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The kidney transplant waiting list length in North-Western Europe: costs, predictors and policy intervention

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Abstract

Since the practice of organ transplantation became a reliable and effective procedure to treat patients suffering from a number of illnesses, the demand for these procedures has skyrocketed. Kidney transplants are by a great margin the highest in demand, resulting in long kidney transplant waiting lists. This study will address the fact that these long waiting lists come at a high economic and humanitarian cost, as the alternative of renal dialysis is highly costly and patients lose on average a significant number of life years when staying on dialysis instead of obtaining a donor organ. The objective of this study is to assess a number of variables that earlier research put forward as of influence on the organ donation rates to assess their relation to the length of the kidney transplant waiting list, including the adoption of opt-out legislation. This to gain a better understanding of the dynamics of these waiting lists, and what measures could be taken to shorten the lengths of the transplant waiting lists and in doing so reduce the costs associated with them. A linear mixed effects model will be used on a dataset for Eurotransplant and Scandiatransplant member states between 2014 and 2022. Apart from a few significant relations, a number of hypotheses could not be confirmed. Recommendations for further research are made to correct certain limitations of this study. The relevance and importance of further research with regards to this subject will also be addressed.

Introduction

The medical world made enormous progress over the past century, and the first successful human organ transplant in 1954 was one of those remarkable advancements. Since the practice first saw the light of day, it has become a procedure done all around the world and has saved numerous patients who were in need of an organ from a donor. Unfortunately, the practice of organ transplantation “has in some ways become a victim of its own success”, as Pomfret et al. (2008) (p. 745) described. As the number of patients in need has been growing for decades, the number of donors has not followed the same rate of growth. This mismatch between supply and demand has led all over the world to the creation of waiting lists, for patients in need for a transplant for whom there is not yet a compatible donor found. These waiting lists bear a cost, both economically and humanitarian. This is most obvious for the kidney transplant waiting list, in most countries the longest waiting list. A patient in need of a kidney needs to be on dialysis to survive, however the cost of dialysis is high, higher than the cost would be when the patient would obtain a donor kidney. In terms of life quality, the patient would be better off with a transplant, as the expected length of the patient’s life is significantly longer after a transplant than it would be when the patient stayed on dialysis for the rest of his/her life. This illustrates how the organ shortage problem brings a lot of challenges to society, and that the medical world together with policymakers need to take appropriate action to shorten these waiting lists. Some researchers argue that there are some policies that could resolve this issue, like the creation of a market for organs, but others argue that these come with too large ethical drawbacks. Furthermore, the consensus among transplant agencies and health ministries (apart from Iran) is that the sale of human organs is unethical and not desired. But the practice is still debated in academic literature, especially as transplant waiting lists grow longer. Around the world and especially in Europe, policymakers have tried to resolve this shortage by adapting the laws surrounding organ donation. In North-Western Europe for example, some countries adopted “presumed consent” legislation, making every person a potential donor, unless they “opt-out” during their lifetime. There is no academic consensus that this policy measure would shorten the waiting lists. While some studies point out a significant rise in cadaveric organ donation, others warn for a crowding-out effect, pushing back the number of living organ donation. This study aims to identify the predictors of the length of the kidney transplant waiting list using a linear mixed effects model, based on the academic literature and public data provided by the supranational transplantation organizations Eurotransplant and Scandiatransplant. This study will include the member states of these organizations over the time period 2014-2022. The objective is to identify factors that could influence the length of the kidney transplant waiting list in these countries, as well as to evaluate the effectiveness of “opt-out” legislation. This in an effort to provide governments and transplant organizations with extra insights to tackle the problem of long waiting lists and the high economic and the humanitarian cost that accompany those lists.

Literature review

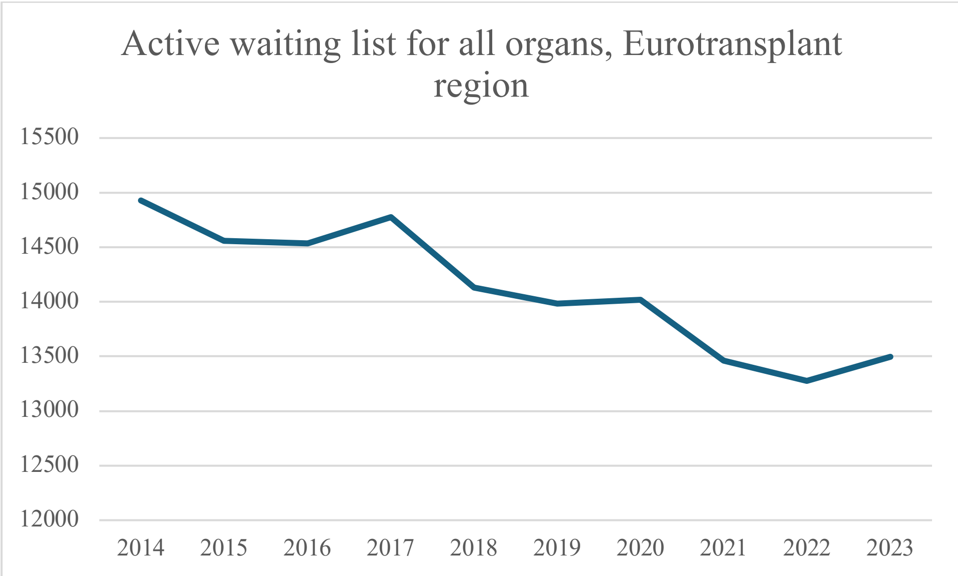
The organ shortage problem

Organ transplantation is a lifesaving and cost-effective way to treat end-stage organ failure (Beard et al., 2013; Lewis et al., 2021) but long waiting lists and organ shortages results in a growing number of organ recipients dying while on such a waiting list (Abouna, 2008; Lewis et al., 2021; Rosseli et al., 2015). Hopeful strides have been made over the past decades, for example the widespread adoption of living organ donors (LOD) for kidney, pancreas liver and lung transplantation (Lennerling et al., 2012; Lewis et al., 2021). The academic discussion to implement policies to increase procurement of donor organs is ongoing and will be discussed later, as well as the ethical considerations surrounding those policies.

At year-end 2023, there was a waiting list of 13498 patients (Figure 1) according to Eurotransplant (*Eurotransplant - Statistics*, 2024), a non-profit organization responsible for allocating and organizing organ donations between its member states (Austria, Belgium, Croatia, Germany, Hungary, Luxembourg and the Netherlands). In total it serves approximately 139 million inhabitants of these member states when in need of an organ. Most of these patients on waiting lists are anticipating a kidney (10,404) or liver transplant (1442), followed by heart (1044), lung (619) and pancreas (437). Only a small minority of patients requires a multitude of transplants. In these countries at year-end 2023, 1314 patients (Figure 2) were actively waiting on a kidney transplant, the highest number of all organs as is the case in the Eurotransplant region.
Another supranational organization in the European context is Scandiatransplant, this, also non-profit organization that facilitates organ donations between its member states (Denmark, Sweden, Norway, Finland, Iceland and Estonia) also communicated detailed statistics to the public. Given the smaller population this organization serves, the number of patients on their waiting lists are typically smaller. At year-end 2023, the number of patients actively waiting on a donor organ was 2049 all organs combined and a total active waiting list for a kidney transplant of 124 patients.

Figure 1

Active waiting list across all organs in Eurotransplant region between 2014 and 2023 (Eurotransplant - Statistics, 2024)

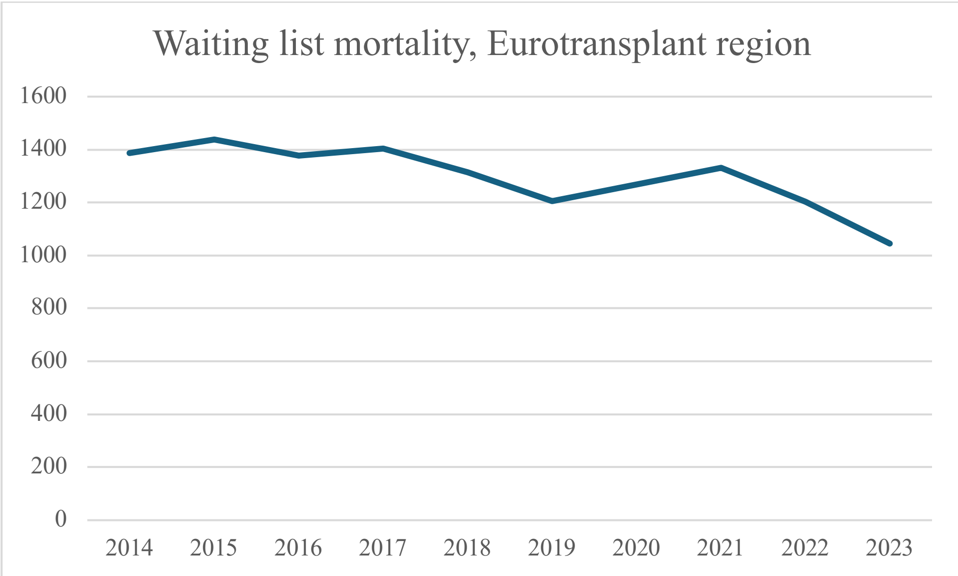


The main reason for examining the transplant market further is to be able to reduce waiting lists that every year result in waiting list deaths, for 2023 in the Eurotransplant-region this number reached 1045 patients (Figure 2). For Scandiatransplant this reached 112 in 2023. This is not only the case in Europe, in most places in the world are medical societies faced with this problem (Beard & Osterkamp, 2013; Lewis et al., 2021; Pomfret et al., 2008). A contributing factor is an increasingly complex population of patients as well as an increasing success rate in transplant procedures (Abouna, 2008; Pomfret et al., 2008).

The length of waiting lists globally, as well as in Eurotransplant and Scandiatransplant countries, are most apparent for patients waiting on a kidney. As a result, the majority of waiting list deaths are patients suffering end-stage renal disease (ESRD) and waiting on a kidney. For Eurotransplant countries this number reached 525 in 2023 (*Eurotransplant - Statistics*, 2024). Given the possibility of living organ donation in this case, the suggestion could be made that policies and incentives could, in part, solve the organ crisis (Beard & Osterkamp, 2013) and result in improvement in quality of life for the thousands of ESRD patients around the world, lowering the economic and humanitarian cost that accompany these waiting lists in the process.

Figure 2

Waiting list mortality across all organs in Eurotransplant region between 2014 and 2023 (Eurotransplant - Statistics, 2024)



Costs of transplant waiting lists

Generally, alternatives to transplantation are falling short in treating patients on waiting lists, the only patients with a reasonable alternative are patients suffering from end-stage renal disease (ESRD), i.e. renal replacement therapy (RRT) (Jarl et al., 2017). However, from both a point of view of both economic cost and quality of life for the patient, preference is given to kidney transplantation over RRT. A multitude of studies point out the initial higher cost during the year of transplantation, but also report costs falling well below yearly RRT costs from year two (Chamberlain et al., 2014; Jarl et al., 2017; Zhang et al., 2023). Zhang et al. (2023) reported an indicated cost saving after kidney transplantation of €72,000 in healthcare costs over the first three years compared to conventional dialysis. Other research in Sweden by Jarl et al. (2017) examined multiple register-based data, using a before-after design to calculate health care costs of kidney transplantation versus dialysis over a period of 10 years. Jarl et al. (2017) concluded that however the cost savings reduce over time, the cost was 75% lower after 6 years, and 66% lower after 10 years post-transplant procedure compared to the alternative of renal replacement therapy. These findings are not limited to Sweden, an analysis of healthcare costs of different renal replacement modalities from the Netherlands, using data from health insurance companies was done by Mohnen et al. (2019). These researchers came to a similar conclusion, showing an average annual healthcare cost in the year of transplantation of €85,127 comparable to the annual healthcare costs of dialysis patients (€77,566-€105,833) after which the average healthcare costs significantly fall to €29,612 and €15,018 respectively in the first and second year after a successful transplant procedure. This study also makes the distinction between healthcare costs of patients who received a kidney from a living donor and those who received a kidney form a deceased donor. Mohnen et al. (2019) reports in their findings a substantially higher cost of care across all components except for donor expenses, in recipients of a deceased donor transplant compared to receiving a transplant from a living donor (averaging respectively €99,450 and €73,376). Pomfret et al. (2008) reported similar findings, stating that transplants carried out with an organ from standard criteria donors resulted in significant cost savings compared to deceased donors or extended criteria donors. Mohnen et al. (2019) also points out that due to the high costs of renal replacement therapy, 1-2% of the national healthcare budget was spent on 0.1% of the population in 2011. This statistic together with earlier mentioned research is a clear message that the cost of not being able to provide patients suffering end-stage renal disease with a kidney transplant bears a large economic cost as well as the humanitarian cost of lower quality of life and waiting list deaths. Becker et al. (2022) report this humanitarian cost argument in a concrete way: a male patient, 45-49 years old survives on average 9 years when he stays on dialysis. But if this patient receives a kidney transplant, on average he will live for 24 more years. The authors make the calculation that these 15 additional life years following a kidney transplant, worth $120,000 per life year, constitutes a $1.8 million difference compared to when this patient would have stayed on dialysis. This can be perceived as a humanitarian cost of kidney transplant waiting lists, and an additional reason to investigate how these waiting lists can be shortened and as much patients as possible, as soon as possible, can be provided a transplant organ. McCormick et al. (2018) states that the premature deaths due to a shortage of kidney transplants are underestimated when looking at the death rate of the kidney transplant waiting list, as a number of patients not on the waiting list would also greatly benefit from a kidney transplant and another group of patients are removed from the waiting list deemed too sick to transplant.

Proposed solutions from earlier research

As there is a considerable amount of evidence suggesting that less long waiting lists and times would be of benefit to society from both an economic and a humanitarian perspective, many researchers have suggested policy changes to address this problem. Most of these proposed solutions push against barriers and spark highly ethical discussions, such as the potential violation of autonomy (Lewis et al., 2021). Additional organ procurement policies from both living and deceased donors are part of the debate (Abouna, 2008; Beard & Osterkamp, 2013; Lewis et al., 2021; Pomfret et al., 2008). A number of, mostly European, countries already implemented (some form of) opt-out legislation (Lewis et al., 2021) where there is no more formal consent needed while the potential deceased donor is still alive. Consent has become the default option in these countries, where people who wish not to donate their organs after death have to actively opt-out during their lifetime. These policies are also known in literature under the term "Presumed consent" (Abouna, 2008; Healy, 2014). While consent legislation would potentially raise organ procurement from deceased donors, another aspect to keep in mind is the evidence surrounding the economical and health superiority of transplants from living donors. Beard & Osterkamp (2013) argues that we collectively made the disaster of the organ crisis and the primary, but by no means solely reason for this is "the almost universal prohibition on compensation for organ provision.". The authors argue that presumed consent legislation can be part of the solution, but that the effect would be too small to resolve the broader shortage. Beard and Osterkamp (2013) suggest that a break from the altruistic model of organ donation is needed and a compensation model needs to be part of the debate, even tough it comes with large ethical conundrums. This suggestion is widely discussed in the literature on the topic by, including but not limited to: Abouna (2008), Beard and Leitzel (2014), Beard and Osterkamp (2013), Becker and Elías (2007) and Pomfret et al. (2008).

In some studies, researchers also point to the Spanish model of organ donation. Matesanz (2003) and Rodríguez-Arias et al. (2010) both identified some possible success factors of this model in the form of higher number of ICU beds per million population to maximize identification of potential donors, comprehensive education processes, hospital reimbursement and quality improvement (Rodríguez-Arias et al., 2010) this in combination with opt-out legislation. Some Spanish regions also adopted some highly watered-down version of the earlier mentioned compensation approach in the form of financial support for funeral costs and repatriation of the donor. A practice Rodríguez-Arias et al. (2010) deems debatable given the Spanish altruistic legal framework, the authors warn that this could jeopardize thrust in the organ donation system by the public.

Barriers and ethical considerations of proposed solutions

As discussed in the previous paragraph, the practice of a market for organ transplants is a highly controversial debate with researchers explicitly for and others against. An economic case in favour of such a market was made by Becker and Elías (2007) and revised in 2022. The authors account for both altruism and paid incentive to reduce the gap between supply and demand. Matas (2004) also suggests a regulated system for kidney sales and emphasizes the importance of vendor selection and follow-up, Beard and Osterkamp (2013) also plead for a similar model with similar safety mechanisms in place to mitigate for possible adverse self-selection by vendors. Opposing arguments of this concept argue that organ sale should remain prohibited. Delmonico et al. (2015) argue that data from the Iranian model leads to discouragement in participation from altruistic donors and additional payments between vendors and brokers. The authors conclude that in a financially incentivized organ donation system the most vulnerable members of society will be disproportionately disadvantaged. Not only for living donation is the case of financial incentivization up for debate, Epstein et al. (2011) warns for a growing acceptance of the idea to financially incentivize deceased donation. The authors warn that such a system could harm the trust between the public and the medical community, that the trust needed to accept the diagnosis of death of a loved one would be undermined when there is ambiguity in the possible financial gain of those involved. Rothman and Rothman (2006) poses the question that a system of organ sale might not necessarily mean more available organs, as a crowding-effect between the vendors and voluntary donors might occur. The authors also point to other problems such as the selection mechanism of vendors as Matas (2004) proposes, Rothman and Rothman (2006) questions how and on what grounds possible vendors would and could be excluded to potentially gain economically from the sale of their organ. Even tough there are strong opposing opinions on this topic, there are points of consensus among some researchers of opposing sides. One of them is limiting financial disincentives associated to organ donation. Gaston et al. (2006) points to the economic benefits associated with kidney transplantation when compared to dialysis to make funds available to limit certain disincentives an altruistic donor might experience in relation to donation. The authors argue that a compensation or safety net for the risk of death or bodily injury, loss of wages and other financial hurdles, what in monetary terms would be significantly lower than what open markets would dictate, more potential donors could be encouraged to pursue their altruistic impulses. Tushla et al. (2016) also formulate some policy changes to obtain financial neutrality for potential living donors in the form of a standardized system for reimbursement of lost wages and the development of specialized legislation to protect the living donor in their professional and insurance situations as well as educational platforms with regards to financial impacts.

Empirical evidence for opt-out (presumed consent) versus opt-in (informed consent) legislation

Some empirical work surrounding opt-in versus opt-out legislation has been done since the start of the 21st century. Abadie (2006) start from the observation that refusals when families were approached with the request for organ donation were significantly higher in the U.S. and the UK, informed consent countries, compared to some countries in continental Europe where presumed consent was already the norm. The authors main focus in this study is to analyze whether a significant rise in cadaveric donor rates are consistently higher in presumed consent countries. Abadie (2006) conclude that: "once other determinants of organ donation are accounted for, cadaveric organ donation rates are 25%-30% higher on average in presumed consent countries" (p. 613).

Another study, done by Da Silva et al. (2007), comes to similar conclusions using quantile regression for longitudinal data. Da Silva et al. (2007) reports a positive effect on donation rates of 21%-26%. Whereas previously mentioned studies found a significantly positive effect on donation rates, a multivariate analysis done for multiple types of donor organs by Arshad et al. (2019) does not find this significant positive effect on deceased kidney-donor rates for opt-out countries. To take this point even further, a study done by Dickert-Conlin et al. (2019) suggested a crowding-out effect where cadaveric donation rates increase in countries that implemented opt-out legislation, but a reduction in living donation rates.

This implies that it would be overly simplistic to presume that the implementation of opt-out legislation would automatically increase donation rates (the sum of deceased and living donation rates) and have a significantly negative effect on the length of waiting lists, which in turn triggers large economic and humanitarian costs (Becker et al., 2022; Chamberlain et al., 2014; Held et al., 2016; Jarl et al., 2017; Mohnen et al., 2019; Zhang et al., 2023).

As the existing research is limited regarding consent legislation on one hand and cost/cost driver on the other, there seems to be a place for a synthesis of these two topics using contemporary data. This possibly to provide countries still debating over opt-in versus opt-out legislation with extra data-based arguments regarding the possible reduction of a significant cost driver in transplant healthcare, the renal transplant waiting lists.

Research question

The main research question for this paper is defined as follows: “To what extent is opt-out legislation an effective tool in reducing the kidney transplant waiting lists, and what are the predictors of the length of this waiting lists?”. This given the academic consensus that these waiting lists are a significant economic as well as humanitarian cost driver, as patients that stay on renal replacement therapy waiting on a kidney will have a lower quality of life as well as a shorter estimated lifespan (Becker et al., 2022; Held et al., 2016).

To elaborate on this research question, this study attempts to evaluate the implementation of opt-out or presumed consent legislation in its effectiveness and statistical significance in reducing the ESRD waiting lists, defined as shortening the transplant waiting list per million inhabitants, compared to countries with an opt-in legal structure. There will also be an evaluation of possible predictors of the kidney transplant waiting lists as put forward by earlier research into donation rates (Abadie, 2006; Dickert-Conlin et al., 2019; Gimbel et al., 2003, Healy, 2014; Neto et al., 2012). This study will be performed in a North-Western European context and will use public data made available by supranational transplantation organizations (Eurotransplant and Scandiatransplant) as well as EuroStat. These results can provide valuable insights in the performance of this policy tool to combat against an increasing economic and humanitarian cost that is driven by the kidney transplant waiting lists, which in turn is driven by an international trend of rising numbers of ESRD patients (Lewis et al., 2021).

Methods and data collection

To answer this research question, a linear mixed effects model will be used to assess the structural impact of legislation type (opt-in/opt-out) on the length of renal waiting lists defined as active patients on waiting list per million population. The choice for this model is based on the ability to analyze time series data (indicators used are measured every year for every country over a period 2014-2022) and the assessment of both fixed and random effects, which is a necessary adaptation from regular fixed-effects models as correlation between measurements within the same country over time will unavoidably be correlated. This specification of the model is inspired by earlier research (Healy, 2014) in terms of model used and academic research since will be reviewed in terms of further specification of the model used as well as to identify relevant independent variables. Adjustments will be made to the model to fit the available data and to answer the research question from this paper for the case of the selected European countries, using insights from the academic literature surrounding this topic in the broader sense. Public and contemporary data will be used in this analysis, made available by The Global Observatory on Donation and Transplantation as well as national and supranational organizations on organ transplantation (i.e. Eurotransplant, Scandiatransplant). Data on other, more broad indicators such as economic and on healthcare systems will be accessed trough the OECD and governmental databases.

Specification of the model

As earlier mentioned, given the nature of the dataset used (cross-sectional, time-series) this longitudinal study opts to use a mixed-effects model (Raudenbush et al., 1993) to assess the effect of opt-in versus opt-out legislation on the length of kidney transplant waiting lists. The dependent variable is defined as the length of transplant waiting lists per million population, sourced for subject countries. Independent variables include GDP per capita, type of legislation (opt-in/opt-out) where presence of opt-in legislation adopts the value 0 and the presence of opt-out legislation 1 in the form of a dummy variable (Table 1), traffic fatality rate (per million people), fatality rate from cardiovascular diseases (per million people), proportion of people with tertiary education (in percent) number of hospital beds (per million people). These independent variables are selected based on earlier research (Abadie, 2006; Arshad et al., 2019; Healy, 2014; Rithalia et al., 2009).

Following the introduction of the chosen model and variables, it is possible to formulate the model equation for a linear mixed-effects model in this specific case.

$$Waiting\ list\ length_{ij} = \beta_0 + \beta_1 GDP_{ij} + \beta_2 Legislation + \beta_3 Traffic + \beta_4 Cardio + \beta_5 Education + \beta_6 Beds + \mu_i + \epsilon_{ij}$$

With $Waiting\ list\ length_{ij}$ defined as the length of the waiting list per million people for country i at time j. β_0 as the intercept term and $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ and β_6 as the coefficients for the independent variables, also known as the coefficients of the fixed-effects of the model. μ_i represents the random effect between the different countries in the dataset. Finally ε_{ij} represents the residual errors.
Assumptions made in accordance with the use of the chosen model are important to note. This model assumes a normal distribution of the random effect μ_i with mean 0 and covariance matrix σ_μ^2. For the error term ϵ_{ij} we assume homoscedasticity with regards to the dependent variable.
We expect the dependent variable to be dependent on these independent variables after extensive literature review regarding the models used. GDP per capita is expected to have a negative effect on the length of a country's kidney transplant waiting list, as wealthy countries are expected to have a more sophisticated health system in place (Healy, 2014; Neto et al., 2012), raising the possibilities to procure and transplant the available organs, shortening the transplant waiting lists as a result. Legislation, defined as opt-in or opt-out systems in this model, are as the hypothesis states, expected to have a negative effect on waiting list length in the case of an opt-in system. Even tough some

literature (Beard et al., 2013; Dickert-Conlin et al., 2019; Shepherd et al., 2014) suggests that the rising number of deceased donors offsets the number of living donors, what would imply that the effect would be less significant than is hypothesized. As this study focusses on waiting list length and less so on procurement rates, we would expect to see insignificant results for the legislation variable if there indeed is an offset in donation rates among living and deceased donors. This finding would confirm that these previously mentioned findings are needed to take into account when suggesting a legislative change to enhance organ donation and shorten waiting lists. The traffic fatality rate is expected to have a negative relationship with the dependent variable, as a higher rate of traffic fatalities corresponds with a higher number of available deceased donors, as Dickert-Conlin et al. (2019) reports a rise in deceased donor availability in the U.S. in states with less strict motorcycle helmet laws. Worth to mention is that the authors also find a crowding out effect with regards to living donors in these areas. Another study assessing the inflow of deceased donor organs is done by Goldberg and Lynch (2019), these authors observe a rise in cadaveric donation in the U.S. that is almost solely driven by the opioid epidemic. While a noteworthy conclusion, this is expected to be less of an effect in a North-Western European context. The cardiovascular death rate is also incorporated in this model as this would also be an important inflow factor (Healy, 2014) of deceased organ procurement and would be also negatively related to the dependent variable. Altough one could argue that the effect on the length of waiting lists would be more ambiguous for this variable, as organs from a donor with cardiovascular problems might be less fit for transplantation. Education level as a percentage of the population with a degree in higher education is expected to have a negative effect on the length of waiting lists as earlier research by Gimbel et al. (2003) found a significant positive relationship between education level of the population level and donation rates, this seems plausible as there could be a better general understanding of the importance of donation. Lastly, the number of hospital beds per million population is implemented as a general measure of the extensiveness of the health system of a country, we expect a negative relation between the number of hospital beds per million population and the length of the waiting list per million population, as it is not farfetched to expect that an extensive and well funded healthcare system would be more efficient in organizing as many transplantations as possible and thus limiting the length of waiting lists.

Data collection

This study will be conducted from a North-Western European perspective, data on kidney transplant waiting lists will be recovered from the Eurotransplant and Scandiatransplant statistics library. These countries (Austria, Belgium, Croatia, Germany, Hungary, Luxembourg, Netherlands, Slovenia, Denmark, Finland, Sweden, Norway and Iceland) will be the focus of this study. Indicators other than the waiting list length will be accessed through the Eurostat database for the respective countries for the respective years. Table 1 summarizes the legislation types active in each selected country.

Table 1

Overview of legislative types in the selected countries and their abbreviations used in the dataset (Eurotransplant, 2024; Scandiatransplant, 2024)

Abbreviations	Country	Type of legislation in place
A	Austria	Opt-out
B	Belgium	Opt-out
HR	Croatia	Opt-out
G	Germany	Opt-in
H	Hungary	Opt-out
L[a]	Luxembourg[a]	Opt-out[a]
NL[b]	The Netherlands[b]	Opt-out[b]
SL	Slovenia	Opt-out
DK	Denmark	Opt-in
FIN	Finland	Opt-out
NO	Norway	Opt-out
I[a]	Iceland[a]	Opt-out[a]
SW	Sweden	Opt-out

[a]Given the absence of a country-specific waiting list for Luxembourg and Iceland, these countries will be excluded from the model as well as further analysis.

[b]The Netherlands made a legislative change form opt-in to opt-out legislation in July 2020, as our model allows for variation in this variable over time The Netherlands will be considered an “opt-out

country” from the year 2021. Assuming that there is a transition period between legislation implementation and the visible effects.

Hypothesis

We expect to find statistically significant indications of shorter waiting lists per million inhabitants in countries who adopted opt-out legislation compared to those with opt-in legislation in place. This corresponding to research done by Abadie (2006) and Da Silva et al. (2007) reporting higher donation rates in countries with opt-out legislation. Resulting in a decrease of a large economic and humanitarian cost driver in the healthcare sector, the kidney transplant waiting list.
Other (independent) variables incorporated in this linear mixed-effects model are also part of the hypothesis, as they have been selected based on earlier empiric literature surrounding the subject.

- GDP per capita is expected to have a negative effect on the length of kidney transplant waiting lists, as wealthy countries are expected to have a more equipped healthcare system that possibly facilitates better, faster and more qualitative identification of patients and donors (Healy, 2014; Neto et al., 2012).
- Traffic fatality rate (PMP) is also expected to be negatively associated with the length of kidney transplant waiting lists. As this is an inflow variable with regards to the available donor pool (Dickert-Conlin et al., 2019).
- Cardiovascular death rate (PMP) is also expected to correspond negatively to the length of kidney transplant waiting lists. As this variable is in earlier empiric research seen as an important inflow factor of the available organs (Healy, 2014).
- Education level of the population (percentage of the population with tertiary education) is expected to be negatively associated to the dependent variable, as Gimbel et al. (2003) found a statistically significant relationship between education level and donation rates, pointing to a possibly better understanding by the population of the importance of organ donation. Which is expected to result in a lower number of patients on the kidney transplant waiting lists per million population.
- The number of available hospital beds (PMP) is incorporated as a predictor of healthcare expenditure within a country. This level of healthcare expenditure is expected to impact the length of the kidney transplant waiting list in a negative manner, as we expect these countries to perform kidney transplants in a more efficient way, utilizing more of the available organs and resulting in a shorter waiting list.

Results

After the data is collected from the sources defined in the methodology and data collection section of this research paper, and some data cleaning operations with regards to missing data points, it is useful to take a first look at the descriptive statistics. Figure 3 shows the mean, Q1 and Q3 and possible outliers of the dependent variable, the kidney waiting list length per million inhabitants (y-axis) for each analyzed country (x-axis). Abbreviations used in the dataset to identify the different countries correspond can be consulted in Table 1 of the paragraph with regards to data collection.

Figure 3

Descriptive statistics of the dataset, length of the kidney transplant waiting list per country in a boxplot format

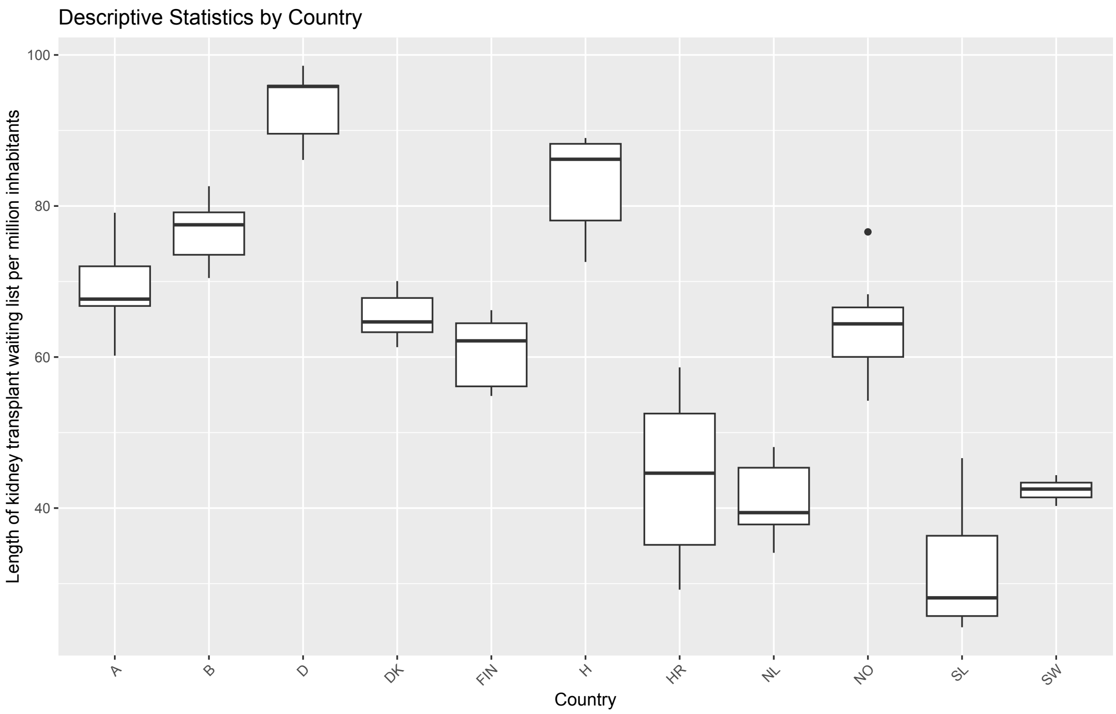


Figure 3 shows that there is a large heterogeneity in lengths of active kidney transplant waiting lists across the European continent, even tough international alliances are in place to organize organ donation and allocation. The extremes in average length of active kidney transplant waiting lists consist of Germany and Slovenia, both member state of the Eurotransplant region. Over the analyzed time period the average length of the active kidney transplant waiting list in Germany consisted over 90 patients per million inhabitants whereas Slovenia averaged below 30 patients per million inhabitants. Other countries in the dataset averaged between 40 and 80 patients on the active kidney transplant waiting list per million inhabitants, except for the Netherlands, which averages just below 40. One outlying datapoint is identified in Norway. After this first glance analysis of the dataset, the specified linear mixed-effects model was executed.

The linear mixed-effects analysis was performed using the R language and the Rstudio interface. The model specification was selected based on AIC, BIC and log-likelihood values (Akaike, 1998), compared to other possible specifications and a trade-off between possible under- and overspecification (Stoica & Selén, 2004).
A summary of the fixed-effects coefficients from the linear mixed-effects model of kidney transplant waiting lists and corresponding p-values are visualized in Table 2.
Surprisingly, the estimated coefficient of the legislation type is substantial in the unexpected direction, while this result cannot be interpreted as statistically significant, this might be an indication in favour of the crowding-out effects discussed earlier. In fact, the only fixed variable with a significant impact on the length of the kidney waiting list for a given country is the cardiovascular death rate. With a negative effect of -0.022 patients on the kidney waiting list per million people per percent increase in cardiovascular death rate. The education level of the population, while only significant under a 10% or higher significance level, is suggested to have a negative effect on the length of waiting lists. This effect, while not significant under the strict 5% condition, is in line with our expectations. Table 3 summarizes the statistical output with regards to the random effect, as specified in this linear mixed-effects model. The output and its substantial values obtained suggests that the choice for a mixed-effects model in this case is useful and could fit the model in a more accurate manner than a more simple fixed-effects model could have. Since the random effects are not a variable of interest in this study, they will not be reported in further analyses or discussions.
Given these, surprising and mostly insignificant results with regards to the fixed-effects coefficients, the logical path to follow before an in-depth analysis of the results of the model used, is to analyze if the identified model is effective in explaining the observed data. Figure 4 plots the standardized residuals per country in a boxplot format.

Table 2

Fixed-effects Coefficients of the specified model

	Value	Std. Error	DF	t-value	p-value
(Intercept)	122.27411	38.43713	60	3.181145	0.0023
Legislation	5.11012	23.10660	9	0.221154	0.8299
Traffic fatalities (pmp.)	0.01542	0.15200	60	0.101472	0.9195
Cardiovascular death rate	-0.02358	0.00629	60	-3.746331	0.0004
Tertiary education level (percentage of pop.)	-0.58305	0.51908	60	-1.123245	0.2658
Hospital beds (pmp.)	-0.00203	0.00328	60	-0.619113	0.5382
GDP per capita	-0.00025	0.00035	60	-0.706999	0.4823

AIC: 569.992. BIC: 590.099. Log-likelihood: -275.996

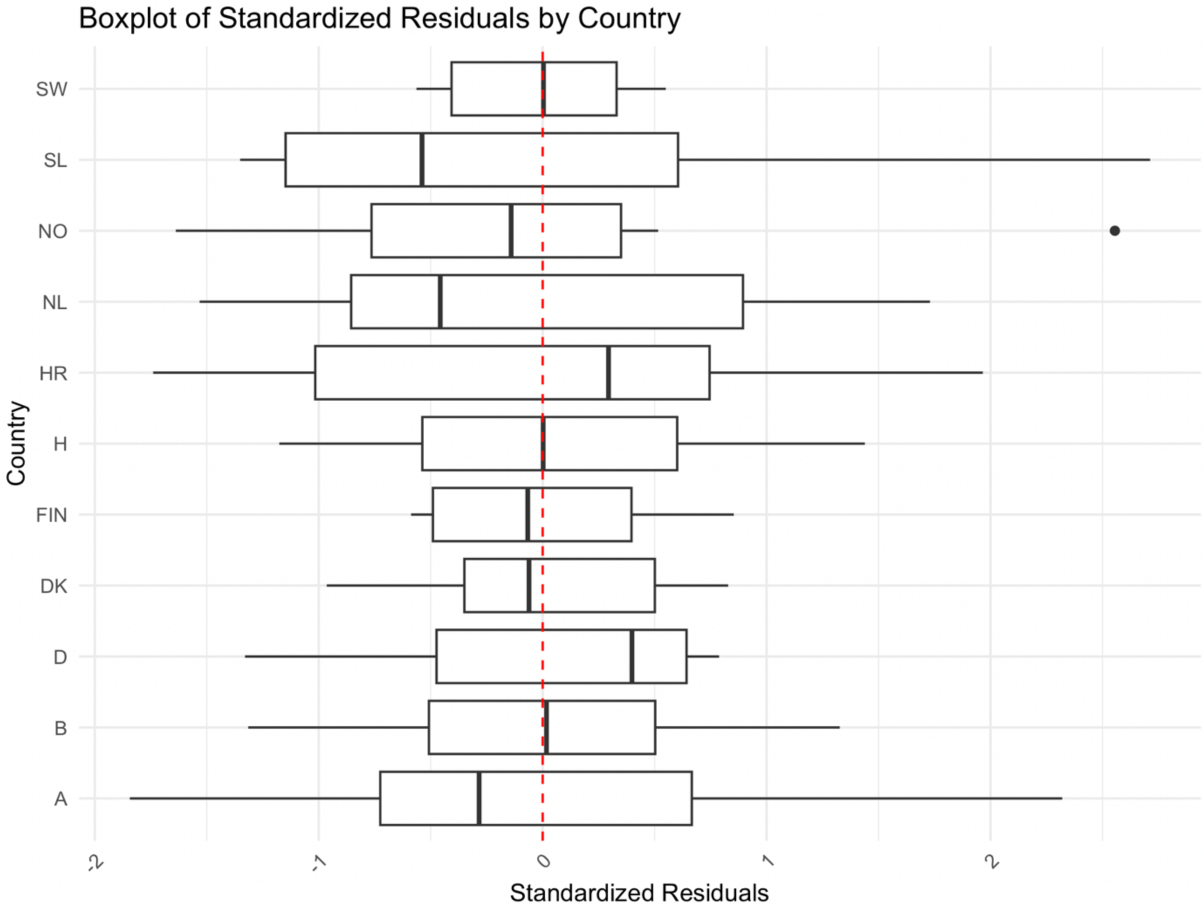
Table 3

Random effect between countries

	σ^2	SD
Country (Intercept)	1118.5172	33.44377
Residual	31.8733	5.64561

Figure 4

Standardized residuals per country



While there is a subjective component with regards to the interpretation of a plot, the model does seem to be effective in explaining the observed data. One outlier is identified, Norway saw a sharp rise in patients on its waiting list in 2020. This observation brings an interesting point to light and may require further research, COVID may have had an impact on the length of waiting lists in specific countries under specific conditions. To explore this possibility, we added a "covid-year" variable into the model (0 for non-covid years, 1 for covid-years). Years 2020, 2021 and 2022 are considered covid years as the World Health Organization declared the pandemics end on May 5, 2023. The results of this adapted linear mixed effects model is summarized in Table 4. We also consider a model without the new "covid-years" variable, but with the outlier of Norway in 2020 removed, to determine which one is more suited to use in the further stages of this study. These results are presented in Table 5.

Table 4

Fixed-effects coefficients of the specified model with a "Covid-years" variable introduced

	Value	Std. Error	DF	t-value	p-value
(Intercept)	117.45322	38.13344	59	3.080058	0.0031
Legislation	4.97960	21.85169	9	0.227882	0.8248
Traffic fatalities (pmp.)	0.06780	0.18407	59	0.368331	0.7139
Cardiovascular death rate	-0.02324	0.00635	59	-3.661677	0.0005
Tertiary education level (percentage of pop.)	-0.74311	0.59280	59	-1.253562	0.2149
Hospital beds (pmp.)	-0.00115	0.00334	59	-0.344542	0.7317
GDP per capita	-0.00013	0.00038	59	-0.342525	0.7332
Covid-years	1.83173	2.95719	59	0.619418	0.5380

AIC: 567.6518. BIC: 589.8469. Log-likelihood: -273.8259

Table 5

Fixed-effects coefficients of the specified model after removal of the outlier

	Value	Std. Error	DF	t-value	p-value
(Intercept)	102.38131	37.56663	59	2.725326	0.0084
Legislation	9.69957	22.32191	9	0.434531	0.6741
Traffic fatalities (pmp.)	0.04896	0.14574	59	0.335934	0.7381
Cardiovascular death rate	-0.02354	0.00602	59	-3.911700	0.0002
Tertiary education level (percentage of pop.)	-1.00979	0.51989	59	-1.942297	0.0569
Hospital beds (pmp.)	-0.00032	0.00321	59	-0.100298	0.9204
GDP per capita	0.00039	0.00041	59	0.960870	0.3405

AIC: 557.0286. BIC: 577.0042. Log-likelihood: -269.5143

While theoretically the “covid-years” variable is an interesting part of the equation to assess in further research, the limited number of observations in the dataset used makes it somewhat difficult to take another variable into account. Given the insignificance of the “covid-years” variable in Table 4, we cannot draw any meaningful conclusions from the results for the coefficient of this variable. The lower AIC, BIC and log-likelihood statistics for the model without the “covid-years” variable and with the outlier removed suggests that this model is a better fit for the data at hand. As a result we will use the results of this model (Table 5) in the remainder of this study.

As expected, this adaptation to the dataset does make a substantial difference to the fixed-effects coefficients and p-values from the original model, with the original dataset (Table 3). Even tough they do amplify the earlier discussed findings with regards to the cardiovascular death rate and the education level of the population and their relation to the length of the kidney transplant waiting list. But even in this revised dataset, the lack of significance in most of the independent variables is somewhat surprising. Figure 5 plots the fitted values against the residuals to evaluate the assumptions made in our methodology, the seemingly random pattern in this plot does not show signs that the assumptions have been violated. Moreover, a fitted QQ plot of the residuals (Figure 6) suggests suggests a normal distribution of the residuals. Another indicator of model assumptions that are met.

Figure 5

Fitted Vs. Residual plot

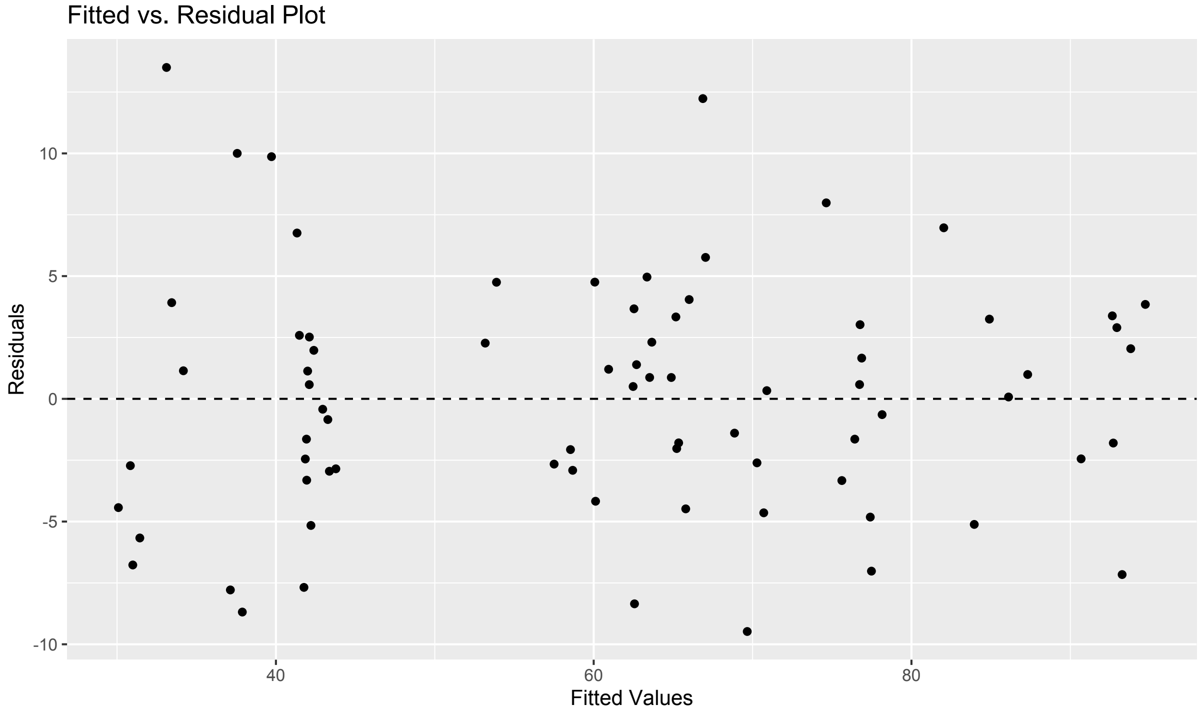
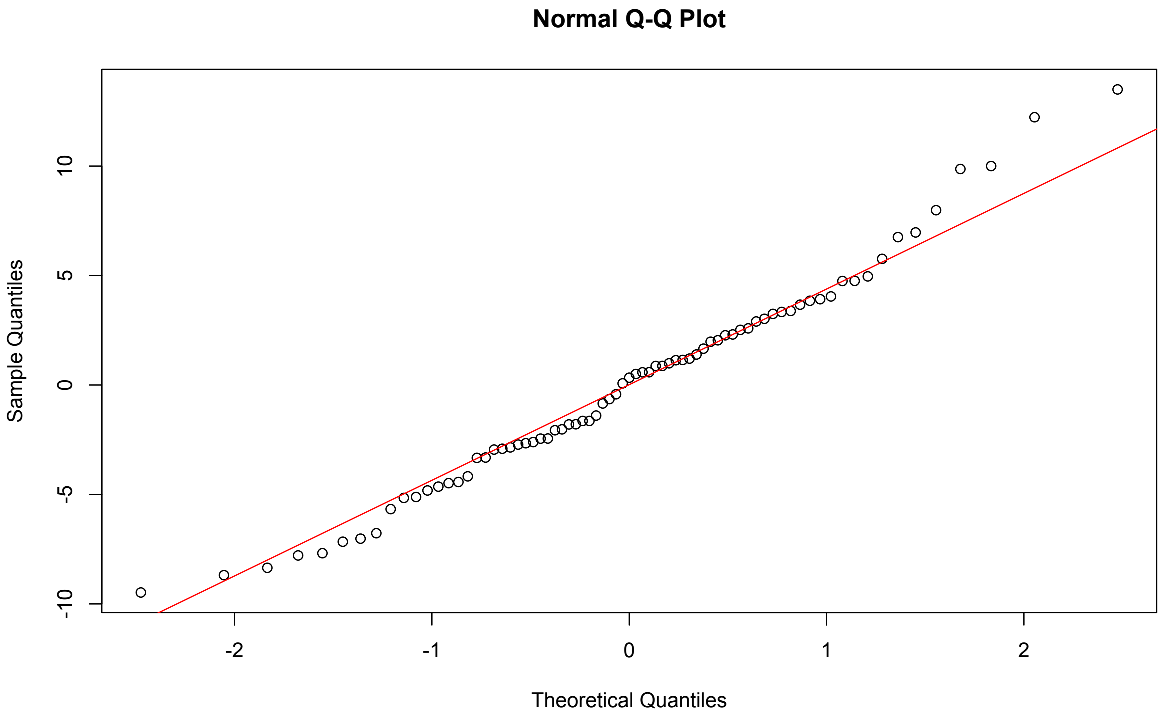


Figure 6

residual QQ plot



When analyzing the coefficients from the revised dataset (Table 5), only a slightly negative effect on the kidney waiting list of -0.0235 patients per million inhabitants on average by a rise of 1 per million inhabitants in cardiovascular death rate can be deemed statistically significant. The percentage of inhabitants with a tertiary education shows strong signs of being associated with shorter kidney transplant waiting lists per million inhabitants (-1.00979) with a sightly too high p-value to be significant on a 5% significance level, but is considered significant under a 10% significance level. The coefficient of this variable suggests that per percent increase of the population who have a tertiary education level, the number of patients on the kidney transplant waiting list per million inhabitants drop, ceteris paribus, by 1.00979. Surprisingly, coefficients of variables number of hospital beds per million inhabitants and GDP per capita are not statistically significant (respective p-values: 0.9204 and 0.3405) in influencing the length of waiting lists in this study. Even tough signs of this were showing in the descriptive analysis (Figure 3), as on average lower GDP per capita countries such as Slovenia and Croatia, seemed to have over the analyzed time period, on average less long kidney transplant waiting lists per million population. That being said, given the analysis made, we can also not draw the conclusion that a lower GDP per capita would automatically result in shorter waiting lists. The number of traffic fatalities per million population also cannot be deemed statistically significant (p-value: 0.7381) when analyzing the results of the analysis. Perhaps the most surprising finding of them all is the positive coefficient (9.69957) and the non-significance (p-value: 0.6741) of the variable legislation, where presence of an opt-out legal framework shows weak signs of positive associations with the waiting list length, which is the opposite of what was hypothesized. In the discussion of the results will be further discussed what this could mean and what possible limitations of the model and the data used are. As well as suggestions for further research to assess the effectiveness of this policy measure further.

Discussion

The purpose of this study was to focus on the different predictors and in particular the policy driven predictor (opt in-/opt-out legislation) of the length of the kidney transplant waiting list, as the alternative for these patients is the use of renal replacement therapy (RRT) or commonly known as dialysis (Becker et al., 2022) . However this form of treatment is costly, both in economic as in humanitarian terms, as extensively discussed in academic literature and in the literature review of this paper. Following the literature review, the model was formed based on the available academic research. A first analysis of the dataset revealed an outlier, the kidney transplant waiting list in Norway in 2020 showed a sharp rise compared to the years before and after, this could be explained trough a rising number of patients during the COVID pandemic, or a change in the reporting of the numbers. This could be a topic for further research, as in this study, the choice was made not to incorporate time as a fixed effect. Given the limited public data available, caution is advised when defining the model and the number of variables.

Based on earlier studies (Abadie, 2006; Dickert-Conlin et al., 2019; Gimbel et al., 2003; Healy, 2014; Neto et al., 2012), the hypotheses for each variable were constructed. The study contained a number of variables that showed insignificant results in contrast to the expectations. The insignificance of these results could be assigned to the low sample size of this study, which is the main limitation of this study. Further research could enlarge the pool of countries studied to strengthen the dataset or expand the timeframe studied, provided that this data could be made available. The model specification could also be adapted to better capture relations between variables, for example by narrowing the scope and incorporating fewer variables or choosing other variables of interest.

A variable of high interest in this study was the legislation variable (opt-in/opt-out), as the academic literature is not in consensus on the effects on this policy. There are two main different stances by researches. Beard et al. (2013), Dickert-Conlin et al. (2019) and Shepherd et al. (2014) are examples of research suggesting that the implementation of opt-out legislation crowds out voluntary donation rates, altering the ratio of cadaveric and living donation. Other research in favor of this policy measure underlines the significantly higher cadaveric donation rates, Da Silva et al. (2007) reports a rise in donation rates up to 26%. We hypothesized that these higher donation rates would have a shortening effect on the kidney transplant waiting list. While the beta coefficient for this variable takes on a positive value (9.69957), the large standard deviation (22.32191) and the insignificance of the result (p-value: 0.6741) dictate that we cannot draw any conclusions in favour for one of the possible effects described in the academic literature.

A rather small but significant (p-value: 0.0002) negative relationship is found between the kidney transplant waiting list and the death rate for cardiovascular diseases. The results of this study suggest that a rise of 1% in the cardiovascular death rate within a country corresponds to, on average a decrease in the length of the kidney transplant waiting list of -0.02354 per million inhabitants. However a small effect, it confirms our hypothesis that this a higher death rate as a consequence of cardiovascular diseases shortens the kidney transplant waiting list, this in line with the observation of Healy (2014), stating that the cardiovascular death rate is a significant inflow factor of cadaveric organs.

The percentage of the population that attended tertiary education shows also in line with our hypothesis, a negative relationship with regards to the kidney transplant waiting list. While this is not a significant result when evaluated on a 5% , it is considered significant on a 10% level (p-value: 0.0569). Even tough the significance level is an important point to address and this could be further examined in later research, the results suggest that the relationship between the tertiary education level and the kidney transplant waiting list is in line with our hypothesis, as Gimbel et al. (2003) found a positive relationship between the education level of the population and donation rates. This effect is possibly explained due to the better understanding of the population of the importance of organ donation. On average, a rise of 1% in the level of tertiary education of the general population, the length of the kidney transplant waiting list decreases by -1.00979 patients per million inhabitants.

As earlier mentioned in this study, the importance of shortening the kidney transplant waiting list lies in both the economic and humanitarian cost with regards to this waiting list. As the alternative of renal replacement therapy or dialysis is significantly more expensive to society in terms of healthcare cost and loss of life years (Held et al., 2016). When we apply the cost estimations done by Held et al. (2016) and Becker et al. (2022) to the Eurotransplant and Scandiatransplant regions, we could estimate to what magnitude of the humanitarian and economic costs are associated to the kidney transplant waiting list and what possible reductions of this list could mean in terms of cost reductions. We use the calculations made by Becker et al. (2022) to estimate the cost of the kidney transplant waiting list for 2022 in the Eurotransplant region, we estimate a lost value of human life years, using the same value of $120,000 per lost life year and the estimation that patients dying while on a kidney transplant waiting list forfeit on average 15 life years. The statistics, made public by Eurotransplant (Eurotransplant - Statistics, 2024) report a waiting list mortality for patients waiting on a kidney transplant of 604 in the year 2022. The estimation for the value lost in result of the inability to provide these patients with a donor organ is about $1,09 billion for the case of the Eurotransplant region in 2022, not accounting for the lower quality of life during the years of renal replacement therapy while waiting on a transplant organ. This substantial amount gives an idea of the humanitarian cost associated with these long kidney transplant waiting lists. For the aspect of economic cost, the potential cost saving by reducing the length of the kidney transplant waiting list is also substantial, as already stated in the literature review. As research done on Swedish data by Zhang et al. (2023) reported an indicated cost saving after kidney transplantation of €72.000 in healthcare costs over the first three years compared to conventional dialysis. The Eurotransplant annual report of 2022 indicates a median of 51 months on the kidney transplant waiting list before obtaining a transplant (Eurotransplant, 2023). With the knowledge that in 2022, 10,373 patients were represented on the kidney transplant waiting list in the Eurotransplant region, the economic cost reduction to the healthcare system could be substantial when these waiting times can be reduced and the waiting lists shortened. This way, the disproportional health expenditure as a result of the costly renal replacement therapy for these patients as pointed out by Mohnen et al. (2019) in the Netherlands, where 1-2% of the national healthcare budget was spent on 0.1% of the population in 2011, could be attributed to other causes in the healthcare system while improving the prognosis and quality of life of the end-stage renal disease patients.

Conclusion

The research question constructed for this study was the following: *"To what extent is opt-out legislation an effective tool in reducing the kidney transplant waiting lists, and what are the predictors of the length of this waiting lists?"*. In an attempt to answer this question in a North-Western European context, a linear mixed model analysis was conducted based on earlier research and public data by Eurotransplant, Scandiatransplant and Eurostat.
As the result of the model used in terms of the legislation variable was insignificant, we cannot confirm the effectiveness of this policy measure in terms of shortening the kidney transplant waiting list. Nor is it possible, based on these results, to confirm one of the two academic strains surrounding this policy measure, namely the studies that point to a significant rise in organ procurement (Da Silva et al., 2007) and studies that identify a crowding-out effect of living donations when such policy is implemented (Beard et al., 2013; Dickert-Conlin et al., 2019; Shepherd et al., 2014). A small but significant negative effect on the kidney transplant waiting list was found for the cardiovascular death rate, in line with the hypothesis made and earlier research suggesting that this variable constitutes an inflow factor for donor organs Healy (2014). Another interesting result was the effect of the tertiary education level of the population on the kidney transplant waiting list, albeit not strictly significant using a 5% significance level (p-value: 0.0569), in line with the hypothesized expectations, and in line with the findings done by Gimbel et al. (2003). An effect possibly explained by the idea that well-educated populations are to a higher degree aware of the fact that organ donation is an important practice. For the other independent variables used in the model (GDP per capita, number of hospital beds per million population and traffic fatalities per million population) no significant results with relation to the length of the dependent variable (length of the kidney transplant waiting list per million population) could be identified.

An important limitation of this study to take into account is the limited sample size, which could theoretically be responsible for insignificant results. Given the fact that this study was conducted using publicly available data, there could be the limitation of a measurement error, that could not be investigated in this study. The use of a broader timeframe and/or more countries that are taken into account is a recommendation to be made to researchers who will conduct research on this topic later on. Preferably obtaining data and metadata directly from the national agencies and thus correcting for potential differences in measuring and reporting. Also the assessment of the impact of the

COVID-19 pandemic had on the kidney transplant waiting lists is a suggestion we make to include in further research, possibly with a more focused approach with regards to this parameter.

We can also conclude that the significant costs associated with the kidney transplant waiting list can be attributed to the cost of the alternative, i.e. renal replacement therapy (RRT), and that failing to keep these waiting lists as short as possible comes with a high cost to both the healthcare system and society in the form of economic and humanitarian costs. To address these shortages and shortening these waiting lists, other measures than the status-quo seem to be necessary, measures such as limiting disincentives associated for living donors, legislation (opt-in versus opt-out) and even the creation of a marketplace for donor organs could be part of the solution as described in the literature review. One more controversial than the other.
This study could not prove the hypothesized effect of the legislational effect on the transplant waiting list, tough further research is necessary to better understand the effectiveness of policy in reducing the length of the kidney transplant waiting lists and the resulting costs that come along with those lists. Along with research to assess the effectiveness of other alternative solutions to the organ shortage crisis, while not losing sight of the ethical considerations in this sensitive topic. By gaining understanding in the dynamics of these transplant organ systems, adjustments to the current practice can be made in a scientifically based manner. As a result more patients can be saved and the transplant waiting list would be less costly, both in economic and humanitarian terms.

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