidai et al., 2015). This portrayal aligns with the norm of giving as an active process that exists in countries where philanthropy is high (Shepherd et al., 2014). Conversely, opt-out policies depict donation as a mundane form of community service, akin to paying one’s tax (Davidai et al., 2015). In turn, this representation may encourage donation in countries where altruism is lower. Again, however, we are cautious in our interpretation as altruism was not found to be a robust predictor in all our specifications.

Taken together, our findings suggest a tension between applying the tools characteristic of a country’s legal style and its prevalent social attitudes and preferences: despite the unambiguous impact of legal origins, many legislators across the globe seem to have been responsive to the preferences and beliefs of their people. The implication is clear: when calls are made for governments to switch to presumed consent, discussions should move beyond behavioral science research to consider the broader socio-cultural context of a country.

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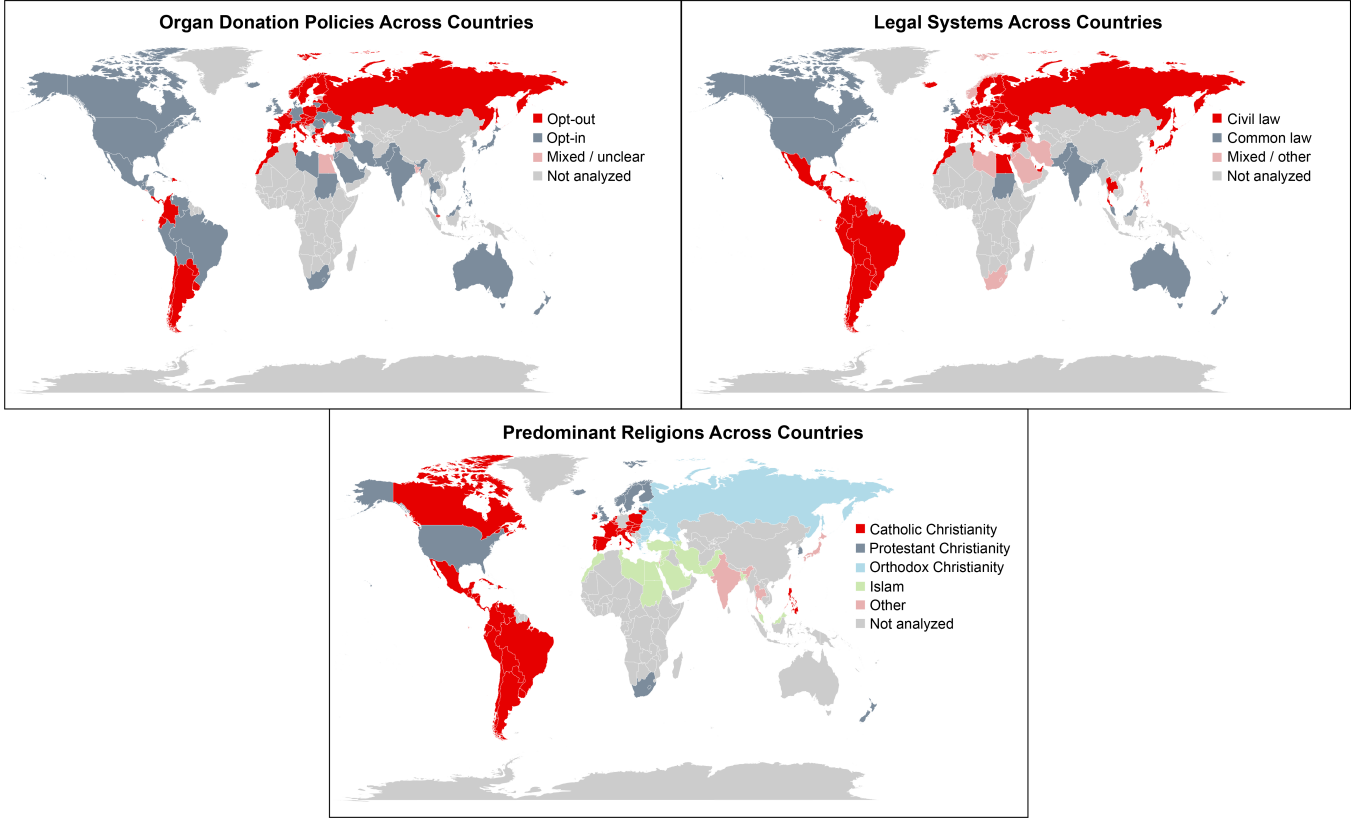


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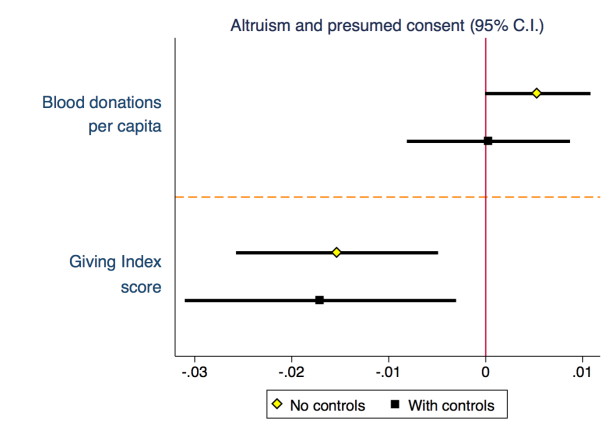
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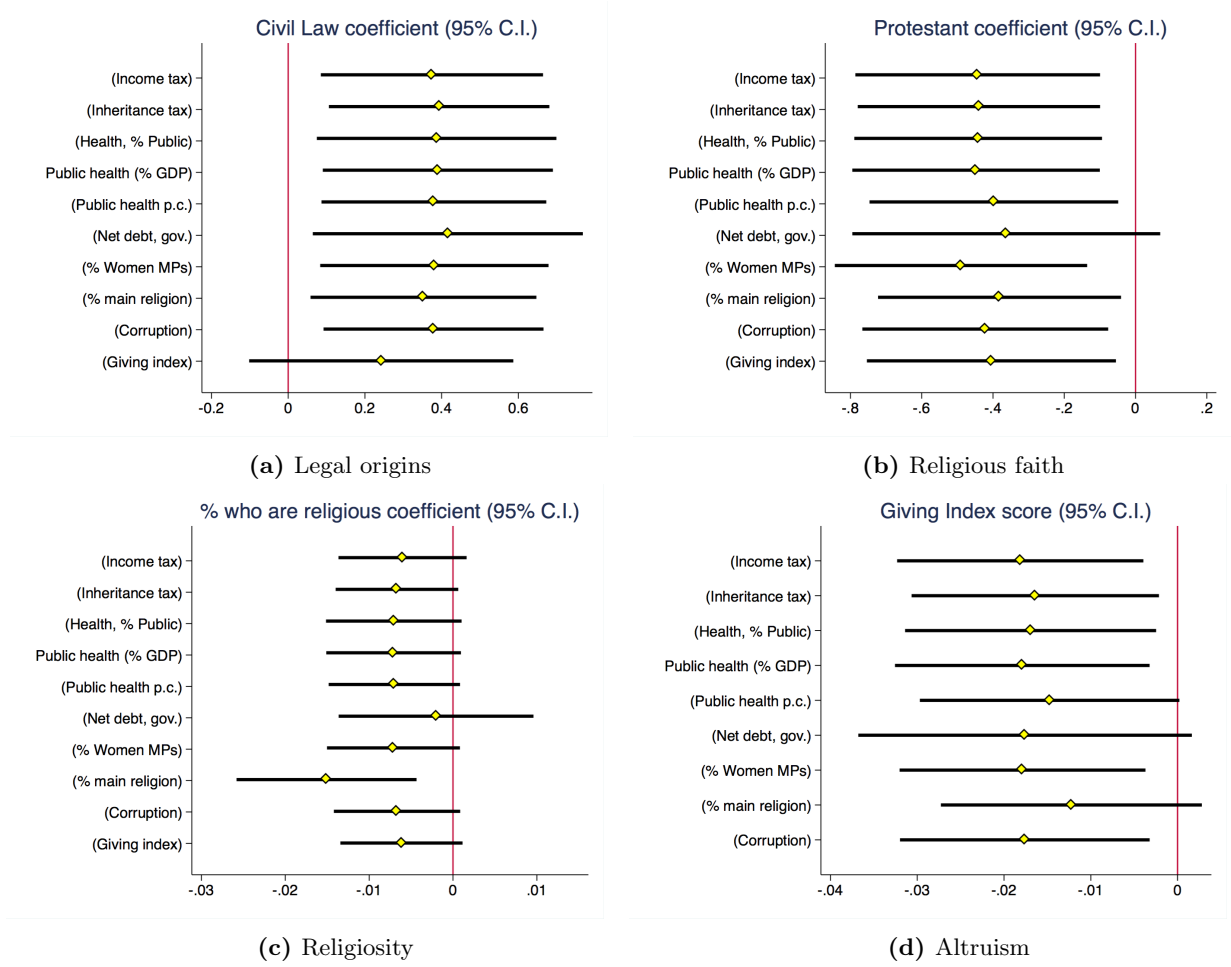
## 5 Figures



**Figure 1:** Organ donation policies (top left), legal origins (top right), and predominant religions across the globe (bottom). Countries were included in the analyses if they were part of the International Registry in Organ Donation and Transplantation (IRODaT). As Australia and Germany had more than one predominant religion, they were excluded from analyses where predominant religion was the regressor.



**Figure 2:** Bars with an empty diamond show the 95% confidence interval for the coefficient on the relevant variable on presumed consent when no controls are included. Specifically, for the  $\gamma$  in  $Policy_i = \alpha + \gamma z_i + \varepsilon_i$ , where  $i$  denotes country,  $Policy_i$  is a dummy for adoption of presumed consent, and  $z$  denotes the variable at hand. Bars with a solid square show 95% confidence intervals of coefficients when the full model with controls is used. Specifically, for the  $\gamma$  in  $Policy_i = \alpha + X_i' \beta + \gamma z_i + \varepsilon_i$ , where  $X_i$  is a vector of country specific controls: state religion, main religion, percent who are religious, legal origins, GDP per capita, democracy index, and OECD membership.



**Figure 3:** 95% confidence intervals of the coefficient for the variable of interest  $x$  (title) when the the full model with controls is used and an extra variable  $z$  (vertical axis) is included (i.e., bars represent the coefficient for the *same* variable all throughout). Specifically, the model is  $Policy_i = \alpha + X_i' \beta + \gamma z_i + \varepsilon_i$ , where  $i$  denotes country,  $Policy$  is a dummy for adoption of presumed consent, and  $X$  is a vector of country specific controls comprised of legal origins, GDP per capita, State religion, main religion, percent who are religious, democracy index, and OECD membership.  $z$  is the new control variable added in each regression.

## 6 Tables

**Table 1:** Drivers of *presumed consent* legislation

Dependent Variable: Presumed consent (opt-out)				
	(1)	(2)	(3)	(4)
Civil Law	0.454*** (0.133)	0.447** (0.135)	0.481*** (0.136)	0.386* (0.150)
log (GDP) p.c.	0.038 (0.056)	-0.022 (0.081)	-0.005 (0.081)	0.021 (0.080)
% sec. school	-0.000 (0.003)	-0.001 (0.003)	-0.003 (0.003)	-0.002 (0.004)
Public sector size	0.007 (0.005)	0.007 (0.005)	0.008 (0.005)	0.007 (0.005)
State religion	0.078 (0.125)	0.134 (0.133)	0.218 (0.142)	0.273 (0.156)
Democracy index		0.104 (0.069)	0.103 (0.068)	0.161 (0.083)
OECD		0.061 (0.166)	-0.006 (0.170)	0.032 (0.170)
Urbanization		-0.000 (0.004)	-0.002 (0.004)	-0.003 (0.004)
% religious			-0.006 (0.004)	-0.009* (0.004)
Main religion:				
Protestant				-0.449* (0.174)
Orthodox				0.049 (0.186)
Islam				0.003 (0.213)
Observations	87	87	87	85
R <sup>2</sup>	0.195	0.230	0.254	0.342

Standard errors in parentheses.

\*\*\* p<0.001, \*\* p<0.01, \* p<0.05

Only countries with well-defined policies included. Dependent Variable: 1=Presumed consent (“opt-out”); 0=Explicit consent (“opt-in”). Civil Law: legal system based on civil law only (base category: common law or neither. Unreported category: both civil law and common law). log (GDP) p.c.: Natural logarithm of GDP per capita (in 2016 USD). State religion: dummy variable for holding an official, government-endorsed religion. Public sector size: government total expenditure as % of GDP. Main religion: base category=‘Catholic’; unreported category=‘Other’. OECD: member of the OECD (dummy variable). See Table 3 and Table 4 in the Supplementary Materials for more details on the variables.