Paris Seminar in Economic Demography (PSED)

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Long term decline of mortality in France, some biases which hide the Gompertz law of mortality and the plateauing of life expectancy

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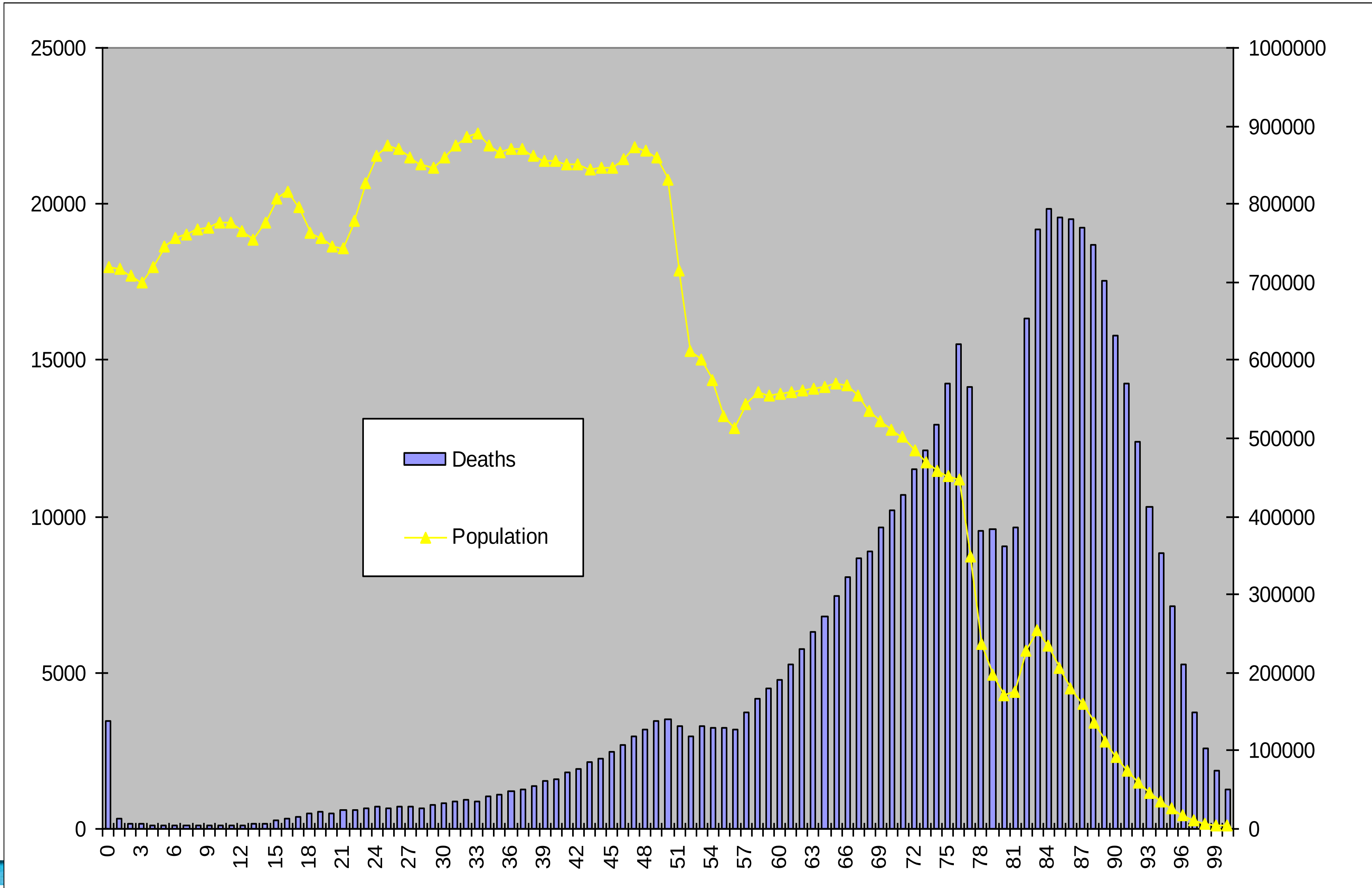
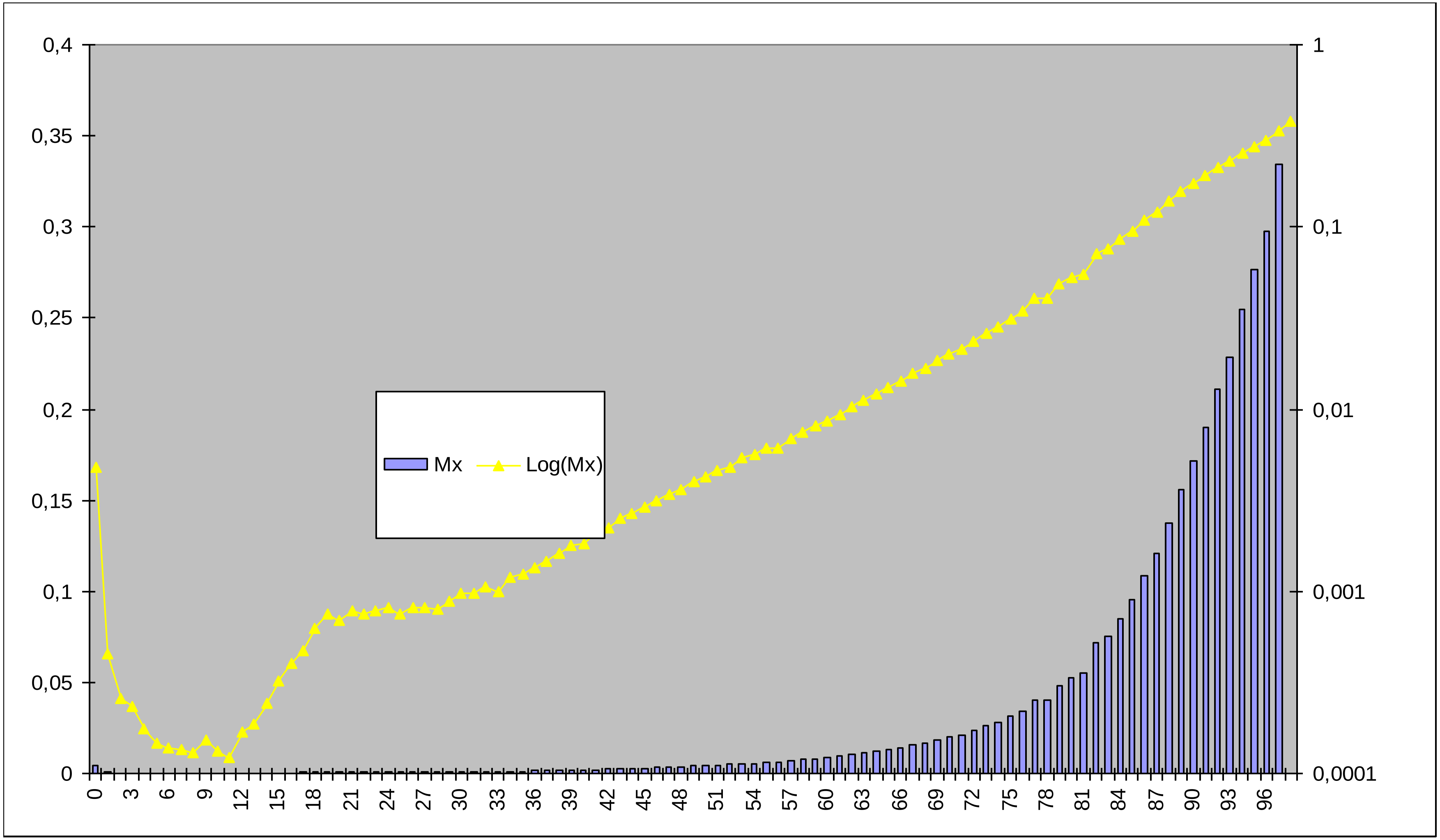
Controversy on longevity ?

- Which controversy :
  - On the inflection and even a decrease of the force of mortality at oldest ages (J. Vaupel).
  - Which consequence could be a high proportion of super centenarians (>110 years) at long term (2050-2100)
- What consequences on short term (2020) :
  - few, very few in comparison to other new phenomena like
  - the massive increase of the population aged 85-90 with probably new needs for long term care.

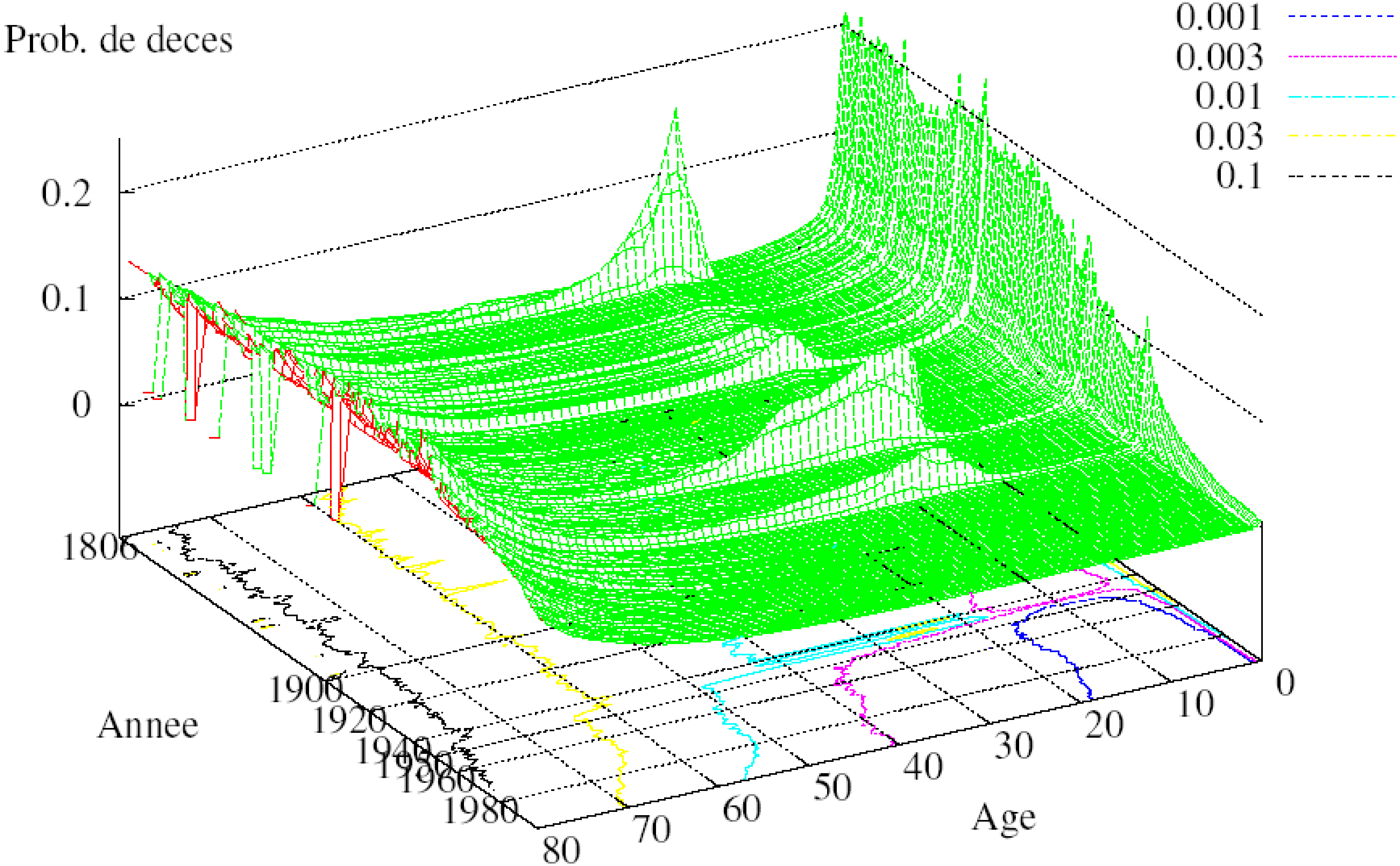
Raw distribution of deaths according to age. In relation with the cohorts at risk at the same age. France 1997.



Central mortality rates by single age. Would tend to the force of mortality if age was in semester, trimester, month etc. raising estimation problems



Probabilite annuelle de deceder en France et pour les hommes (1806-1997)

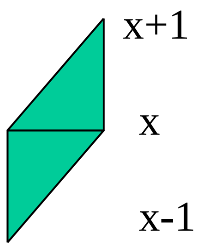


Difficulties to measure the force of mortality at old ages

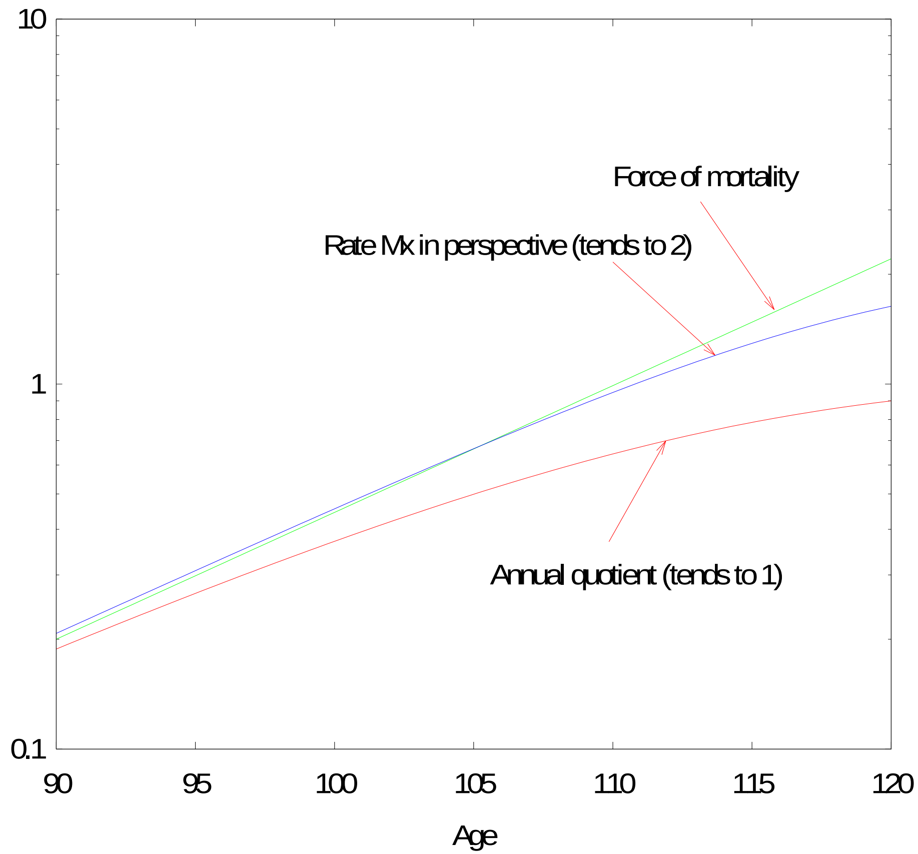
- Both deaths and populations at risk are few (<200).
- Population estimated by the census (even by the new census) give wrong estimates (age >95)
- Wrong declaration of age at deaths which can't be checked with birth certificate, only at very high ages.
- Extinct cohort method shortens the period of estimation

Probability of death, central rate instead of perspective mortality rate, force of mortality: bias at old ages where the mortality level is higher than 0.2 per year. Artificial plateau

The perspective mortality rate, Mx (as calculated in France) is not bound by μ∝(x-1) but is lower and tends to 2 at oldest ages



Lexis Diagram



If the force of mortality μ(120) was 2.1 per year, that is 2.1/12=0.18 per month, on 100 persons reaching 120 years, 18 would die before the first month.

Annual probability of dying, 1Qx, is diverging from the force of mortality since the age of 90 years (0.2/an) and tends to 1.

Uncertainty and consequences of the Gompertz law

Hyp A: Gompertz law fits old ages.

Question: If the current world population of 7 billions was 90 years old today, how survivors would reach the age of 120?

Hyp B: Force of mortality is plateauying at 0.2 per year since the age of 90.

Same question

Uncertainty and consequences of the Gompertz law

Answers to the question:

hyp. A : even not a single person, 1/10 person!

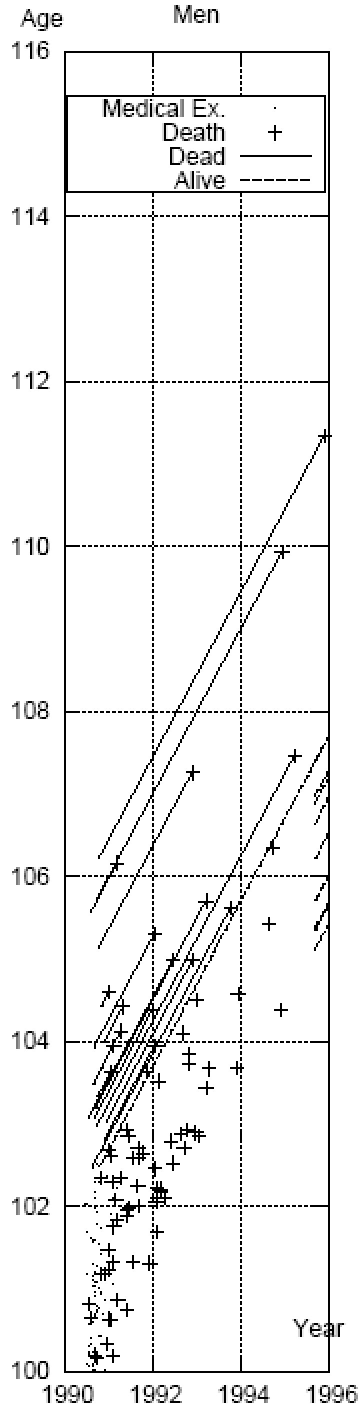
hyp. B : a few millions!

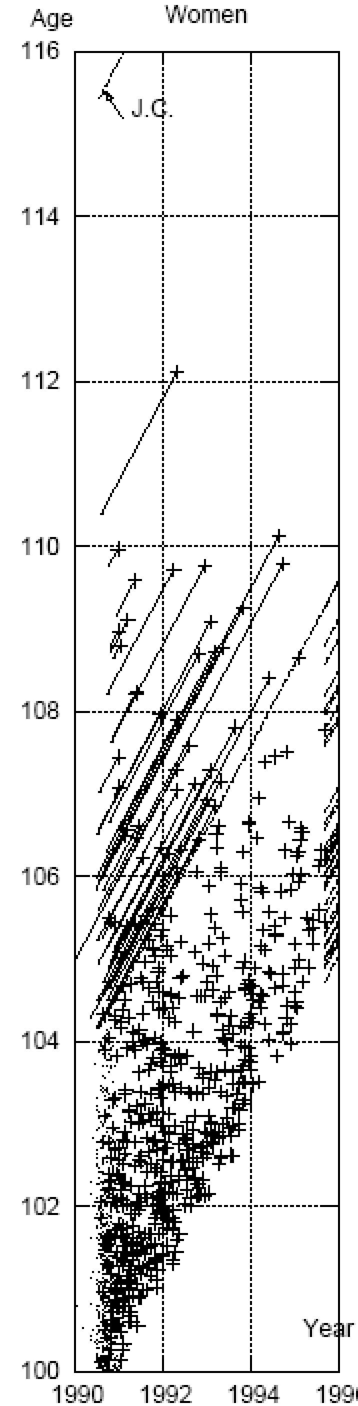
Bias in ad-hoc surveys on centenarians. The IPSEN survey of 1991

- *January to May 1990* : Identification of 2859 probably centenarians (born before 1890) living in France. (Identification via a network of GP and geriatricians.

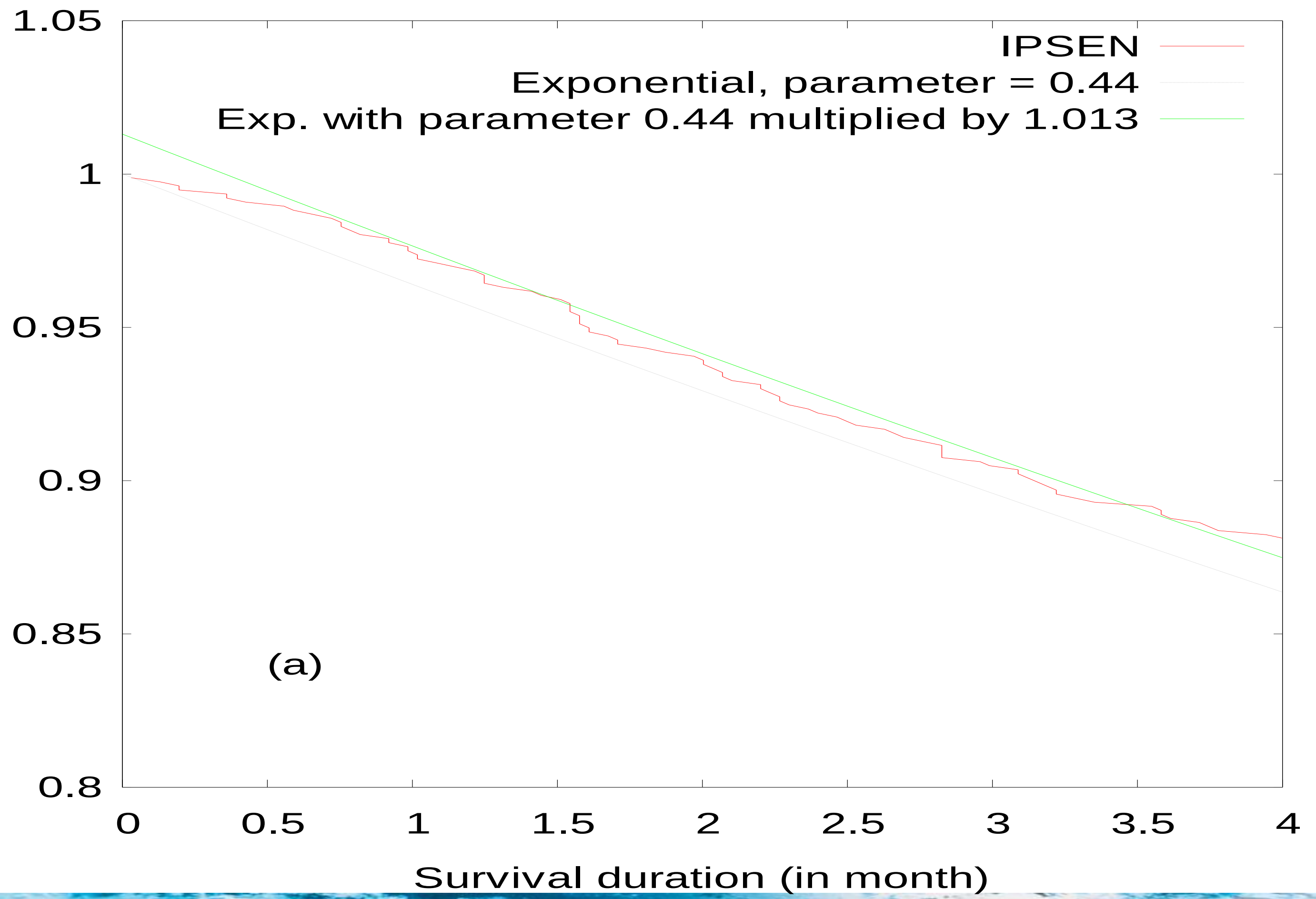
- *Up to April 1991*: only 907 medical exams (entries in the follow-up). Reasons invoked for the attrition:
  - Double or triple counts
  - Mortality (25%)
  - Do not apply to the protocol, refusal

- Size of the final sample: 756 centenarians followed up to 31 December 1995 (or to death)

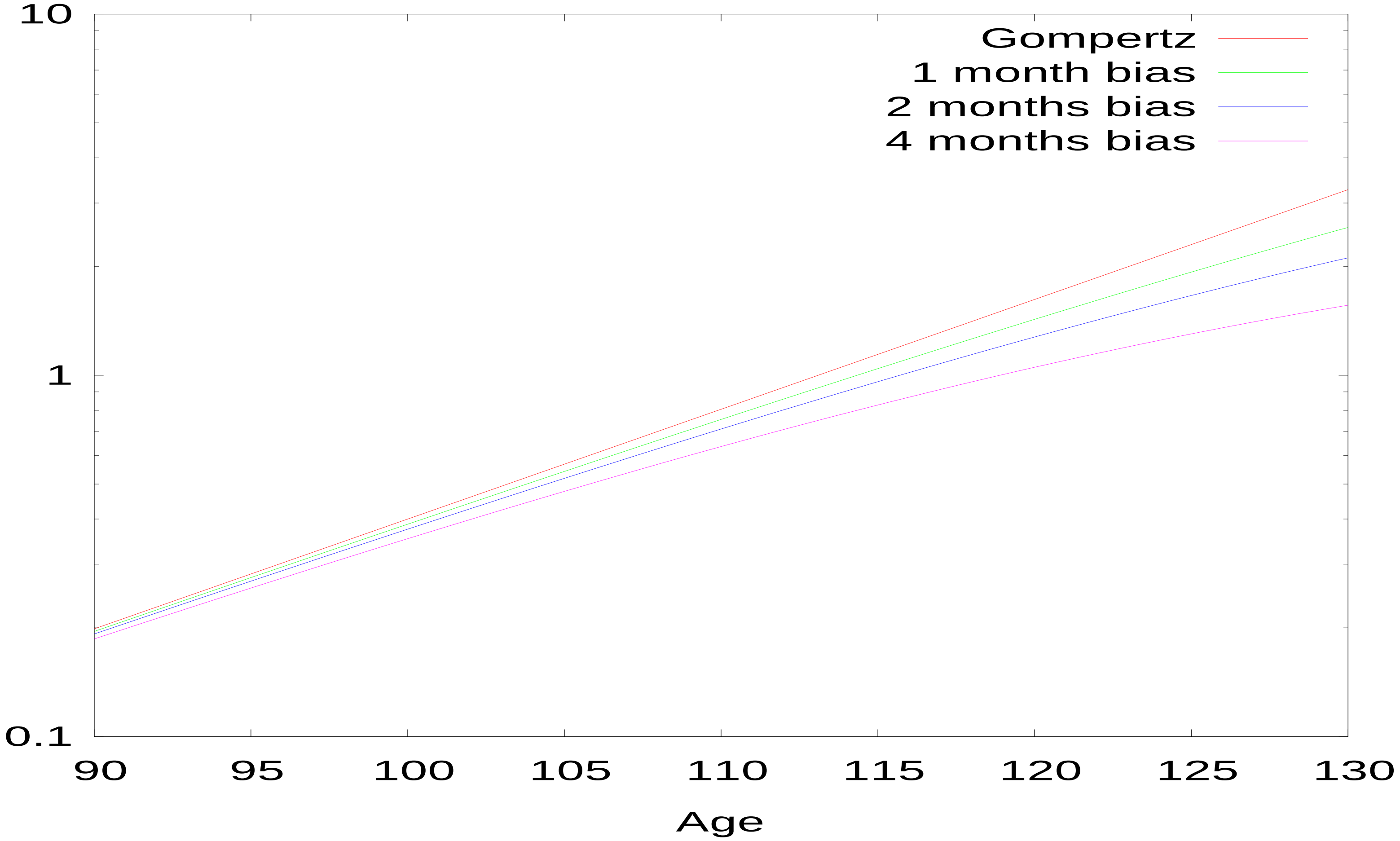

Age
Men
116
114
112
110
108
106
104
102
100
Medical Ex.
Death
Dead
Alive
Year
1990
1992
1994
1996


Age
Women
116
114
112
110
108
106
104
102
100
J.C.
Year
1990
1992
1994
1996

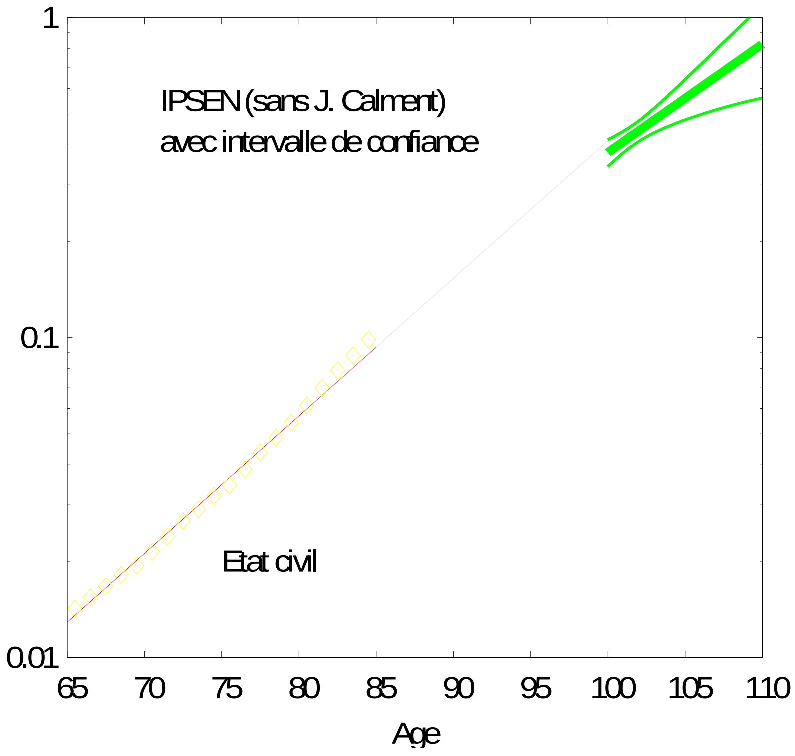
Kaplan Meyer of the whole sample, fitted by an exponential model (0.44 per year). Under-representation of short survivals durations

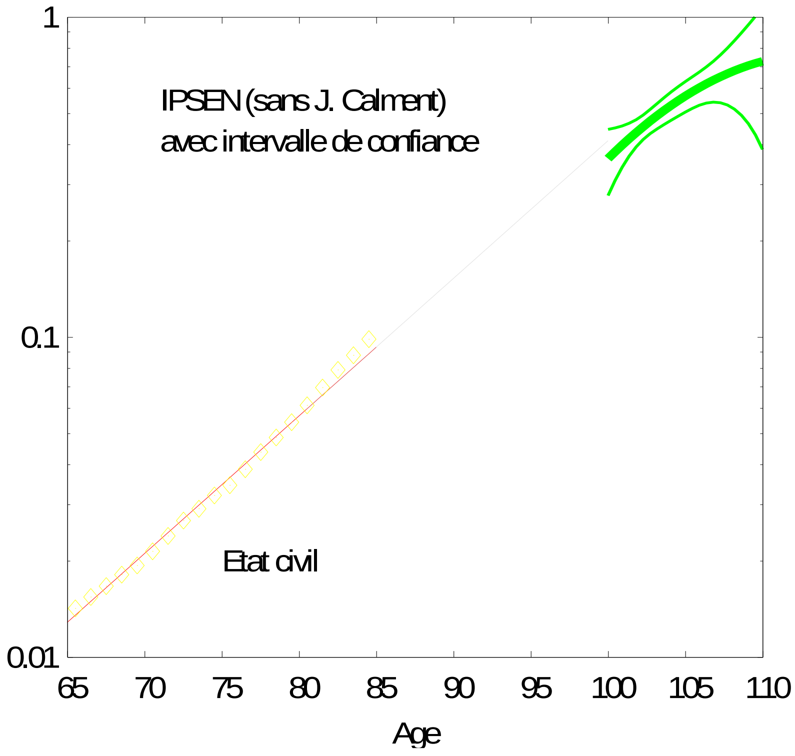


What if short survival durations (1, 2, 4 months) where suppressed from the sample: artificial plateau

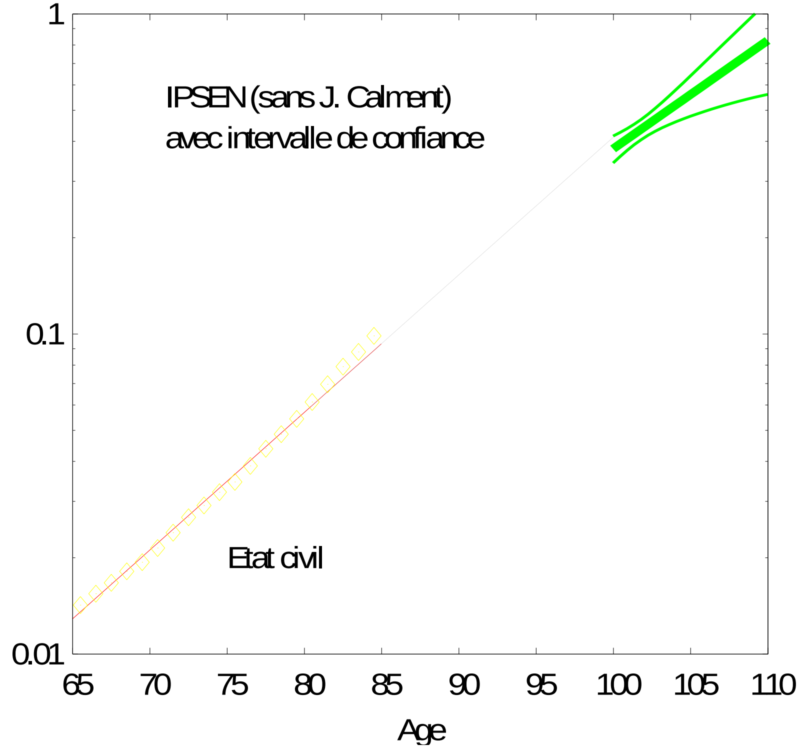


Confidence intervals of force of mortality estimated from IPSEN survey and vital statistics 1990 (maximum likelihood)

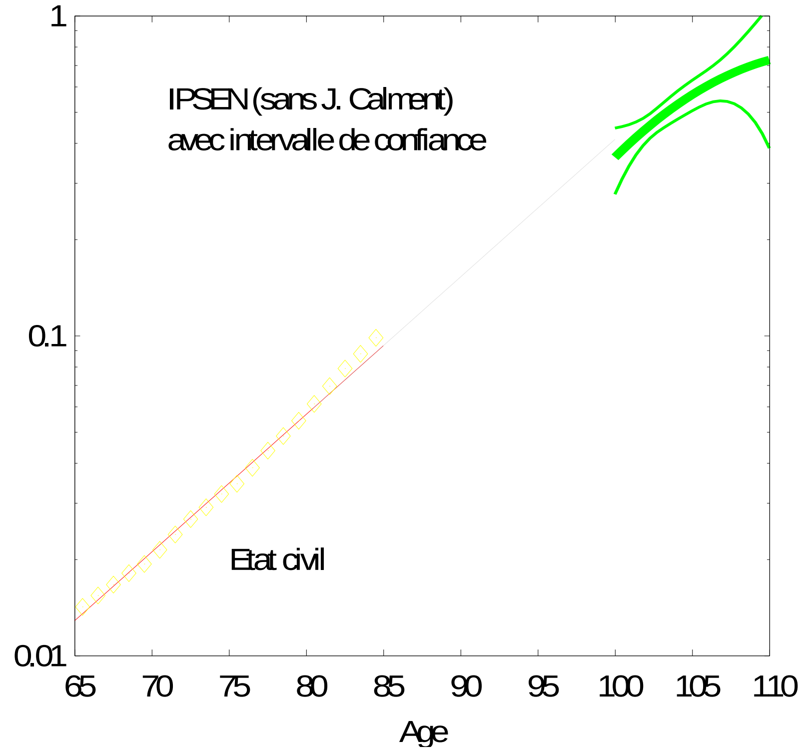




Confidence intervals of the force de mortality estimate from the IPSEN survey. Extrapolation of the Gompertz law estimate from vital statistics in France 1990. The JC case (without)



Confidence intervals of the force de mortality estimate from the IPSEN survey. Extrapolation of the Gompertz law estimate from vital statistics in France 1990. The JC case (with!)



Projections of mortality in France

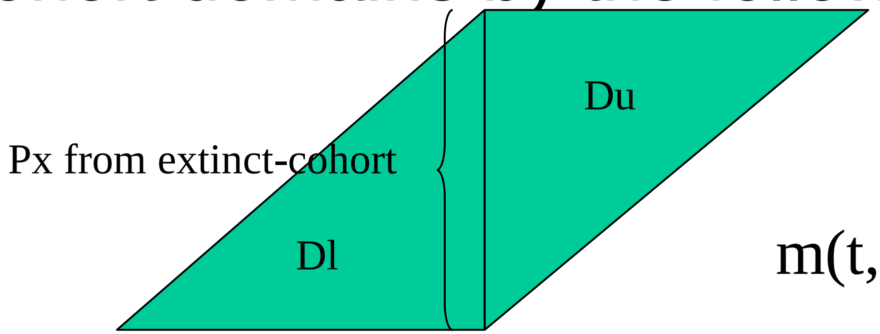
- Data available until 2009. Extinguished cohorts method from oldest ages up to age 95.
- Mortality after 2002 is thus unknown at oldest ages.
- Only cohorts of a minimum size can be involved in the regression. Summing deaths amongst various cohorts even at the same age are inducing a plateau because as mortality declines, more recent cohorts are at lower risks of dying than former cohorts. The heterogeneity created in these super cohorts induces an artificial plateau.

Heterogeneity of cohort conducts to a reduction of the speed of the risk of mortality...

- but what would be the speed of the risk (age profile of the force of mortality) if the cohort was homogeneous?
- Answer : the “natural” law of mortality amongst an homogeneous cohort is probably a kind of accelerating exponential increase with age.

Lexis domains used in the projection

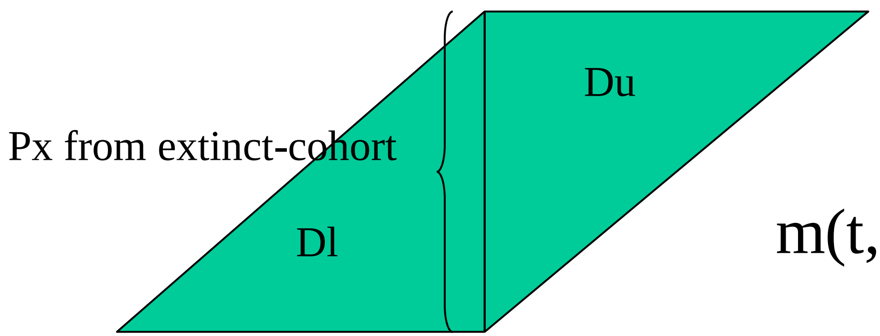
- Latest data on mortality: year 2009.
- Minimum of 200 deaths => latest year 2002.
- Annual rates might be estimated on such cohort domains by the following formula:



$$m(t,x)=(Du+Dl)/Px$$

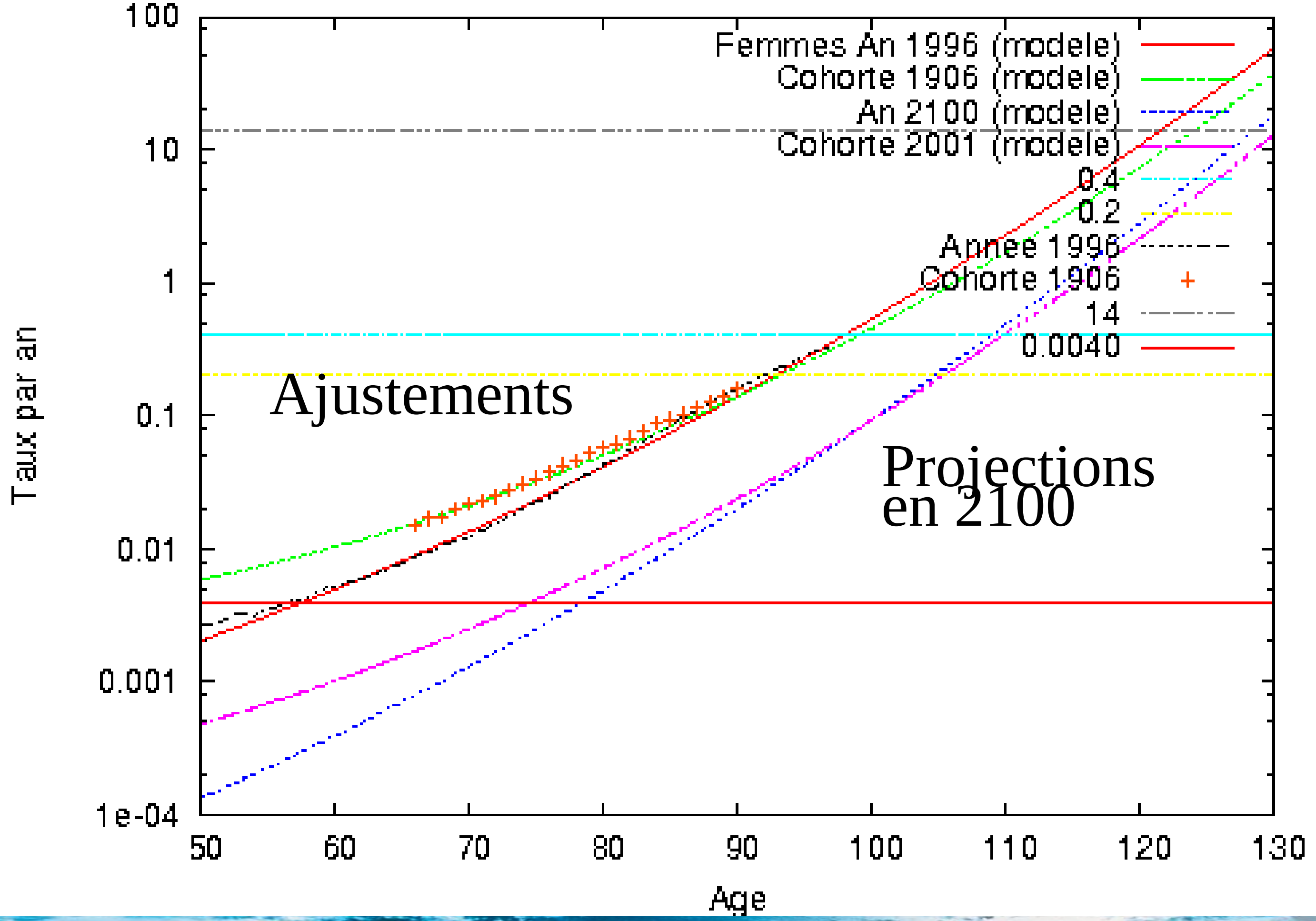
Lexis domains used in the projection

- Latest data available: year 2009.
- Minimum of 200 annual deaths in a single cohort => last useable year is 2002.
- Annual rates might be computed on such cohort domains by the following formula:



$$m(t,x)=(Du+Dl)/Px$$

Model for the estimation of the annual rate of mortality, m_x, 1950-2003 in France and projection until 2100 $\log(m(t,x))=a + bx + ct + dtx + ex^2$



Results

- Slope is increasing with time
- Slope is higher for females (lower mortality) than for males.
- => Rectangularization not a simple shift.
- => Slow process (year 2100 on previous graph!).

The secular steady increase of the highest observed age at death

- each calendar year among two countries
  – Sweden (J. Wilmoth, Experiment. Geront., 2000)
  – France (J. Vallin, F. Meslé)

For the current period (last 20 years), does the increase result from the decline of the mortality at the oldest ages (>100) or from the decline before age 100?

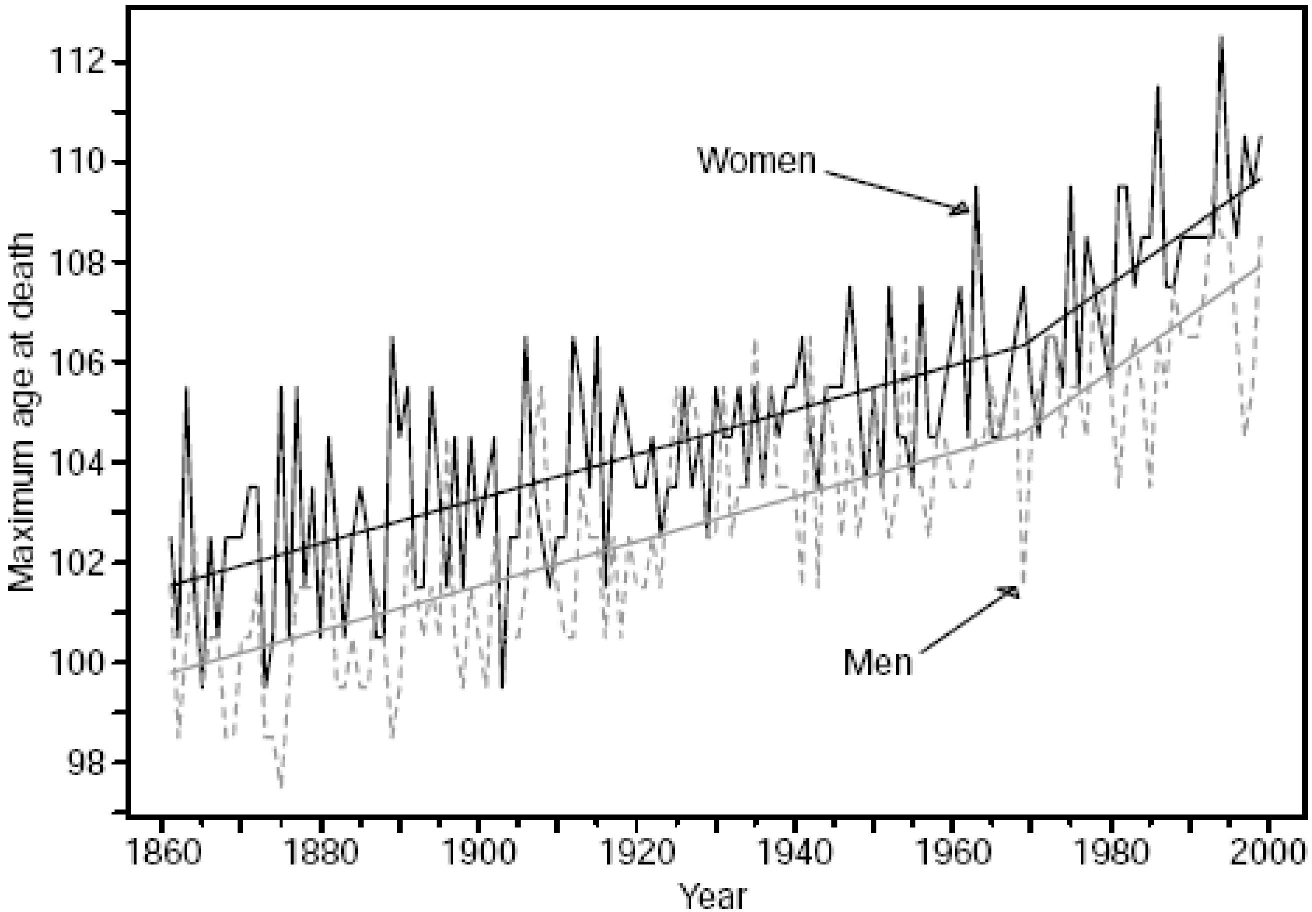


Fig. 3. Maximum reported age at death, Sweden, 1861–1999. Graph shows maximum reported age at death

Mean age at death of last survivor

- In a cohort of n survivors, if the force of mortality is a constant μ, the modal age or mean age at death of last survivor is $\frac{\ln(n)}{\mu}$
- At age 100, μ is about 0.4 yr^{-1}
- Among 100 centenarians, this ultimate age is 100+ln(100)/0.4=111.5 years.
- Among 1000, it is 100+ln(1000)/0.4=117.3

=> 5.8 years gap due to cohort size

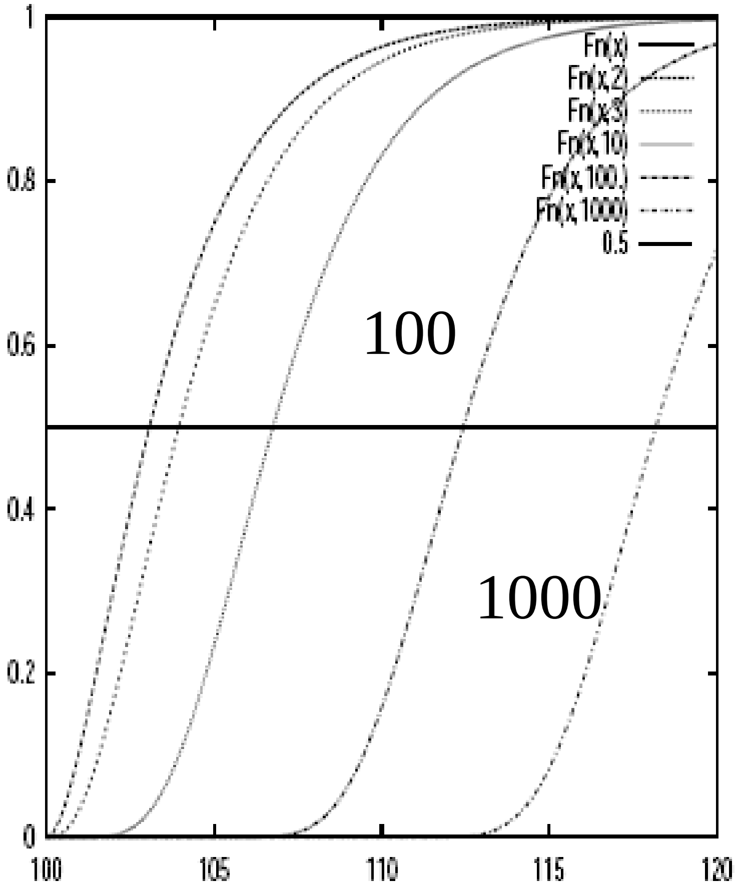


FIG. 2 – Fonctions de répartition de la loi du dernier survivant parmi n nouveaux centenaires.

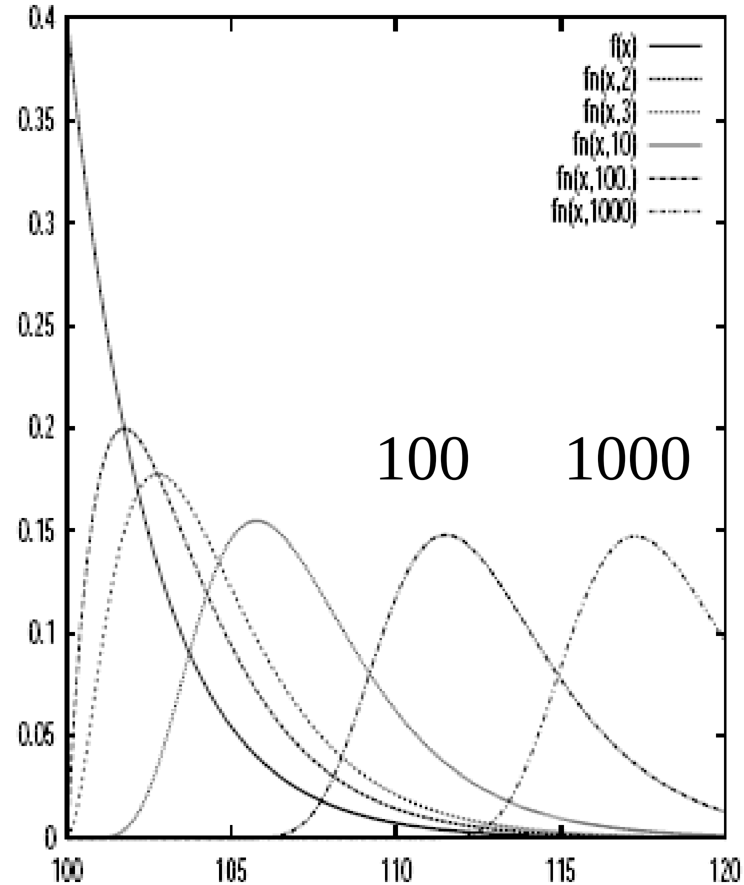
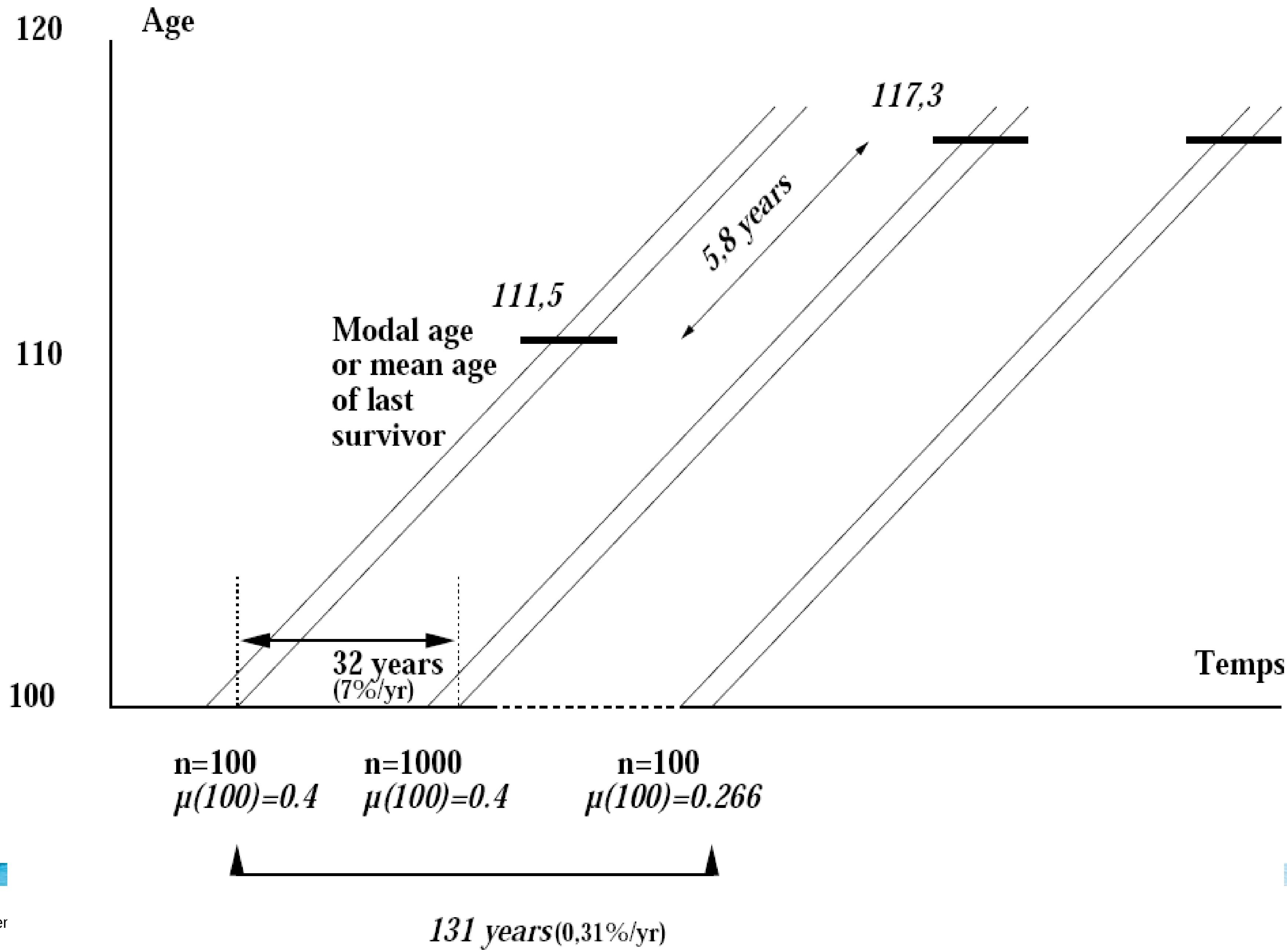


FIG. 3 – Distribution des âges au décès.



120
Age
117,3
5,8 years
111,5
Modal age
or mean age
of last
survivor
110
32 years
(7%/yr)
Temps
100
n=100
μ(100)=0.4
n=1000
μ(100)=0.4
n=100
μ(100)=0.266
131 years (0,31%/yr)

Cohort size effect ...

- Growth rate of centenarians is about 7% per year. It means that a cohort of 100 reaches 1000 in 32 years.
- Thus currently, the consequence of a cohort size effect (n=100 to n=1000 in 32 years) is that the extreme age at death is increased by 5.8 years.

...versus decline of force of mortality

Annual increase of life expectancy is about 3 months per year, which roughly corresponds to an annual decline of the force of mortality of 0.31%.

- In 32 years, the force of mortality will drop from 0.4 to 0.36 only! It isn't low enough to postpone the extreme age of 5.8 years.
- 131 years are needed to reach the required force of mortality level of 0.266.

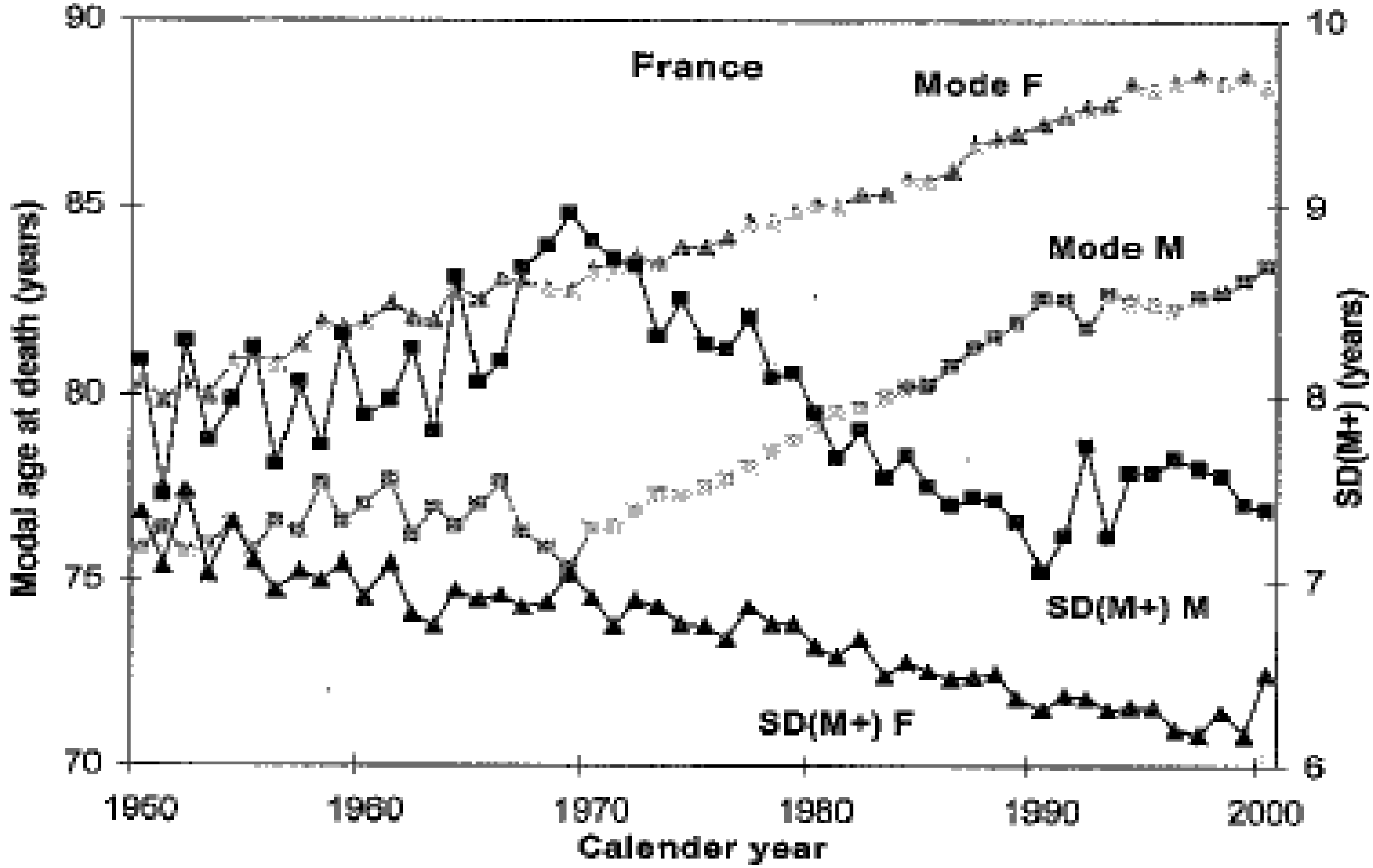
Remarks

- Numerous potential biases
- No deceleration of force of mortality at old ages observed in France when analysis is restricted to reliable data.
- The cohort size effect which results from the historical decline of the mortality before age 100 is much more important than the effect of the mortality decline at and beyond age 100.

Remarks

- This first conclusion came from results of easier calculations under the hypothesis of a constant force of mortality. If we assume, as guessed in the former part, that the Gompertz model holds, the influence of mortality at older age is even more neglectable.

Modal age at death in period life tables
(source: Cheung&Robine Genus 2009)



Probability of death in selected countries (source: UN model life tables Valaoras 1955)

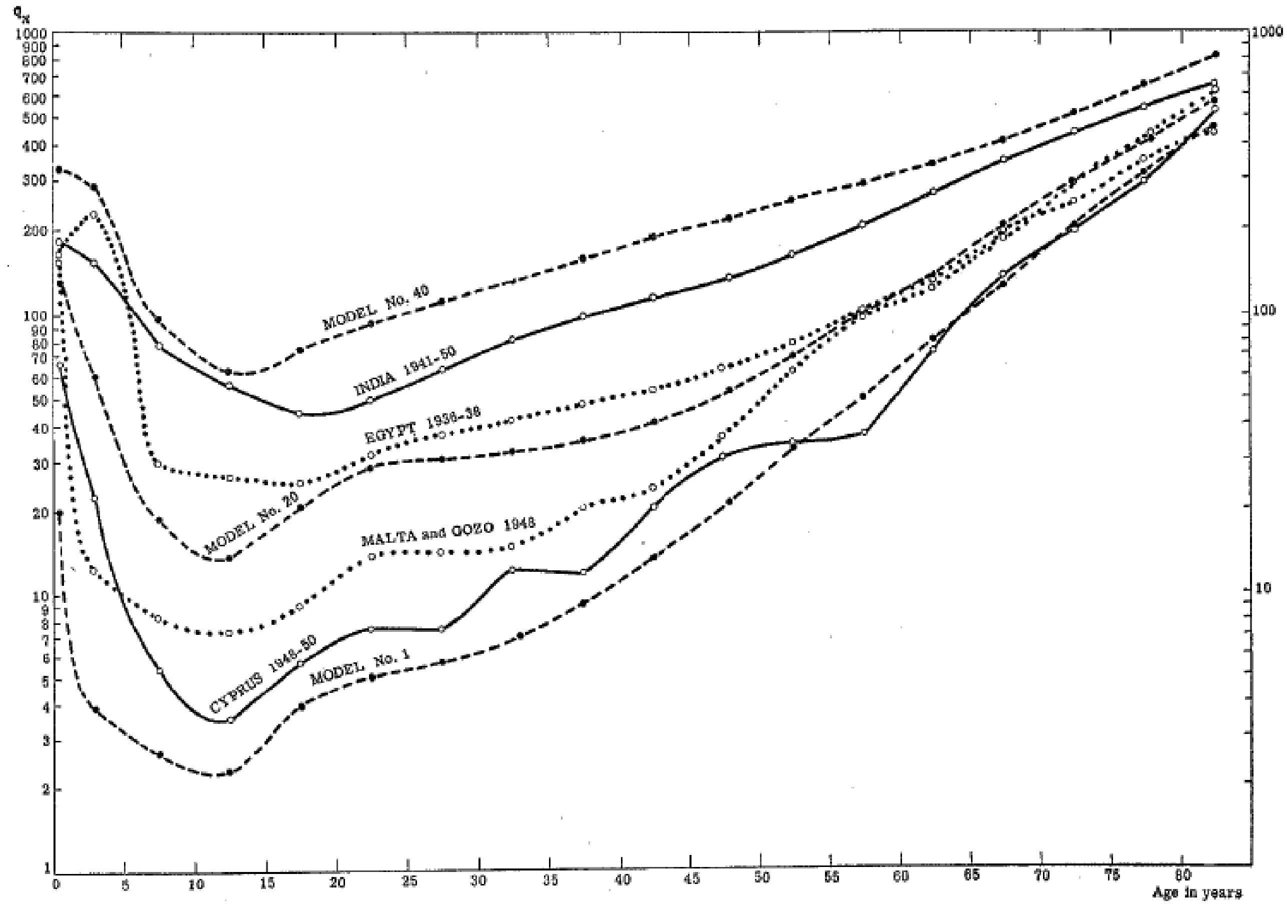


FIGURE 12. COMPARISON OF LIFE-TABLE MORTALITY RATES IN SELECTED COUNTRIES AND CERTAIN MODEL LIFE-TABLES

Probability of death according to UN model life tables (1955)

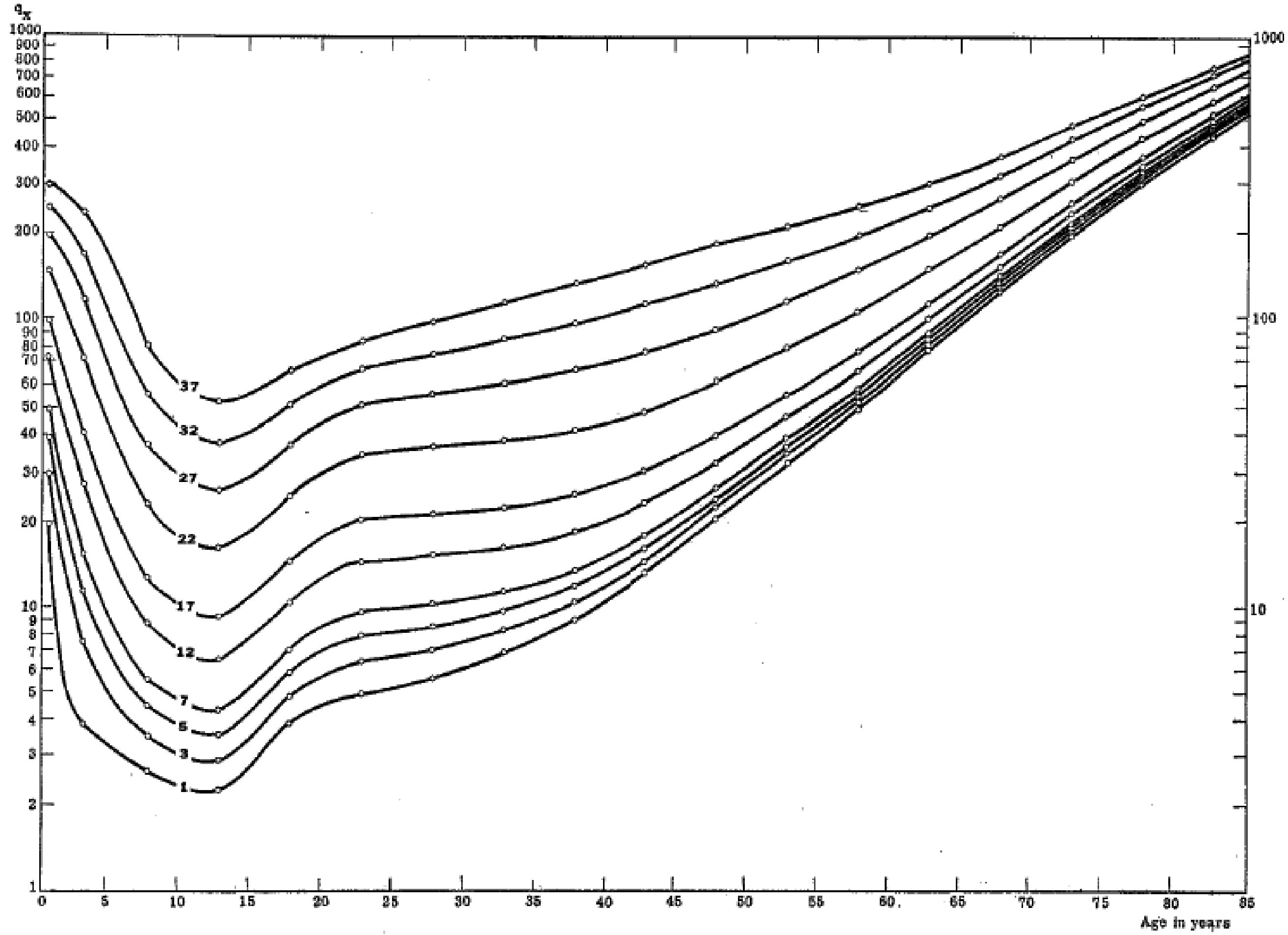
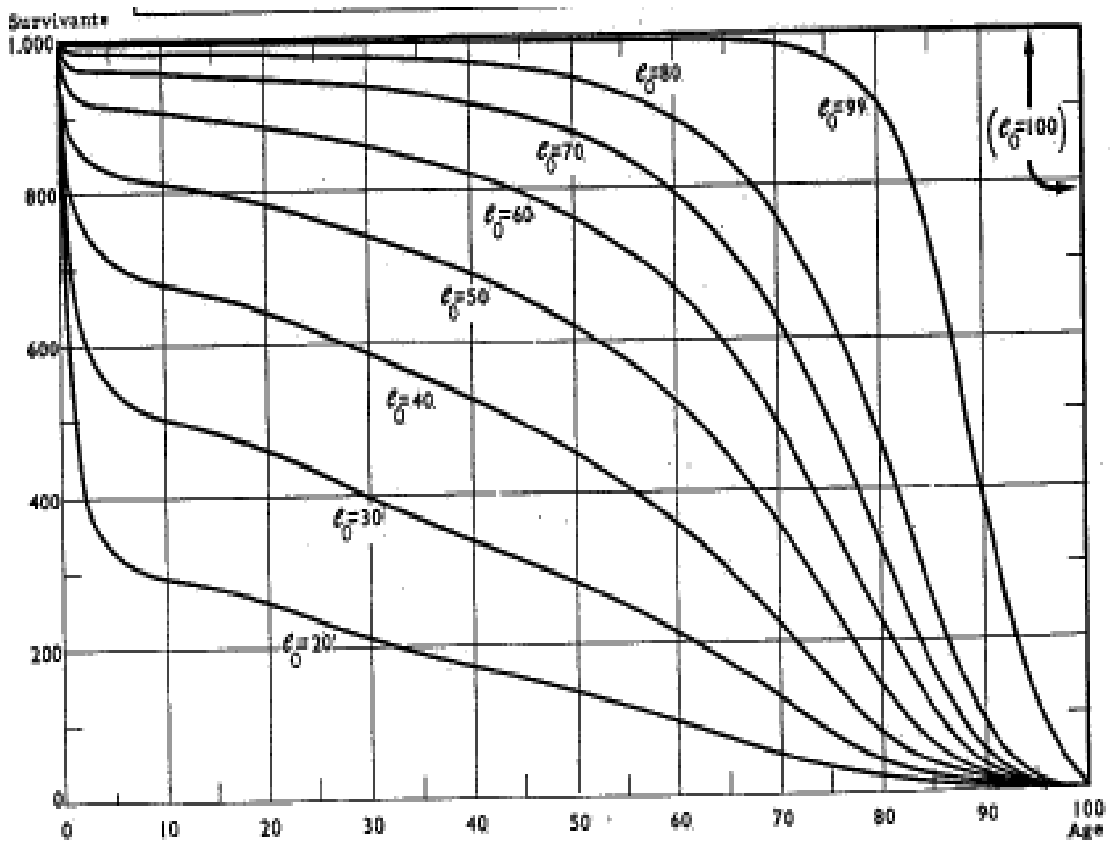


FIGURE 9. MODEL LIFE-TABLES. MORTALITY RATES BY AGE-GROUPS AT SELECTED LEVELS OF GENERAL MORTALITY

Results

- The slope of the Gompertz line increases slightly when mortality declines (coherent with the increase of the modal age in period life tables)
- Higher slope amongst women (lower mortality) than men.
- => Rectangularization and no pure shift.
- => Slow evolution (projections until 2100 !), like in Model life tables

Survival functions
(S. Ledermann model life tables 1969)



GRAPHIQUE 100-1. — Survivants médians selon l'âge sur 1 000 (MF) à la naissance, selon l'espérance de vie e_0 (MF).

END

Projections de la mortalité aux Etats-Unis: polémique

- New England Journal of Medicine 2005
- Jay Olshansky ne croit pas aux projections de la sécurité sociale américaine qui prédisent un accroissement continue de l'espérance de vie en raison principalement de la hausse de l'obésité sous estimée.
- Samuel Prestion soutient les projections mais met en garde également les pouvoirs publics devant l'importance de l'épidémie d'obèses.

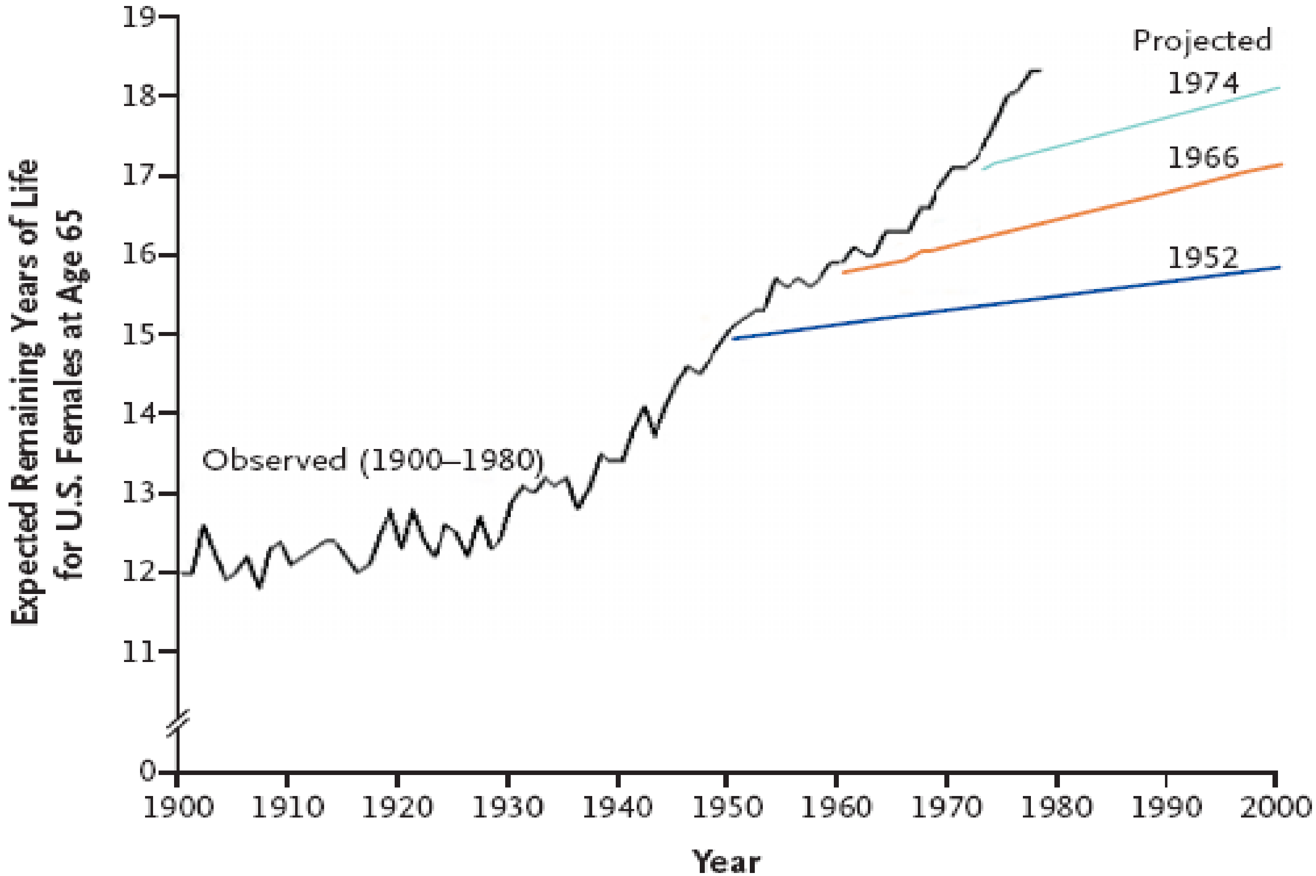


Figure 2. Observed and Projected Life Expectancy at Age 65 for U.S. Females (1900 to 2000).

Shown are observed changes, from 1900 to 1980,[42] in expected remaining years of life at age 65 for females in the United States, and projections of the expected remaining years of life at age 65 made by the SSA in actuarial studies published in 1952,[43] 1966,[44] and 1974.[45]

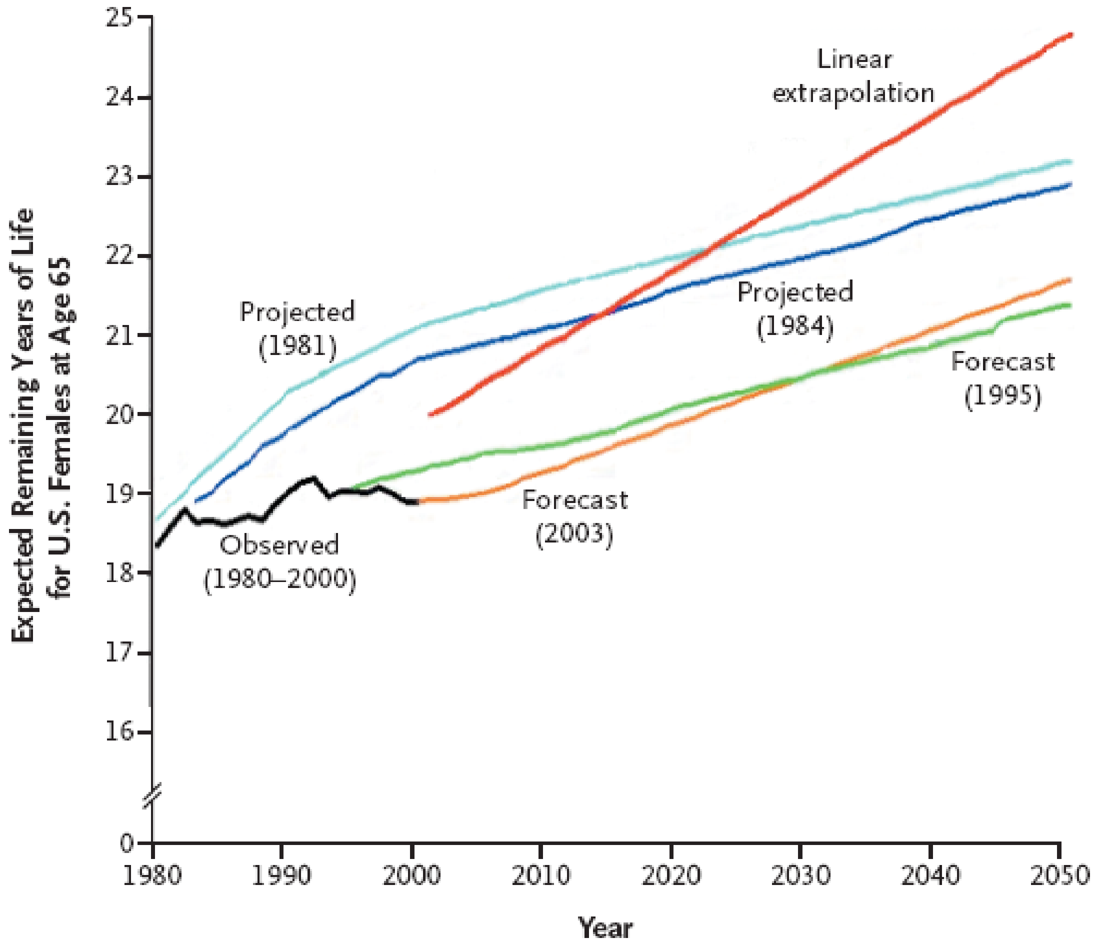


Figure 3. Observed and Projected Life Expectancy at Age 65 for U.S. Females (1980 to 2050).

Shown are observed changes, from 1980 to 2000,[46] in expected remaining years of life at age 65 for females in the United States, projections of the expected remaining years of life at age 65 made by the SSA in actuarial studies published in 1981[46] and 1984,[47] and forecasts based on the SSA's 1995 and 2003 Trustees Reports.[48,49] A forecast of the expected remaining years of life at age 65 for females in the United States, assuming the observed trend from 1940 to 2000 is extrapolated linearly from 2000 to 2050, is shown.

Source: J. Olshansky et al. NEJM, 2005

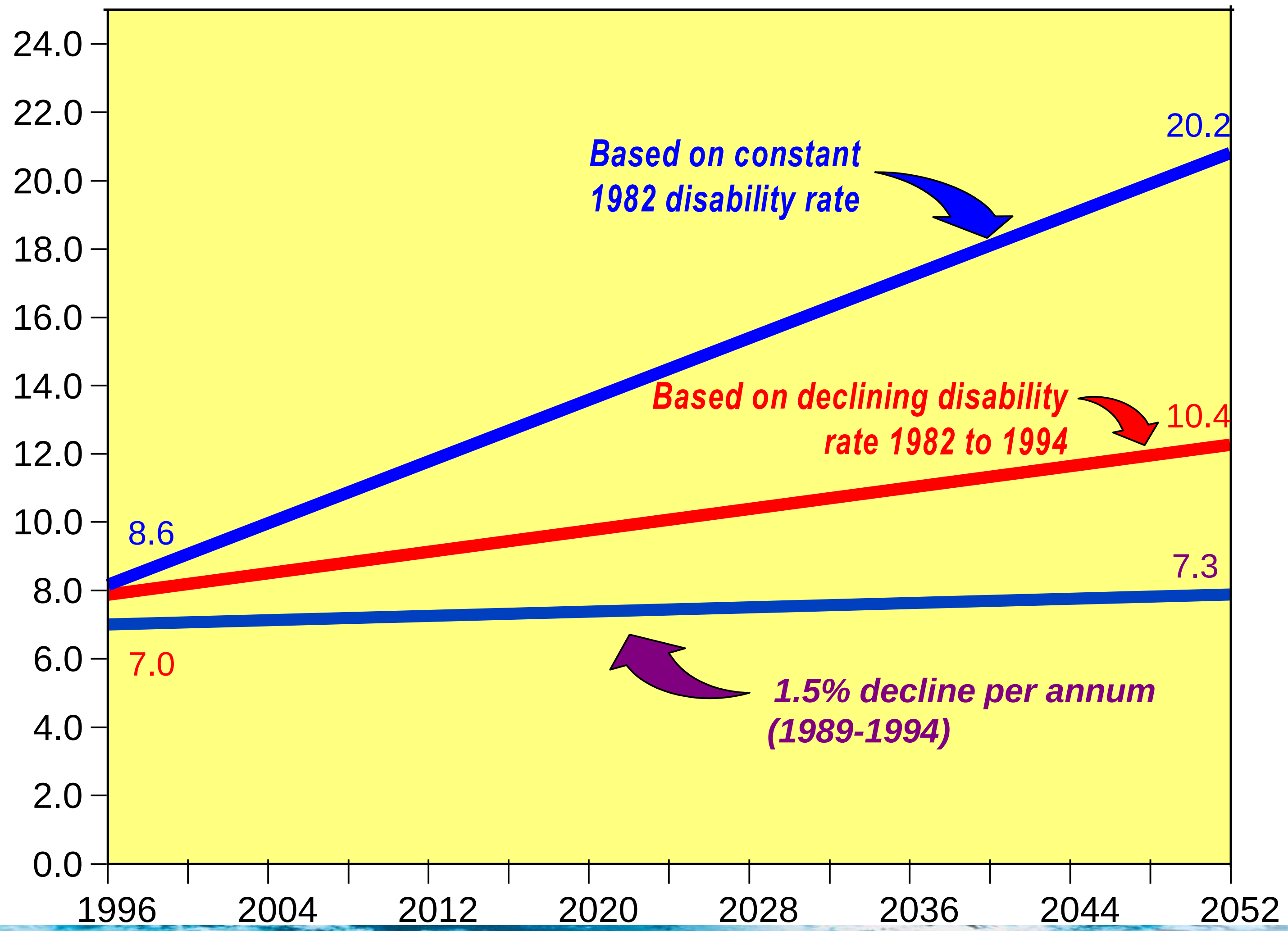
Projections de la mortalité aux Etats-Unis: polémique

- Tabac le point (déclin aux Etats-Unis chez les jeunes
- Cancer du poumon féminin (tabagisme passé) explique la baisse du différentiel H-F aux USA.
- Menaces de l'obésité prise au sérieux (McDonald réduit ses super-size).

Projections de la dépendance aux Etats-Unis

- La dépendance, l'incapacité précèdent la mort.
- Une meilleure prévision de la dépendance induirait une meilleure prévision de la mortalité mais les données manquent.
- Néanmoins, baisse de la dépendance aux Etats Unis mais grande incertitude, encore plus couteuse.

Projections of Number of Disabled Americans Age 65 & Over *(In millions)*

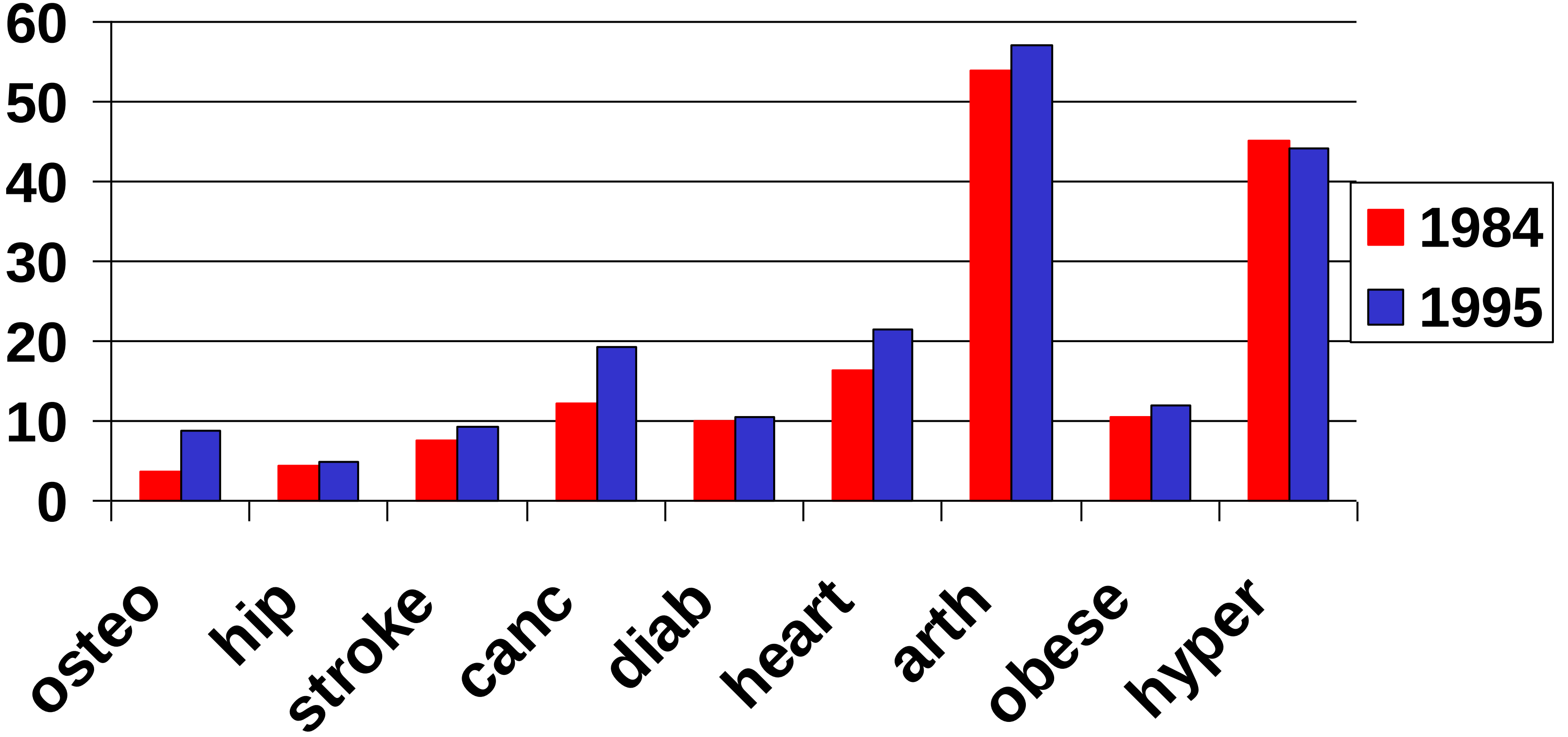


Source: National Long Term Care Survey 1982-1994 (Kenneth Manton, Ph.D.) Revised November 1999

Aux USA

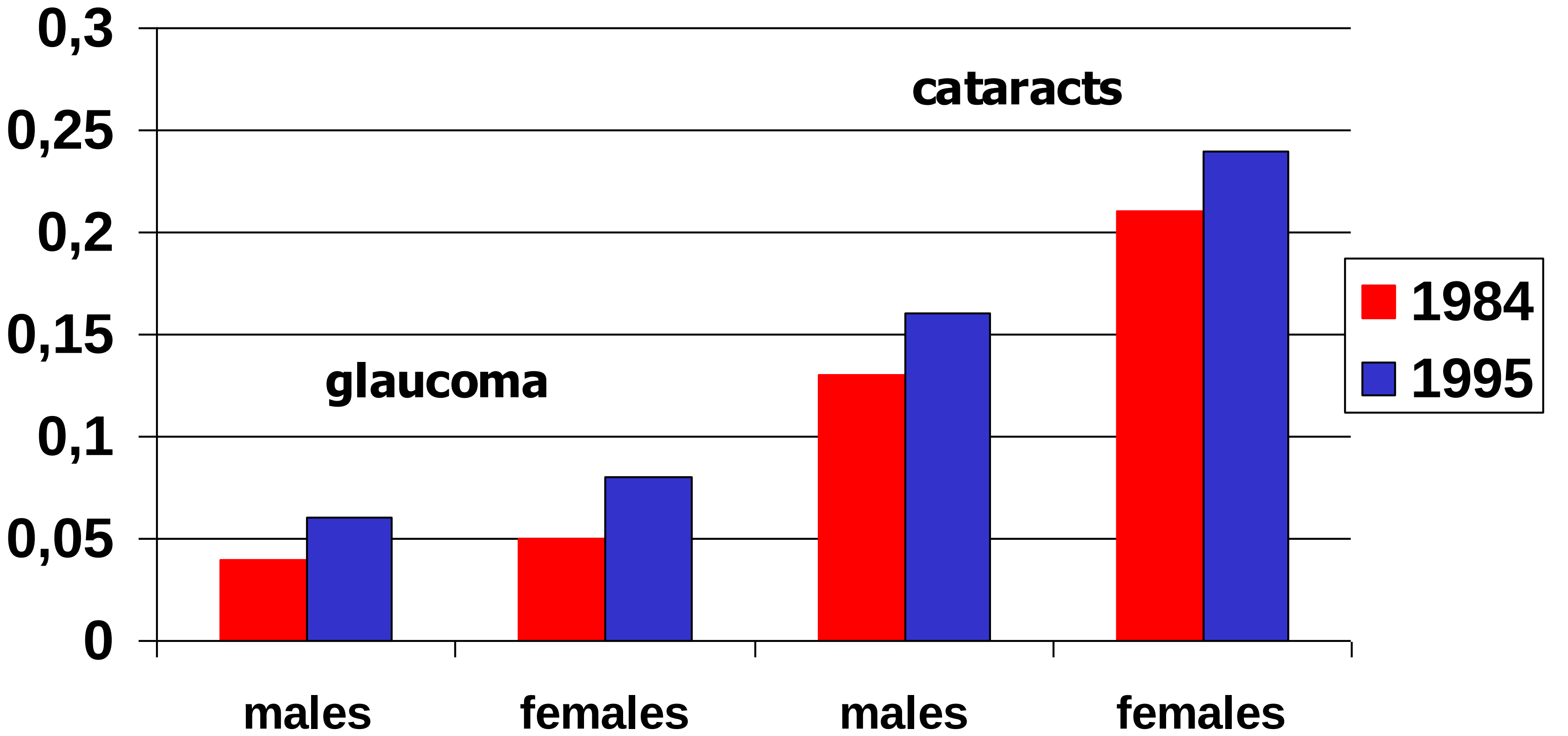
- Relative hausse de la prévalence transversale des maladies chroniques
- Relative baisse de la prévalence des limitations fonctionnelles.

Percent with Chronic Conditions Increased, 70 and Over, 1984 and 1995



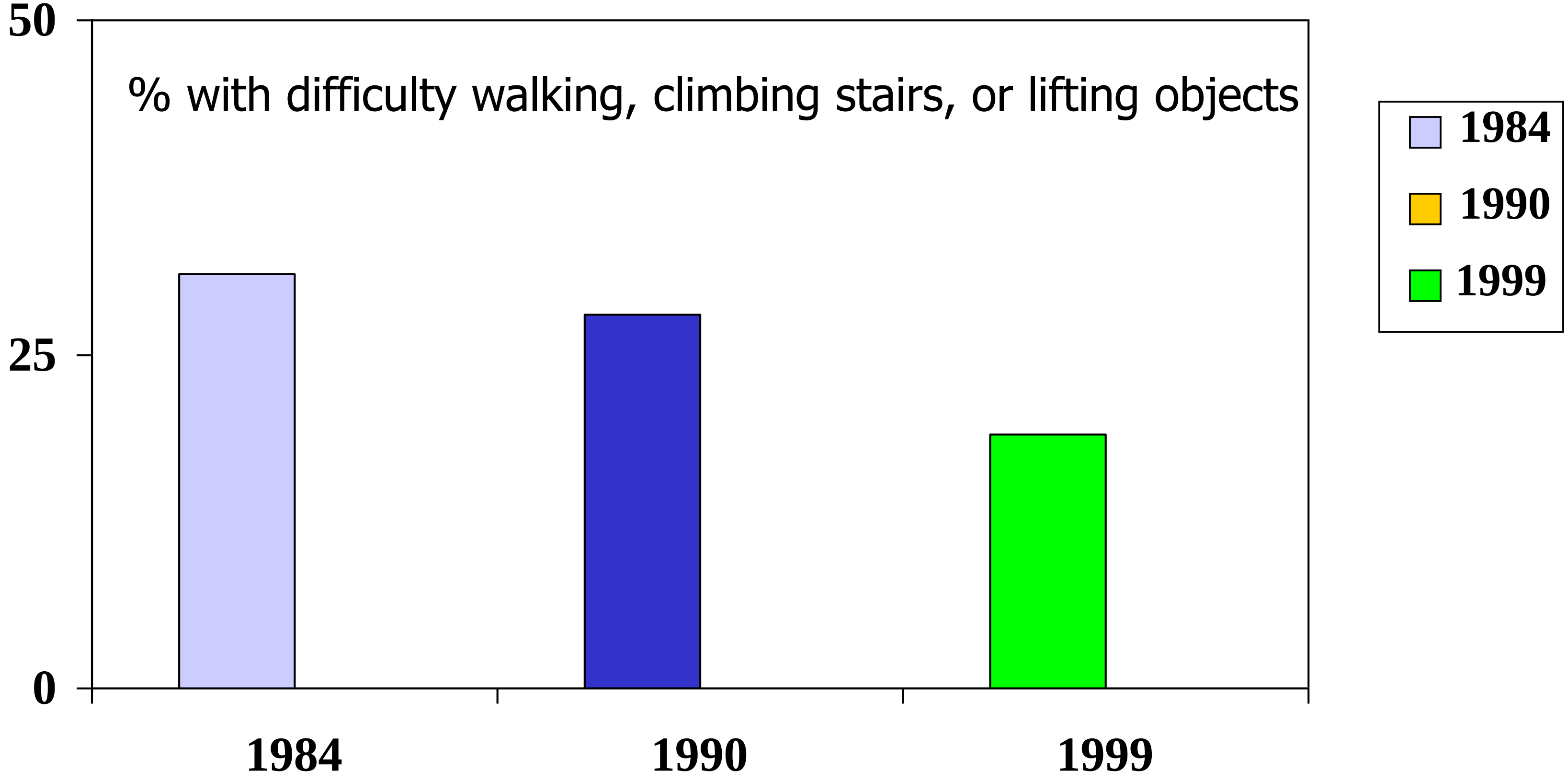
Source: Freedman and Martin, 2000 analysis of SOA I and II

Percent with Vision-Related Chronic Conditions Increased, 70 and Over, 1984 and 1995



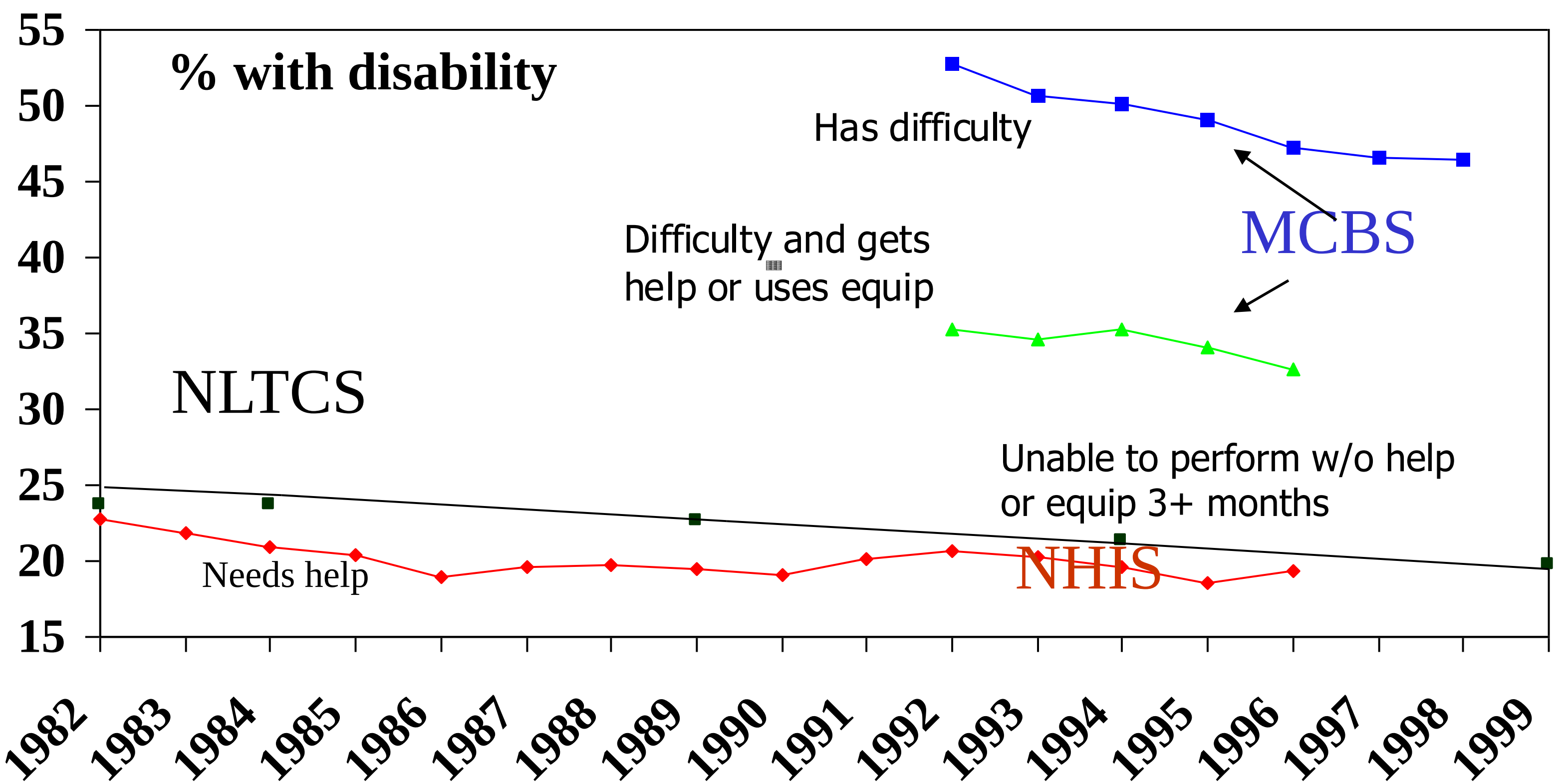
Source: Crimmins and Saito, 2000 analysis of SOA I and II

Percent With Functional Limitations Declined, 65 and Older: 1984, 1990, and 1999



Source: Cutler, 2001, analysis of SIPP.

Physical Disability (ADL or IADL) Declined Among Older Americans, 1982-1996



Source: Schoeni, Freedman, and Wallace, 2001; Manton, 1993; 1997; 2001
Waidmann and Liu, 2000; Unpublished estimates from Lubitz, Kramerow, et al.

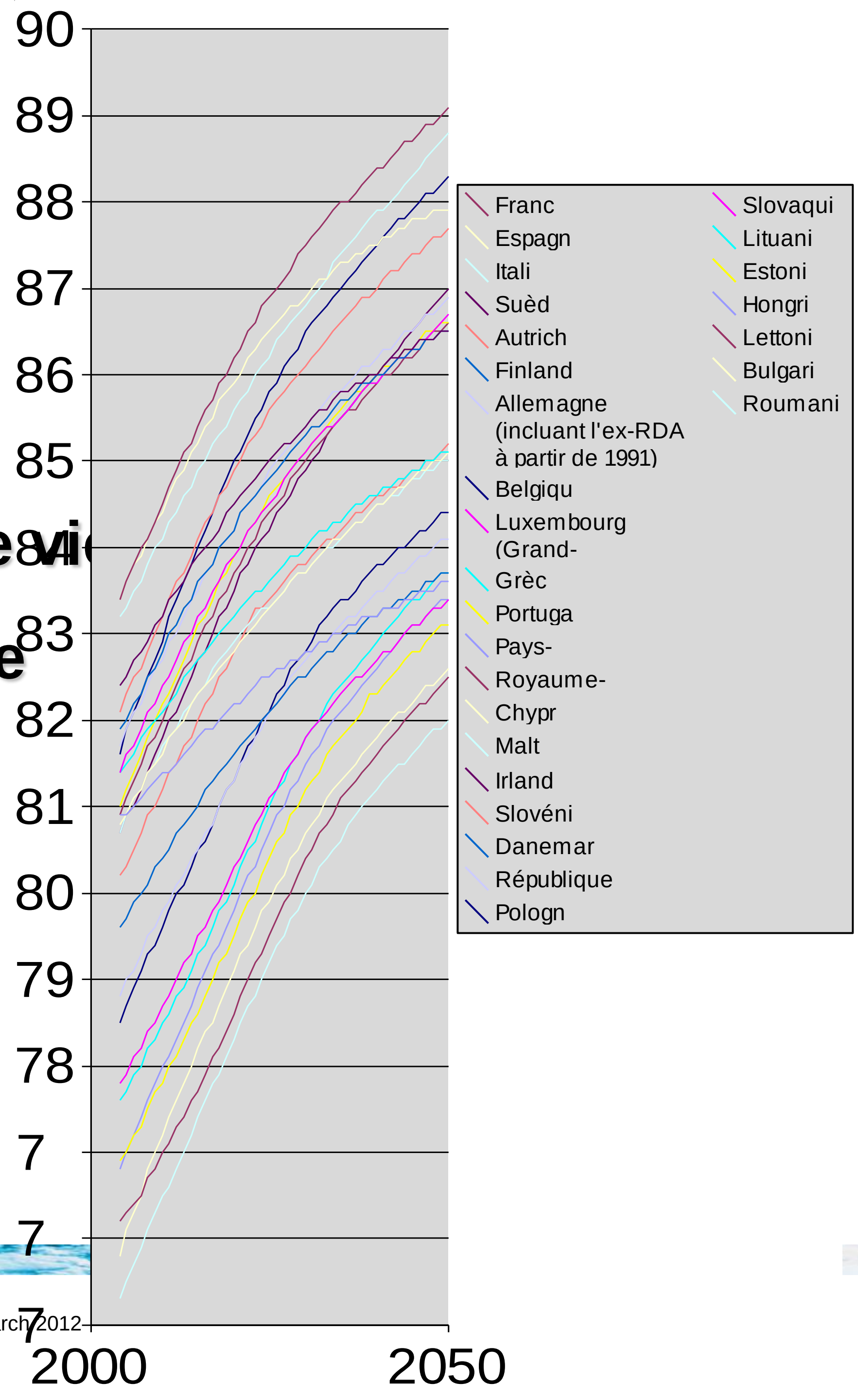
Projection de l'espérance de vie dans l'Union européenne des 25 jusqu'en 2050

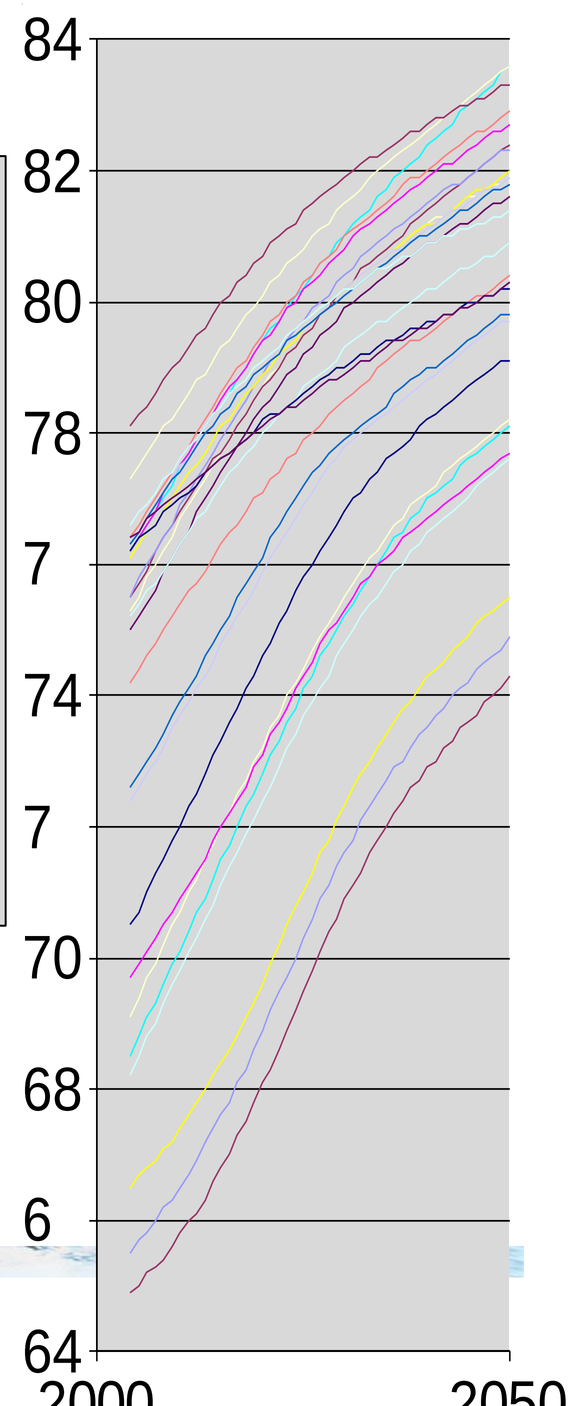
- Les hypothèses sur l'évolution de la mortalité et non plus seulement sur l'évolution de la fécondité sont nouvelles tant à Eurostat qu'à l'INSEE.

Pyramide des âges et rapport de dépendance

- Dans l'UE25, la proportion de personnes âgées (65 ans et plus) qui s'établit à 16,4% en 2004 serait de 29,9% en 2050.
- La proportion des personnes les plus âgées (80 ans et plus) devrait presque tripler au sein de l'UE25, passant de 4,0% en 2004 à 11,4% en 2050.
- Tandis qu'il y avait en 2004 1 inactif (jeune ou âgé) pour deux personnes en âge de travailler, il y aurait en 2050 1,5 inactif pour deux personnes en âge de travailler.

Projection de l'espérance de vie dans l'Union européenne de 2004 à 2050





Decentration of annual central rate of mortality with the increase of age (small effect only)

The rate mx is bounded by μ(x) and μ(x+1) but central age is shifted down from 0.5 to 0.36