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How do Changes in Human Longevity Impact on our Demography?

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How do Changes in Human Longevity Impact on our Demography?

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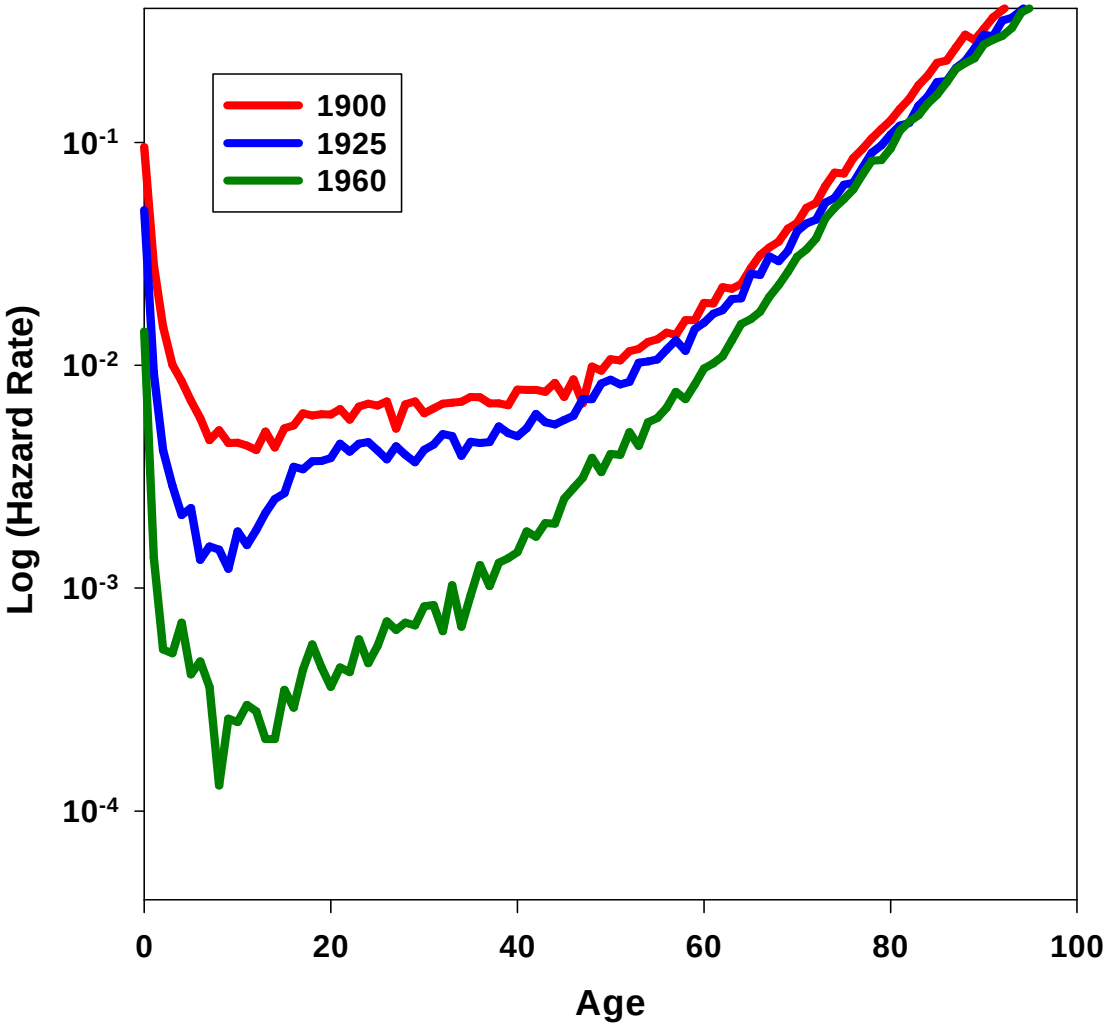
How mortality and longevity changed in the 20th century?

Changes in Mortality, 1900-1960



Swedish females. *Data source*: Human Mortality Database

The Gompertz-Makeham Mortality Law

Death rate is a sum of age-independent component (Makeham term) and age-dependent component (Gompertz function), which increases exponentially with age.

$$\mu(x) = A + R\,e^{\alpha x}$$

risk of death

A – Makeham term or background mortality

$R\,e^{\alpha x}$ – age-dependent mortality; x - age

How can the Gompertz-Makeham law be used?

By studying the historical dynamics of the mortality components in this law:

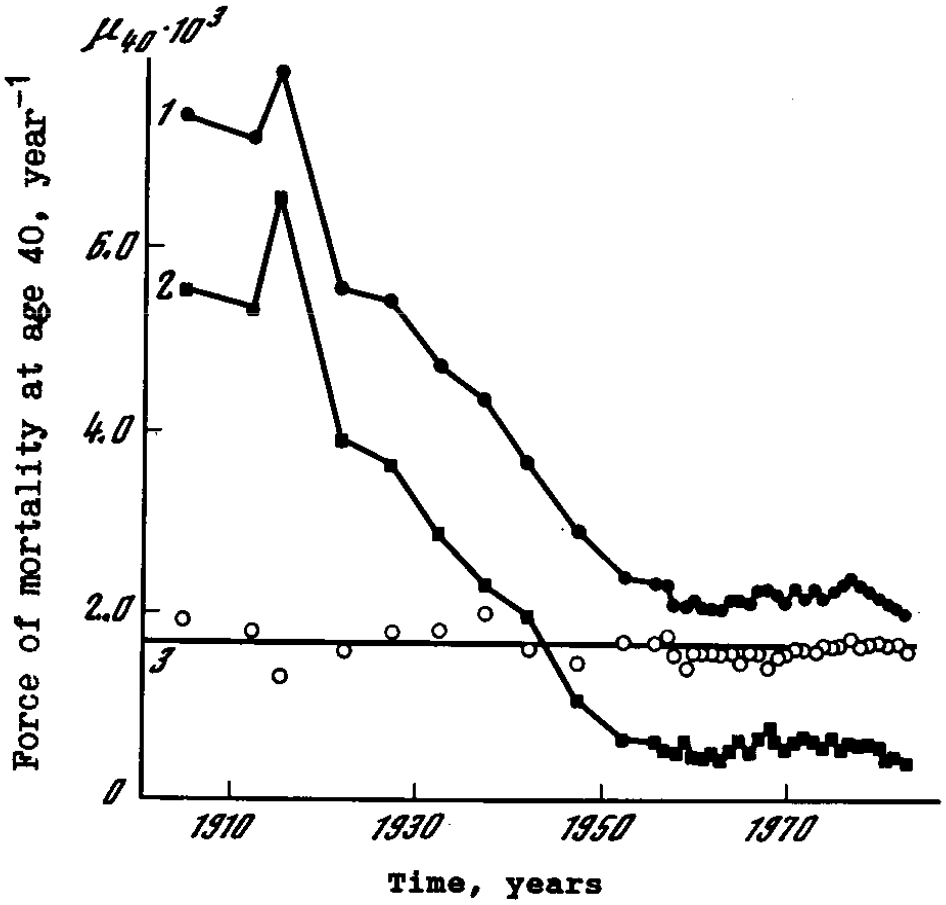
$$\mu(x) = A + R\,e^{\alpha x}$$

Makeham component

Gompertz component

Historical Stability of the Gompertz Mortality Component

Historical Changes in Mortality for 40-year-old Swedish Males



1. Total mortality, μ_{40}
2. Background mortality (A)
3. Age-dependent mortality ($Re^{\alpha 40}$)

- Source: Gavrilov, Gavrilova, "*The Biology of Life Span*" 1991

In the end of the 1970s it looked like there is a limit to further increase of longevity

Debate

Gerontology 29: 176–180 (1983)

0304–324X/83/0293–0176$2.75/0

Human Life Span Stopped Increasing: Why?

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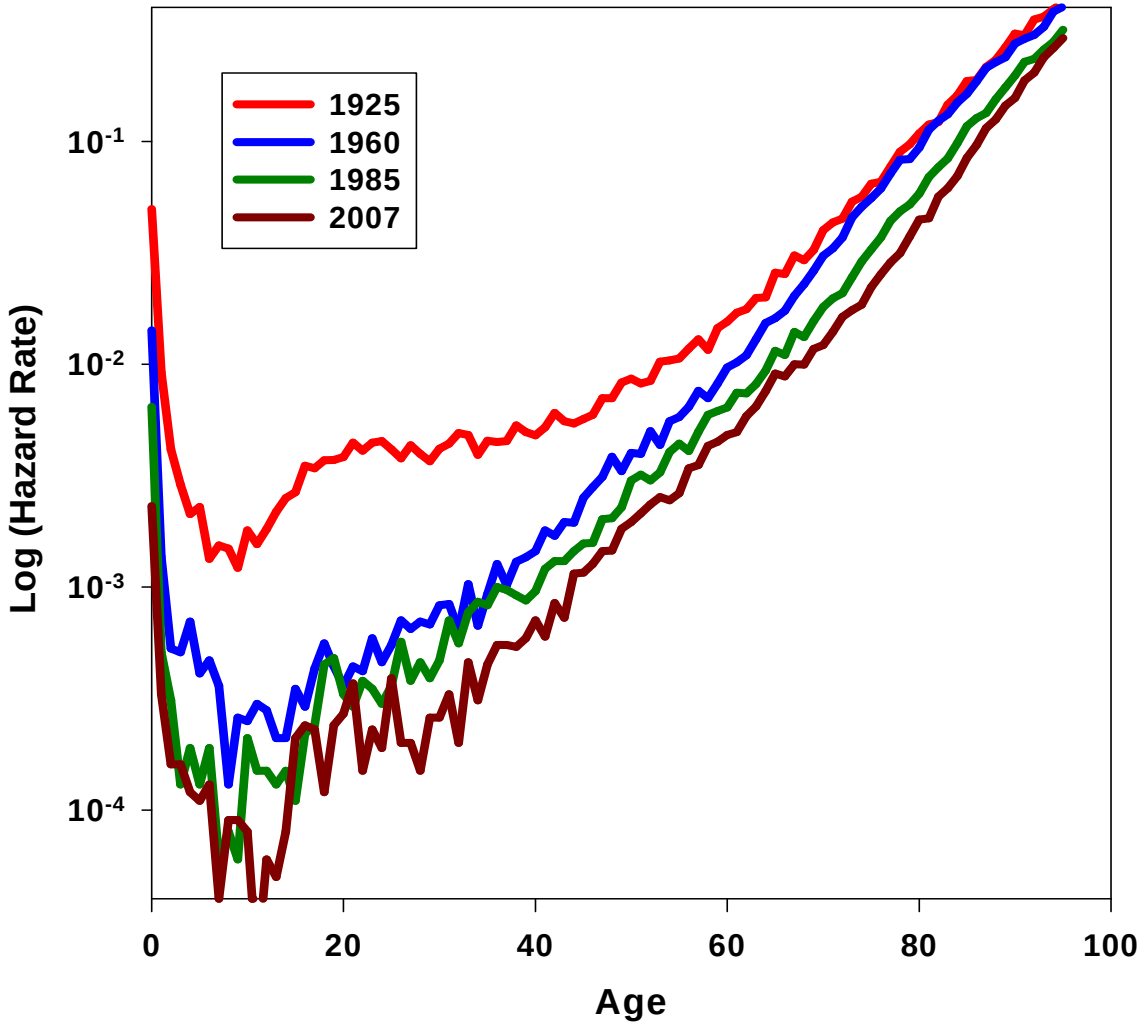
Increase of Longevity After the 1970s

Changes in Mortality, 1925-2007

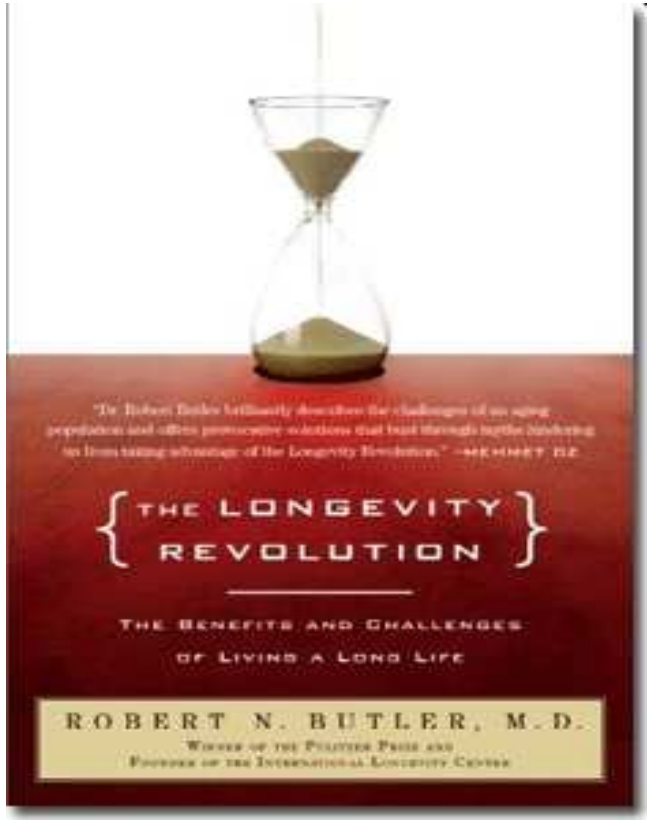


Swedish Females. *Data source*: Human Mortality Database

Preliminary Conclusions

- **There was some evidence for ' biological' mortality limits in the past, but these 'limits' proved to be responsive to the recent technological and medical progress.**
- **Thus, there is no convincing evidence for absolute 'biological' mortality limits now.**
- **Analogy for illustration and clarification: There was a limit to the speed of airplane flight in the past ('sound' barrier), but it was overcome by further technological progress. Similar observations seems to be applicable to current human mortality decline.**

Now We Face a Longevity Revolution Through Biotechnology and Genetic Engineering



- *"... it may soon be possible to delay both aging and age-related disease in humans."* (p. 162)

The Longevity Revolution: The Benefits and Challenges of Living a Long Life. By Robert N. Butler. 553 pp. New York, PublicAffairs, 2008

Longevity Revolution (2)

- *"The present level of development of aging and longevity research justifies an Apollo-type effort to control aging …"* (p. 187)

What May Happen in the Case of Radical Life Extension?

Rationale of our study

- **A common objection against starting a large-scale biomedical war on aging is the fear of catastrophic population consequences (overpopulation)**

Rationale (continued)

- This fear is only exacerbated by the fact that no detailed demographic projections for radical life extension scenario were conducted so far.
- What would happen with population numbers if aging-related deaths are significantly postponed or even eliminated?
- Is it possible to have a sustainable population dynamics in a future hypothetical non-aging society?

The Purpose of this Study

- This study explores different demographic scenarios and population projections, in order to clarify what could be the demographic consequences of a successful biomedical war on aging.

"Worst" Case Scenario: Immortality

- Consider the "worst" case scenario (for overpopulation) -- physical immortality (no deaths at all)
- What would happen with population numbers, then?
- A common sense and intuition says that there should be a demographic catastrophe, if immortal people continue to reproduce.
- But what would the science (mathematics) say ?

The case of immortal population

Suppose that parents produce less than two children on average, so that each next generation is smaller:

$$\frac{\text{Generation } (n+1)}{\text{Generation } n} = r < 1$$

Then even if everybody is immortal, the final size of the population will not be infinite, but just

$$1/(1 - r)$$

larger than the initial population.

The case of immortal population

For example one-child practice (r = 0.5) will only double the total immortal population:

$$1/(1 - r) = 1/0.5 = 2$$

Proof:

Infinite geometric series converge if the absolute value of the common ratio (r) is less than one:

$$1 + r + r^2 + r^3 + \ldots + r^n + \ldots = 1/(1-r)$$

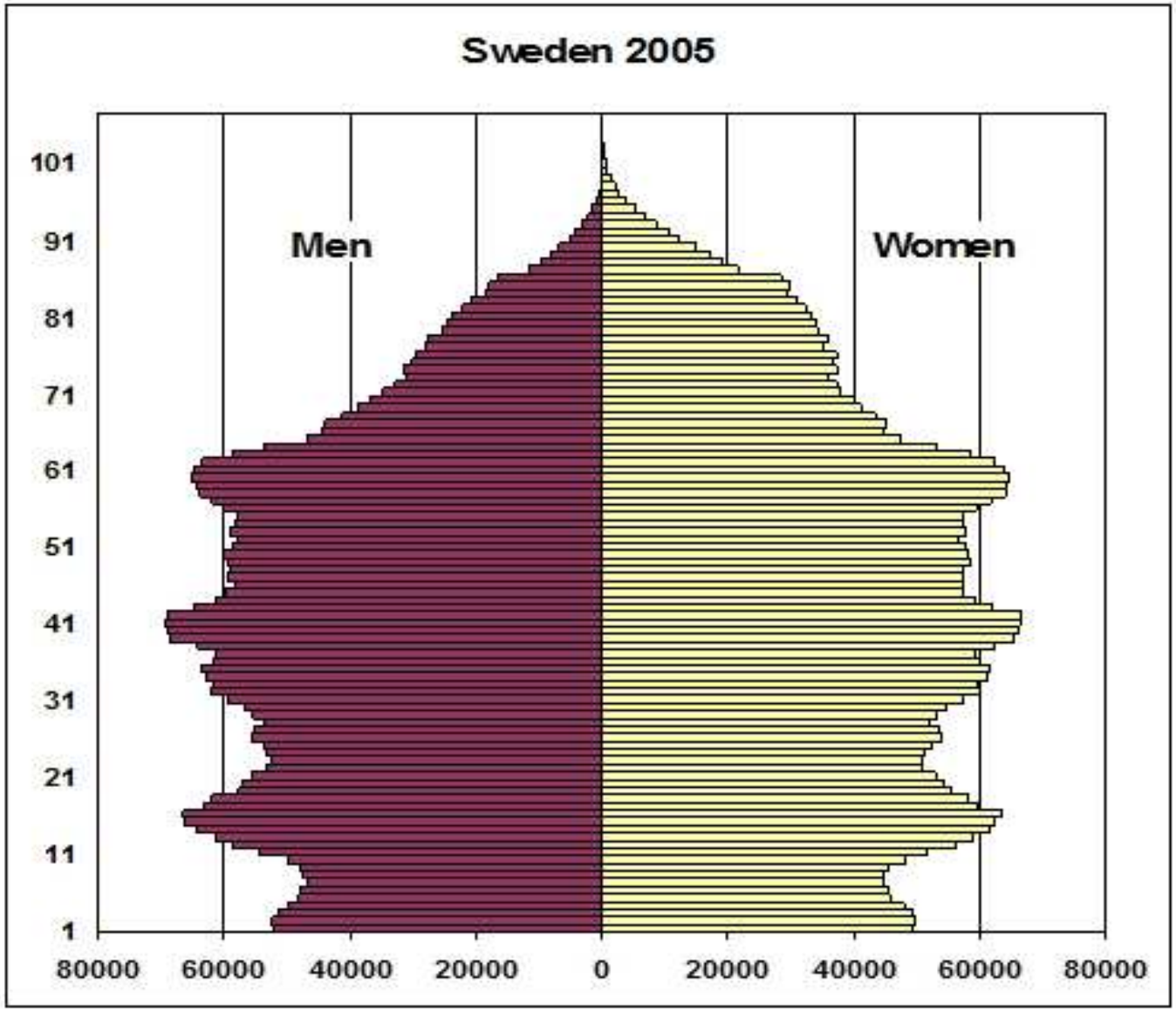
Lesson to be Learned

- Fears of overpopulation based on lay common sense and uneducated intuition could be exaggerated.
- Immortality, the joy of parenting, and sustainable population size, are not mutually exclusive.
- This is because a population of immortal reproducing organisms will grow indefinitely in time, but not necessarily indefinitely in size (asymptotic growth is possible).

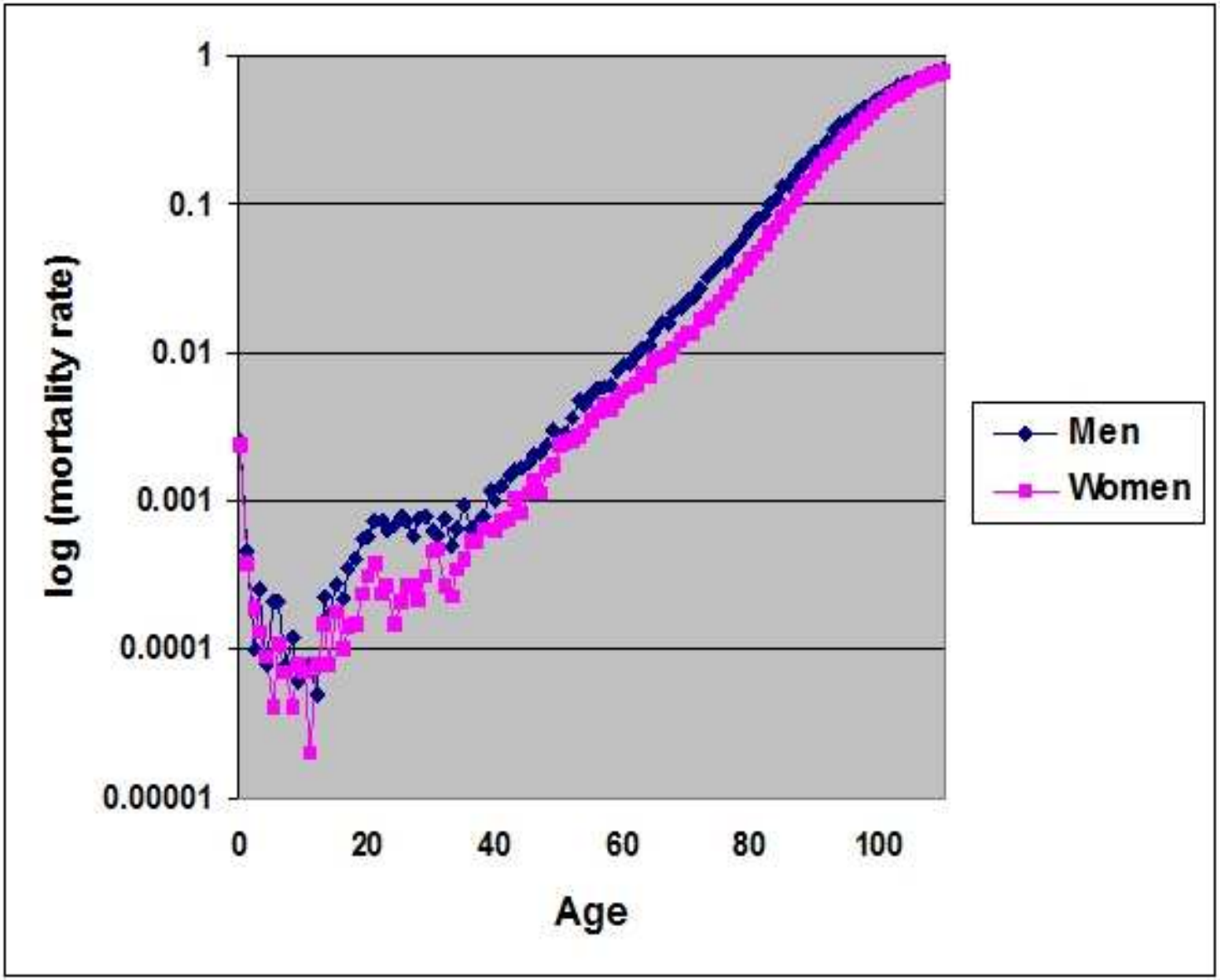
Method of population projection

- **Cohort-component method** of population projection (standard demographic approach)
- Age-specific **fertility** is assumed to **remain unchanged** over time, to study mortality effects only
- **No migration** assumed, because of the focus on natural increase or decline of the population
- New population projection software is developed using Microsoft Excel macros

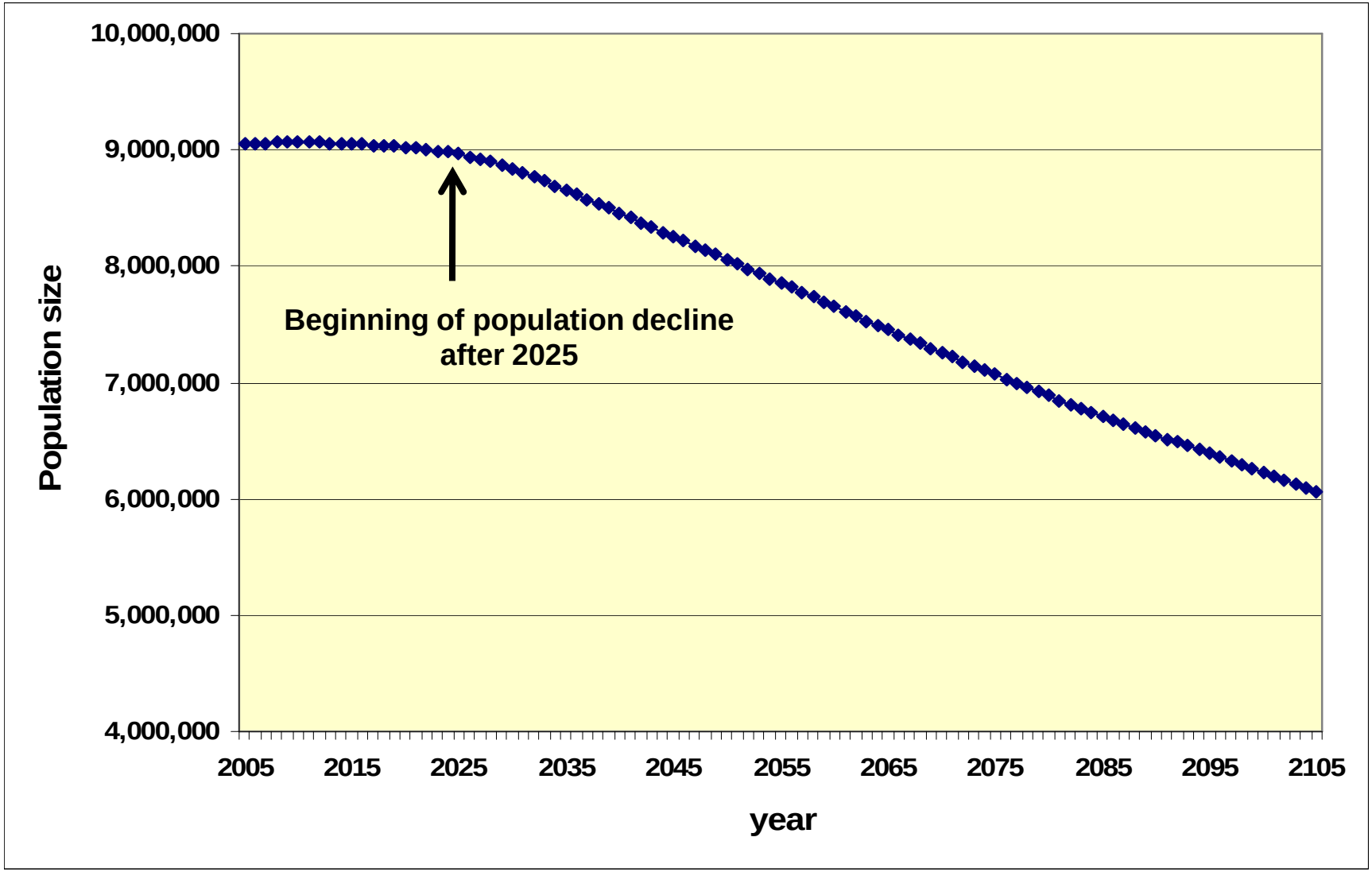
Study population: Sweden 2005



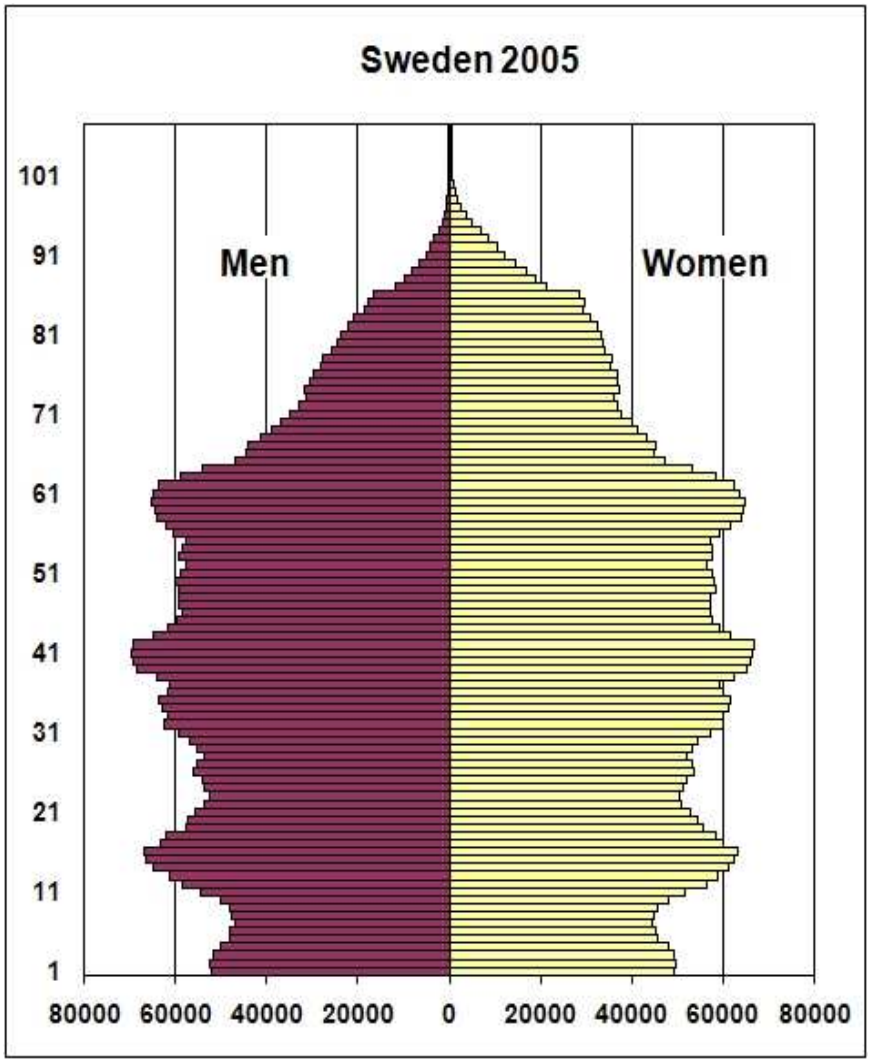
Mortality in the study population

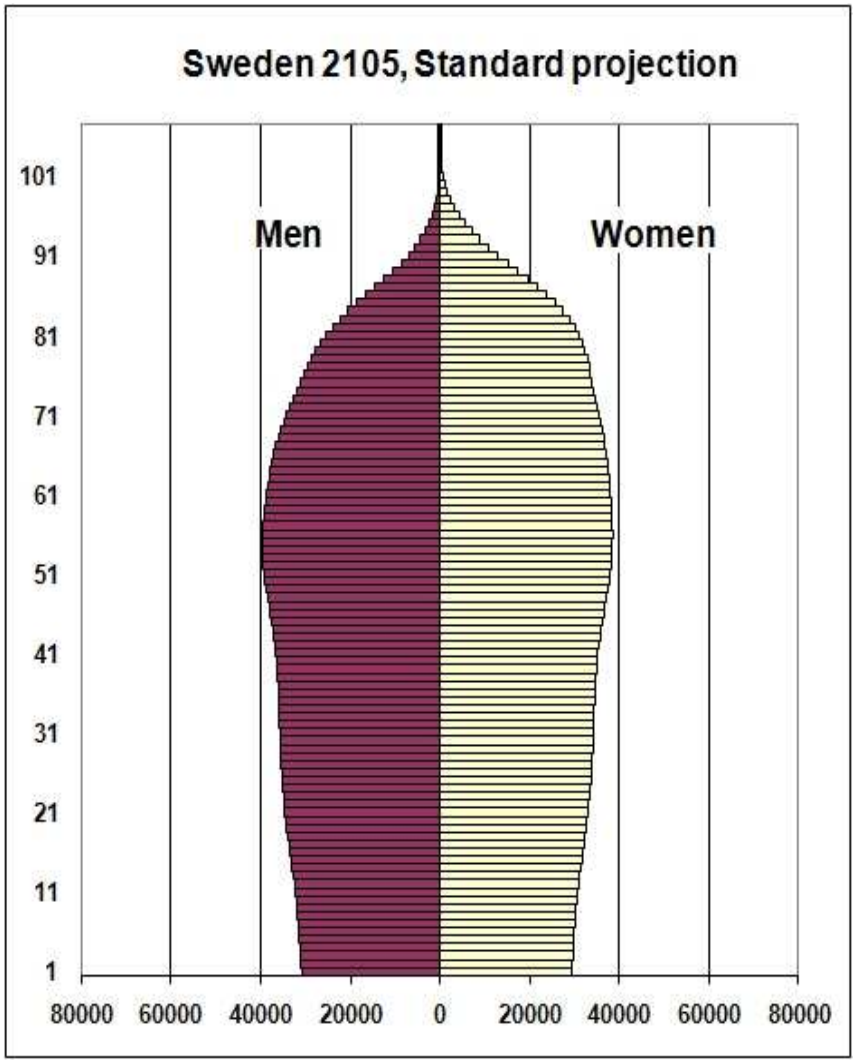


Population projection without life extension interventions



Projected changes in population pyramid 100 years later





Accelerated Population Aging is the Major Impact of Longevity on our Demography

- It is also an opportunity if society is ready to accept it and properly adapt to population aging.

Why Life-Extension is a Part of the Solution, rather than a Problem

- Many developed countries (like the studied Sweden) face dramatic decline in native-born population in the future (see earlier graphs) , and also risk to lose their cultural identity due to massive immigration.

- Therefore, extension of healthy lifespan in these countries may in fact prevent, rather than create a demographic catastrophe.

Scenarios of life extension

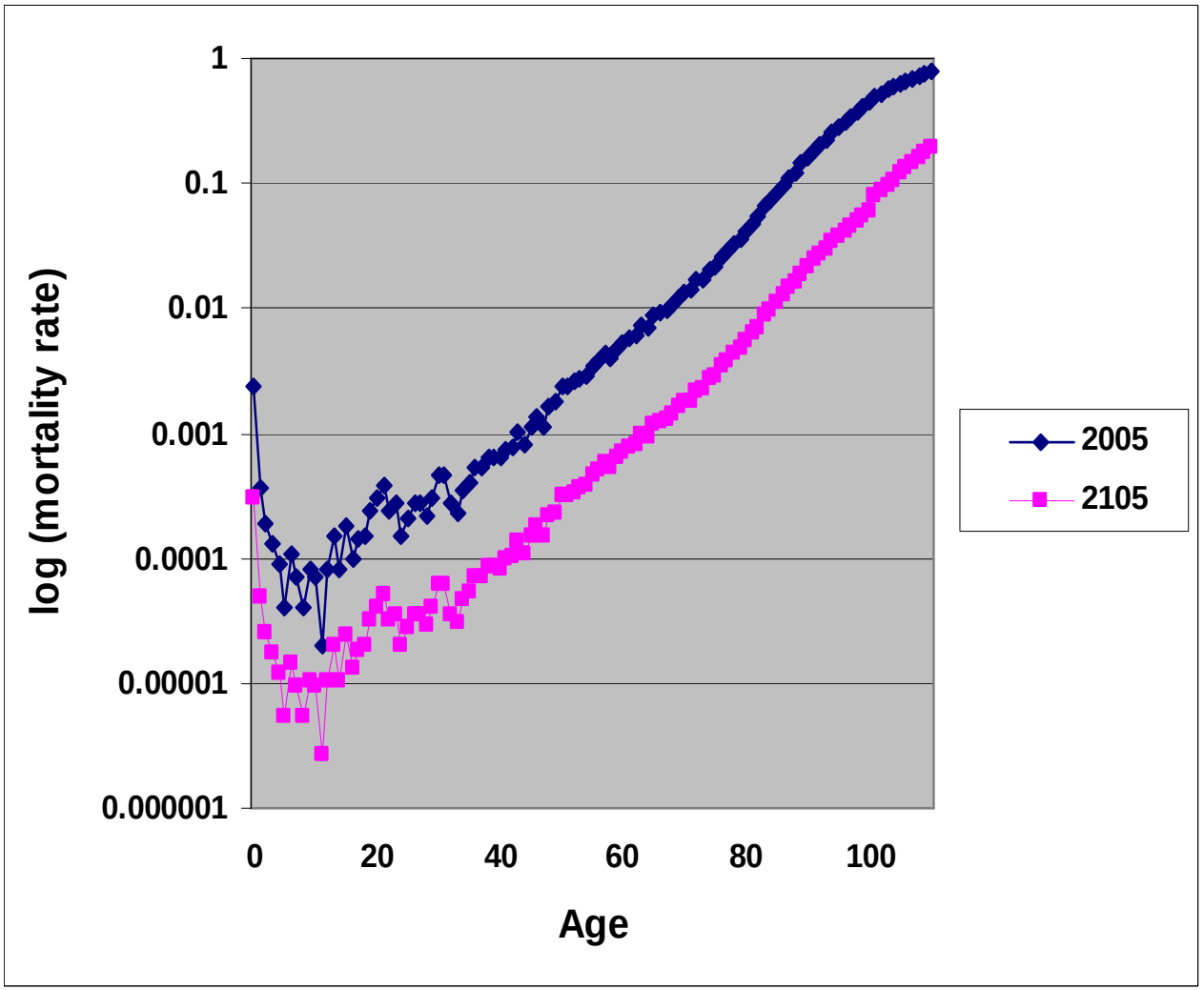
1. **Continuation of current trend in mortality decline**
2. **Negligible senescence**
3. **Negligible senescence for a part of population (10%)**
4. **Rejuvenation (Gompertz alpha = -0.0005)**

All anti-aging interventions start at age 60 years with 30-year time lag

Scenario 1
Modest scenario:
Continuous mortality decline

Mortality continues to decline with the same pace as before (2 percent per year)

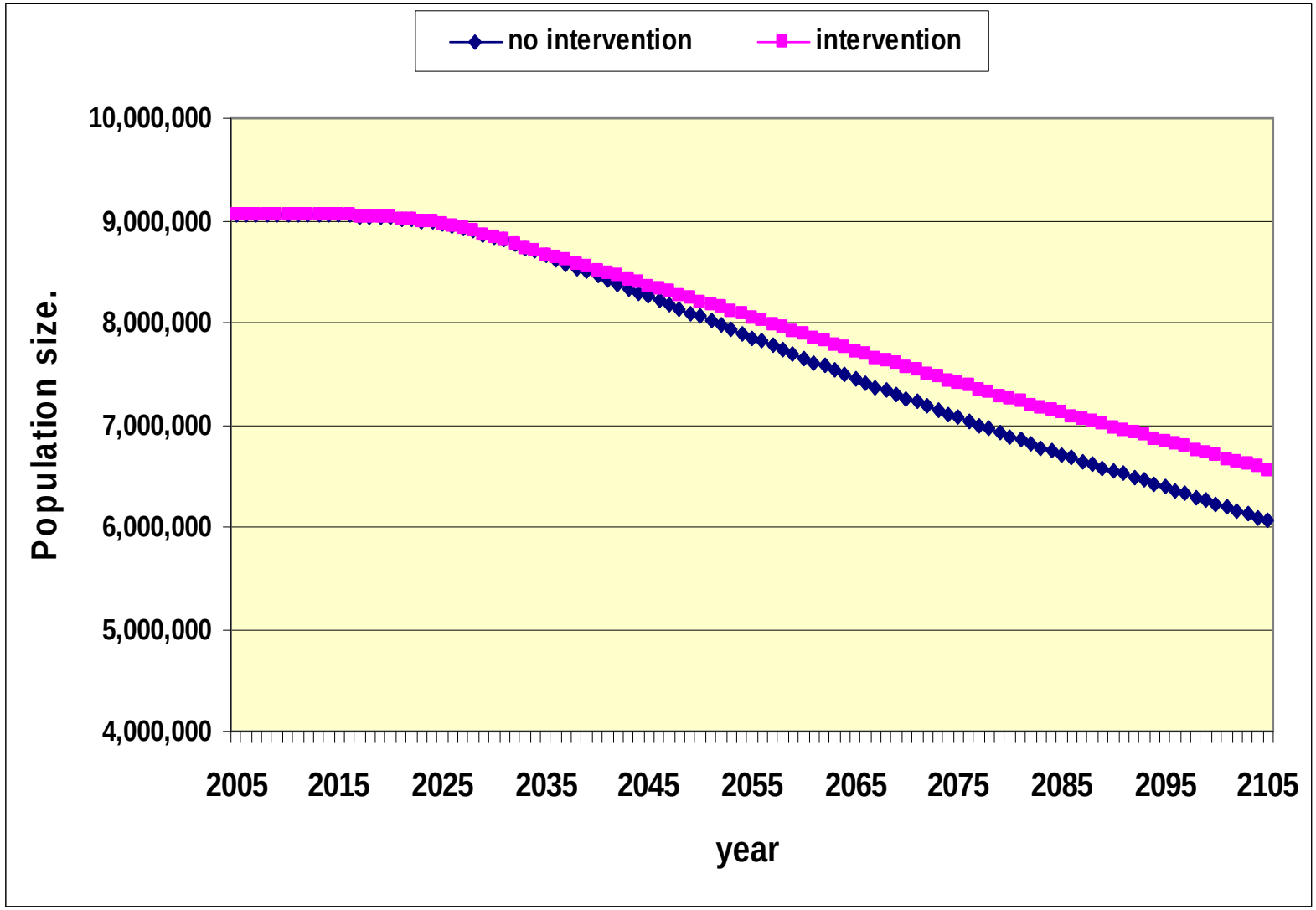
Modest scenario: Continuous mortality decline



An example for Swedish females.

Source: Human mortality database

Population projection with continuous mortality decline scenario

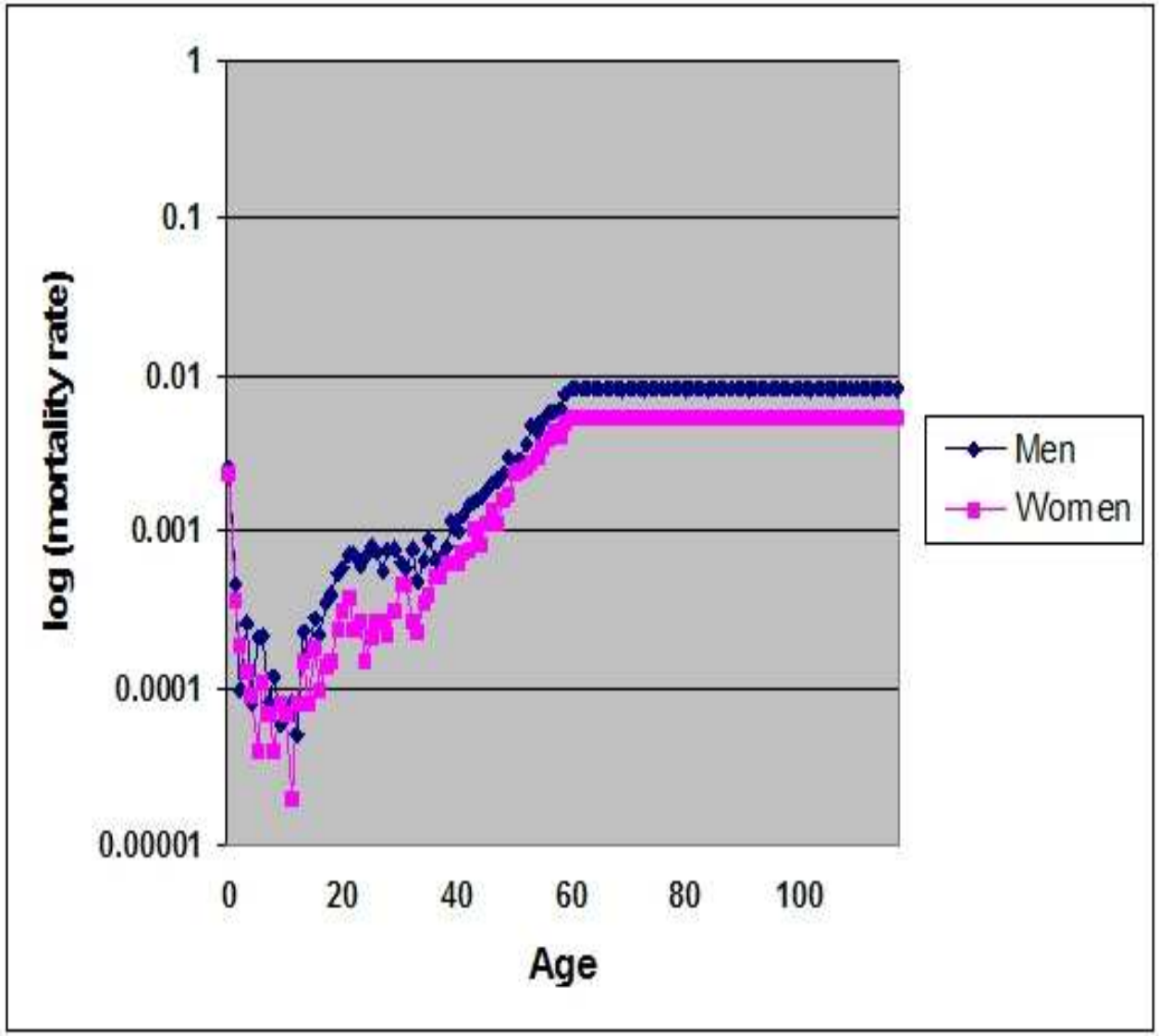


Changes in population pyramid 100 years later

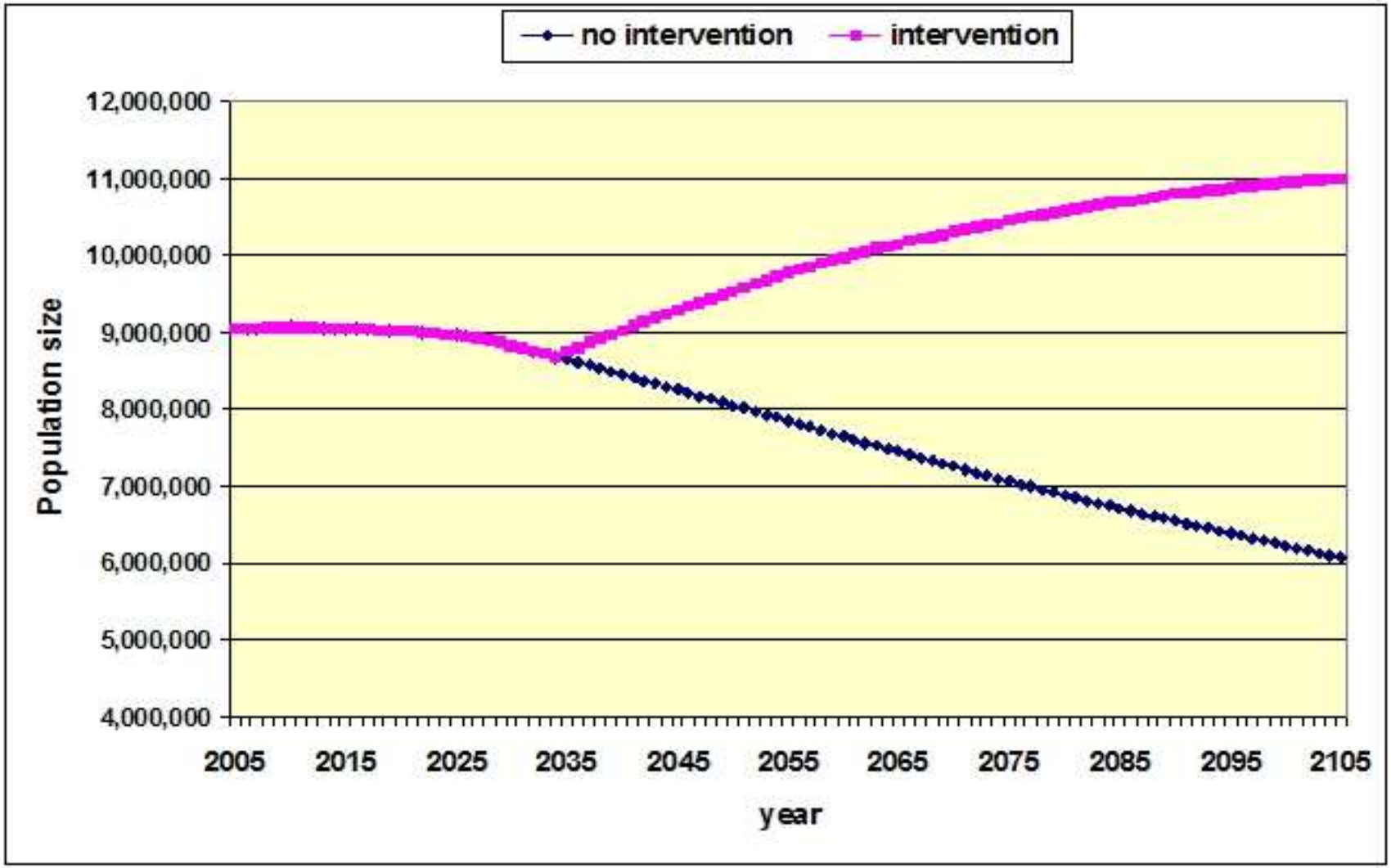
Scenario 2

Negligible senescence after age 60

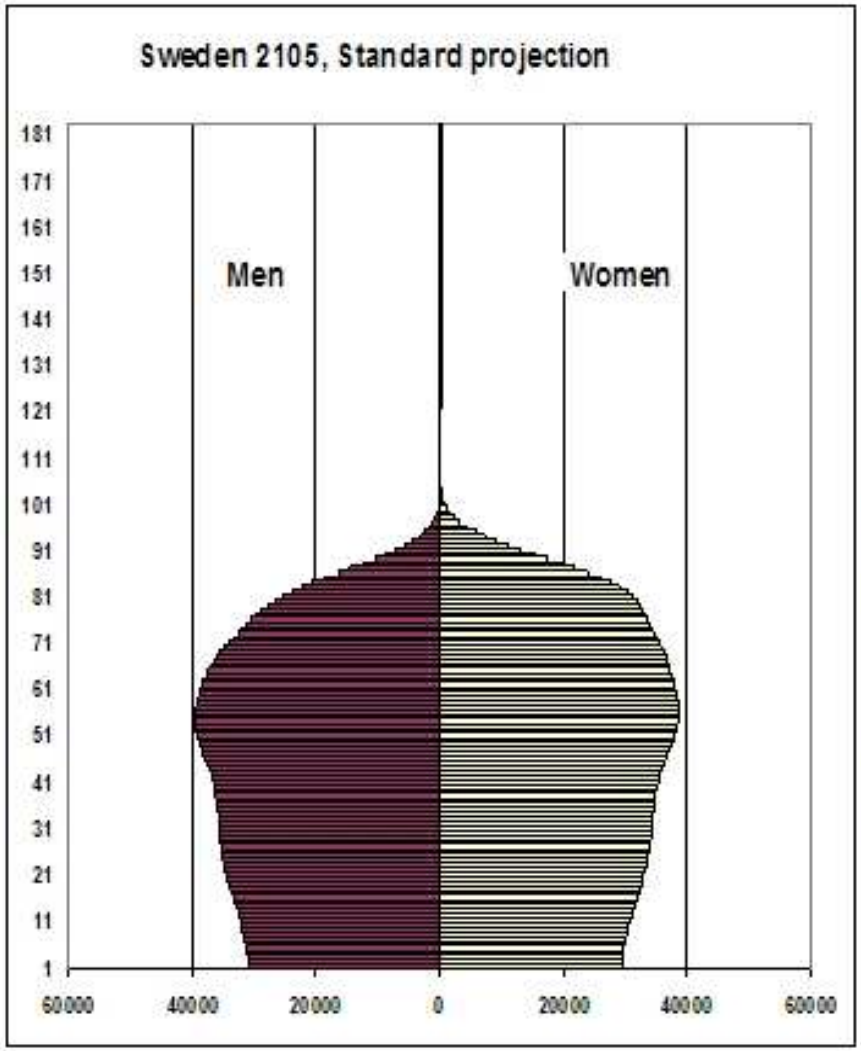
Radical scenario: No aging after age 60

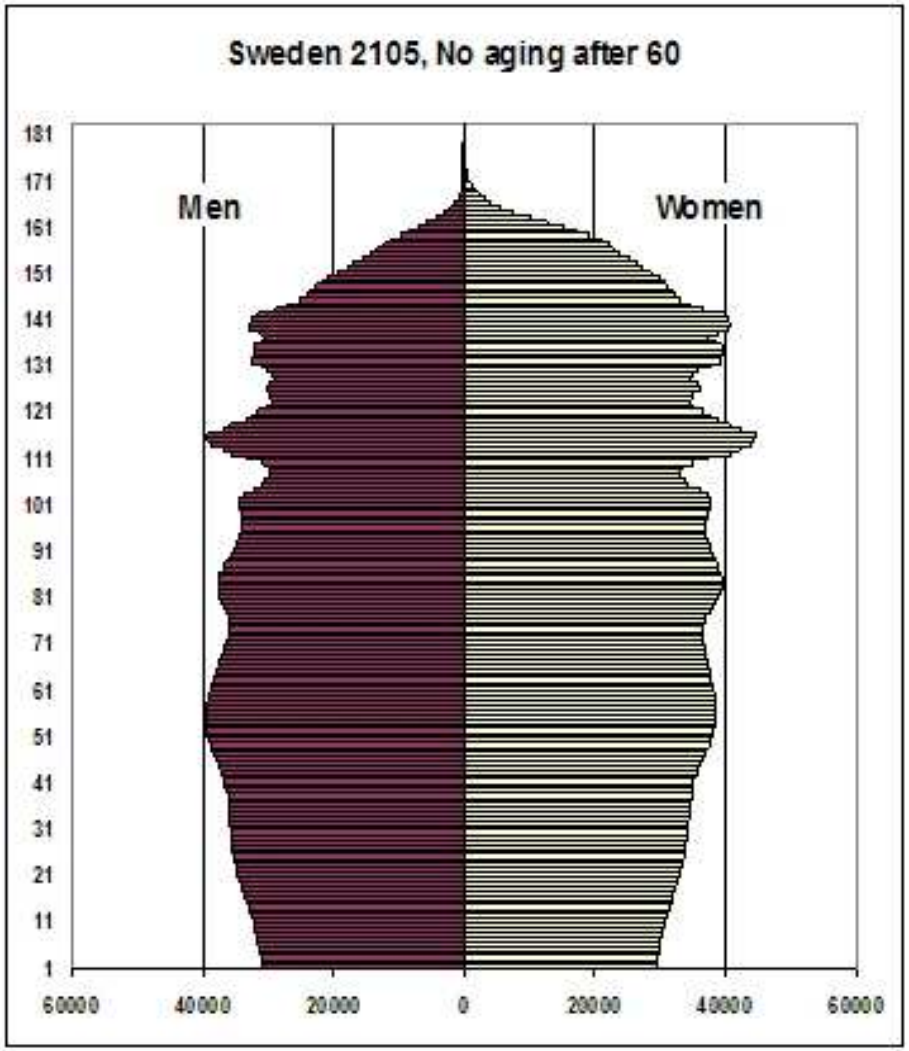


Population projection with negligible senescence scenario



Changes in population pyramid 100 years later





Conclusions on radical scenario

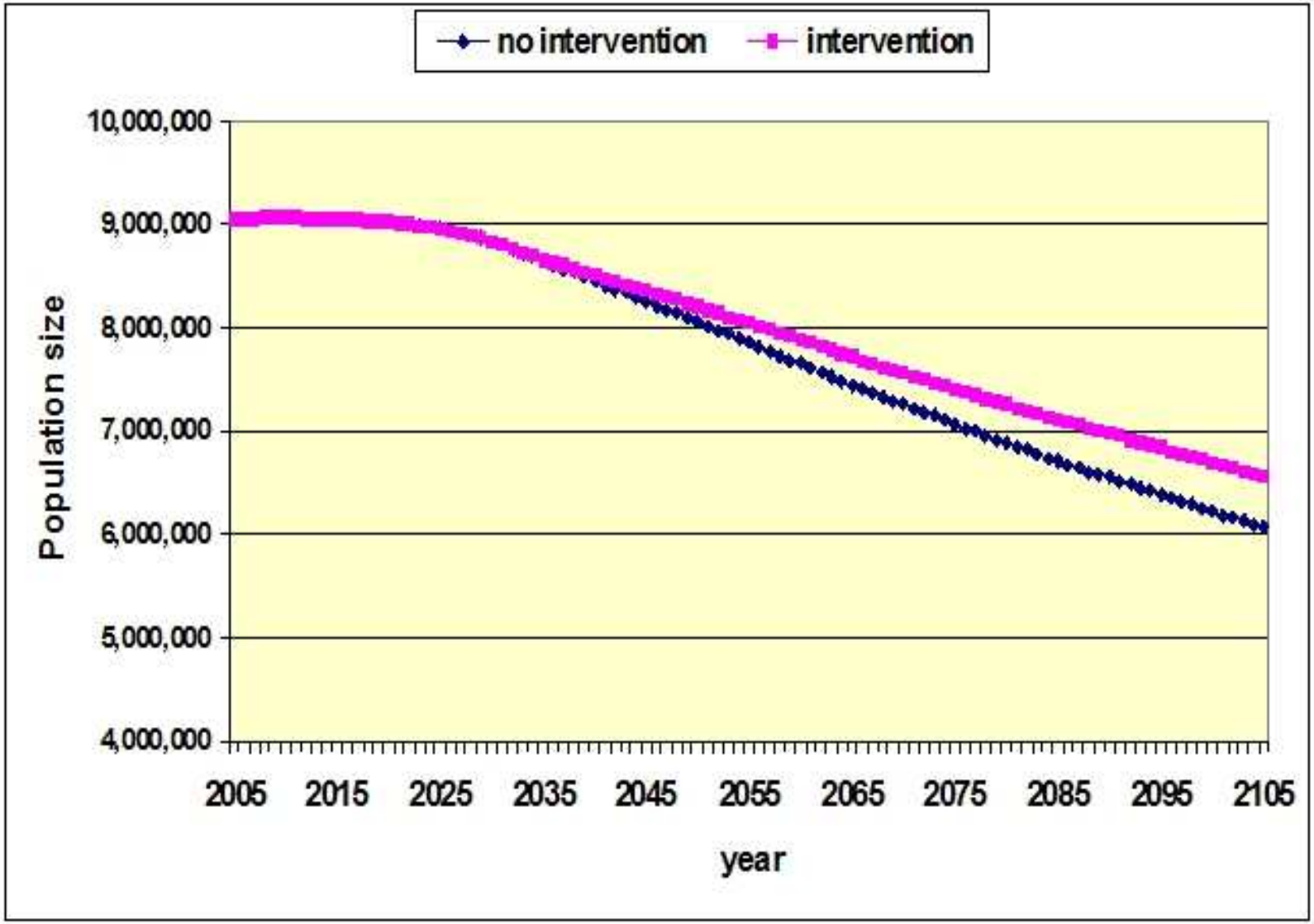
- Even in the case of defeating aging (no aging after 60 years) the natural population growth is relatively small (about 20% increase over 70 years)

- Moreover, defeating aging helps to prevent natural population decline in developed countries

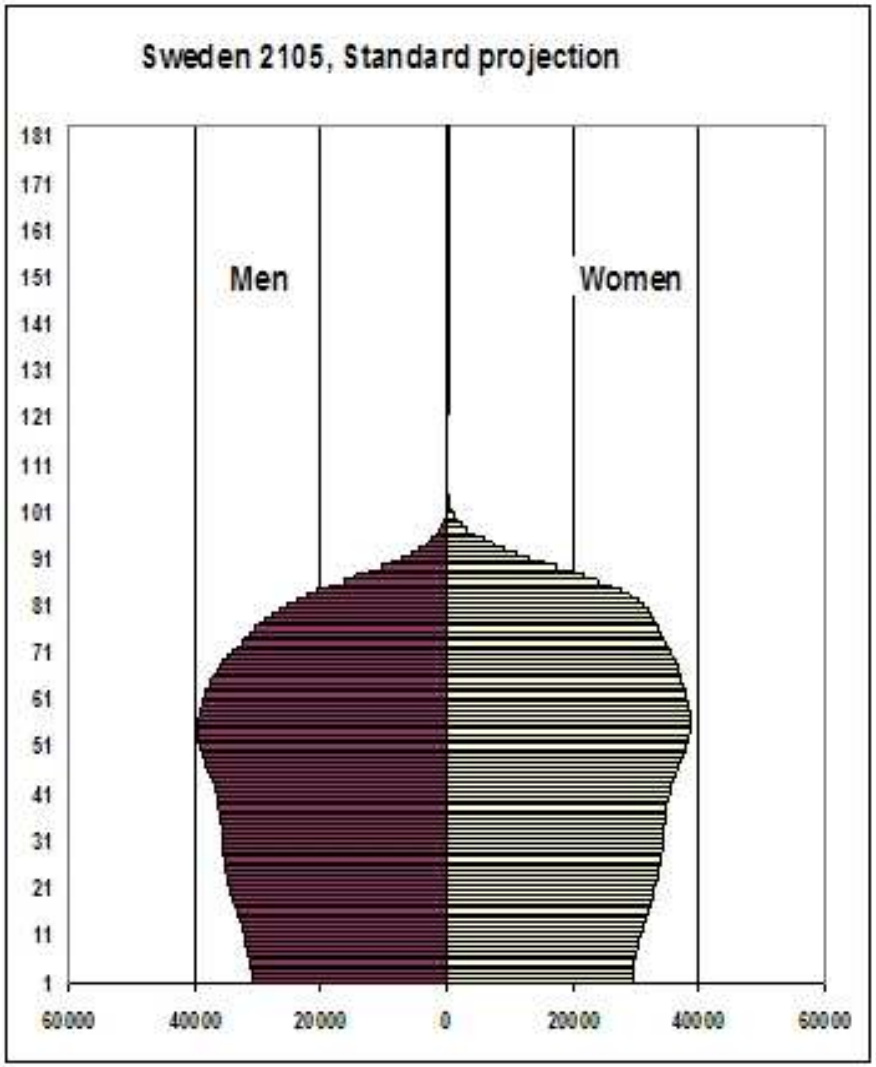
Scenario 3

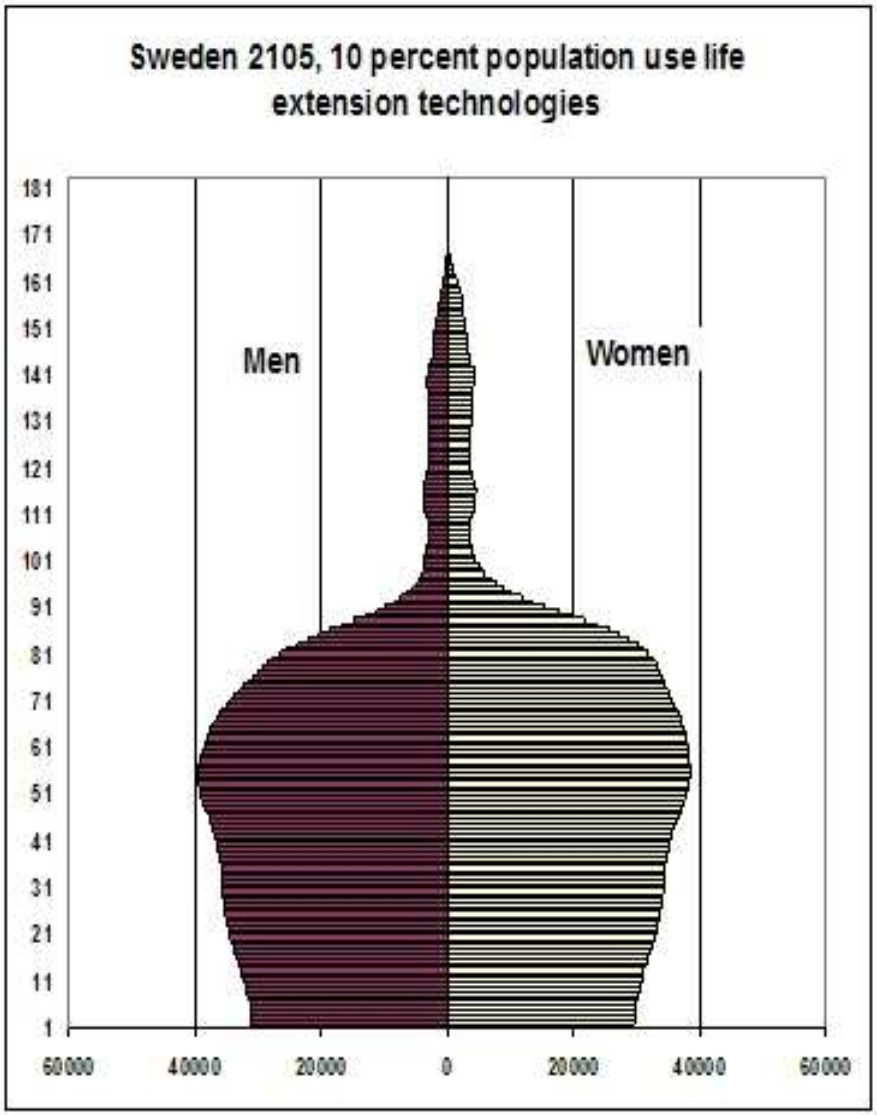
- Negligible senescence for a part of population (10%)
- What if only a small fraction of population accepts anti-aging interventions?

Population projection with 10 percent of population experiencing negligible senescence



Changes in population pyramid 100 years later





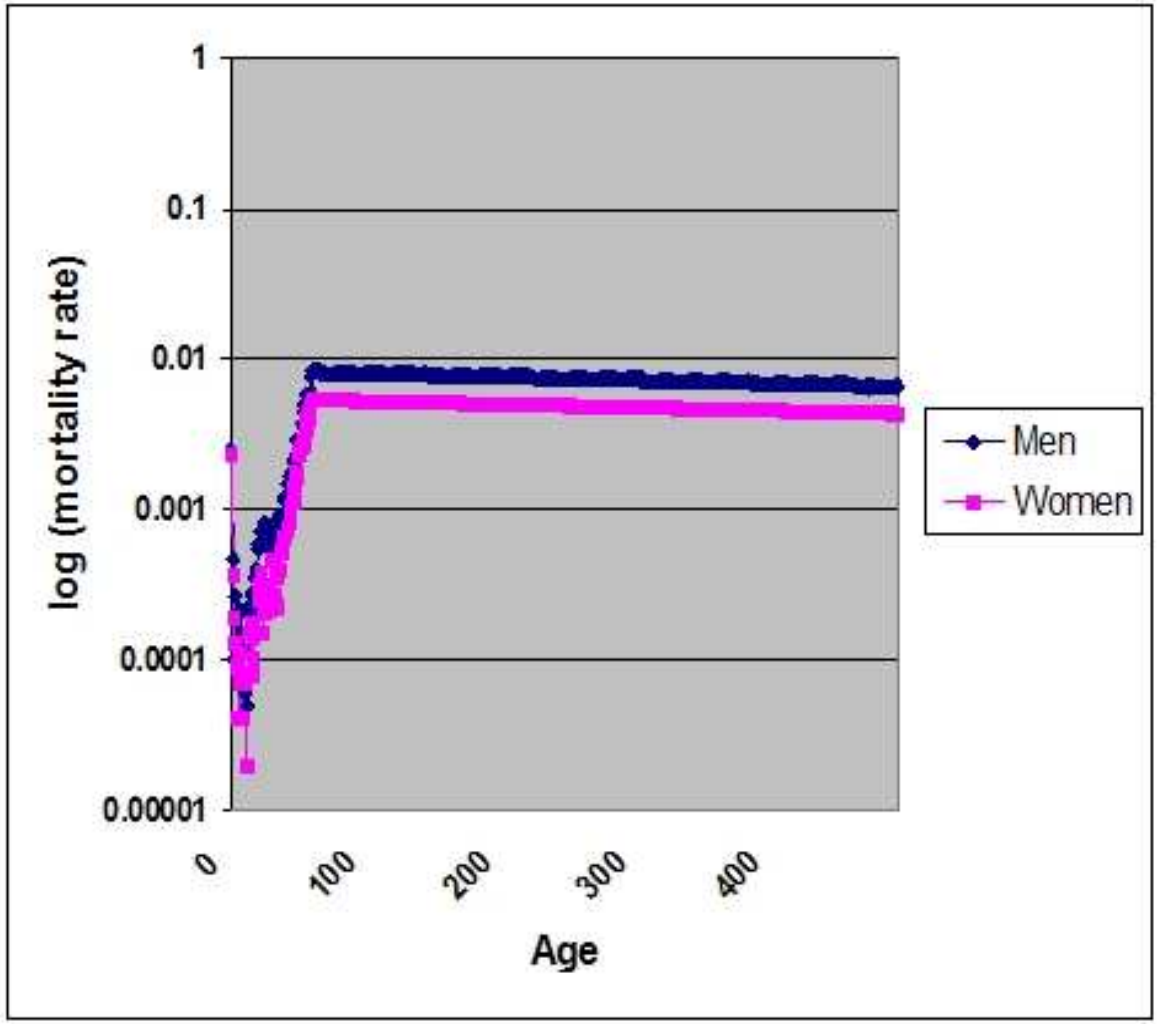
Scenario 4:
Rejuvenation Scenario

Mortality declines after age 60 years until the levels observed at age 10 are reached; mortality remains constant thereafter

Negative Gompertz alpha

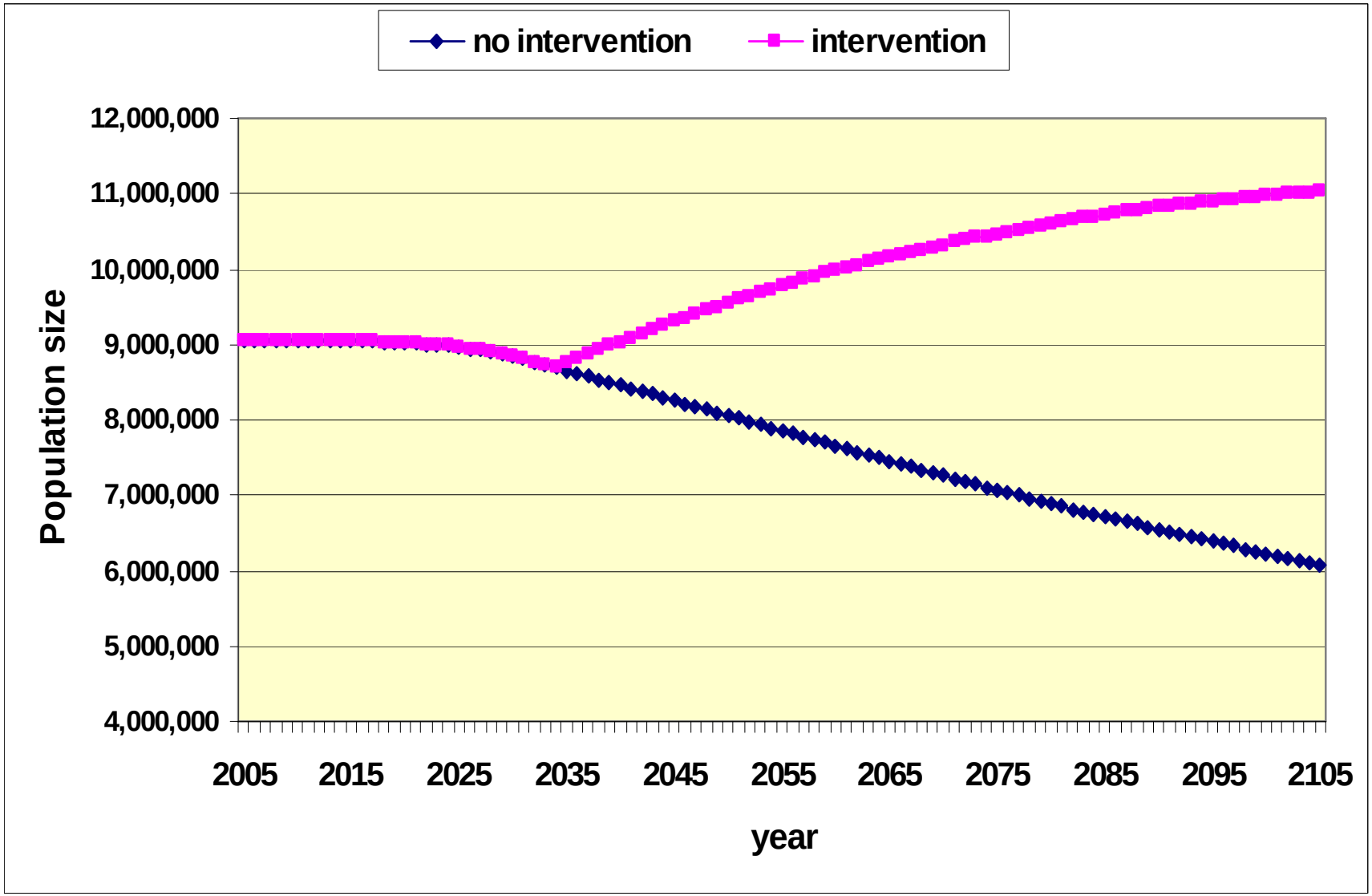
(alpha = -0.0005 per year)

Radical scenario: rejuvenation after 60

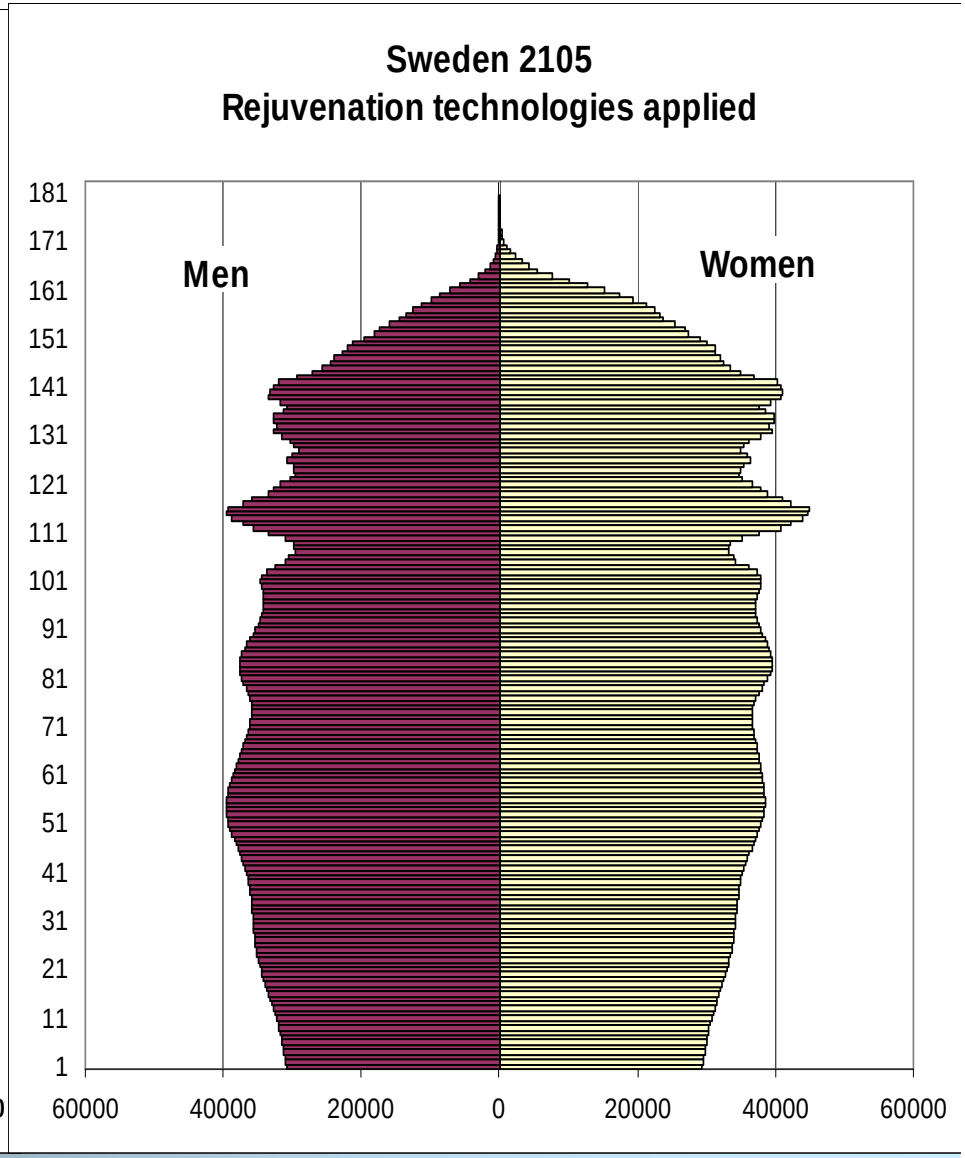


According to this scenario, mortality declines with age after age 60 years

Population projection with rejuvenation scenario



Changes in population pyramid 100 years later



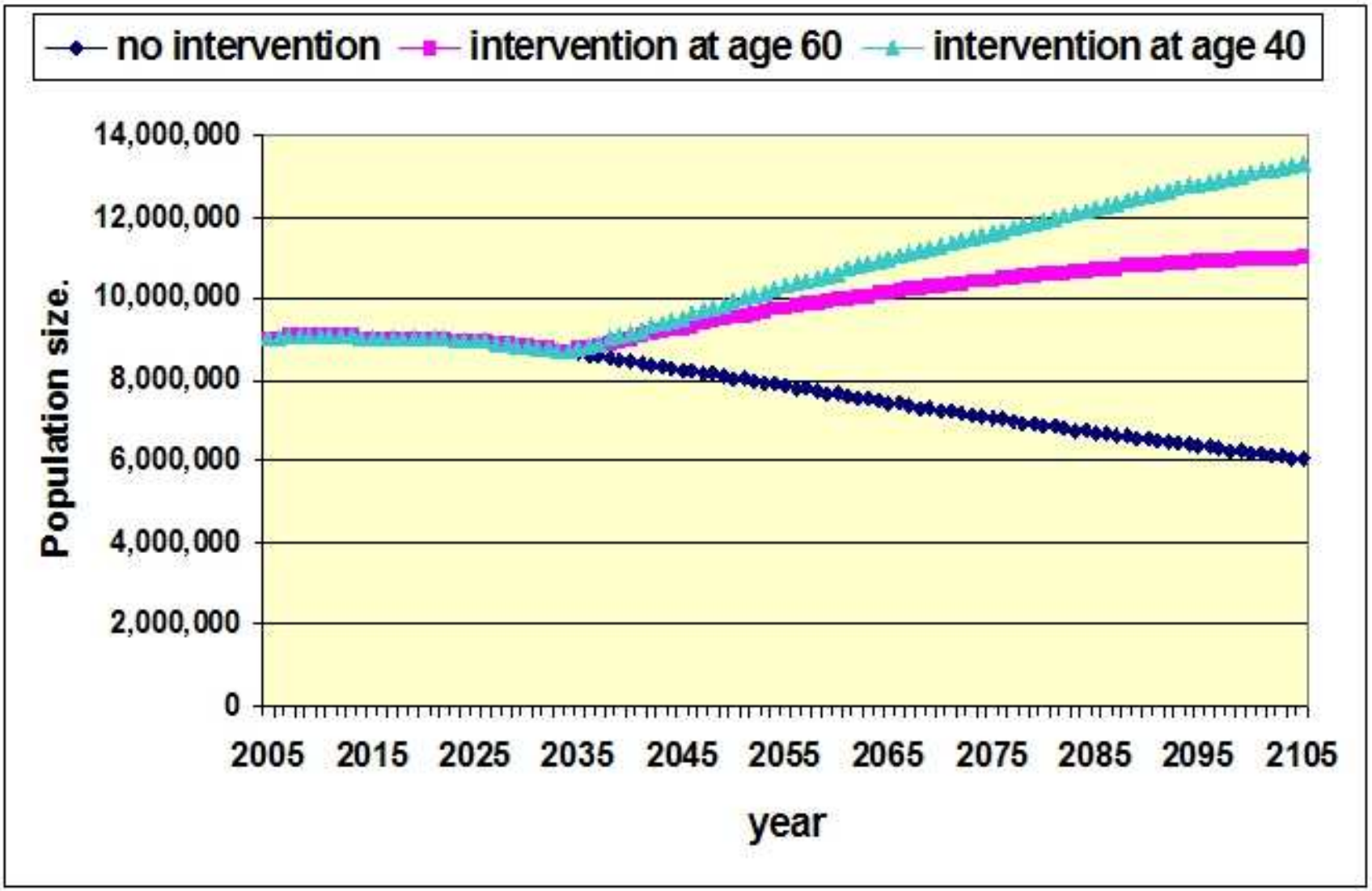
Conclusions on rejuvenation scenario

- Even in the case of rejuvenation (aging reversal after 60 years) the natural population growth is still small (about 20% increase over 70 years)

- Moreover, rejuvenation helps to prevent natural population decline in developed countries

What happens when rejuvenation starts at age 40 instead of age 60?

Population projection with rejuvenation at ages 60 and 40



Conclusions

- A general conclusion of this study is that population changes are surprisingly small and slow in their response to a dramatic life extension.

- Even in the case of the most radical life extension scenario, population growth could be relatively slow and may not necessarily lead to overpopulation.

- Therefore, the real concerns should be placed not on the threat of catastrophic population consequences (overpopulation), but rather on such potential obstacles to a success of biomedical war on aging, as scientific, organizational and financial limitations.

Acknowledgments

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- **generous support from the SENS/Methuselah Foundation**

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- **http://longevity-science.org**

And Please Post Your Comments at our Scientific Discussion Blog:

- **http://longevity-science.blogspot.com/**