# The Great Recession and Lifespan Inequality: causal insights from the European laboratory

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**Abstract**

This paper investigates the pro-cyclical relationship between business cycles and mortality patterns, specifically focusing on the Causal Effect of the 2008 Great Recession on Lifespan Inequality within 26 European countries. To the best of our knowledge, the research is the first to prioritize economic crises as a key determinant in assessing life expectancy disparities. The study employed a causal Difference in Differences methodology, categorizing countries into treatment and control groups based on their exposure to the Great Recession, measured through variations in unemployment rates. This analysis revealed a significant, beneficial, and long-lasting effect of the Great Recession on Lifespan Inequality for approximately three years, signifying a reduction in lifespan disparities and suggesting potential health benefits in affected countries (in line with the so-called Thomas Effect). The manifestation of this effect aligns congruently with the intensity of the crisis endured by individual countries.

# 1 Introduction

The relationship between business cycles and mortality has been a subject of debate for nearly a century, recently rekindled in scholarly dispute. Ogburn and Thomas (1922) were pioneers in identifying a counter-intuitive correlation between economic cycles and mortality rates in the United States. Termed as "pro-cyclical," this relationship implies that mortality rates rise during economic expansions and fall during recessions. This early work was later substantiated by Eyer (1977), who first coined the term "Thomas Effect" to describe this phenomenon. After Eyer, the work of Ruhm (2000) served as a turning point by confirming the initial observations of Ogburn and Thomas, specifically that mortality from major causes increased in expansions and declined in recessions. In the subsequent years, this association has been corroborated globally, with studies conducted in Europe, including Germany (Neumayer 2004), Spain (Tapia Granados 2005), France (Buchmueller, Jusot, Grignon, et al. 2007), Sweden (Tapia Granados 2008), and England and Wales (Tapia Granados 2012). Investigations have also been carried out in Asia, encompassing Japan (Tapia Granados 2008) and Asian-Pacific countries (Lin 2009). In the Americas, studies have been performed in the United States (Tapia Granados and Diez Roux 2009) and Canada (Ariizumi and Schirle 2012). Further research has extended to Oceania, specifically New Zealand (Greenaway-McGrevy 2021). Moreover, studies encompassing OECD countries as a whole have been conducted confirming the existence of this association (Gerdtham and Ruhm 2006).

The Thomas Effect, while counter-intuitive, has plausible explanations. Catalano, Goldman-Mellor, et al. (2011) provide a comprehensive framework that encapsulates the decreased cost of time during economic downturns, reduced air pollution, fewer occupational accidents, diminished job-related stress, and enhanced sleep patterns, contributing to lower rates of respiratory and cardiovascular diseases. Similar arguments have been used to explain lower excess mortality in some countries during the period of reduced mobility due to the COVID-19 pandemic (Basellini et al. 2021; Santos et al. 2021; Antonio-Villa et al. 2022; D.í.az Ramírez, Veneri, and Lembcke 2022).

Nevertheless, the pro-cyclical association has faced skepticism and challenges (Falagas et al. 2009; Stuckler, Basu, et al. 2009; Kentikelenis et al. 2011; Stuckler and Basu 2013; Karanikolos et al. 2013). Furthermore, the concept of "ecological fallacy" has been raised as a concern (Catalano and Bellows 2005). According to the counter-argumentation posit by Tapia Granados (2005) in response to this claim, aggregate analyses, which encompass both the employed and unemployed populations, suggest that the beneficial effects of economic downturns might be more pronounced among those who remain employed. The selective focus on the unemployed in micro-level studies could introduce a selection bias, obscuring the potentially counterbalancing positive effects on those who retain their employment. This interpretive framework, actually, aligns with the perspective put forth by many scholars (Eyer 1976a; Eyer 1976b; Cohen and Felson 1979; Gravelle, Hutchinson, and Stern 1981; Wagstaff 1985; Cook and Zarkin 1986; Kasl 1979; Ruhm 2000; Ruhm 2008; Tapia Granados 2008; Tapia Granados 2012; Kasl and B. A. Jones 2000).

Some counter-cyclical dynamics, however, have been observed in specific countries such as France (Brüning and Thuilliez 2019, in which the counter-cyclicality manifests solely in specific aspects of their model and is, therefore, feeble), Sweden (Gerdtham and Johannesson 2005), and Australia (Khemka and Roberts 2015). Moreover, the association under scrutiny may take an opposite direction from the Thomas Effect in the long term and/or during periods of economic and demographic expansion. This contrasting pattern has been observed in certain developing countries, such as India (Bhalotra 2010) and China (Sun et al. 2021).

The 2008 Great Recession (GR) presented a unique opportunity to investigate this relationship further, at least in the European context. In fact, various European studies have confirmed a pro-cyclical trend in mortality during this period (Toffolutti and Suhrcke 2014; Regidor et al. 2016; Tapia Granados and Ionides 2017; Baumbach and Gulis 2014; Ballester et al. 2019; Cervini-Plá. and Vall-Castelló 2021). Moreover, a causal methodology of Difference in Differences (DiD) used by Salinari and Benassi (2022) not only confirmed the presence of the Thomas Effect but also its persistence over time. Our study builds on this last approach, aiming to scrutinize the robustness of their findings concerning the potential for ecological fallacy. We shift the focus from aggregate mortality rates to Lifespan Inequality (LI) within European countries. The primary objective is to causally-explore whether the GR had an effect (also) on lifespan inequality and in which direction.

## 2 Lifespan Inequality as a measure of inequality in Life Expectancy. A brief overview

Life expectancy (LE) represents the average number of years remaining for a given population at a specific age (typically at birth). However, by its very nature, LE as an aggregate measure may obscure significant internal variations. To provide a general illustrative example, disregarding LI while solely examining LE could lead to the observation that, despite males generally exhibiting lower LE and higher mortality rates across all age groups, there exists a considerable likelihood for males to outlive females in certain circumstances (Bergeron-Boucher et al. 2022).

In general, there has been a consistent decline in LI globally from 1950 to 2015, although a notable trend of heterogeneity has emerged within the elderly population (Edwards and Tuljapurkar 2005; I.ñ.aki Permanyer and Scholl 2019). This decline aligns with the well-established pattern of global LE growth, wherein an overall increase in LE tends to correspond with a decrease in LI. However, it is important to note that substantial variation exists across populations and over time, as highlighted by N.é.meth (2017). Within this field of research, two distinct patterns have been observed. As summarized by Vigezzi, Aburto, Iñaki Permanyer, et al. (2022), certain empirical evidence suggests a positive association between mortality and LI (Wilmoth and Horiuchi 1999; Sasson 2016; Brø.nnum-Hansen 2017; Aburto and A. v. Raalte 2018), while others indicate a negative relationship (Kannisto 2001; Smits and Monden 2009; Vaupel, Zhang, and A. A. v. Raalte 2011; Colchero et al. 2016; Aburto, Villavicencio, et al. 2020).

In the demographic and epidemiological literature, it is common to examine the relationship between mortality shocks and LI. However, these studies often analyse the association between mortality and LI without specifically considering the presence of an economic crisis. Changes in mortality trends can occur independently of fluctuations in the business cycle, such as during drug crises, epidemics, wars, or natural disasters (e.g., let us consider the case of the American opioid crisis —Wilmoth, Boe, et al. 2011; Case and Deaton 2020—, which unfolded independently without being accompanied or succeeded by an economic crisis).

For instance, Vigezzi, Aburto, Inaki Permanyer, et al. (2021) observed that during periods of mortality crises, relative LI tends to increase while the absolute variation declines, followed by a rapid return to pre-crisis levels. Additionally, Vigezzi, Aburto, Iñaki Permanyer, et al. (2022) examined LI patterns surrounding various mortality crises and found that even when infant mortality rates are high, mortality among older age groups can significantly influence LI.

Several attempts have been made, instead, to investigate the relationship between the GR and, more generally, social inequalities in health. A comprehensive overview of the existing literature on this subject is provided by Heggebø. et al. (2019), who conclude that the GR in Europe tends to be followed by increasing socioeconomic inequalities in health. In their review of 49 papers, however, the primary focus was on capturing health inequalities using socioeconomic indicators such as employment status, educational attainment, income/wealth, and occupational class. These variables are considered as social determinants of health inequalities, in line with the definition proposed by Marmot (2005).

To the best of our knowledge, therefore, the prevailing literature is devoid of a focus that prioritizes economic crises as a trigger event under examination associated specifically with LE rather than broad socioeconomic indicators. After all, inequality in LE represents the most fundamental form of all inequalities; every other form thereof is contingent upon the precondition of being alive (Van Raalte, Sasson, and Martikainen 2018). This, furthermore, enables a holistic examination of health during crises, as opposed to a selective analysis of only certain facets thereof. In our work, thus, we decided to shift the focus towards disparity in LE (captured by LI) thereby addressing this gap in the literature, existing with a few exceptions.

For example, Maynou and Saez (2016) examined various health outcomes, including LE, all-cause mortality, ischemic heart disease mortality, cancer mortality, and mortality from larynx, trachea, bronchus, and lung cancer, among the 27 countries in the European Union. They employed a dynamic panel model and found a significant increase in inequalities for all health outcomes in 2010, although the increase was less pronounced for cancer mortality. On the other hand, Brø.nnum-Hansen et al. (2015) focused solely on disability free LE as the health outcome. Through a descriptive analysis of Danish data, they observed a steeper increase in LE without limitations among higher-educated men (no such trend was found among women), as well as a steeper increase in LE with good self-rated health among higher-educated men and women. Finally, Regidor et al. (2016) employed a spatio-temporal ecological mixed regression to analyze population-level mortality in the city of Barcelona (Spain) and found that the risk of dying increased to a greater extent in the most economically deprived neighborhoods.

Furthermore, Khang et al. (2005), found no increase in geographic inequalities in overall mortality following the economic crisis in South Korea. Notwithstanding, socioeconomic disparities in mortalities due to external causes were indeed affected. Palè.ncia et al. (2020) conducted an analysis on nine urban areas in Europe, revealing general significant disparities in mortality rates among men across various socioeconomic indicators, time periods, and urban areas studied. However, no noteworthy changes were observed during the economic crisis period. Laliotis and Stavropoulou (2018) identified a non-linear and asymmetric response of mortality to unemployment during Greek national economic crises, implying that the impact on death rates alters significantly for extremely high levels of unemployment and depends on its direction.

Overall, the existing literature suggests that the economic crises are often accompanied by a rise in socioeconomic inequalities in health.

In conclusion, there is a notable research gap in the literature regarding the impact of major economic crises, such as the GR, on the dynamics of LI, particularly within European countries. Our study aims to address this gap by examining the effects of the GR on LI using a causal approach, specifically the DiD methodology. By focusing on European countries, we seek to contribute to the understanding of how such a significant economic crisis can shape the patterns of LI over time.

# 3 Empirical analysis: logic and methodological aspects

## 3.1 Data

The necessary data to compute the LI metric (see subsection 3.3) have been extracted from the life tables available in the Human Mortality Database—HMD (2023). In addition, it was imperative to identify an economic variable associated with the GR that would serve the purpose of delineating the control and treatment groups. As explained in the next section, we selected the unemployment rate, following the classification created by Tapia Granados and Ionides (2017). The analysis is conducted on a group of 26 European countries, composed of Norway, Switzerland, the United Kingdom and the countries of the European Union (with the exclusion of Romania because of data unavailability, and Luxembourg, Malta, and Cyprus because of the too small size).

The analysis covered the period 2004-2019. Although we could have set 2001 as the starting point, we decided to start in 2004 as this allowed us to mitigate the potential perturbation caused by the short economic crisis that occurred in 2000-2001. Starting from 2004 still ensured an adequate number of pre-treatment observations (see subsection 3.2).

### 3.2 The relevance of European laboratory

One of the methodological key aspects of our research pertains to the robust differentiation of countries into the treatment group, defined as those countries that have undergone substantial adversity as a consequence of the GR, and the control group, composed by the countries where the GR had much milder consequences or no consequence at all. Consequently, it is essential to identify a trustworthy variable capable of quantifying the magnitude of the crisis experienced by each country. To this aim, we adopted the classification framework established by Tapia Granados and Ionides (2017). That approach employs the variation in unemployment rate between 2007 and 2010 as the discriminating variable. Utilizing this classification scheme, we categorized the countries into three distinct groups based on their exposure to the GR: Group 1 comprised countries that either did not encounter GR or experienced it in a mild form (unemployment rate change smaller than 2 percent), Group 2 consisted of countries that faced GR in a moderate form (unemployment rate change between 2 percent and 4 percent), and Group 3 encompassed countries that endured GR in a severe form (unemployment rate change exceeding 4 percent). Group 1 served as control group, while group 2 and 3 served as treatment groups. Group 1 included Austria, Belgium, Finland, France, Germany, the Netherlands, Norway, Romania, and Switzerland. Group 2 included Bulgaria, Croatia, the Czech Republic, Denmark, Hungary, Italy, Poland, Portugal, Slovakia, Sweden, and the United Kingdom. Finally, Group 3 included Estonia, Greece, Ireland, Latvia, Lithuania, Slovenia, and Spain. Salinari and Benassi (2022) have conducted comprehensive checks on this classification, and all of their findings have consistently confirmed its validity. We refer directly to their paper for the technical details of these tests.

The causal approach followed by this study entails conducting comparisons between the treatment group (countries who experienced the crisis) and the control group (countries who did not experience the crisis). This allows us to estimate the causal effect of interest, namely, the impact of GR on the evolution of LI in Europe. The primary comparison in this analysis will involve contrasting Group 1 with the combined Groups 2 and 3. Specifically, we will compare countries who did not experience the crisis with those who did, irrespective of whether their experience was moderate or severe.

Additionally, it is important to note that in Group 1, as defined, we cannot rule out the possibility that there are also countries that have been affected by the crisis in some mild form. For this reason, it is important to keep in mind that the measure of the effect of GR on LI that results from our analysis should be interpreted as a conservative measure.

Finally, in addition to classifying countries into the three groups, the unemployment rate serves as a valuable indicator for determining the initiation of the crisis in the countries under investigation, specifically in the year 2009. The selection of this particular year has undergone rigorous robustness checks, the details of which can be found in Salinari and Benassi (2022), particularly in their Figure 2 and Figure 3.

## 3.3 Measurement of LI

LI can be measured with different indexes, each with its own underlying properties that may not necessarily be equivalent to one another. Nonetheless, these different measures are strongly correlated with each other and demonstrate similar patterns in sensitivity across different age groups, as highlighted by Van Raalte and Caswell (2013).

We opted to use the Lifetime losses, $e_x^\dagger$, so-called e-dagger, as a measure of LI for a specific age x, which is included within the formulas proposed in Shkolnikov and Andreev (2010). The fundamental conceptual insight of this measure is based on Keyfitz's idea that "*everybody dies prematurely,*" and that every death, in some way, "*deprives the person involved of the reminder of his expectation of life*" (Keyfitz 1977). More recently, the concept of $e_x^\dagger$ emerged from a non-traditional decomposition of changes in life expectancy by Vaupel and Romo (2003). Beyond simply acting as an index of life-table dispersion, e-dagger also bears significant implications for public health. Its values represent the average life expectancy losses due to death, formally (in its discrete version):

$$LI_x = e_x^\dagger = \frac{1}{l_x}\sum_{y=x}^{\omega-1}\left[d_y(e_{y+1}+1-a_y)\right] + \frac{l_\omega}{2l_x}e_\omega, \tag{1}$$

where $\omega$ is the maximum age at death observed in the life table, $d_x$ represents the count of observed deaths between the age interval of $x$ and $x$+1, $l_x$ denotes the count of individuals who have survived up to age $x$, $e_x$ represents the average life expectancy at age $x$.

To answer our research question, we eventually compared the evolution of LI at age 0 ($LI_0$ or $e_x^\dagger$) between the control (no crisis) and treatment (crisis) groups implementing a DiD strategy outlined above. Therefore, from this point forward, we will refer to $LI$ as $LI_0$ (measured by $e_x^\dagger$).

## 3.4 General framework

Before delving into the explanation of the DiD strategy, it is necessary to elucidate the general notation (we will use Hernan and J. Robins 2020's here).

We define $W(i)$ as a probabilistic function connecting each country $i$ to a treatment indicator value (0 or 1) as follows:

$$W(i) = \begin{cases} 1 & \text{if country } i \text{ suffers GR} \\ 0 & \text{otherwise} \end{cases}.$$

Thus, $W$ is a random variable representing the set of 1 and 0 values for all countries, the so-called assignment mechanism. In this manner, for each country $i$ at time $t$, we can define the counterfactual (or potential distribution) $LI_t^w$. Specifically, $LI_t^1$ represents the distribution of LI at time $t$ under a counterfactual scenario in which all countries have undergone the GR, whereas $LI_t^0$ represents the distribution of LI in the opposite scenario in which no country has suffered the crisis. In other words, we assume two possible scenarios for each country in each period. Of course, we can only observe one realization of the two potential distributions (which is known as the fundamental problem of causal inference).

Therefore, it is necessary to find a way to infer the missing potential distribution (the so-called counterfactual), which refers to what would have happened to the countries at time t if they had received the treatment opposite to what they actually received (or, in other words, if the alternative potential distribution had been realized instead of the actual one).

The most crucial assumption DiD methodology relies on is the Parallel Trend Assumption (PTA). According to this assumption, the evolution of the missing potential distributions for the treated units during the post-treatment periods is equivalent to what is observed in the untreated units during the same periods. This assumption, in turn, requires the condition that no unit is treated prior to the realization of the treatment. Note that, within our specific context, the units of analysis are represented by individual countries, and the terms "units" and "countries" will be used interchangeably throughout our study, as well as "treatment" and "crisis."

To formalize these two assumptions, let us first consider the simplest case where we have two (group of) units, one treated and one not (our control group), and two time periods (the so-called 2x2 DiD design). Suppose that the treatment occurs at period $t$, thus making the pre-treatment period equivalent to time $t$-1.

First and foremost, it must hold true that:

$$LI_{t-1} = LI^0_{t-1},$$

that is, no unit is treated in $t$-1.

At this point, we can formalize the PTA as follows:

$$E\left(LI^0_t - LI^0_{t-1} \mid W = 1\right) = E\left(LI^0_t - LI^0_{t-1} \mid W = 0\right).$$

By way of explanation, for the treated unit (conditioning on $W$=1), the evolution between $t$ and $t$-1 would have been the same as in the untreated unit (conditioning on $W$=0) had the treated unit not suffered the crisis. If this assumption holds, we can define the Average Treatment Effect on the Treated ($ATT$) in the following straightforward manner:

$$\begin{aligned} ATT &= E\left(LI^1_t - LI^0_t \mid W = 1\right) \\ &= E\left(LI_t - LI_{t-1} \mid W = 1\right) - E\left(LI_t - LI_{t-1} \mid W = 0\right). \end{aligned} \tag{2}$$

Figure 1 visually depicts this assumption and the variables involved in Equation 2.

Also note that to calculate the average effect between time $t$ and time $t$-1, for two distinct groups of countries, it is crucial to consider an additional significant assumption. This assumption pertains to the behaviour of units and posits that no unit can modify its actions or responses before undergoing treatment, based on whether it possesses prior knowledge about the treatment (referred to as the "non-anticipation assumption").

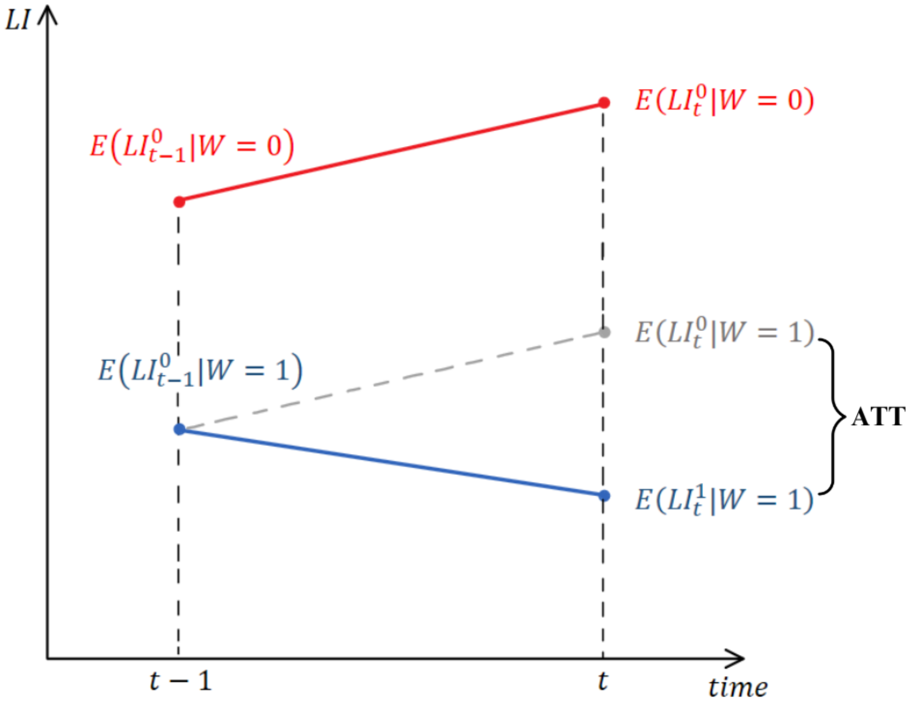


Figure 1: **Intuitive illustration of the Parallel Trend Assumption in the simplified version of the Difference in Differences strategy, known as the 2x2 DiD (Two-by-Two Difference in Differences) design. In this version, there are two groups of units (treatment and control) and two time periods (pre- and post-treatment).**

The next step involves expanding the framework to encompass a greater number of time periods beyond 2, denoted as $t$=1,...,$T$. Accordingly, it becomes necessary to add a new supplemental treatment indicator variable as follow:

$$D_t = \begin{cases} 1 & \text{if } t \text{ is a post-treatment period} \\ 0 & \text{otherwise} \end{cases}.$$

Within this framework, a regression approach is the most widely employed methodology, as specified in the following equation:

$$LI_{i,t} = \theta_t + \eta_i + \delta W(i) D_t + \epsilon_{i,t}. \tag{3}$$

In the Equation 3, $\theta_t$ denotes the time fixed effect, while $\eta_i$ represents the country fixed effect. The model error terms are denoted by $\epsilon_{i,t}$, and $\delta$ corresponds to the estimated average treatment effect on the treated ($ATT_t$[1]).

This methodology under consideration is commonly referred to as Two Way Fixed Effects (TWFE) and has gained significant prominence in applied research in the analysis of inequality in the last decade (among others: Rao et al. 2014; Engzell, Frey, Verhagen, et al. 2020; Yu, Xiao, and Chang 2021).

[1]Henceforth, we will refer to the $ATT$ as $ATT_t$. This is because, when accounting for more than two time periods, an $ATT$ will exist for each period subsequent to the initiation of the treatment.

The estimation of $ATT_t$ can be carried out through three different estimation techniques: outcome regression, inverse probability weighting and doubly-robust (DR) estimators. They are equivalent from an identification point of view; however, using DR estimators (introduced by J. M. Robins, Rotnitzky, and Zhao 1995; J. M. Robins 2000; Bang and J. M. Robins 2005) is particularly suitable in our context as they rely on less stringent modelling conditions than the other two (Callaway and Sant'Anna 2021).

The primary advantage, in the present settings, of employing the methodology proposed by Callaway and Sant'Anna over the traditional TWFE lies in the use of the DR estimator.

Nevertheless, the framework developed by Callaway and Sant'Anna encompasses the possibility of incorporating a comprehensive measure that captures the Overall Treatment Effect (OTE) throughout the entire duration of the study period. This summary measure is denoted as:

$$\vartheta = \frac{1}{T - 2009 + 1} \sum_{t=2}^{T} \mathbf{1}_{2009 \leq t} \, \mathrm{ATT}_t, \tag{4}$$

and which we used as one of the two robustness checks (see section 4)[2]. In other words, $\vartheta$ corresponds to the arithmetic mean of all $ATT_t$ calculated for the periods subsequent to the commencement of treatment. In further work we will also refer to $\vartheta$ as Overall Treatment Effect (OTE).

Confidence intervals on both $ATT_t$ and $\vartheta$ are constructed through a specific bootstrapping procedure proposed by Callaway and Sant'Anna (2021).

In our analysis, we applied this methodology utilizing the R *did* library developed by them.

# 4 Results

Figure 2 illustrates the temporal progression of LI from 2004 to 2019. It is important to highlight that all three groups exhibit a relatively linear time trend, that further strengthens the a priori non-rejection of PTA, aligning with the general linearity observed in life expectancy (Oeppen and Vaupel 2002; White 2002; Lee 2019.

Additionally, the groups originate from distinct LI levels, indicating that the occurrence of GR is not random across European countries. This circumstance supports the adoption of a strategy such as Difference-in-Differences (DiD). Lastly, it is worth noting that Group 3 comprises a smaller population (consisting of only 7 countries) and exhibits greater internal variability.

The pivotal result of our analysis is depicted in Figure 3. This figure showcases the $ATT_t$ calculated for all years examined, accompanied by their corresponding confidence intervals (with both 95%—solid horizontal error lines—and 90%—dashed

[2] In general, the notation $\mathbf{1}_{condition}$ represents an indicator function, which assumes a value of 1 when condition is satisfied, and 0 otherwise.

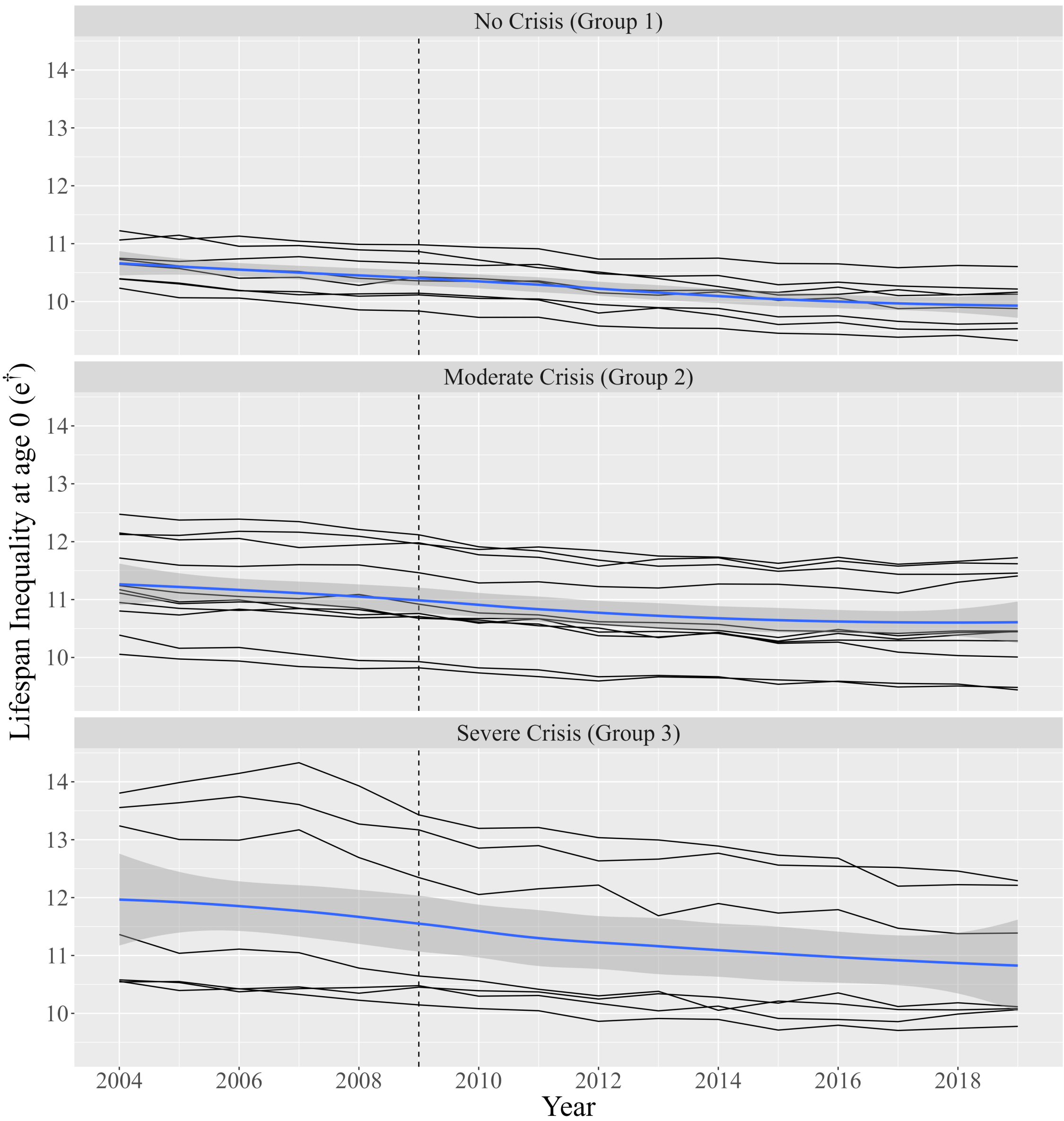


Figure 2: **Evolution of Lifespan Inequality at age 0 from 2004 to 2019 in 26 European countries.**
Note: Countries have been classified into three main groups (No Crisis, Moderate Crisis, and Severe Crisis) based on the change of unemployment rate between the pre-crisis years and the crisis years: less than 2%.
The vertical dashed line indicates the initial year of the crisis (2009).
The blue dashed line has been estimated through local polynomial regression (LOESS), whereas the grey area represents the 95% confidence interval around this estimate.
Source: Human Mortality Database (HMD)

horizontal error lines—confidence level). The analysis is based on the comparison between Group 1, serving as a baseline reference for the entire work, and the combined Groups 2 and 3.

The findings are unequivocal: there exists a significant causal impact of GR on LI, characterized by a negative effect that persists for a duration of three years (that becomes four with a 90% confidence level) after the departure of the crisis. Consequently, it can be inferred that GR not only appears to have conferred certain benefits in terms of mortality upon the affected countries but has also contributed to a more equitable distribution of mortality within these crisis-stricken countries compared to those that remained unscathed. In essence, GR leads to a reduction in Lifespan Inequality for a period of three-four years.

Furthermore, it is important to acknowledge that the PTA, despite not testable by

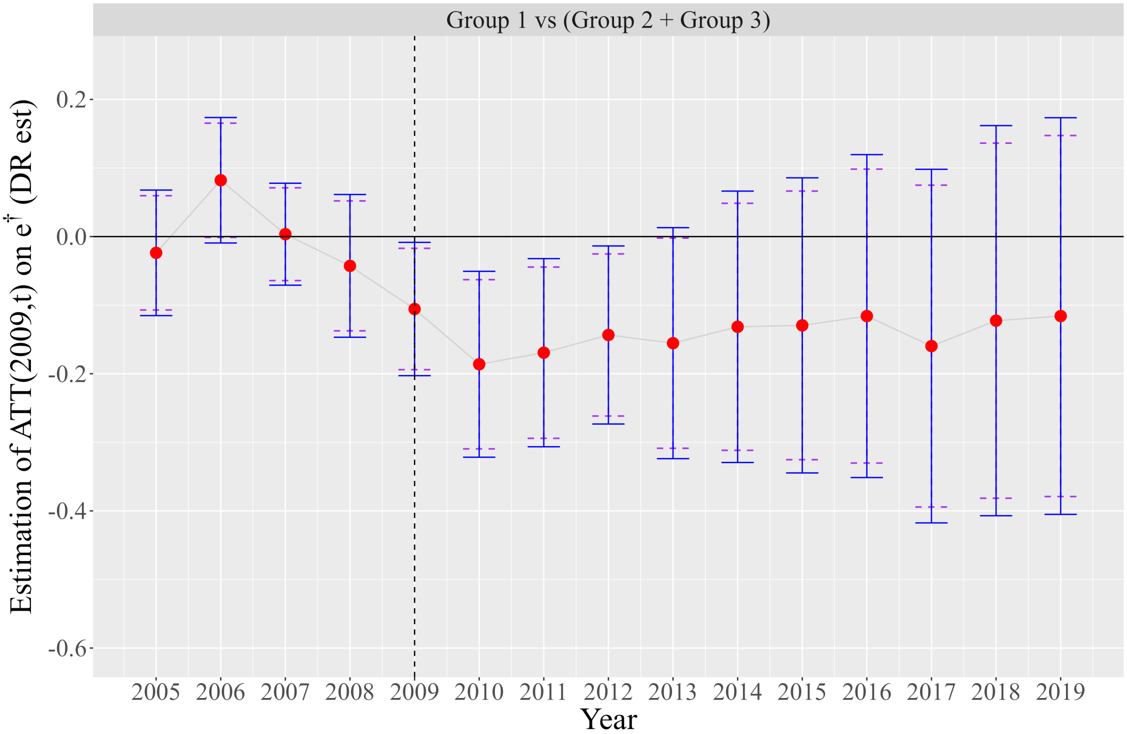


Figure 3: **The (year-to-year) Effect of the Great Recession on the European Lifespan Inequality**
Estimation of the Average Treatment Effect on the Treated—$ATT_t$—with Doubly-Robust estimator.
Horizontal error lines: Solid 95% CI; Dashed 90% CI
Source: Human Mortality Database (HMD)

its inherent nature, does not exhibit a priori rejection from this alternative standpoint as well. This assertion is supported by the fact that in all pre-crisis years, the $ATT_t$ remains not significant and displays no discernible pattern (this is true also if we consider the 90% confidence interval). In contrast, in all post-treatment years, regardless of significance, the estimated $ATT_t$ consistently has a negative sign. This outcome cannot be attributed to chance, as it would only occur with a probability not greater of $0.5^{(2019-2009+1)} < 0.001$[3].

To assess the robustness of our findings we repeated the same analysis separately for Group 2 and 3. (we define this as Robustness Check 1, RC1). The results, depicted

[3] This value is an approximation, which can be interpreted as a rough p-value, at least from an intuitive perspective.

in Figure 4, are consistent with the major previous one.

The reduction in Lifespan Inequality is stronger in Group 3 (severe crisis) than in Group 3 (moderate crisis), across all post-treatment years. Furthermore, countries in Group 2 display a tendency to revert to pre-crisis levels. On the other hand, countries in Group 2 display a tendency to revert to pre-crisis levels, whereas countries in Group 3 experience a heightened negative (but, remember, positive in terms of health) impact, which continues to intensify over time, with a further increase in intensity observed from 2017. In any case, and that's most evident in the comparison between Group 1 and Group 3, there is never a positive effect observed in any post-treatment year, reaffirming the same conclusions drawn earlier regarding the main comparison of our study (Group 1 vs Groups 2 and 3).

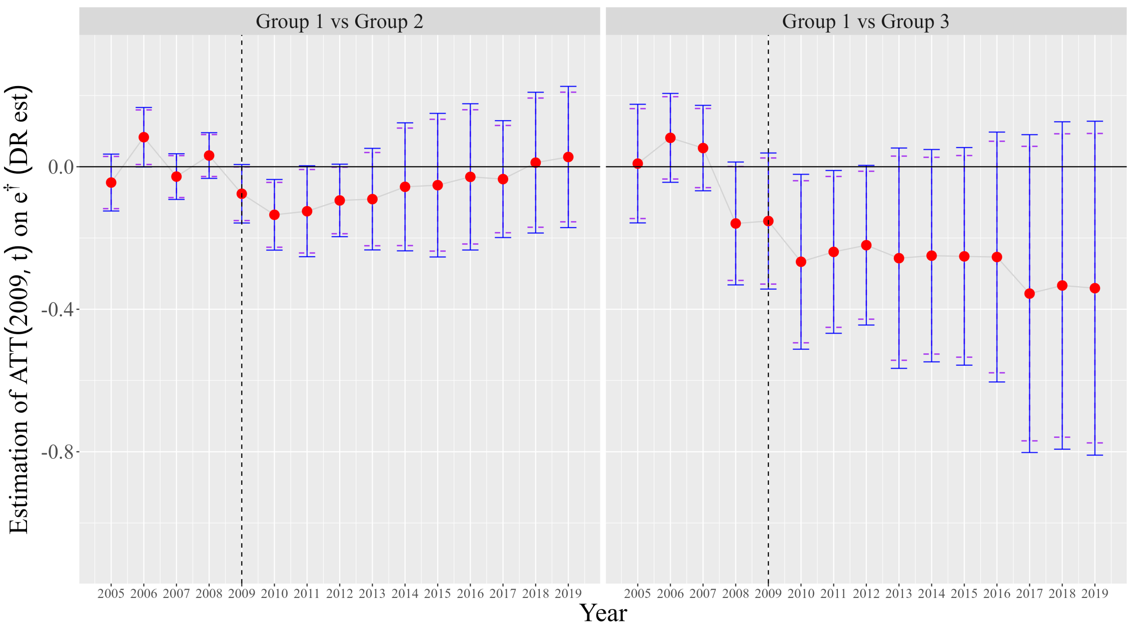


Figure 4: **RC1 – Robustness check of the (year-to-year) Effect of the Great Recession on the European Lifespan Inequality**
Estimation of the Average Treatment Effect on the Treated—$ATT_t$—with Doubly-Robust estimator, according to the level of severity of the crisis.
Horizontal error lines: Solid 95% CI; Dashed 90% CI
Source: Human Mortality Database (HMD)

Pertaining to significance , the $ATT_t$ of the comparison Group 1 vs Group 2 (left panel) remains statistically significant at the 5% level during the two years subsequent to the crisis and at the 10% level throughout the four years following the crisis. Regarding the comparison of Group 1 vs Group 3 (right panel), the effects maintain significance at the 5% level for two post-crisis years and at the 10% level for three, thereby corroborating the primary outcome. One must take into account that the entities under consideration in the RC1 are subgroups of countries which, attributable to their diminished dimensions, inherently possess augmented variability. This intrinsic variability sequentially influences the levels of significance pertaining to the estimations. This phenomenon is especially pronounced for Group 3, the assembly characterized by a reduced number of countries and heightened variability, as illustrated in Figure 2.

To further strengthen these arguments and with the aim of evaluating the long-term magnitude of the effect of GR on mortality inequality, we performed an additional robustness check (we define this as Robustness Check 2, RC2), which includes the entire period under investigation.

The results are shown in Figure 5.

Firstly, we have obtained empirical evidence substantiating the existence of a signif-

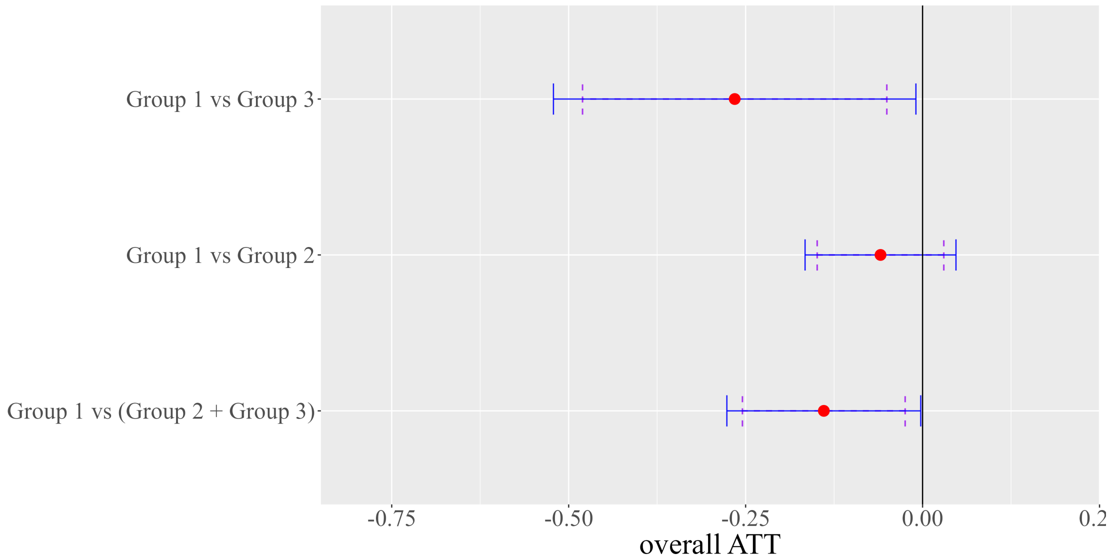


Figure 5: **RC2 – Robustness check utilizing the Overall Treatment Effect of the Great Recession on the European Lifespan Inequality (entire period 2004-2019)**
Estimations of the OTE, according to the level of severity of the crisis.
Vertical error lines: Solid 95% CI; Dashed 90% CI
Source: Human Mortality Database (HMD)

icant (long-lasting) negative OE within the primary comparison (Group 1 vs Group 2 and 3). Additionally, we have obtained corroboration of the consistent relationship between the intensity of the effect and the intensity of GR (the greater the intensity of the crisis, the greater the reduction in lifespan inequality). Moreover, we obtain overall statistical significance for the effect in Group 3. In our perspective, we consider this effect to be relevant, aligning with the severity of the crisis observed in the countries belonging to Group 3. This may drive the overall significance of the main comparison.

Concerning the overall non-significance of the comparison between Group 1 and Group 2, in our view, it again supports our results. The year-to-year effects observed in the main comparison and the first test of RC1 (Group 1 vs. Group 2) demonstrate statistical significance (Figure 3 and Figure 4). However, their temporal duration is relatively brief, thereby limiting the overall significance of the effect across the entire period. In contrast, in the second test of RC1 (the comparison between Group 1 and Group 3), the situation unfolds in an entirely opposite manner: although the effects observed on a yearly basis do not reach statistical significance, they show significantly greater intensity and a longer duration. Consequently, when considering the effect over the entire period, it emerges as statistically significant.

These outcomes confirm that, albeit varying according to the specific group (as expected), GR significantly improves the progression of inequality in European mortality.

# 5 Conclusions and discussion

We found that the Great Recession had a beneficial effect on lifespan inequality (and thus public health) in Europe, reducing disparities on survival rates with a duration of approximately three years. Hence, it can be considered a short-term effect, albeit one that maintains its significance over the medium term (spanning from 2009 to 2019), particularly when considering the subset of countries who experienced the crisis in a severe form. These findings are in accordance with the previous findings by Salinari and Benassi (2022) regarding LE, not only in terms of the direction of the effect but also in its duration.

The result proved to be robust and consistent when subjected to two types of robustness checks: comparison by separate groups and analysis on the entire period rather than year-by-year.

The general picture arising from this work is novel and fills a gap in the ongoing debate concerning the pro-cyclical relationship between the economic cycle and mortality patterns. To the best of our knowledge, previous scientific endeavours have primarily focused on the overall mortality level, neglecting the investigation of its variability. Furthermore, our outcome inherently encompasses mortality variability, removing the necessity for employing any mediators (e.g. ischemic heart disease mortality, cancer mortality, larynx, trachea, bronchus and lung cancer mortality, etcetera) to interpret the outcome as seen in other studies. Our approach mitigates the inherent risk involved in selecting a mediator from a wide (potentially infinitive) range of possibilities and determining its true mediating role (which is not so obvious).

This study contributes to another closely related discussion concerning the connection between life expectancy (and/or mortality) and lifespan inequality (regardless of the GR). As stated in the introduction, the existing literature presents seemingly contradictory findings, with some studies reporting a positive correlation while others suggest a negative association. This contradiction is probably only apparent, because, whether the relation between LE and LI is positive or negative depends on what is called the threshold age between early ages and late ages: while decreases of death rates at any age will always increase life expectancy, lifespan disparity will narrow if the mortality improvement happens below the threshold age, because it compresses the distribution of lifespans; it will widen if the improvement happens above this age, because it expands the distribution by increasing the average remaining lifespan of survivors (Vaupel, Zhang, and A. A. v. Raalte 2011; Aburto, Villavicencio, et al. 2020). The threshold age is generally (but not always) just below life expectancy. Thus, our results provide not only a demonstration of a causal link between the GR and the dynamics of lifespan inequality, but also that that this relation acted through the conferral of a mortality advantage at "young" ages, or, in any case, ages below the life expectancy.

Importantly, our study stands out as one of the few that adopts a causal approach within this field of inquiry, and thus strives to go beyond the branch of mere association. It has successfully withstood two rigorous robustness tests, thereby reinforcing its significance and credibility within the under-way dispute. In such GR manner, we have successfully established a causal link between the LE-LI relationship and the GR.

In the advanced countries, particularly in those with aging populations, there is a noticeable increase in the frequency of economic crises. They are characterized by prolonged durations, heightened intensity, and closer proximity to one another. It is plausible that these recurrent and systemic crises are becoming a regular occurrence in advanced societies, potentially resulting from the repercussions of emerging global economic powers. Not to mention the pervasive uncertainty instigated by the resurgence of bellicose aspirations, which reignite an international peril of sad memory. Consequently, it is of growing importance for social scientists to examine the ramifications of the economic crisis's effects, particularly in relation to inequality.

# References


Aburto, José. Manuel and Alyson van Raalte (2018). "Lifespan dispersion in times of life expectancy fluctuation: the case of Central and Eastern Europe". In: *Demography* 55.6, pp. 2071–2096.

Aburto, José. Manuel, Francisco Villavicencio, et al. (2020). "Dynamics of life expectancy and life span equality". In: *Proceedings of the National Academy of Sciences* 117.10, pp. 5250–5259.

Antonio-Villa, Neftali Eduardo et al. (2022). "Comprehensive evaluation of the impact of sociodemographic inequalities on adverse outcomes and excess mortality during the coronavirus disease 2019 (COVID-19) pandemic in Mexico City". In: *Clinical infectious diseases* 74.5, pp. 785–792.

Ariizumi, Hideki and Tammy Schirle (2012). "Are recessions really good for your health? Evidence from Canada". In: *Social science & medicine* 74.8, pp. 1224–1231.

Ballester, Joan et al. (2019). "Effect of the Great Recession on regional mortality trends in Europe". In: *Nature Communications* 10.1, p. 679.

Bang, Heejung and James M. Robins (2005). "Doubly robust estimation in missing data and causal inference models". In: *Biometrics* 61.4, pp. 962–973.

Basellini, Ugofilippo et al. (2021). "Linking excess mortality to mobility data during the first wave of COVID-19 in England and Wales". In: *SSM-Population Health* 14, p. 100799.

Baumbach, Anja and Gabriel Gulis (2014). "Impact of financial crisis on selected health outcomes in Europe". In: *The European Journal of Public Health* 24.3, pp. 399–403.

Bergeron-Boucher, Marie-Pier et al. (2022). "Probability of males to outlive females: an international comparison from 1751 to 2020". In: *BMJ open* 12.8, e059964.

Bhalotra, Sonia (2010). "Fatal fluctuations? Cyclicality in infant mortality in India". In: *Journal of Development Economics* 93.1, pp. 7–19.

Brø.nnum-Hansen, Henrik (2017). "Socially disparate trends in lifespan variation: a trend study on income and mortality based on nationwide Danish register data". In: *BMJ open* 7.5, e014489.

Brø.nnum-Hansen, Henrik et al. (2015). "Educational inequalities in health expectancy during the financial crisis in Denmark". In: *International journal of public health* 60, pp. 927–935.

Brüning, Max and Josselin Thuilliez (2019). "Mortality and macroeconomic conditions: what can we learn from France?" In: *Demography* 56.5, pp. 1747–1764.

Buchmueller, Thomas C., Florence Jusot, Michel Grignon, et al. (2007). "Unemployment and mortality in France, 1982-2002". In.

Callaway, Brantly and Pedro HC Sant'Anna (2021). "Difference-in-differences with multiple time periods". In: *Journal of econometrics* 225.2, pp. 200–230.

Case, Anne and Angus Deaton (2020). *Deaths of Despair and the Future of Capitalism*. Princeton University Press.

Catalano, Ralph and Benjamin Bellows (2005). "Commentary: if economic expansion threatens public health, should epidemiologists recommend recession?" In: *International Journal of Epidemiology* 34.6, pp. 1212–1213.

Catalano, Ralph, Sidra Goldman-Mellor, et al. (2011). "The health effects of economic decline". In: *Annual review of public health* 32, pp. 431–450.

Cervini-Plá., María and Judit Vall-Castelló (2021). “Business cycle and mortality in Spain”. In: *The European Journal of Health Economics* 22.8, pp. 1289–1299.
Cohen, Lawrence E. and Marcus Felson (1979). “On estimating the social costs of national economic policy: A critical examination of the Brenner study”. In: *Social indicators research*, pp. 251–259.
Colchero, Fernando et al. (2016). “The emergence of longevous populations”. In: *Proceedings of the National Academy of Sciences* 113.48, E7681–E7690.
Cook, Philip J. and Gary A. Zarkin (1986). “Homicide and economic conditions: A replication and critique of M. Harvey Brenner’s new report to the US Congress”. In: *Journal of Quantitative Criminology* 2, pp. 69–80.
D.í.az Ramírez, Marcos, Paolo Veneri, and Alexander C Lembcke (2022). “Where did it hit harder? Understanding the geography of excess mortality during the COVID-19 pandemic”. In: *Journal of Regional Science* 62.3, pp. 889–908.
Edwards, Ryan D. and Shripad Tuljapurkar (2005). “Inequality in life spans and a new perspective on mortality convergence across industrialized countries”. In: *Population and Development Review* 31.4, pp. 645–674.
Engzell, Per, Arun Frey, Mark D. Verhagen, et al. (2020). *Learning inequality during the COVID-19 pandemic.*
Eyer, Joseph (1976a). “Rejoinder to Dr. Brenner”. In: *International Journal of Health Services* 6.1, pp. 157–168.
— (1976b). *Review of mental illness and the economy.*
— (Jan. 1977). *Prosperity as a Cause of Death.* URL: https://journals.sagepub.com/doi/abs/10.2190/9WA2-RVL3-MT9D-EL9D.
Falagas, ME et al. (2009). “Economic crises and mortality: a review of the literature”. In: *International journal of clinical practice* 63.8, pp. 1128–1135.
Gerdtham, Ulf-G. and Magnus Johannesson (2005). “Business cycles and mortality: results from Swedish microdata”. In: *Social science & medicine* 60.1, pp. 205–218.
Gerdtham, Ulf-G. and Christopher J. Ruhm (2006). “Deaths rise in good economic times: evidence from the OECD”. In: *Economics & Human Biology* 4.3, pp. 298–316.
Gravelle, Hugh SE, Gillian Hutchinson, and Jon Stern (1981). “Mortality and unemployment: a critique of Brenner’s time-series analysis”. In: *The Lancet* 318.8248, pp. 675–679.
Greenaway-McGrevy, Ryan (2021). “Mortality and fluctuations in macroeconomic activity in New Zealand”. In: *The New Zealand Medical Journal (Online)* 134.1533, pp. 46–6.
Heggebø., Kristian et al. (2019). “Socioeconomic inequalities in health during the Great Recession: a scoping review of the research literature”. In: *Scandinavian journal of public health* 47.6, pp. 635–654.
Hernan, MA and J. Robins (2020). “Causal inference: What if. boca raton: Chapman & hill/crc”. In.
HMD (2023). *Human Mortality Database.* Data provided by the Max Planck Institute for Demographic Research, University of California, Berkeley, and French Institute for Demographic Studies. Data downloaded in 2023. HMD. URL: http://www.mortality.org.

Kannisto, Vaino (2001). "Mode and Dispersion of the Length of Life". In: *Population: An English Selection* 13.1. Publisher: Institut National d'Études Démographiques, pp. 159–171. ISSN: 1169-1018. URL: https://www.jstor.org/stable/3030264.

Karanikolos, Marina et al. (2013). "Financial crisis, austerity, and health in Europe". In: *The Lancet* 381.9874, pp. 1323–1331. ISSN: 0140-6736. DOI: https://doi.org/10.1016/S0140-6736(13)60102-6. URL: https://www.sciencedirect.com/science/article/pii/S0140673613601026.

Kasl, Stanislav V. (1979). "Mortality and the business cycle: some questions about research strategies when utilizing macro-social and ecological data." In: *American Journal of Public Health* 69.8, pp. 784–788.

Kasl, Stanislav V. and Beth A. Jones (2000). "The impact of job loss and retirement on health". In: *Social epidemiology*, pp. 118–136.

Kentikelenis, Alexander et al. (2011). "Health effects of financial crisis: omens of a Greek tragedy". In: *The Lancet* 378.9801, pp. 1457–1458.

Keyfitz, N. (1977). *Applied Mathematical Demography*. 1st ed. New York: John Wiley.

Khang, Young Ho et al. (2005). "Changes in mortality inequality in relation to the South Korean economic crisis: use of area-based socioeconomic position." In: *Journal of preventive medicine and public health* 38.3, pp. 359–365.

Khemka, Gaurav and Steven Roberts (2015). "Impact of economic cycles on mortality: the Australian context". In: *Journal of Population Research* 32, pp. 139–155.

Laliotis, Ioannis and Charitini Stavropoulou (2018). "Crises and mortality: Does the level of unemployment matter?" In: *Social Science & Medicine* 214, pp. 99–109.

Lee, Ronald (2019). *Mortality forecasts and linear life expectancy trends*. Springer International Publishing.

Lin, Shin-Jong (2009). "Economic fluctuations and health outcome: a panel analysis of Asia-Pacific countries". In: *Applied Economics* 41.4, pp. 519–530.

Marmot, Michael (2005). "Social determinants of health inequalities". In: *The lancet* 365.9464, pp. 1099–1104.

Maynou, Laia and Marc Saez (2016). "Economic crisis and health inequalities: evidence from the European Union". In: *International journal for equity in health* 15.1, pp. 1–11.

N.é.meth, László (2017). "Life expectancy versus lifespan inequality: A smudge or a clear relationship?" In: *PLoS One* 12.9, e0185702.

Neumayer, Eric (2004). "Recessions lower (some) mortality rates:: evidence from Germany". In: *Social science & medicine* 58.6, pp. 1037–1047.

Oeppen, Jim and James W. Vaupel (2002). *Broken limits to life expectancy*.

Ogburn, William F. and Dorothy S. Thomas (Sept. 1, 1922). "The Influence of the Business Cycle on Certain Social Conditions". In: *Journal of the American Statistical Association* 18.139. Publisher: Taylor & Francis, pp. 324–340. ISSN: 0162-1459. DOI: 10.1080/01621459.1922.10502475. URL: https://www.tandfonline.com/doi/abs/10.1080/01621459.1922.10502475.

Palè.ncia, Laia et al. (2020). "Effect of the recent economic crisis on socioeconomic inequalities in mortality in nine urban areas in Europe". In: *Gaceta sanitaria* 34, pp. 253–260.

Permanyer, I.ñ.aki and Nathalie Scholl (2019). "Global trends in lifespan inequality: 1950-2015". In: *PloS one* 14.5, e0215742.

Rao, Mala et al. (2014). “Changes in addressing inequalities in access to hospital care in Andhra Pradesh and Maharashtra states of India: a difference-in-differences study using repeated cross-sectional surveys”. In: *BMJ open* 4.6, e004471.

Regidor, Enrique et al. (2016). “Mortality decrease according to socioeconomic groups during the economic crisis in Spain: a cohort study of 36 million people”. In: *The Lancet* 388.10060, pp. 2642–2652.

Robins, James M. (2000). “Robust estimation in sequentially ignorable missing data and causal inference models”. In: *Proceedings of the American Statistical Association*. Vol. 1999. Indianapolis, IN, pp. 6–10.

Robins, James M., Andrea Rotnitzky, and Lue Ping Zhao (1995). “Analysis of semiparametric regression models for repeated outcomes in the presence of missing data”. In: *Journal of the american statistical association* 90.429, pp. 106–121.

Ruhm, Christopher J. (May 1, 2000). “Are Recessions Good for Your Health?” In: *The Quarterly Journal of Economics* 115.2, pp. 617–650. ISSN: 0033-5533. DOI: 10.1162/003355300554872. URL: https://doi.org/10.1162/003355300554872.

— (2008). “Macroeconomic conditions, health and government policy”. In: *Making Americans healthier: Social and economic policy as health policy*, pp. 173–200.

Salinari, Giambattista and Federico Benassi (2022). “The long-term effect of the Great Recession on European mortality”. In: *Journal of Population Research* 39.3, pp. 417–439.

Santos, Alcione Miranda dos et al. (2021). “Excess deaths from all causes and by COVID-19 in Brazil in 2020”. In: *Revista de saude publica* 55.

Sasson, Isaac (2016). “Trends in life expectancy and lifespan variation by educational attainment: United States, 1990–2010”. In: *Demography* 53.2, pp. 269–293.

Shkolnikov, Vladimir M. and Evgeny M. Andreev (2010). “Spreadsheet for calculation of life-table dispersion measures”. In: *Rostock: Max Planck Institute for Demographic Research*.

Smits, Jeroen and Christiaan Monden (2009). “Length of life inequality around the globe”. In: *Social science & medicine* 68.6, pp. 1114–1123.

Stuckler, David and Sanjay Basu (2013). *The body economic: why austerity kills*. Basic Books (AZ).

Stuckler, David, Sanjay Basu, et al. (2009). “The public health effect of economic crises and alternative policy responses in Europe: an empirical analysis”. In: *The Lancet* 374.9686, pp. 315–323.

Sun, Ting-Ting et al. (2021). “How do economic fluctuations affect the mortality of infectious diseases?” In: *Frontiers in Public Health* 9, p. 678213.

Tapia Granados, José. A (2005). “Recessions and mortality in Spain, 1980–1997”. In: *European Journal of Population/Revue européenne de Démographie* 21, pp. 393–422.

— (2008). “Macroeconomic fluctuations and mortality in postwar Japan”. In: *Demography* 45.2, pp. 323–343.

— (2012). “Economic growth and health progress in England and Wales: 160 years of a changing relation”. In: *Social science & medicine* 74.5, pp. 688–695.

Tapia Granados, José. A and Ana V Diez Roux (2009). “Life and death during the Great Depression”. In: *Proceedings of the national academy of sciences* 106.41, pp. 17290–17295.

Tapia Granados, José. A and Edward L Ionides (2017). “Population health and the economy: Mortality and the Great Recession in Europe”. In: *Health economics* 26.12, e219–e235.

Toffolutti, Veronica and Marc Suhrcke (2014). “Assessing the short term health impact of the Great Recession in the European Union: a cross-country panel analysis”. In: *Preventive medicine* 64, pp. 54–62.

Van Raalte, Alyson A. and Hal Caswell (2013). “Perturbation analysis of indices of lifespan variability”. In: *Demography* 50.5, pp. 1615–1640.

Van Raalte, Alyson A., Isaac Sasson, and Pekka Martikainen (2018). “The case for monitoring life-span inequality”. In: *Science* 362.6418, pp. 1002–1004.

Vaupel, James W. and Vladimir Canudas Romo (2003). “Decomposing change in life expectancy: A bouquet of formulas in honor of Nathan Keyfitz’s 90th birthday”. In: *Demography* 40, pp. 201–216.

Vaupel, James W., Zhen Zhang, and Alyson A. van Raalte (2011). “Life expectancy and disparity: an international comparison of life table data”. In: *BMJ open* 1.1, e000128.

Vigezzi, Serena, José. Manuel Aburto, Inaki Permanyer, et al. (2021). “Divergent Trends of lifespan variation during mortality crises”. In.

Vigezzi, Serena, José. Manuel Aburto, Iñaki Permanyer, et al. (2022). “Divergent trends in lifespan variation during mortality crises”. In: *Demographic Research* 46, pp. 291–336.

Wagstaff, Adam (1985). “Time series analysis of the relationship between unemployment and mortality: a survey of econometric critiques and replications of Brenner’s studies”. In: *Social science & medicine* 21.9, pp. 985–996.

White, Kevin M. (2002). “Longevity advances in high-income countries, 1955–96”. In: *Population and Development Review* 28.1, pp. 59–76.

Wilmoth, John R., Carl Boe, et al. (2011). “Geographic differences in life expectancy at age 50 in the United States compared with other high-income countries”. In: *International differences in mortality at older ages: Dimensions and sources*, pp. 333–366.

Wilmoth, John R. and Shiro Horiuchi (1999). “Rectangularization revisited: Variability of age at death within human populations”. In: *Demography* 36.4, pp. 475–495.

Yu, Fan, De Xiao, and Meng-Shiuh Chang (2021). “The impact of carbon emission trading schemes on urban-rural income inequality in China: A multi-period difference-in-differences method”. In: *Energy Policy* 159, p. 112652.