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Factors influencing deceased organ donation rates in OECD countries: a panel data analysis

Zhi Qu ,[1,2,3] Carina Oedingen,[2,3,4] Tim Bartling,[2,3,5] Harald Schrem,[3] Christian Krauth[2,3]

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HS and CK contributed equally.

HS and CK are joint senior authors.

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For numbered affiliations see end of article.

Correspondence to
Dr Zhi Qu;
qu.zhi@mh-hannover.de

ABSTRACT

Objectives This study aims to investigate factors with a significant influence on deceased organ donation rates in Organisation for Economic Co-operation and Development (OECD) countries and determine their relative importance. It seeks to provide the necessary data to facilitate the development of more efficient strategies for improving deceased organ donation rates.

Design Retrospective study.

Setting Publicly available secondary annual data.

Participants The study includes 36 OECD countries as panel members for data analysis.

Outcome measures Multivariable panel data regression analysis was employed, encompassing data from 2010 to 2018 for all investigated variables in the included countries.

Results The following variables had a significant influence on deceased organ donation rates: 'opt-in' system (β=−4.734, p<0.001, ref: 'opt-out' system), only donation after brain death (DBD) donors allowed (β=−4.049, p=0.002, ref: both DBD and donation after circulatory death (DCD) donors allowed), number of hospital beds per million population (pmp) (β=0.002, p<0.001), total healthcare employment pmp (β=−0.00012, p=0.012), World Giving Index (β=0.124, p=0.008), total tax revenue as a percentage of gross domestic product (β=0.312, p=0.009) and percentage of population aged ≥65 years (β=0.801, p<0.001) as well as high education population in percentage (β=0.118, p=0.017).

Conclusions Compared with the promotion of socioeconomic factors with a positive significant impact on deceased organ donation rates, the following policies have been shown to significantly increase rates of deceased organ donation, which could be further actively promoted: the adoption of an 'opt-out' system with presumed consent for deceased organ donation and the legal authorisation of both DBD and DCD for transplantation.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ A comprehensive data source was used for the investigation of the significance of the influence of socioeconomic factors on deceased organ donation rates among OECD countries.
⇒ The study effectively identifies and quantifies various influential factors that contribute to deceased organ donation rates, which could lead to practical and feasible improvements in organ donation rates without requiring a substantial allocation of additional resources.
⇒ Lack of availability of data on further potential confounding factors.

BACKGROUND

Organ transplantation is the gold standard treatment for patients with end-stage organ failure to improve not only life expectancy but also quality of life. However, the availability of (deceased and living) donor organs remains a critical bottleneck in this life-saving process, resulting in a continued disparity between supply and demand for organs across different countries.[1] Therefore, patients' deaths on the waiting list for an organ offer are mainly a direct consequence of the increasing gap between the demand and supply of suitable deceased donor organs per million population (pmp). This situation remains a serious worldwide challenge that is still limiting the potential benefits of transplantation.[2] For example, 13 462 patients were waiting for at least one donor organ for transplantation within the Eurotransplant region, which contains seven OECD countries at the end of 2021, while only 5624 transplants from 1897 deceased organ donors and 1181 transplants from living donors were performed in the same year.[3] Deceased organ donors can donate several organs essential for survival including heart, lungs, liver, kidneys, pancreas and small bowel, while living organ donors can only donate either one kidney or parts of their lungs or liver. This results in far less living donor transplantations as compared with deceased donor transplantations. Although organ donation rates have continuously increased in the past decades and novel developments in organ preservation and surgical techniques have significantly improved, the demand for donor organs continues to grow even faster.[4] Thus, there remains a growing and urgent need

to enlarge the pool of deceased donor organs, and to increase the conversion rate from potential organ donors to realised donations, and ultimately achieve successful transplantations.[5]

To address this gap, different strategies have been developed regarding the infrastructure to facilitate deceased organ transplantations. The debate on increasing organ donation rates by changing policies from an opt-in system (termed 'explicit consent') to an opt-out system (termed 'presumed or deemed consent') for organ donation is still ongoing. Previous studies have demonstrated that adopting the policy of presumed consent ('opt-out') rather than explicit consent ('opt-in'),[6–9] higher socioeconomic status within society (eg, high education level),[9–12] high availability of the required infrastructure for transplantation services[9 13] and the increased gross domestic product (GDP) per capita and investment in healthcare services[9 10] have an influence on successfully realised organ transplantations. While various factors are known to affect organ donation rates, none of these aforementioned studies has investigated the independence of the influence of socioeconomic factors on deceased organ donation rates.

Therefore, the goal of this study is to investigate factors with a significant influence on deceased organ donation rates and their relative weights in OECD countries and provide the data that are required to enable the most efficient strategies for the improvement of deceased organ donation rates.

METHODS

Patient and public involvement

None.

Data sources

This study used publicly available secondary annual data since 2010 to compare annual deceased organ donations pmp (deceased organ donation rates) in countries within the OECD.[14] Deceased organ donation rates were extracted from the Global Observatory for Donation and Transplantation[15] with any missing data sought from the International Registry in Organ Donation and Transplantation.[16] Socioeconomic variables were collected for multivariable panel data analysis from the following data sources that have open access: OECD,[14] Road Safety Annual Report published on the International Transport Forum,[17] WHO,[18] World Bank[19] and European Commission.[20] Specified data extracted for analysis include the following: country population, population aged 65 years or older in percentage, annual GDP per capita (US$, in US dollar), out-of-pocket healthcare costs in percentage, total tax revenue as a percentage of GDP, healthcare expenditure of GDP in percentage, deaths due to circulatory disease per 100 000 population, deaths due to external causes per 100 000 population, road traffic fatality rates (pmp), World Giving Index, population achieving tertiary education in percentage, individuals using the internet percentage of population, total healthcare employments (pmp), number of hospital beds (pmp), number of intensive care unit beds (pmp), type of deceased organ donor allowed (donation after brain death (DBD) only or donation after circulatory death (DCD)+DBD), legal system type (common vs civil law), main religion type and consent system on donation (opt-in vs opt-out). Data for the years after 2018 could not be used for further analysis due to abundant missing data for some key socioeconomic data.

Inclusion and exclusion criteria for OECD countries

OECD countries that reported information on deceased organ donation rates for the years 2010 to 2018 were included in this study. Two of the 38 OECD countries (Costa Rica and Colombia) had to be excluded because of missing values for key variables.

Inclusion and exclusion criteria for variables used for risk adjustment

A complete overview of all variables and their data sources with references is summarised in online supplemental appendix table 1. The variables summarised in tables 1 and 2 were finally chosen for the purposeful selection of covariates in panel data regression modelling after the exclusion of covariates with more than 10% missing data (online supplemental appendix table 2).

Statistical analyses

Descriptive statistics of the investigated variables were analysed (tables 2 and 3). Time-dependent effects were examined by visually depicting the trends in correlation coefficients between potential influencing factors and deceased organ donation rates over time.

Panel data were used for the purpose of gaining more informative insights and better control over individual variations.[21] Multivariable panel data regression analysis was employed with included countries as panel members with separate data for all investigated variables for each investigated year. This allows time-series observations across various cross-sectional units.

Within the panel data analysis, certain adjustments were made. Specifically, time-invariant covariates such as the legal system, consent system for donation, types of deceased organ donors allowed and the predominant religion were included. Additionally, healthcare-related covariates, such as the number of ICU beds, and socioeconomic covariates, like annual GDP per capita, spanning the entire 9-year period, were introduced as covariates varying over time in each panel member country. Modelling started with the global model with subsequent backwards stepwise removal of the variables with the most insignificant p values and re-estimation of the model until only significant variables remain in the final model.[22]

In the analysis, consideration was given to the year of data collection and the country as estimators with random effects. Since panel data are a combination of cross-sectional and time-series data, they may exhibit

Table 1 Distribution of investigated continuous variables between countries in the investigated time that justify the investigation of these variables as potential influence factors for deceased organ donation rates based on previous publications (Ref.)

Continuous variables	Mean	SD	Lower quartile	Median	Upper quartile	Ref.
Deceased organ donation rates	17.0	8.6	10.9	16.4	22.4	
Population (in millions)	35.4	58.6	5.4	10.6	47.8	10
Population aged 65 years or older (in %)	16.4	3.9	14.1	17.2	18.8	10
Annual GDP per capita (in US$)	40278.9	15750.2	28865.3	39010.5	47311.6	9–11
Out-of-pocket healthcare costs (in %)	20.4	8.6	13.7	18.2	24.5	9 10
Total tax revenue as a percentage of GDP	33.5	7.3	28.5	33.2	38.7	10
Healthcare expenditure of GDP (in %)	8.8	2.3	7.0	8.9	10.3	10
Deaths due to circulatory disease per 100000 population	322.8	152.7	219.4	267.5	353.6	40
Deaths due to external causes per 100000 population	51.1	17.8	38.5	47.7	59.2	40
Road traffic fatality rates	54.7	29.8	35.6	51.4	68.2	41
World Giving Index (score)*	37.5	12.9	26.0	38.0	47.0	9
Money	42.0	19.8	25.0	41.0	60.0	9
Time	23.4	10.6	14.0	23.0	32.0	9
Helping stranger	47.4	12.0	38.0	47.0	55.0	9
Population achieving tertiary education (in %)	40.3	12.3	33.5	41.9	47.2	12
Individuals using the internet (% of population)	85.6	8.1	80.5	86.5	91.0	10
Number of ICU beds (pmp)	11.9	7.6	6.6	9.7	13.8	13
Total healthcare employments (pmp)	48499.7	24197.1	27601.7	50922.4	65541.5	9
Number of hospital beds (pmp)	4801.9	2514.2	2927.3	4153.5	6215.5	9

*World Giving Index represented the percentage of people in each country who were willing to donate money, spend time or help a stranger, for more details see online supplemental appendix table 1.
GDP, gross domestic product; ICU, intensive care unit; pmp, per million population.

cross-sectional effects, time effects or both. Using a random effects model allowed for the comprehensive exploration of differences in error variances. The random effects model was developed on the basis of the current panel data and was specified as:

$$y_{it} = \boldsymbol{\beta}_i \boldsymbol{X}_{it} + \alpha + (\rho_i + \delta_{it})$$

where y_{it} is the number of deceased donations pmp for each individual country i and each investigated year t with $\boldsymbol{\beta}_i$ is a column vector of size [k×1] assuming k regression variables (k=1 for the OECD data panel) and $\mathbf{X}_{it}$ is a row vector of size [1×k] expressing time-varying variables (annual GDP per capita, healthcare expenditure of GDP in percentage, etc) while α is the mean of all individual-specific effects which forms the intercept of the linear regression model, and ρ_i is individual-specific effects which capture all time-invariant factors for each individual country and δ_{it} is the balance amount of error from all other sources introduced for unit i at investigated year t.

The threshold for statistical significance was set for all statistical tests to p values <0.05. All data processing and statistical analyses were performed using SAS V.9.4 (SAS Institute, Cary, North Carolina, USA). The procedure used for multivariable analysis is PROC PANEL in SAS.

RESULTS

Descriptive analysis

The distribution of investigated variables in each country and each investigated year are summarised in table 1 for continuous variables and table 2 for categorical variables. The year-by-year developments of correlation coefficients between continuous variables and deceased organ donation rates are shown in figure 1.

It is observable that the developments of Pearson correlation coefficients between deaths due to external causes per 100000 population and deceased organ donation rates as well as between the World Giving Index and deceased organ donation rates showed increasing trends over time, while Pearson correlation coefficients between total tax revenue as a percentage of GDP and deceased organ donation rates, and the number of hospital beds pmp and deceased organ donation rates showed a decreasing trend over time. These observations clearly indicate several time-dependent effects. The

Table 2 Distribution of investigated categorical variables between countries in the investigated time that justify the investigation of these variables as potential influence factors for deceased organ donation rates based on previous publications (Ref.)

Categorical variables	Number	Percentage	Ref.
Consent system on donation			7 9 24
Opt-in	17	47.2	
Opt-out	19	52.8	
Type of deceased organ donor allowed			
Only DBD	17	47.2	
DBD and DCD	19	52.8	
Legal system type			7 9 24
Common Law	7	19.4	
Civil Law	29	80.6	
Main religion type			7 9 24
Roman Catholic	15	41.7	
Catholic	4	11.1	
Evangelical Lutheran	3	8.3	
Lutheran	3	8.3	
Christian	2	5.6	
Other	9	25.0	

DBD, donation after brain death; DCD, donation after circulatory death.

developments of the trends of Pearson correlation coefficients between the other variables and deceased organ donation rates over time were not as clearly visible as shown in figure 1.

Multivariable panel data regression analysis

The multicollinearity test showed variance inflation factors (VIFs) that excluded relevant collinearities for subsequent multivariable panel data regression analysis (VIF <10). Multivariable panel data regression analysis revealed that R^2 equals 0.413. This is a fair amount of variability that the model appears not to explain. The mean square error of the transformed model was 12.791.

The following variables had a significant influence on deceased organ donation rates: 'opt-in' system (β=−4.734, p<0.001, ref: 'opt-out' system), only DBD donors allowed (β=−4.049, p=0.002, ref: both DBD and DCD) donors allowed), number of hospital beds pmp (β=0.002, p<0.001), total healthcare employment pmp (β=−0.00012, p=0.012), World Giving Index (β=0.124, p=0.008), total tax revenue as a percentage of GDP (β=0.312, p=0.009) and percentage of population aged ≥65 years (β=0.801, p<0.001) as well as high education population in percentage (β=0.118, p=0.017) (table 3). All other investigated variables did not have a significant influence (table 3).

DISCUSSION

The establishment of clinical organ transplantation as a routine procedure for the treatment of end-stage organ failure during the second half of the last century belongs to the undisputed major success stories in the history of modern medicine. These developments have produced new levels of societal achievement for humanity, while low organ donation rates still limit the benefits of transplantation for many patients with end-stage organ failure. This study demonstrates strikingly that the most impactful positive significant influences on deceased organ donation rates could be achieved by a shift from an 'opt-in' to an 'opt-out' system and expanding the scope of donors to include both DCD and DBD for transplantation. Interestingly, both of these factors can be influenced by national organ donation policy changes which would require substantial public support, while these changes would not require the provision of large additional resources for implementation when compared with the other investigated socioeconomic variables (eg, total tax revenue as a percentage of GDP). This observation is in line with previous observations. One study showed that European countries that implement a presumed consent policy are likely to have an increase in deceased organ donation rate of 6.14 more donors pmp than the mean for countries without the presumed consent policy, if all other variables are held constant.[12] The effects of an opt-out system on organ donations have been debated for a long time.[23] Several authors consider it unlikely that an opt-out system alone is able to explain the variation in organ donation rates between countries.[7 9 24] This view is supported strongly by the results of this study that identified additional factors with a significant influence on deceased organ donation rates.

Shepherd *et al* found in 2014 that the number of deceased donors in countries with an opt-out system is higher and that this presumed consent led to both, a relative increase in the total number of livers and kidneys transplanted.[9] Arshad *et al* found in a comparatively recent study that an opt-out system was predictive of fewer living donors which was not associated with the number of deceased donors or with transplantation rates in 35 OECD countries.[24] This is in contrast to the findings of this study that identified a significant influence of an opt-out versus opt-in system on deceased organ donation rates. One reason for this observation is likely associated with the identified significant time dependency as expressed by the impact of the year of data collection in the final multivariable model in this study. Therefore, an introduction of the opt-out system could be viewed as an important first step to increase deceased organ donation rates. Meanwhile, the underlying public attitudes may impact the effect of possible legislative change. Furthermore, deceased organ donation procedure optimisations may play an even more important role in practice.[7]

It is obvious that legislations that do not allow DCD donors for transplantation reduce the available donor pool. During past decades, increasingly more countries

Table 3 Shown are the results of multivariable panel data regression analysis to demonstrate the individual influence of variables on deceased organ donation rates

Variables	Coefficient (β)	SE	P value
Intercept	–11.808	10.985	0.283
Population (in millions)	0.010	0.013	0.440
Population aged 65 years or older (in %)	0.801	0.189	**<0.001**
Annual GDP per capita (in US$)	0.000	0.000	0.642
Out-of-pocket healthcare costs (in %)	–0.156	0.083	0.063
Total tax revenue as a percentage of GDP	0.312	0.119	**0.009**
Healthcare expenditure of GDP (in %)	0.040	0.318	0.900
Deaths due to circulatory disease per 100 000 population	0.003	0.006	0.643
Deaths due to external causes per 100 000 population	0.074	0.039	0.056
Road traffic fatality rates	0.016	0.020	0.425
World Giving Index	0.124	0.056	**0.028**
Population achieving tertiary education (in %)	0.118	0.049	**0.017**
Individuals using the internet (% of population)	0.081	0.119	0.498
Total healthcare employments (pmp)	–0.00012	0.000	**0.012**
Number of hospital beds (pmp)	–0.002	0.000	**<0.001**
Number of ICU beds (pmp)	0.106	0.091	0.245
Consent system on donation opt-in/opt-out	–4.734	1.405	**0.001**
Type of deceased organ donor allowed (DBD only or DCD+DBD)	–4.049	1.318	**0.002**
Legal system type	–1.389	2.191	0.527
Main religion type	0.284	0.153	0.064

Variables with significant influences are marked by bold letters.
DBD, donation after brain death; DCD, donation after circulatory death; GDP, gross domestic product; ICU, intensive care unit; pmp, per million population.

adopted policies that emphasise DCD in order to bridge the widening gap between the demand and supply of donor organs.[25–27] However, this particular setting necessitates specific programmes led by the local procurement and transplantation network to enhance donor selection, organ allocation and organ preservation, and additional ethical and legal considerations present formidable challenges.[28] A shift of national policies towards allowing and supporting DCD may therefore lead to an overall reduction in the number of transplants performed during the challenging implementation phase.[25] This study shows for the first time in a comprehensive multivariable analysis covering the vast majority of OECD countries that a policy decision in favour of allowing DBD and DCD has a statistically significant influence on deceased organ donation rates. Policies in favour of DCD should in our opinion be actively promoted in countries that are struggling with low donation rates.[29]

Furthermore, other notable influences on deceased organ donation rates include the underlying transplantation infrastructure, as well as the level of wealth and investment in healthcare. These factors are indirectly expressed, to some extent, through the observed significant impacts of variables. The number of hospital beds and total societal healthcare employments showed a negative impact on deceased organ donation rates in the current study. The potential explanation might be that having more hospital beds and healthcare employees does not necessarily mean that there is a robust infrastructure for organ procurement and transplantation. The effectiveness of organ procurement organisations and transplant centres plays a crucial role in promoting deceased organ donation. This can also be observed in the case of a country with leading deceased donation rates: Spain has relatively low numbers of healthcare resources; however, the promising growth in deceased organ donation rates provides a model for countries with a huge demand for donor organs.[2] The current analysis suggests that initiatives and continuous efforts made by the transplant community, such as donor coordinators, high transport efficiency and comprehensive training programmes, take priority over the capacity of healthcare resources. These initiatives have also succeeded in most countries,[30] despite other relevant factors disproportionally affecting deceased organ donations.

Total tax revenue as a percentage of GDP indicates the share of a country's output that is collected by the government through taxes. Therefore, it can be regarded as one measure of the degree to which the government controls the economy's resources, it is

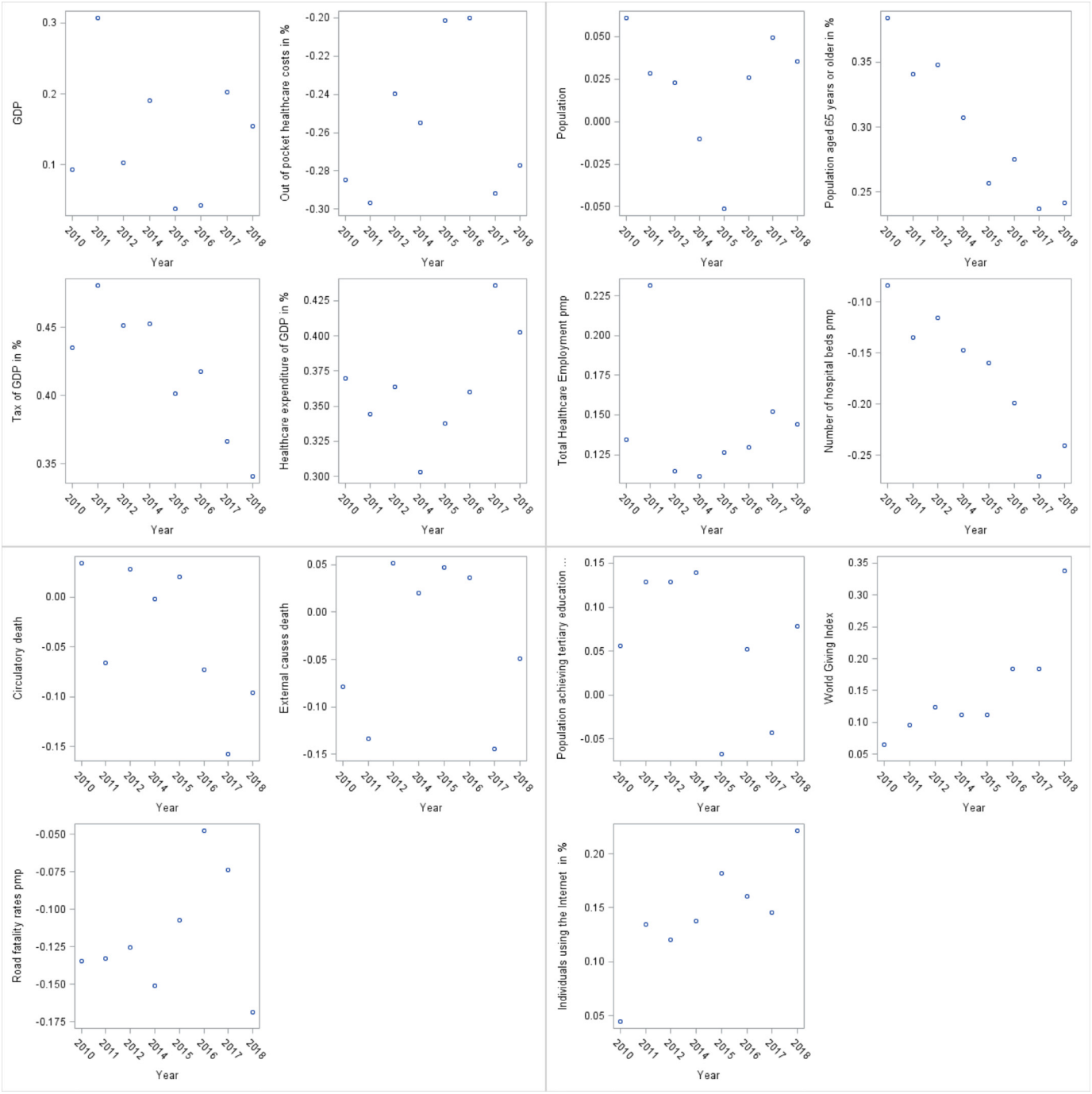

Figure 1 Illustration of the potential of time-dependent effects by plotting the development of correlation coefficients between potential influence factors and deceased organ donation rates among OECD countries for the years 2010 to 2018. GDP, gross domestic product; pmp, per million population.

considered the most reliable way to finance public expenditures from long-term prospects.[31 32] The current study shows that the total tax revenue as a percentage of GDP is a factor with a significant influence on deceased organ donation rates. This finding suggests that the economic environment plays a major role in the realisation of deceased organ donation rates. This is in contrast to previous observations.[33] However, the causation remains to be further investigated. Deceased organ donations for transplantation are an anonymous, altruistic act that is more likely to occur in societies with a stronger focus on social well-being and coherence as compared with societies with a more individualistic focus. Total tax revenue as a percentage of GDP may be a differentiator of countries in this respect. This may provide an explanation for the identified relevance of this factor in this study at least to some degree. Although both healthcare expenditure as a percentage of GDP and total tax revenue as a percentage of GDP significantly affect

deceased organ donation rates, these indicators are broad and lack a specific focus on deceased organ donation rates.

The percentage of the population aged 65 years or older showed a positive significant impact on annual deceased organ donations in this study, which may be attributed to an increase of potential donors,[34] as the 'no age limit' principle was increasingly accepted.[35] However, as older donor age is still a risk factor for allograft failure,[36] this may lead to a challenge on conversion rates among this subpopulation and a further reduction of deceased organ donation rates when the elderly population is predominant in the age structure. The peer study also demonstrated that older populations have a greater donation potential, but effectiveness decreases with older donors.[37] As the characteristics of the donor populations and the conversion rates between countries differ, age-standardised rates would provide a more precise approach to measuring and comparing donation rates between different countries. However, this study shows clearly that the percentage of the older population is an important factor for risk adjustment when analysing the impact of socioeconomic factors on deceased organ donation.

The positive impact of higher education levels on organ donation rates is evident through various channels. Individuals with advanced education tend to be more informed about the critical need for organ donation, often possessing a deeper understanding of medical procedures and ethical considerations. Moreover, higher education levels are often associated with greater socioeconomic resources, enabling individuals to engage more actively in organ donation programmes and navigate the complex healthcare system with ease. Additionally, education can foster a sense of civic responsibility and community engagement, leading to a higher willingness to contribute to the welfare of others.[38] Consequently, the correlation between higher education and increased organ donation rates underscores the potential for educational initiatives and awareness campaigns to further promote this life-saving practice, ultimately benefiting patients in need of organ transplants and strengthening the healthcare system.

Similarly, altruistic behaviour reflected in the World Giving Index also positively influences deceased donation rates through a comparable mechanism. Countries with a strong tradition of charitable giving and community engagement, as reflected in a high World Giving Index, often have populations that are more receptive to altruistic acts like organ donation.[9] A high World Giving Index can serve as a reinforcing factor that aligns with the positive impact of education, fostering a greater willingness among educated individuals to donate organs and save lives, both locally and on a global scale.[39]

A major strength of this study is the comprehensive data source that was used for the investigation of significant socioeconomic factors on deceased organ donation rates. The treatment of time as a random effect in the multivariable model is appropriate due to the illustration of time-dependent effects in figure 1. The limitations of this study include a lack of availability of data on further potential confounding factors such as more specific causes of death, different criteria for brain death diagnosis and circulatory death diagnosis. While OECD country-level data are often complete, it is believed to be coarse data. These data may be helpful in explaining what is happening on average for a country while conclusions for individuals may be imprecise which is also due to the fact that potentially important factors may not be available for analysis. This may introduce biased model estimates. Data for the years 2019–2022 could not be analysed in this study due to a substantial lack of publicly available data for most OECD countries at the time of the analysis was carried out.

Conclusions

The following policies have been shown to significantly increase rates of deceased organ donation, which could be further actively promoted: the adoption of an 'opt-out' system with presumed consent for deceased organ donation and the legal authorisation of both DBD and DCD for transplantation.

Author affiliations
[1]Transplant Center, Hannover Medical School, Hannover, Germany
[2]Institute for Epidemiology, Social Medicine and Health Systems Research, Hannover Medical School, Hannover, Germany
[3]Center for Health Economics Research Hannover (CHERH), Hannover Medical School, Hannover, Germany
[4]Erasmus School of Health Policy and Management, Erasmus Universiteit Rotterdam, Rotterdam, The Netherlands
[5]FutureTech, itsc GmbH, Hannover, Germany

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ORCID iD
Zhi Qu http://orcid.org/0000-0003-0578-939X

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