

Diversity in Causes of Death: A New Framework to Account for Multiple Causes of Death

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Background

- Changing structure of causes of death over time
 - Decrease importance from cardiovascular diseases
 - Increased diversity in causes of death
- Causes diversity
 - Usually studied by looking at the underlying causes only
 - One study analyse diversity in multiple causes of death (MCoD)
 - Diversity in MCoD can be understood as both “quantity” and “quality”
- Learning from biodiversity study
 - Richness: Number of causes
 - Evenness: How common/rare are the causes in terms of relative abundance

Aim

Develop a framework to study cause-of-death diversity while accounting for MCoD. The framework should:

- Be age-standardized
- Allow to study both richness and evenness
- Indices must be decomposable (not shown)

Data

Sources:

- Denmark: Danish Causes of Death registry – 2002:2022
 - France: French National Institute for Health and Medical Research (INSERM) – 2006:2022
 - Spain: National Institute of Statistics - 2016-2022.
 - US: Multiple Causes of Death Data from the CDC – 2000:2023
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- Age: 0 to 100+
 - Sex: Females (and males)
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- Causes grouping: Main ICD-10 chapters

Age-standardized approach: Multiple causes of death life table

Add MCoD information to a multiple decrement life table by calculating the death probabilities by underlying cause i with contributing cause j :

$$q(x, i, j) = q(x) \frac{D(x, i, j)}{D(x)}$$

$q(x)$: age-specific death probability

$D(x, i, j)$: number of deaths at age x and from underlying cause i and contributing cause j

Multiple causes of death life table

Example for French females in 2022 for two groups of causes: diseases of the circulatory system (C) and neoplasm (N)

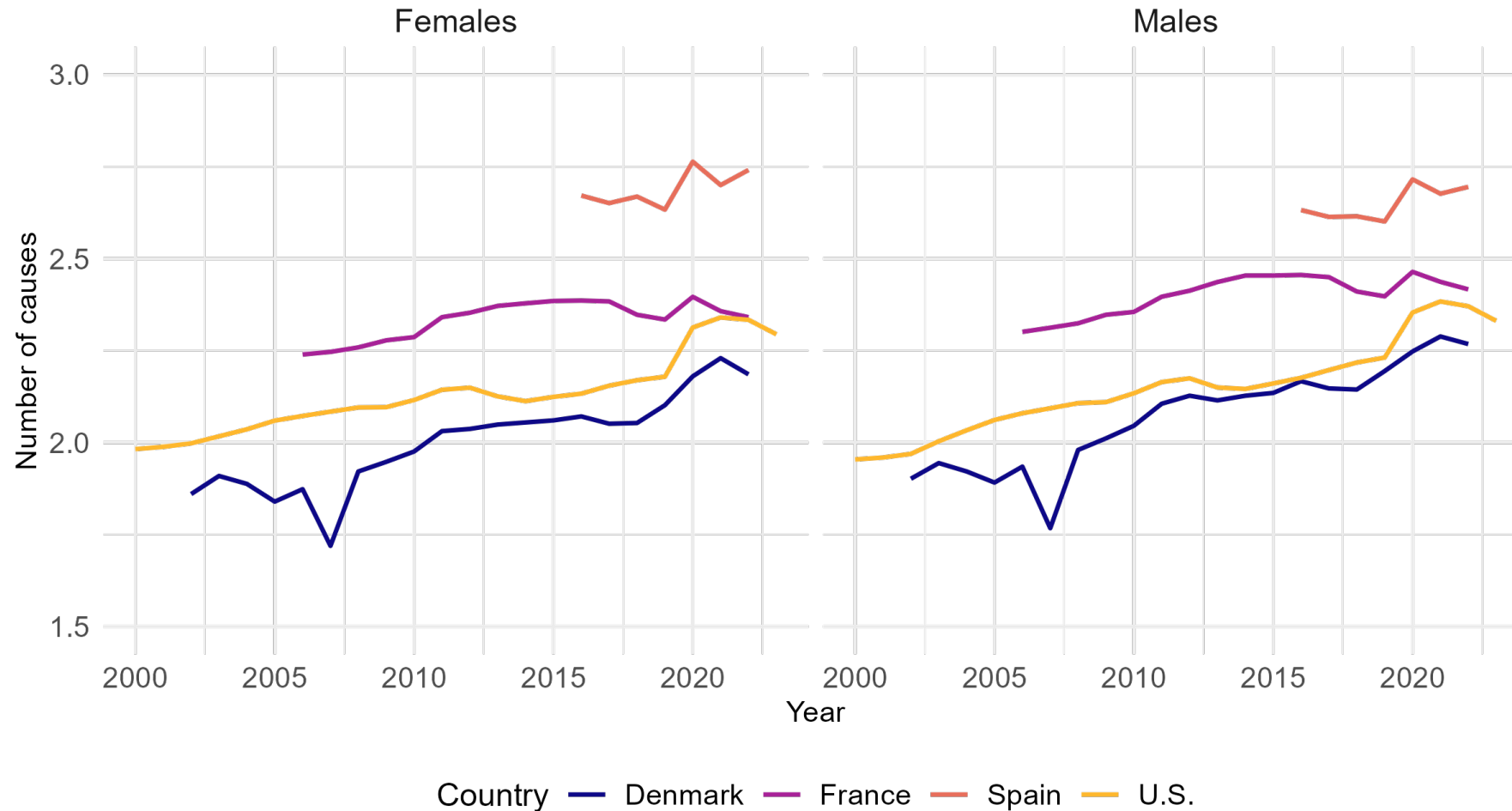
| Age | $q(x)$ | $q(x, C)$ | $q(x, C, N)$ | $q(x, N)$ | $q(x, N, C)$ | $l(x)$ | $d(x)$ | $d(x, C)$ | $d(x, C, N)$ | $d(x, N)$ | $d(x, N, C)$ |
|-------|--------|-----------|--------------|-----------|--------------|--------|--------|-----------|--------------|-----------|--------------|
| 40-44 | 0.0043 | 0.0004 | 0.0000 | 0.0018 | 0.0001 | 98717 | 422 | 40 | 1 | 177 | 15 |
| 45-49 | 0.0069 | 0.0007 | 0.0000 | 0.0032 | 0.0003 | 98296 | 679 | 66 | 2 | 319 | 32 |
| 50-54 | 0.0113 | 0.0010 | 0.0001 | 0.0057 | 0.0005 | 97617 | 1100 | 95 | 6 | 556 | 50 |
| 55-59 | 0.0169 | 0.0016 | 0.0001 | 0.0088 | 0.0009 | 96516 | 1633 | 158 | 7 | 846 | 90 |
| 60-64 | 0.0257 | 0.0028 | 0.0001 | 0.0133 | 0.0016 | 94883 | 2439 | 263 | 14 | 1263 | 149 |
| 65-69 | 0.0379 | 0.0047 | 0.0003 | 0.0180 | 0.0025 | 92444 | 3503 | 435 | 29 | 1667 | 230 |
| 70-74 | 0.0563 | 0.0082 | 0.0005 | 0.0239 | 0.0036 | 88941 | 5007 | 726 | 43 | 2124 | 324 |
| 75-79 | 0.0915 | 0.0159 | 0.0008 | 0.0324 | 0.0057 | 83934 | 7682 | 1339 | 66 | 2720 | 478 |
| 80-84 | 0.1684 | 0.0352 | 0.0017 | 0.0437 | 0.0093 | 76251 | 12841 | 2681 | 130 | 3332 | 711 |
| 85-89 | 0.3185 | 0.0795 | 0.0029 | 0.0562 | 0.0142 | 63410 | 20194 | 5038 | 185 | 3564 | 898 |
| 90-94 | 0.5562 | 0.1511 | 0.0051 | 0.0629 | 0.0189 | 43216 | 24037 | 6528 | 222 | 2717 | 819 |
| 95-99 | 0.7752 | 0.2185 | 0.0062 | 0.0572 | 0.0190 | 19179 | 14867 | 4191 | 118 | 1097 | 364 |
| 100+ | 1.0000 | 0.2671 | 0.0074 | 0.0421 | 0.0133 | 4312 | 4312 | 1152 | 32 | 181 | 57 |

Number of causes - Richness

The age-standardized average number of distinct groups of causes present on the death certificates, N , can be directly estimated from $d(x, i, j)$

$$N = 1 + \sum_x \sum_j \sum_i d(x, i, j)$$

Number of causes - Richness



Evenness and diversity – First model

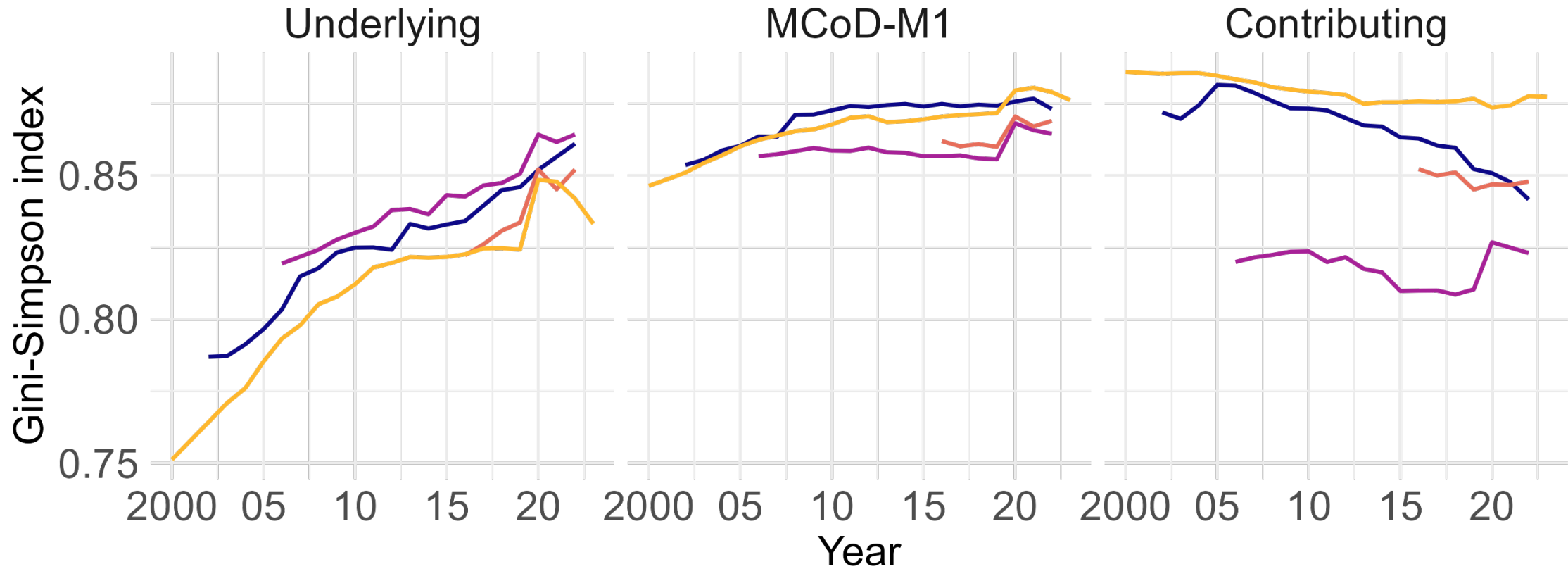
Assumption: all causes listed on the death certificate, regardless of their role in the morbid process, contribute to the complexity of the mortality process.

Gini-Simpson (GS) index is used to calculate cause diversity

$$GS = 1 - S = 1 - \sum_i d(i)^2$$

Same index can be applied to the distribution accounting for all causes or underlying cause only.

Evenness and diversity – First model (M1)



Country — Denmark — France — Spain — U.S.

Evenness and diversity – Second model

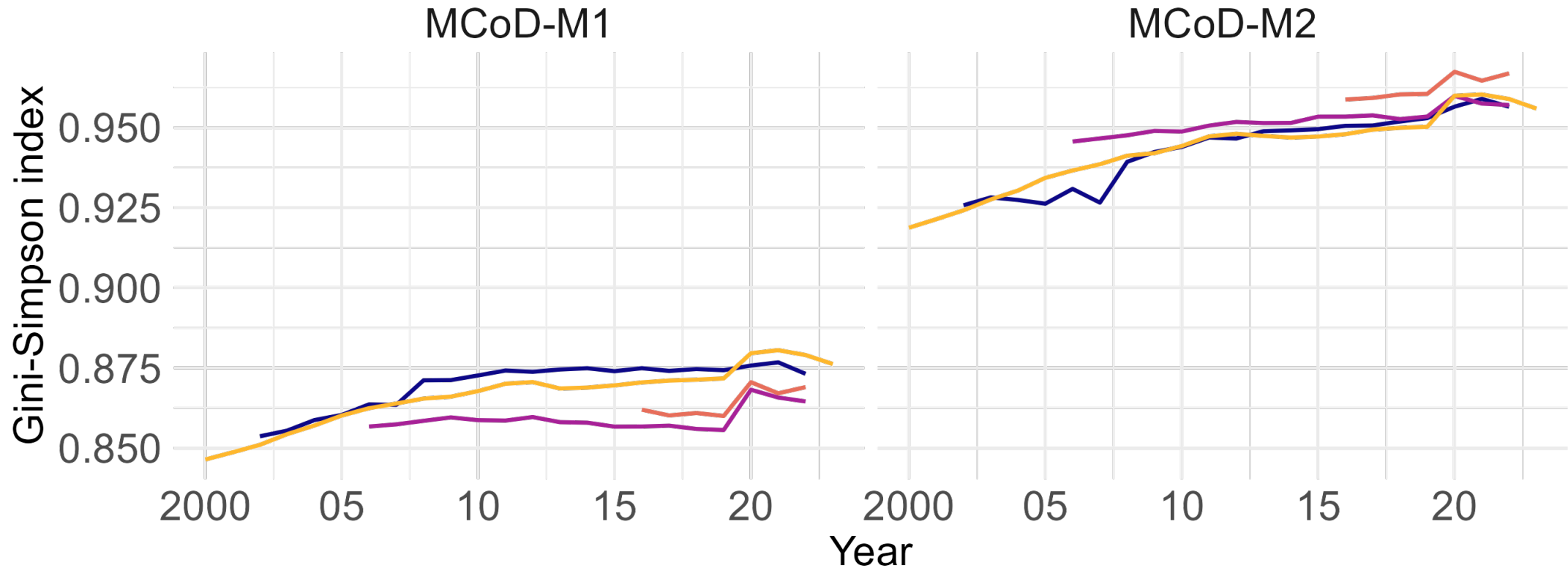
Assumption: the UCD provides the baseline representation of cause diversity, with each contributing cause adding to this initial level.

We here suggest an extension of the Gini-Simpson index:

$$GS' = 1 - \sum_i d(i)^2 S(i)$$

$S(i)$ is the Simpson index calculating cause diversity for each underlying cause i .

Evenness and diversity – Second model (M2)



Country — Denmark — France — Spain — U.S.

Discussion & Conclusion

- UCD downplay the complexity of the mortality process
- But, MCoD diversity increase more slowly than the UCD-diversity
- Should M1 or M2 be used to study cause diversity?
- Data quality?
- High diversity = Low predictability
- High diversity = Divided efforts to reduce mortality

Thank you!



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