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science for global insight

# Projecting health trajectories in Europe using microsimulation

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# EU-Funded ATHLOS Project

- Ageing Trajectories of Health: Longitudinal Opportunities and Synergies
  - “aims to achieve a better understanding of ageing by identifying patterns of healthy ageing trajectories, the determinants of those patterns, the critical points in time when changes in trajectories are produced, and to propose timely clinical and public health interventions to optimize healthy ageing”
- Microsimulation task (ATHLOS-Mic)
  - Developing a methodological tool to project a health metric of elderly and a set of risk factors for a selection of European countries
    - Stochastic simulation of individual life courses (Monte-Carlo)

# Health metric

- Composite index of health developed by Caballero et al. (2017)
- The health status is conceptualized as a vector of functioning in different domains ranging from simple to complex (e.g., vision, walking, kneeling, Activities of Daily Living, Instrumental Activities of Daily Living)
- Range from 0 to 100
- Does not suffer from the problems associated with the either objective or subjective discretization of health in different categories

# ATHLOS-Mic

- Built over the CEPAM-Mic model, which is already suitable for a multidimensional population projection including notably age, sex, and education.
  - Continuous time / dynamic / Time-based
  - Built with Modgen
- Implementation of a health module that adds health-related variables
  - the health metric
  - some risk factors
    - Smoking, obesity, arterial hypertension, depression, physical activity
  - cohorts born before 1961 and living in selected countries (data availability)

# Data source

## SHARE - Survey of Health, Ageing and Retirement in Europe

**Table 1 - Sample size by country and wave (in parenthesis, the retention rate, including deceases)**

| Country | Wave 1 (2004) | Wave 2 (2007) | Wave 4 (2011) | Wave 5 (2013) |
|---|---|---|---|---|
| **AT** | 1594 | 1228 (72%) | 5332 (56%) | 4425 (76%) |
| **BE** | 3827 | 3205 (74%) | 5388 (69%) | 5765 (75%) |
| **CZ** | | 2830 | 6196 (49%) | 5926 (69%) |
| **DE** | 3008 | 2614 (53%) | 1623 (54%) | 5719 (65%) |
| **DK** | 1707 | 2666 (76%) | 2393 (68%) | 4268 (85%) |
| **EE** | | | 6828 | 6064 (85%) |
| **ES** | 2396 | 2315 (61%) | 3690 (65%) | 6690 (80%) |
| **FR** | 3193 | 3021 (64%) | 5954 (65%) | 4588 (68%) |
| **GR** | 2898 | 3292 (80%) | | |
| **IT** | 2559 | 3039 (71%) | 3673 (68%) | 4853 (73%) |
| **NL** | 2979 | 2710 (61%) | 2822 (62%) | 4213 (80%) |
| **PL** | | 2467 | 1880 (67%) | |
| **SE** | 3053 | 2802 (68%) | 2122 (60%) | 4713 (72%) |
| **SI** | | | 2756 | 3000 (73%) |
| **Total** | 27214 | 32189 (68%) | 50657 (63%) | 60224 (71%) |

# ATHLOS-Mic

## Five steps

1. Imputing initial health metric and risk factors to the base population
   - Polytomous logistic regressions from the MICE
2. Modeling changes in sociodemographic characteristics
   - CEPAM-Mic already has the core modules to perform a multistate and multiregional population projection projecting the population by age, sex, education, and country of residence.
3. Modeling changes in risk factors
4. Modeling the change in the health metric
5. Implementing the impact of the health metric on mortality

# ATHLOS-Mic

3. Modeling changes in risk factors

   – An autoregressive distributed lag model with duration predicting the value of factor F at time t is used to estimate parameters for the value of F at time t-a and a set of i covariates X at time t-a, being other risk factors and sociodemographic characteristics at time t-a.

$$logit(F_t) = \beta_0 + \beta_1(a-1) + \beta_2 F_{t-a} + \beta_i X_{i,t-a}$$

   – Starting with the imputed value of risk factors in the base population (F'), those parameters are then used to predict stochastically the risk factors F' of individuals at time t+1 throughout the projection

$$F_{t+1} = \frac{\exp(\beta_0 + \beta_2 F_t' + \beta_i X_{i,t})}{1+\exp(\beta_0 + \beta_2 F_t' + \beta_i X_{i,t})} \qquad F_{t+1}' \begin{cases} 1 & F_{t+1} < Z\sim([0,1]), \\ 0 & F_{t+1} \geq Z\sim([0,1]) \end{cases}$$

Where $Z\sim([0,1])$ is a random number uniformly distributed between 0 and 1.

- Strong interrelation between risk factors, except for smoking
- The education has a considerable influence on other risk factors

| | Model for smoking (t) | Model for depression (t) | Model for physical activity (t) | Model for obesity (t) | Model for arterial hypertension (t) |
|---|---|---|---|---|---|
| Edu=Low | 0.007 | 0.493 *** | -0.244 *** | 0.692 *** | 0.313 *** |
| Edu=Med | 0.094 | 0.235 *** | -0.16 ** | 0.358 *** | 0.182 ** |
| Current smoker | 4.288 *** | 0.197 ** | -0.261 *** | -0.068 | -0.041 |
| Depressed | -0.04 | 1.665 *** | -0.399 *** | 0.028 | 0.052 |
| Does physical activity | -0.058 | -0.234 *** | 1.267 *** | -0.124 * | -0.082 * |
| Obese | -0.033 | 0.125 * | -0.333 *** | 3.853 *** | 0.513 *** |
| Has arterial hypertension | -0.005 | 0.11 ** | -0.14 ** | 0.345 *** | 2.625 *** |

Control for age, sex and country

# ATHLOS-Mic

## 4. Modeling the change in the health metric

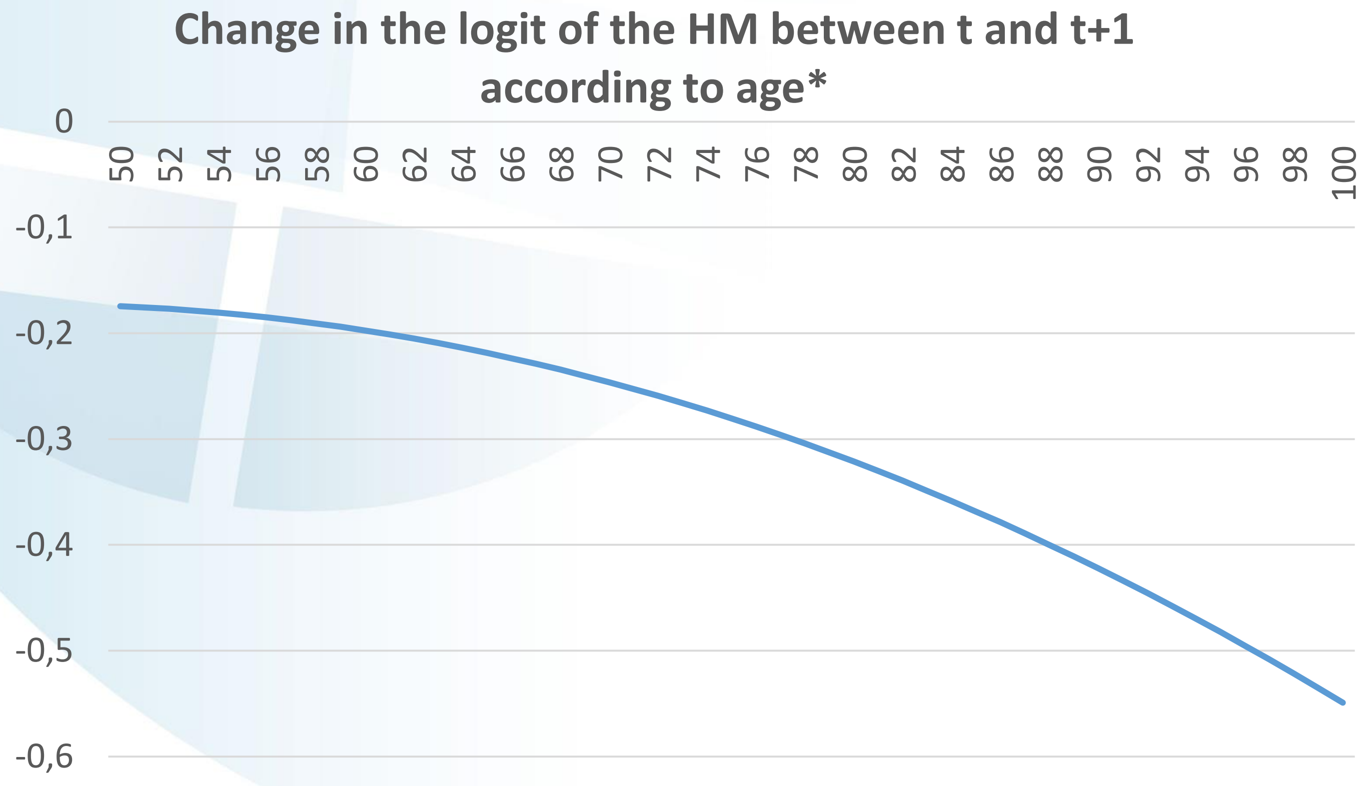
Linear regression model on the difference between the logit of the health metric over a year

$$\frac{logit(HM_t/100) - logit(HM_{t-a}/100)}{a} = \beta_0 + \beta_1(HM_{t-a}/100) + \beta_2\,(HM_{t-a}/100)^2 + \beta_3\,(HM_{t-a}/100)^3 + \beta_i X_{i,t-a}$$

- $\beta_i$ is a set parameters capturing the effect of covariates *X* at time t-a (e.g. sociodemographic characteristics and behavioral and biological factors)
- $\beta_1 + \beta_2 + \beta_3$ allow to take into account that different paces in the change of the health index according to the initial health status
- $a$ is the duration between two observations

# ATHLOS-Mic

The health tends to decline faster as people getting older, following a quadratic trend




*All other covariates = 0, $HM_{t-1}$=0.8

# ATHLOS-Mic

- Smoking, being depressed, being obese and having arterial hypertension accelerate the decline in the health index
- Doing physical activity reduces the decline in the health index
- The health declines faster for women than for men
- The health declines faster for low educated
- Regional variations

| | |
|---|---|
| **Sex=F** | -0.015*** |
| **Edu=Low** | -0.059*** |
| **Edu=Med** | -0.033*** |
| **Was a current smoker** | -0.02*** |
| **Depressed** | -0.035*** |
| **Did physical activity** | 0.017*** |
| **Obese** | -0.033*** |
| **Has arterial hypertension** | -0.011** |

# ATHLOS-Mic

5. <u>Implementing the impact of the health metric on mortality</u>

- SHARE-HD can track participants that died between two waves
- We estimated the impact of the health metric on the probability of dying (q) between t and t+a, controlling for education, age, sex and country

$$logit({}_a q_t) = \beta_0 + \beta_1(a-1) + \beta_2\, HM\_gr_{t-a} + \beta_i X_{i,t-a}$$

  - $\beta_1$ controls for the different duration between observations
  - $\beta_i$ is a vector of parameters controlling the effect of age, education, sex, and country
  - $\beta_2$ captures the effect of a categorical transformation of the health index at time t-a.

.

- We applied on $\beta_2$ a contrast to the weighted population average in order to get parameters for all categories using the whole population as reference.

| Contrasted parameters for $\beta_2$ from equation 5 | | | | |
|---|---|---|---|---|
| **Health index** | Parameter | Odd ratios | Std. Err. | % of N |
| **[0, 30[** | 2.084 | 8.038 | 0.196 | 4% |
| **[30, 40[** | 1.093 | 2.985 | 0.200 | 5% |
| **[40, 50[** | 0.870 | 2.388 | 0.168 | 10% |
| **[50, 60[** | 0.183 | 1.201 | 0.117 | 16% |
| **[60, 70[** | -0.149 | 0.862 | 0.119 | 19% |
| **[70,** | -0.413 | 0.662 | 0.086 | 46% |

- We then used those contrasted parameters ($\beta_2$) to adjust the yearly mortality rates by age, sex, country, and education that were already set in assumptions of the microsimulation

$$ {}_1q_t' = \frac{\exp\left(logit({}_1q_t\ ) + \ \beta_2 HI\_gr_t'\right)}{1+\exp\left(logit({}_1q_t\ ) + \ \beta_2 HI\_gr_t'\right)} $$

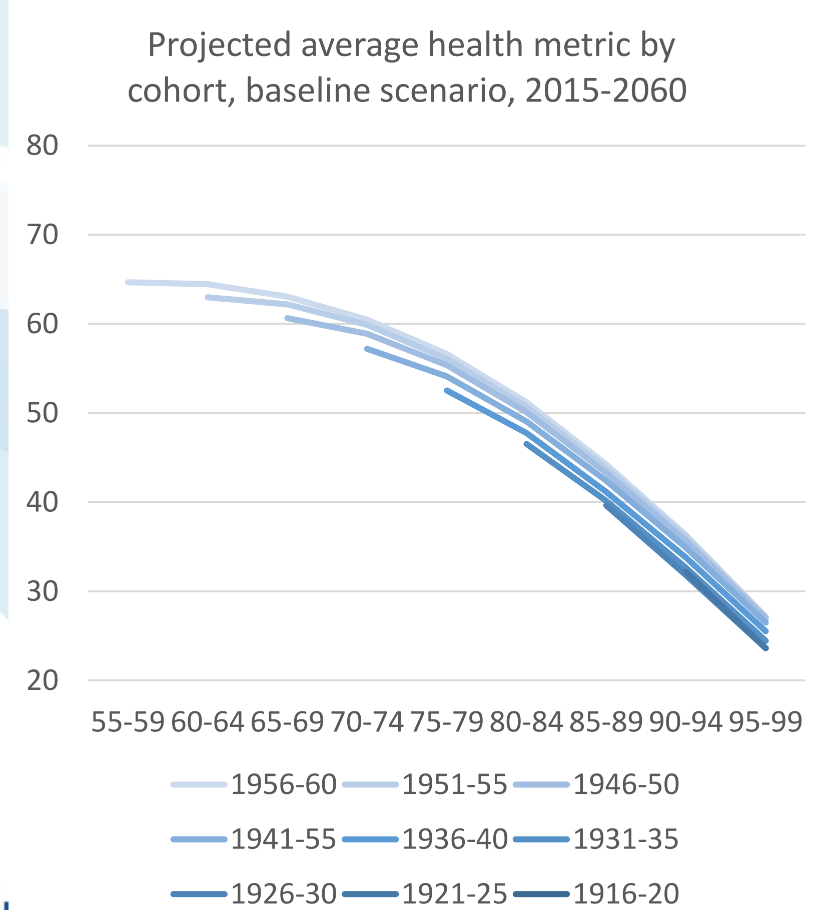
${}_1q_t'$ is the age-, sex-, country, and education-specific mortality rate at time t adjusted by the health index;

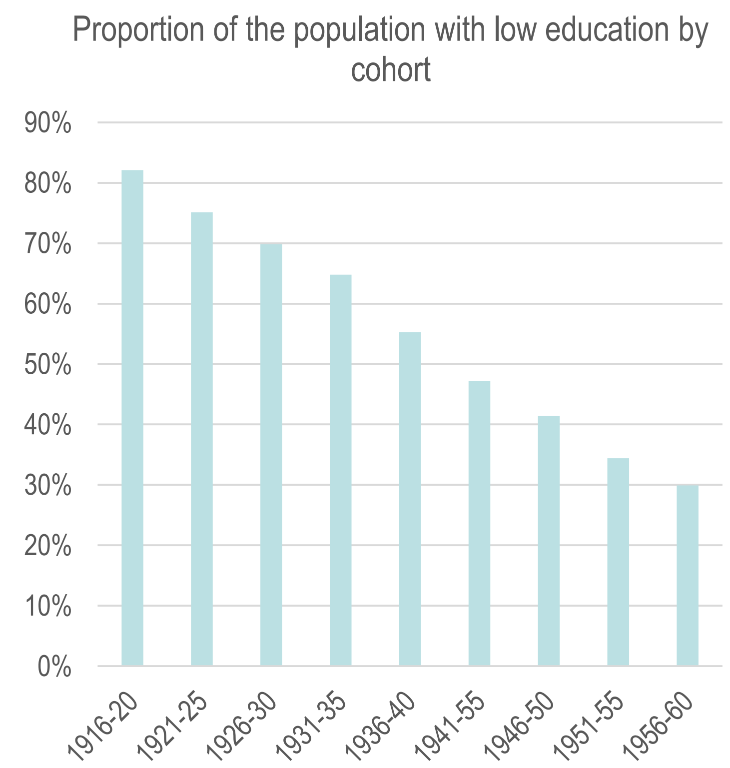
${}_1q_t$ is the age-, sex-, country, and education-specific mortality rate without adjustment;

$HI\_gr_t'$ is the predicted health index (categorized) at time t.

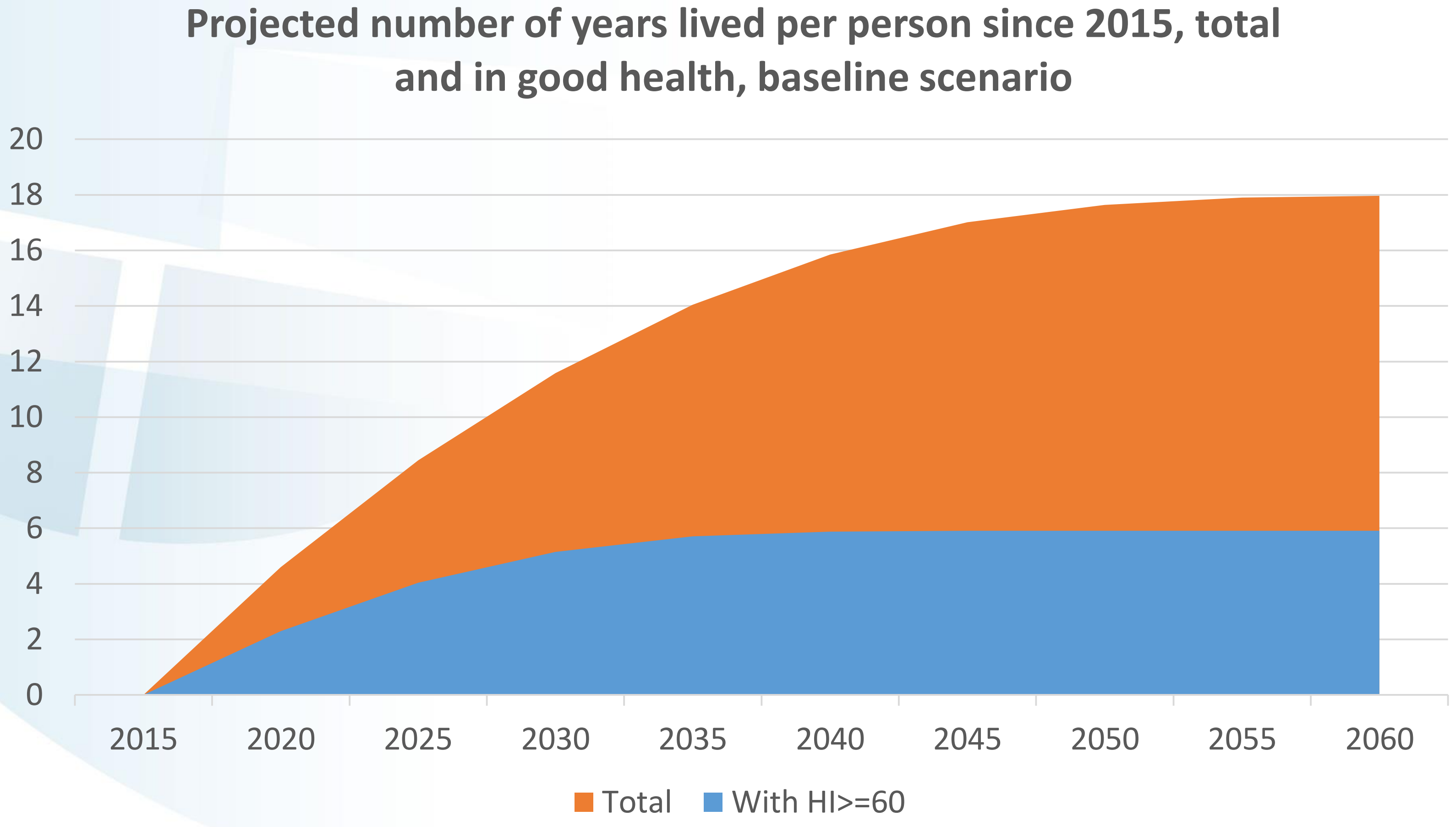
# Examples of scenarios and outputs

- Each generation will be healthier the previous one at the same age
- The better educational attainment of younger cohorts is a major drive or their expecting better health



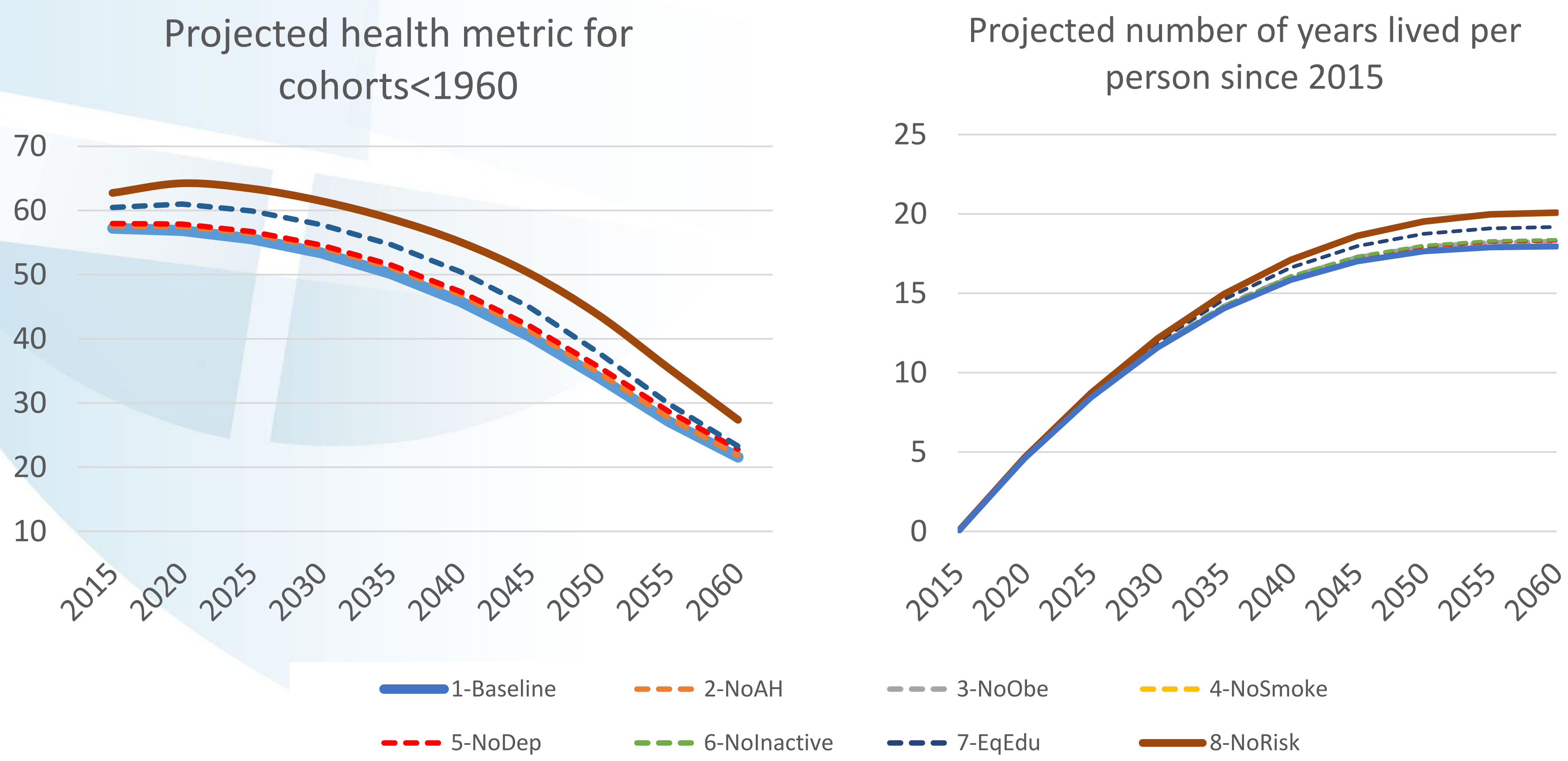
# In average, an individual of our base population (cohorts<1960) will live about 18 years, but only 5 with a HM>=60.



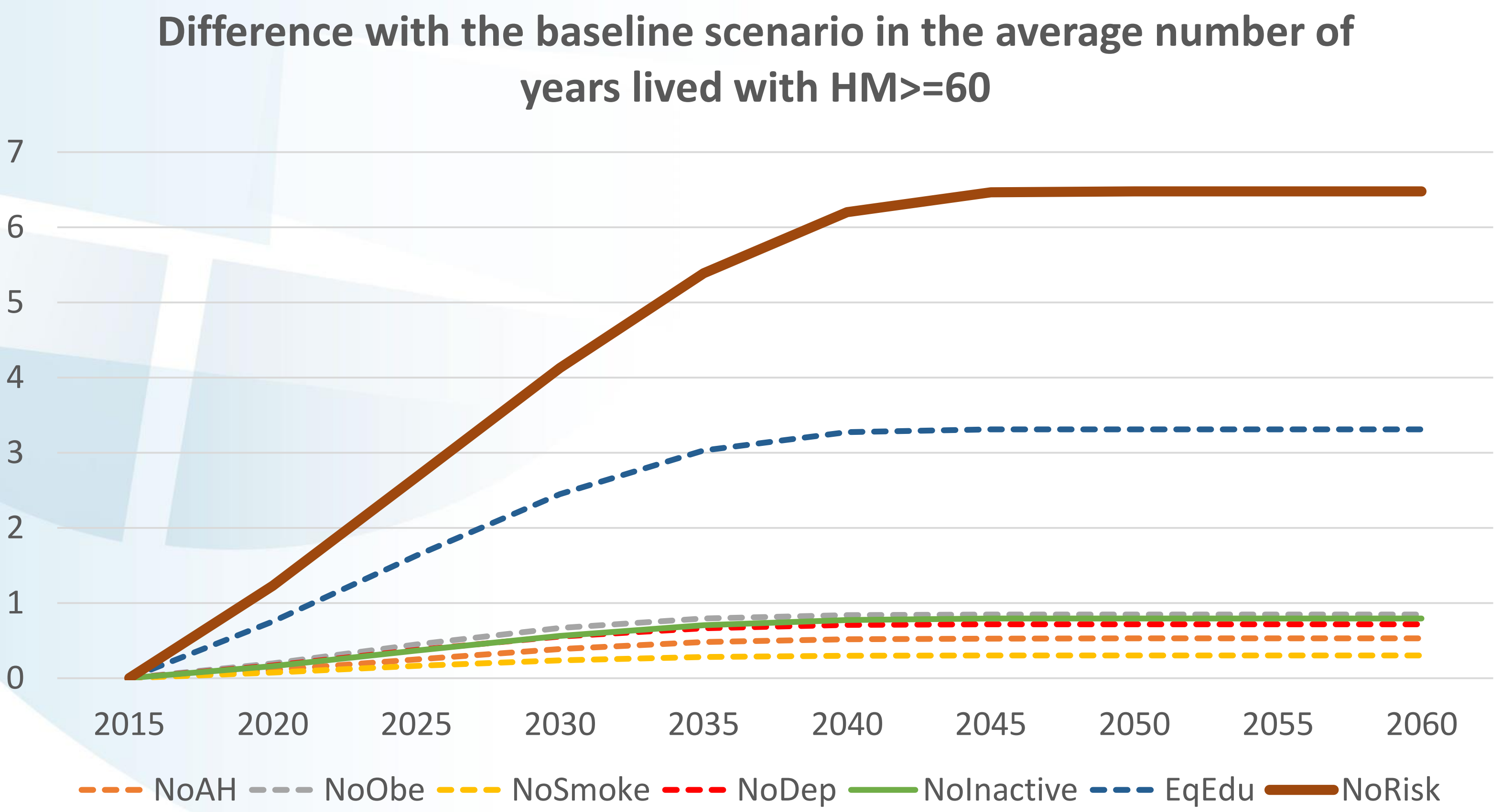
# Scenarios

1. **Baseline**: constant parameters
2. **NoAH**: remove the arterial hypertension in the population;
3. **NoObe**: remove the obesity in the population;
4. **NoSmoke**: remove smoking in the population;
5. **NoDep**: remove depression in the population;
6. **NoInactive**: everyone is doing physical activity;
7. **EqEdu**: equality in health for low- and medium-education;
8. **NoRisk**: remove all risk factors + equality in health for low- and medium-education;

- When all risk factors are removed, the HM is improved significantly.
- The scenario assuming equality in health for low educated is the one having the biggest effect.
- The scenario NoRisk increases by 2 years the average number of years lived by the cohorts since 2015



# Compared to the baseline scenario, the scenario NoRisk adds 2 years of life, but 6 years with HM>=60



# Concluding remarks

- Each generation will be healthier than the previous one at the same age
  - Need to reassess the definition of old-age threshold
- Education stands out among other risk factors as the main determinant of health
  - Possible measurement issue in longitudinal surveys
    - Other studies showed that past smokers have worse health than current smokers, because people in bad health stop smoking
    - People who are in bad health might lose a lot of weight and have a very low body mass index
  - The period of observation (2 years in average) is probably too short to completely remove these reversed causal relationships
- More information on risk factors during the adult life might improve the modeling of the health metric

Thank you

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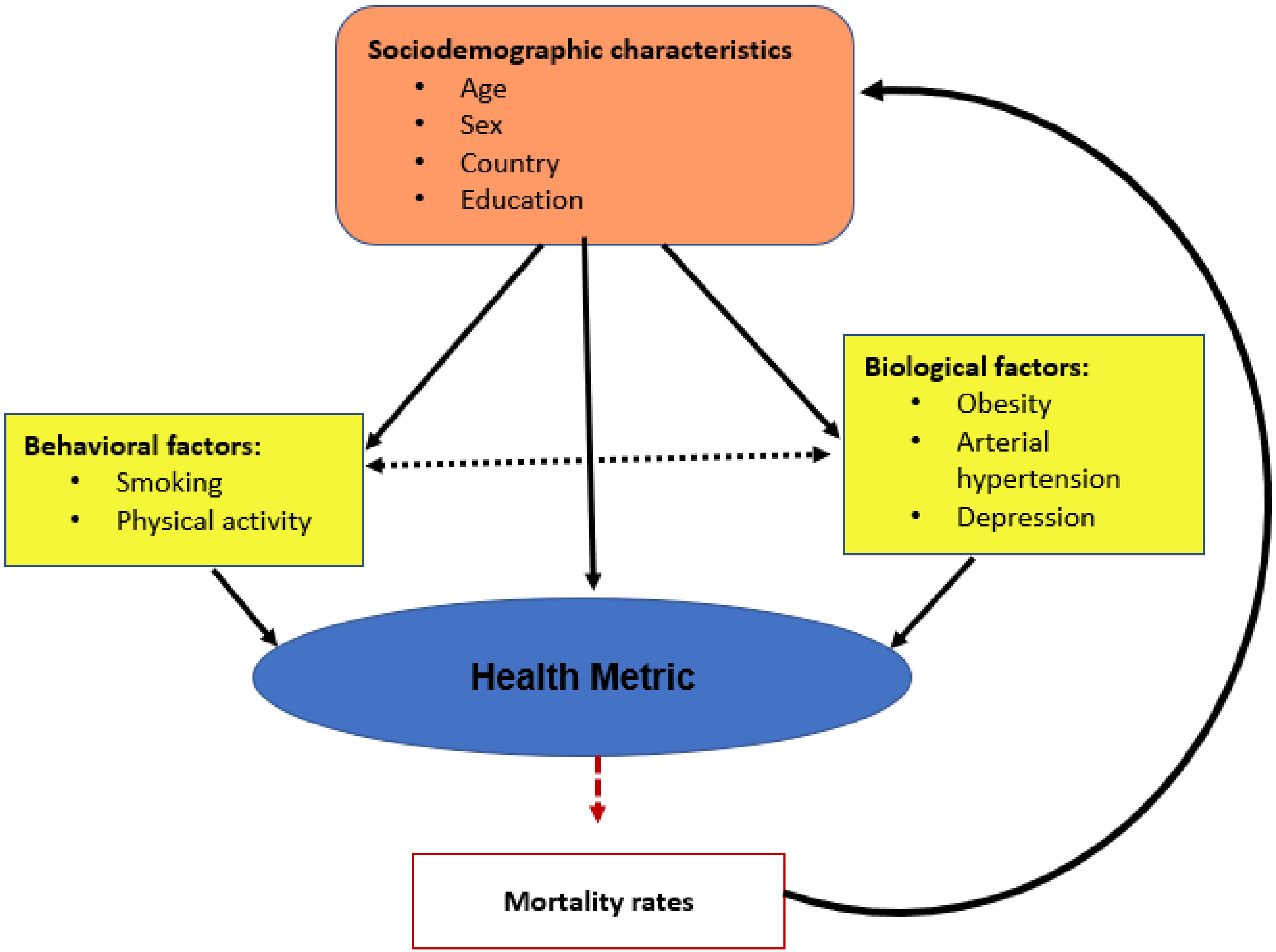
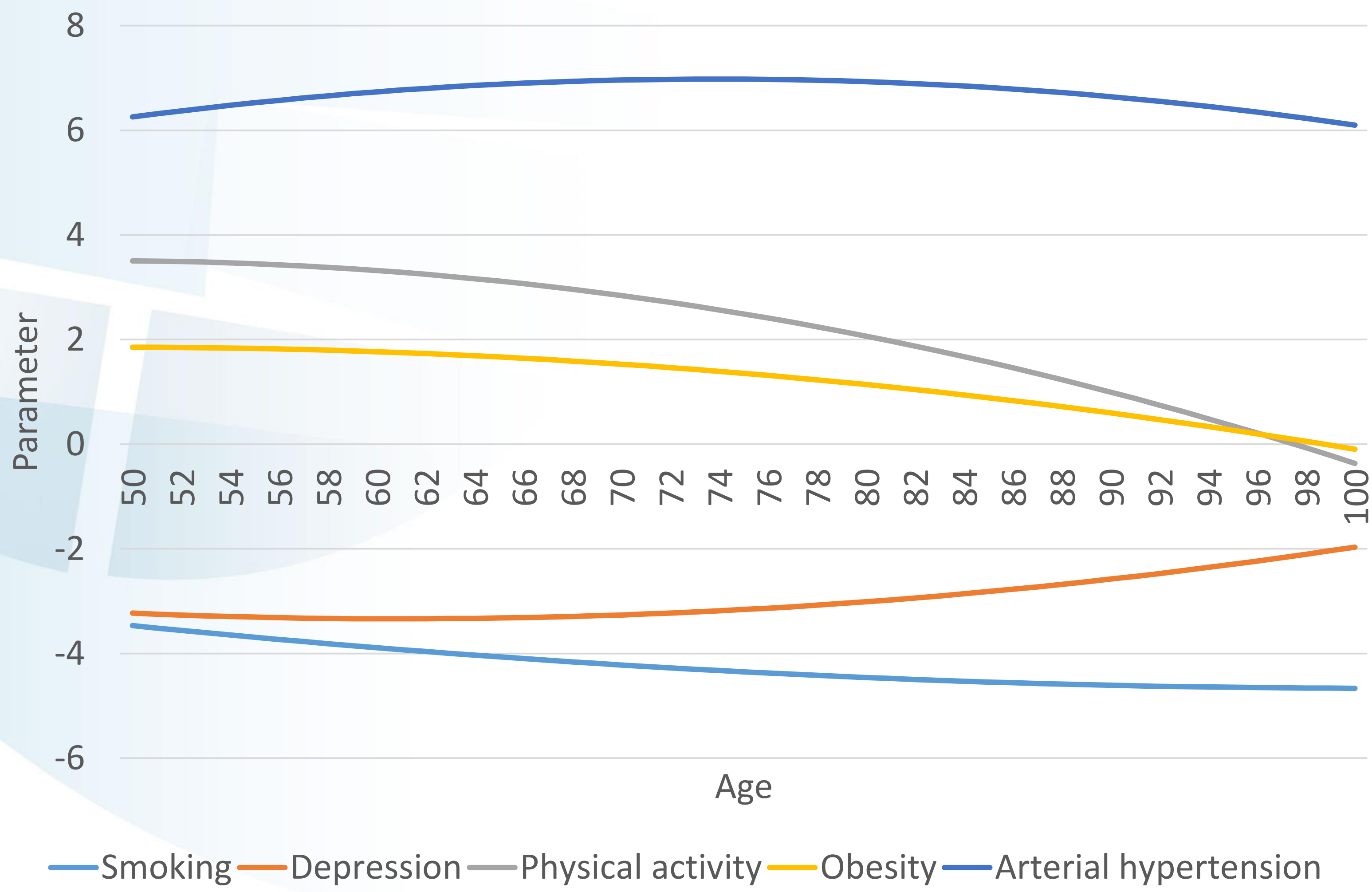
# Framework for ATHLOS-Mic



# Age pattern for risk factors



# ATHLOS-Mic

- People in good health are more likely to see their health declining
- People in medium health would not see lot change in their situation
- People in bad health are likely to see their health improve, at least for those who survive