Diversity in Causes of Death: A New Approach Using Multiple Causes of Death Life Tables

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Introduction

Cause of death structures are currently experiencing important changes in low-mortality countries: the share of deaths due to cardiovascular diseases is decreasing leading to an increasing share of neoplasms as well as of other causes such as Alzheimer's and Parkinson's disease, dementia, endocrine diseases, diseases of the genitourinary and respiratory systems, etc.

This shift led to a **diversification of causes of death**, where the causes of death profile is becoming increasingly complex. Studies of causes diversity usually analyze underlying causes of death (UCD). However, such analysis might only capture the tip of the iceberg, as **multiple causes** can contribute to death.

Research objective

The aim is to develop a framework to study causes diversity accounting for multiple causes of death (MCoD). The proposed approach should (1) allow for comparison over time and countries (age-standardized); (2) capture the two key dimensions of diversity: richness and evenness; (3) provide diversity measures that can be decomposed.

Methods

MCoD life table

By using a life table framework to measure MCoD mortality, we can obtain age-standardized mortality indicators. We can add columns to a multiple decrement life table, to include information on contributing causes (CC), with:

$$q_{x,i,j} = q_x * \frac{D_{x,i,j}}{D_x} \quad (1) \qquad d_{x,i,j} = q_{x,i,j} * l_x \quad (2)$$

where q_x is the death probability at age x and l_x is the survival probability to x. $D_{x,i,j}$ is the number of deaths and $q_{x,i,j}$ the death probability at age x, from UCD i and CC j. $d_{x,i,j}$ is the number of life table deaths that had CC j by age and UCD.

Number of causes

A first key aspect of diversity is the number of causes contributing to death, referred to as "richness" in biodiversity studies. We can estimate the average number of causes in the life table (N) as:

$$N = 1 + \sum_x \sum_i \sum_j d_{x,i,j} \quad (3)$$

Using the Das Gupta decomposition, we can decompose differences in N into contributions from (1) changes in the age at death distribution, (2) changes in the UCD distribution and (3) a general changes in the number of causes across ages and UCD.

Diversity - Method 1 (M1)

The second key aspect of diversity, referred to as "evenness" in biodiversity, captures the relative abundance of causes. We first assume that all causes listed on the death certificate, regardless of their position, contribute to the complexity of the mortality process. From the distribution by cause c, where c represents the cause irrespective whether it is an UCD or CC, we use the Gini-Simpson index (GS) to measure diversity:

$$GS = 1 - \sum_c (d_c)^2 \quad (4)$$

Changes in GS can be decomposed into the contributions of the changes in the age and cause specific death probabilities using the Horiuchi decomposition method.

Diversity - Method 2 (M2)

In a second, more UCD-centric, approach, we assume that the UCD provides the baseline representation of cause diversity, with each contributing cause adding to this initial level, leading to an extension of GS:

$$GS^* = 1 - \sum_i (d_i)^2 S_i \quad (5)$$

where S_i is the Simpson index calculating CC diversity for each UCD i and d_i is the UCD distribution. If there are no contributing causes, $S_i = 1$, and GS^* index equals the index for the UCD only. Using the Kitagawa decomposition, GS^* can be decomposed into (1) changes in UCD-specific CC diversity and (2) changes in the squared share of the UCD.

Data

We compare cause diversity changes over time by sex (results presented for **females**), in three countries: Denmark, France and the U.S. For all countries, we used the life table from the Human Mortality Database (HMD). Data on multiple causes of death come from the Danish Register of Causes of Death, the French Health Registry with data prepared by the French National Institute for Health and Medical Research (INSERM), and the Multiple Causes of Death Data from the Centers for Disease Control and Prevention in the U.S. Causes were grouped into 15 groups, mostly capturing the ICD-10 chapters.

Infectious and parasitic diseases (Inf)	Diseases of the nervous system (Ner)	Diseases of the musculoskeletal system and con. tissue (Mus)
Neoplasms (Can)	Diseases of the circulatory system (Cir)	Diseases of the genitourinary system (Gen)
Diseases of the blood, Immunol. Disorders (Blo)	Diseases of the respiratory system (Res)	Oth. Symptoms, signs, abn. findings, ill-defined causes (Ill)
Endocrine, nutritional and metabolic diseases (Met)	Diseases of the digestive system (Dig)	Diseases of the skin and subcutaneous tissue (Ski)
Mental and behavioral disorders (Men)	External causes (Ext)	Other diseases (Oth)

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Results

Figure 1: Causes diversity in Denmark, France and the U.S., using (A) the number of life table deaths and (B) the Gini-Simpson index to quantify the relative abundance of causes

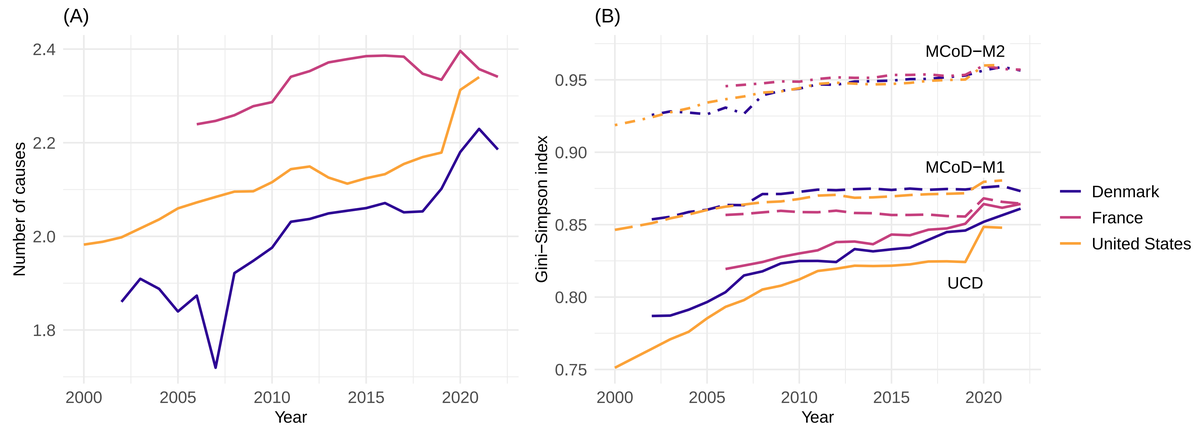

Figure 2: Cause-specific contribution to changes in the Gini-Simpson index based on the UCD and MCoD distribution (M1) in Denmark, France and the U.S. between 2006 and 2019.

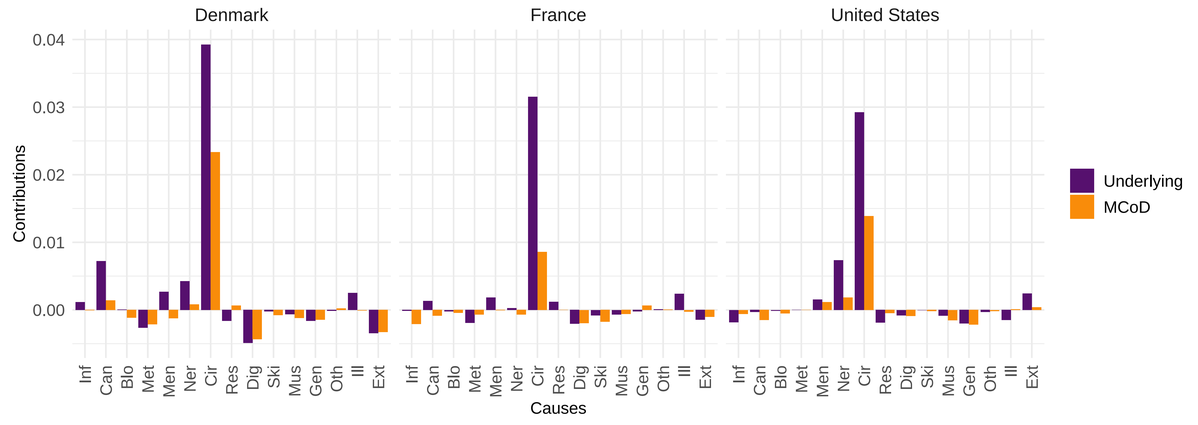

Table 1: Decomposition of the changes in N by contributions from changes in the distribution of death by age and UCD and changes in the number of causes by age and UCD ($N_{x,i}$), between 2006 and 2019

Countries	Age cont.	UCD cont.	$N_{x,i}$ cont.	Total
Denmark	0.002	-0.024	0.240	0.217
France	-0.001	-0.031	0.127	0.095
United States	-0.004	0.023	0.088	0.107

Table 2: Decomposition of the changes in GS^* (M2) by contributions from changes in the UCD distribution and changes in CC-diversity by UCD (S_i), between 2006 and 2019

Countries	UCD cont.	S_i cont.	Total
Denmark	0.010	0.011	0.021
France	0.004	0.004	0.008
United States	0.010	0.004	0.014

Discussion

- MCoD analysis reveals higher causes diversity than studying UCD alone.
- All proposed measures are capturing an increased diversity over time (except M1 in recent years).
- The increase in diversity is primarily driven by (1) mortality decline from diseases of the circulatory system and (2) an increase share of death from UCD with higher CC-diversity.
- The reliability of causes of death data is often questioned, especially regarding the reporting of all contributing causes and selection of the appropriate UCD.
- Which model to use? M1 or M2? The choice of measures depends on how the roles of CC are perceived.