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

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Introduction

In recent years, in low-mortality countries, the causes of death have become more diverse. This entails:

- Increased uncertainties;
- Lower predictability;
- More complex and fragmented efforts to reduce mortality.

Introduction

Studies of causes diversity are relatively recent, but are growing in numbers.

- Most focus on the underlying causes of death (UCD), but ....
- Various measures have been used and proposed:
  - Diversity indices
  - Distance measures
- Focus on low mortality countries, but...

Learning from biodiversity studies

Biodiversity research offers valuable tools to study diversity. There are two key aspects:

- Richness: Numbers/types
- Evenness: Diversity/complexity

Objective

To study diversity in causes of death using multiple causes of death (MCoD) data using the two aspects of diversity.

Framework

We need a framework that:

- allow to quantify both metrics,
- is age-standardized.

Solution: A life table that accounts for MCoD.

MCoD life tables

Multiple decrement life tables calculate the death probability at age x and UCD u, as:

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

The death probability of underlying causes u with contributing cause c can be estimated as:

$$q(x,u,c) = q(x)\frac{D(x,u,c)}{D(x)}$$

Other indicators in an MCoD life tables

Life table deaths (distribution): $d(x,u,c) = q(x,u,c)\ l(x)$

Mortality rates: $m(x,u,c) = \frac{d(x,u,c)}{L(x)}$

Prevalence at death: $PD_{c/u} = \sum_x d(x,u,c)/d(x,u)$

Cause of death association indicator: $CDAI_{u,c} = \sum_x \frac{d(x,u,c)}{d(x,u)} / \sum_x \frac{d(x,c)}{d(x)}$

MCoD life table - Example

Age	d_{u1}	$d_{u1,c2}$	$d_{u1,c3}$	d_{u2}	$d_{u2,c1}$	$d_{u2,c3}$	d_{u3}	$d_{u3,c1}$	$d_{u3,c2}$
0	12	0	2	2	0	0	539	41	0
1	2	0	1	2	0	0	34	5	0
2	1	0	0	2	0	0	20	2	0
...									
65	299	9	113	336	79	113	429	187	14
66	314	10	132	359	88	140	454	203	18
67	341	11	162	375	89	152	471	213	18
...									
109	4	0	2	0	0	0	6	1	0
110+	5	0	2	0	0	0	5	1	0

Data

Application to US data:

1. MCoD data from the Muliple Causes of Death data on CDC Wonder
2. Causes grouping by main ICD-10 chapter
3. Life tables from the Human Mortality Database
4. Period: 2006 to 2021
5. Both sexes combined
6. If a death had multiple entry of the same cause, only one was kept.

Upcoming results for Denmark, Spain and France and by sex.

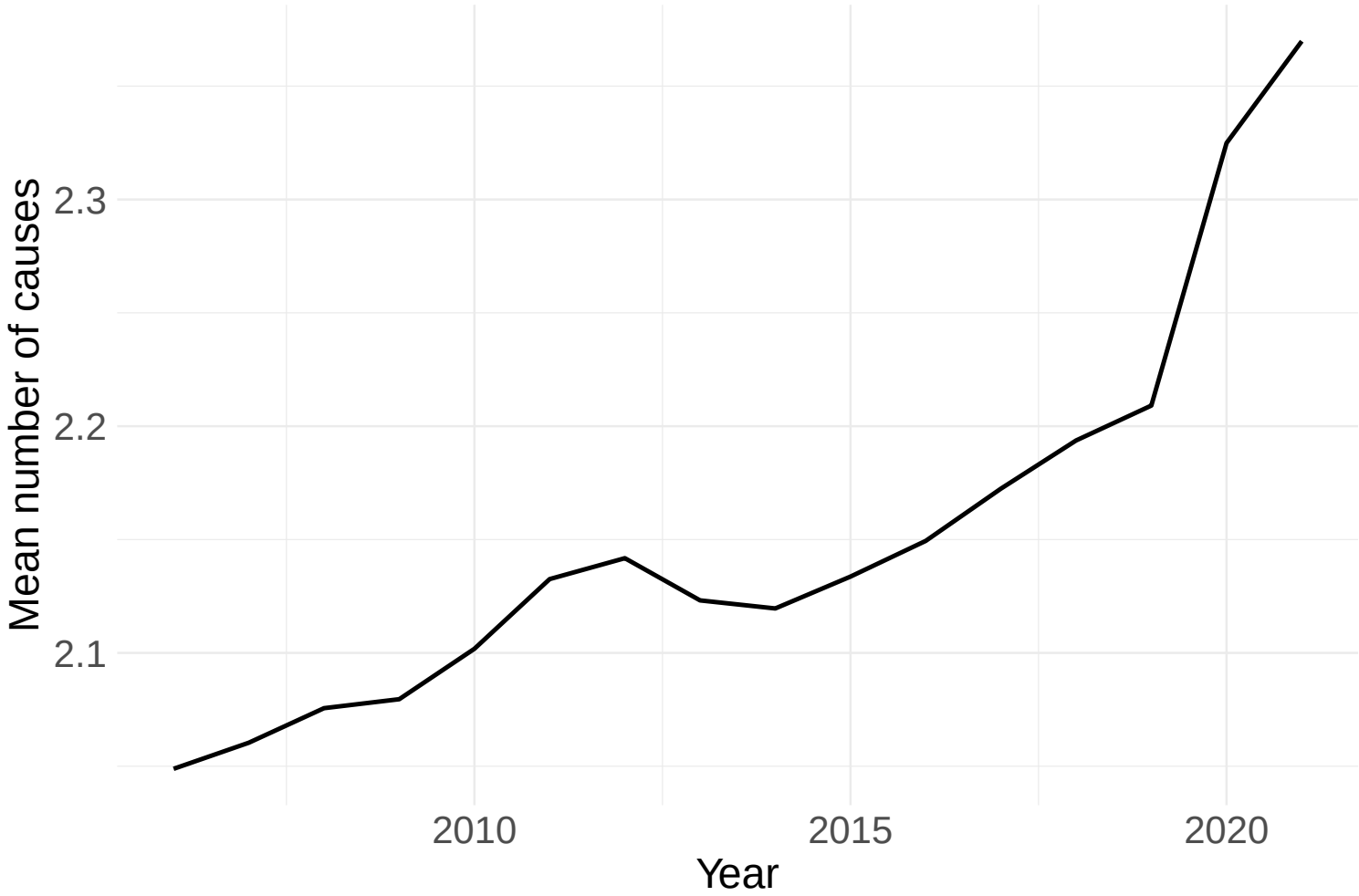
Richness and number of causes

The average number of causes reported on the death certificate is estimated as:

$$N = \sum_x \sum_u \sum_c d(x,u,c)$$

with $N(x) = \sum_u \sum_c d(x,u,c)$ and $N(u) = \sum_x \sum_c d(x,u,c)$

Richness: Time trend



Richness: Decomposition

N can be decomposed by changes in $d(x)$, $d(u)$ and $N(x,u)$, using the Das Gupta decomposition.

	$\Delta d(x)$	$\Delta d(u)$	$\Delta N(x,u)$	Total
2006-2019	-0.004	0.019	0.114	0.129
2019-2021	0.006	-0.024	0.175	0.157

Evenness and diversity: Two approaches

What is diversity in a MCoD context? How to consider the contributing causes?

1. All causes are part of the mortality process, no matter their position.
2. The UCD all come with their own set of contributing causes with a specific diversity.

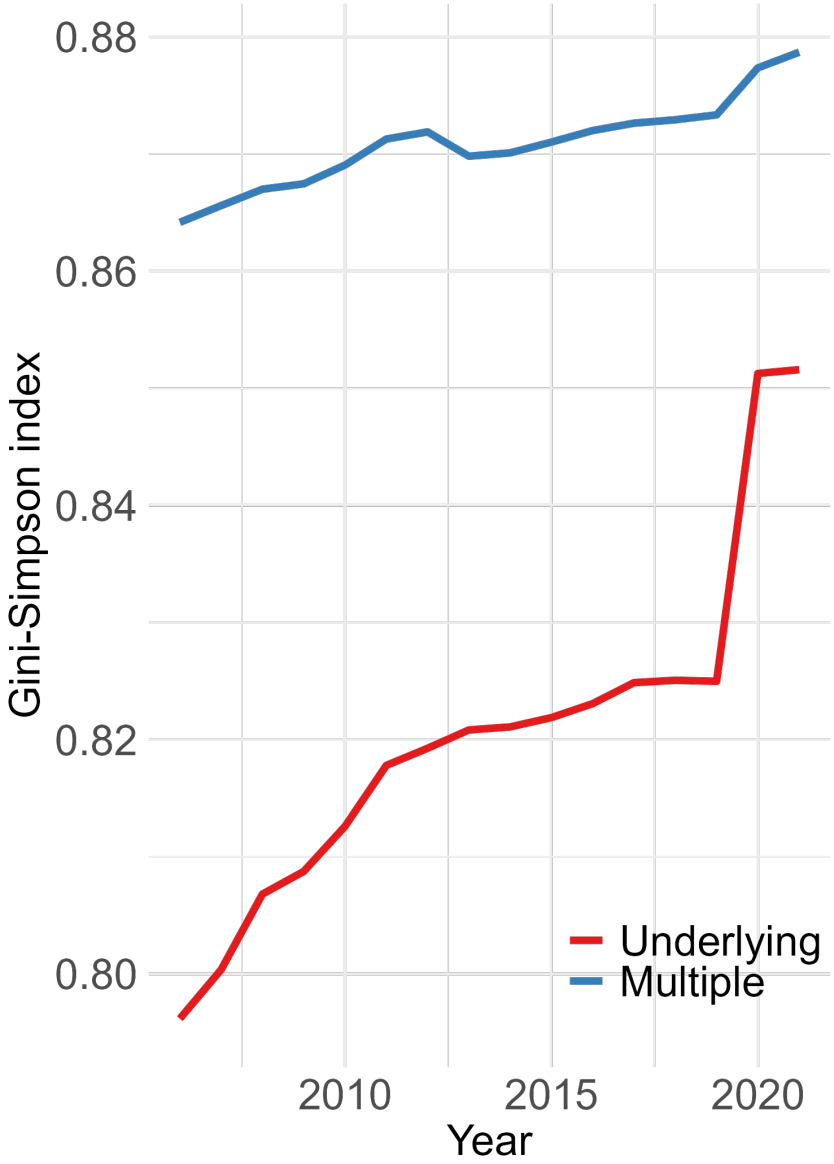
Diversity, First approach

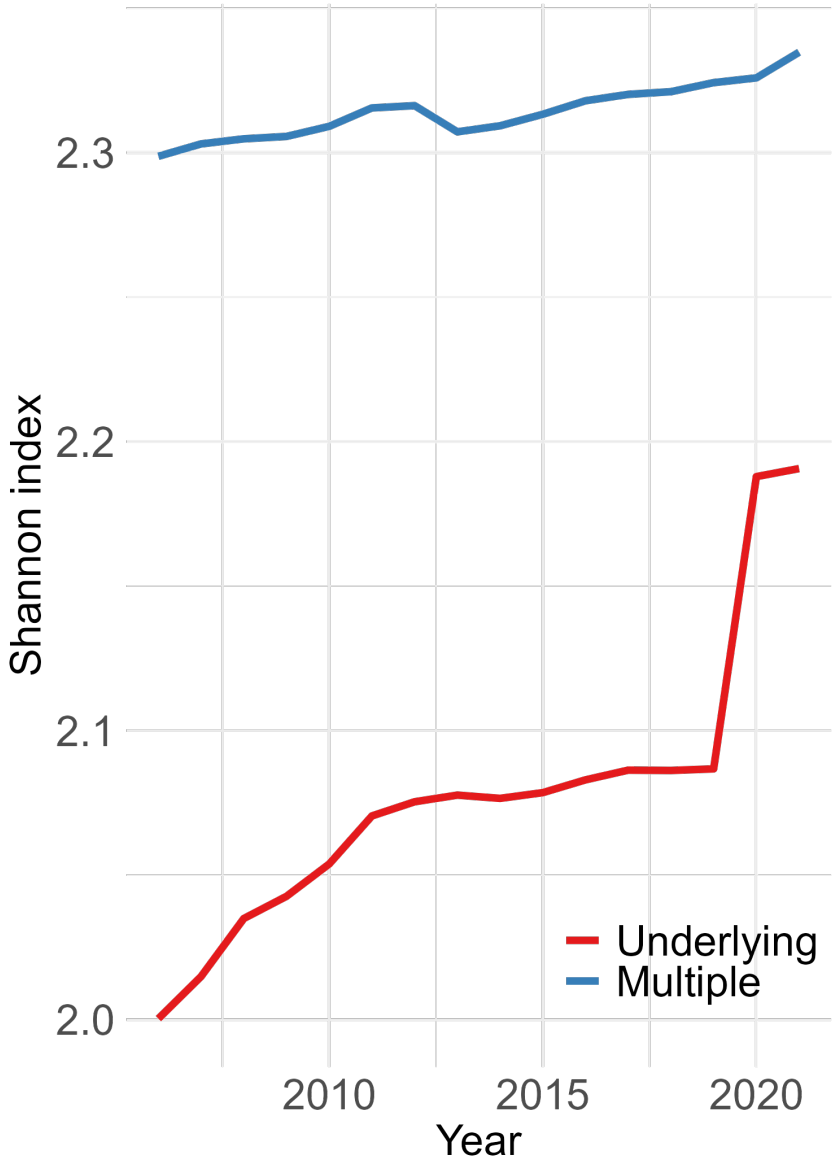
We are interested in studying the distribution $\hat{d}_i$, where i is a given cause no matter its position on the death certificate, such that

$$\hat{d}_i = \frac{d_i}{N}$$

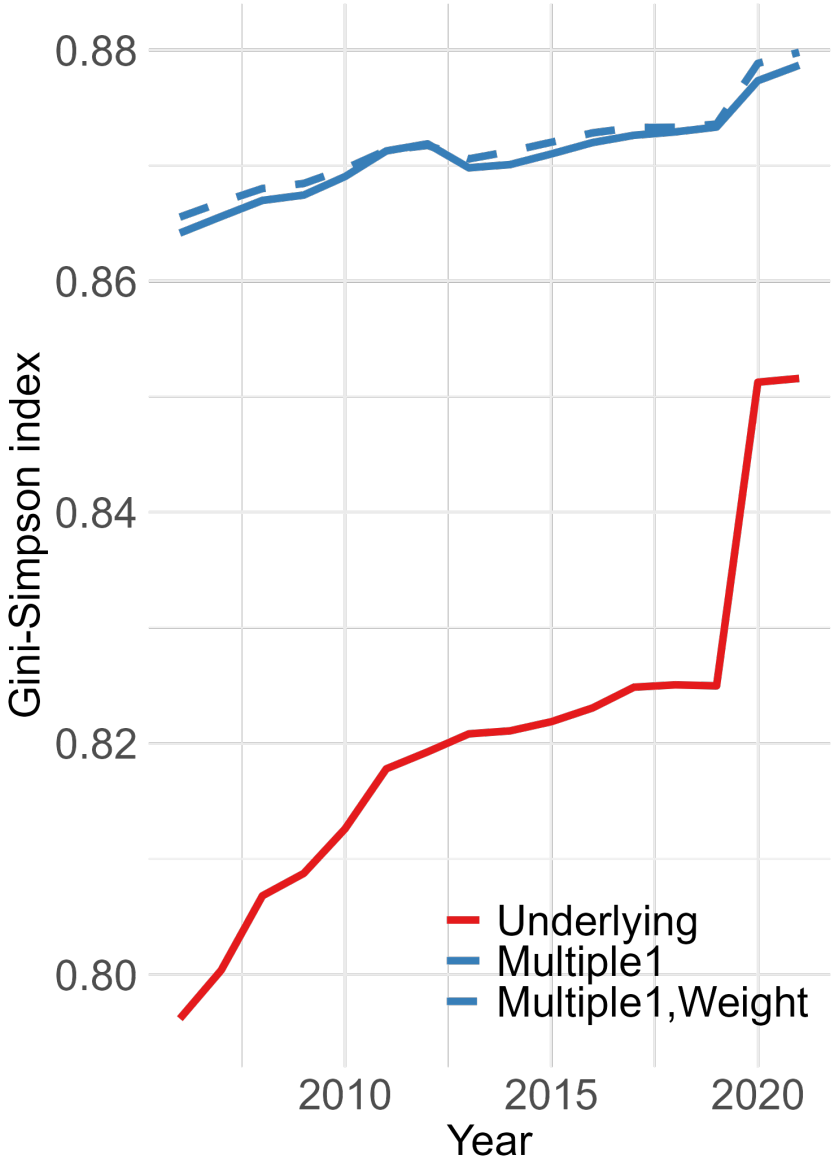
Diversity can be calculated with standard diversity index, such as the Shannon entropy and the Simpson index applied to $\hat{d}_i$.

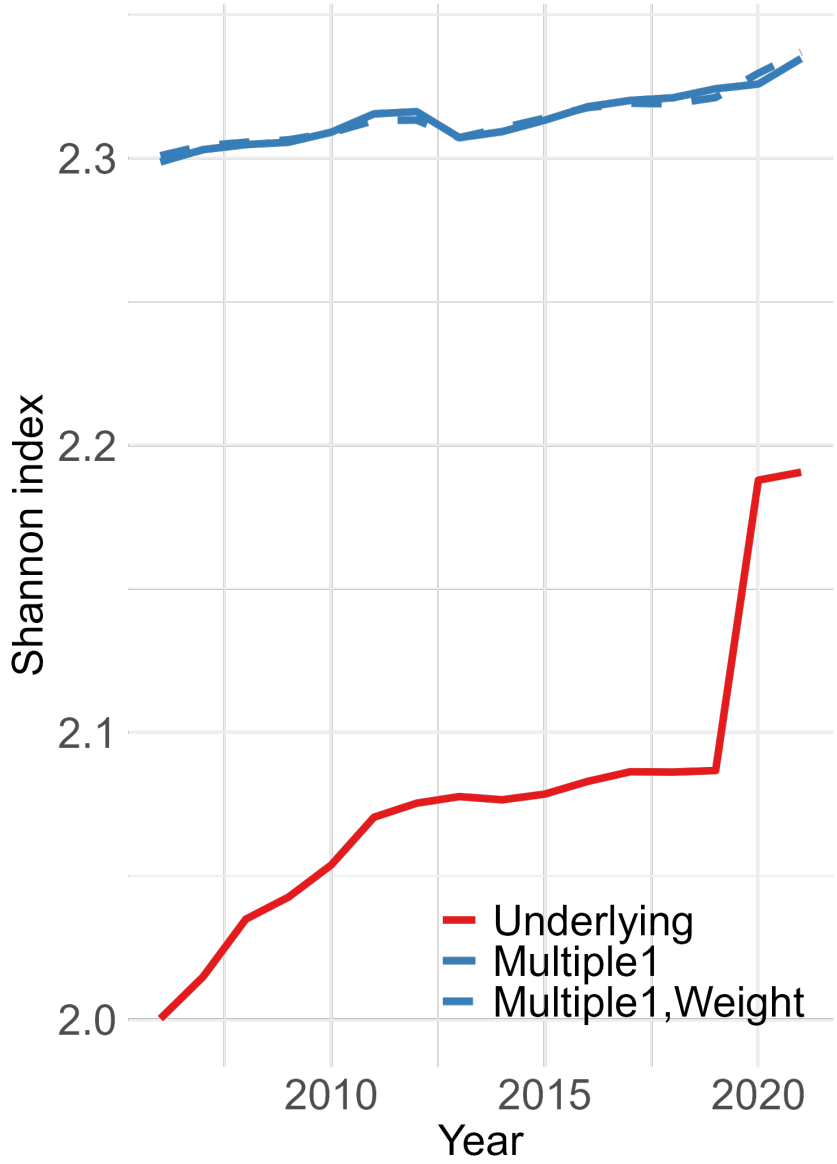
Diversity, First approach, Results





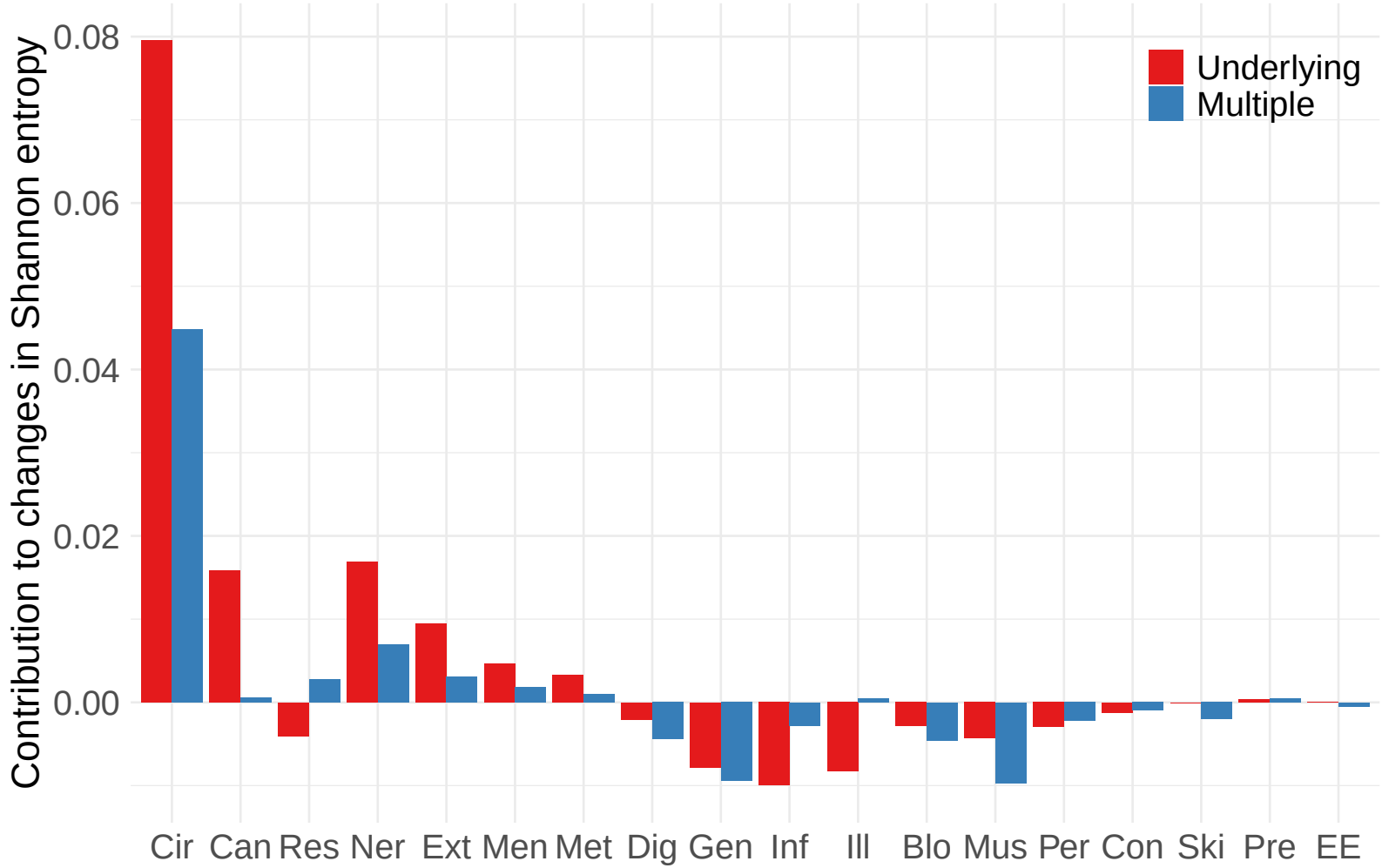
Diversity, First approach, Results with weights





Diversity, First approach, Decomposition

Both indices can be decomposed into the contribution of changes in mortality by age and causes, using the Horiuchi method.



Diversity, Second approach

Let´s assume that each UDC has it's own diversity profile of contributing causes, measured with the Simpson index:

$$S(u) = \sum_{c} (\hat{d}^{u}(c))^2$$

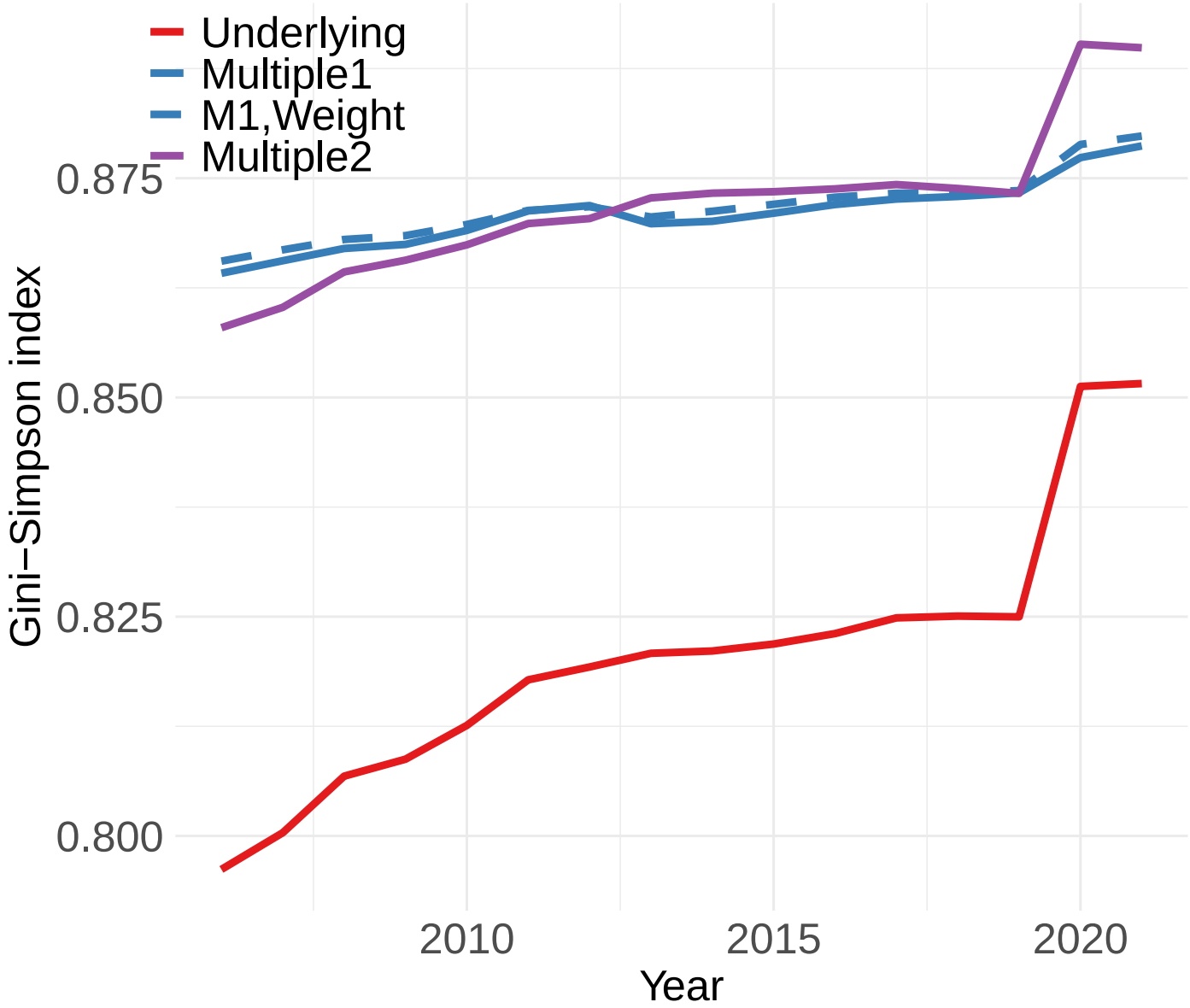
An modified Simpson index can be obtained for all UCD with:

$$S = \sum_{u} (d(u))^2 S(u)$$

The Gini-Simpson index will then be:

$$GS = 1 - S$$

Diversity, Second approach, Results



Diversity, Second approach, Decomposition

The index can be decomposed into changes in $d(u)$ and changes in $S(u)$, using the Kitagawa method.

	$\Delta S(u)$	$\Delta d(u)$	Total
2006-2019	-0.005	0.020	0.015
2019-2021	-0.006	0.022	0.016

Discussion

- Increased diversity due to both richness and evenness;
- Higher level of diversity when MCoD are considered, with both concepts;
- The increase is, in part, due to a shift towards UCD with more complex and numerous contributing causes;
- Increase in diversity indices explained mainly by mortality decrease from diseases of the circulatory system;
- Increase in N(x,u) might be due to changes in CoD reporting or changes in the prevalence of multi-morbidity at death;
- All tested variant of S provide similar results.

Limitations

- Data quality?
- Sensitivity to how we group the causes.
- Which variant of S should be recommended?
- No long-term trends (yet).

Next steps

- Application to other countries;
- Application by sex;
- Testing distance measures;
- Mapping changes by underlying and contributing causes.

Acknowledgement

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