The cohort effect: international comparisons and parameterization

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The cohort effect: international comparisons and parameterization

DISCLAIMER

The views expressed in this presentation are my own, and do not represent the views of the IAA or any of its members.

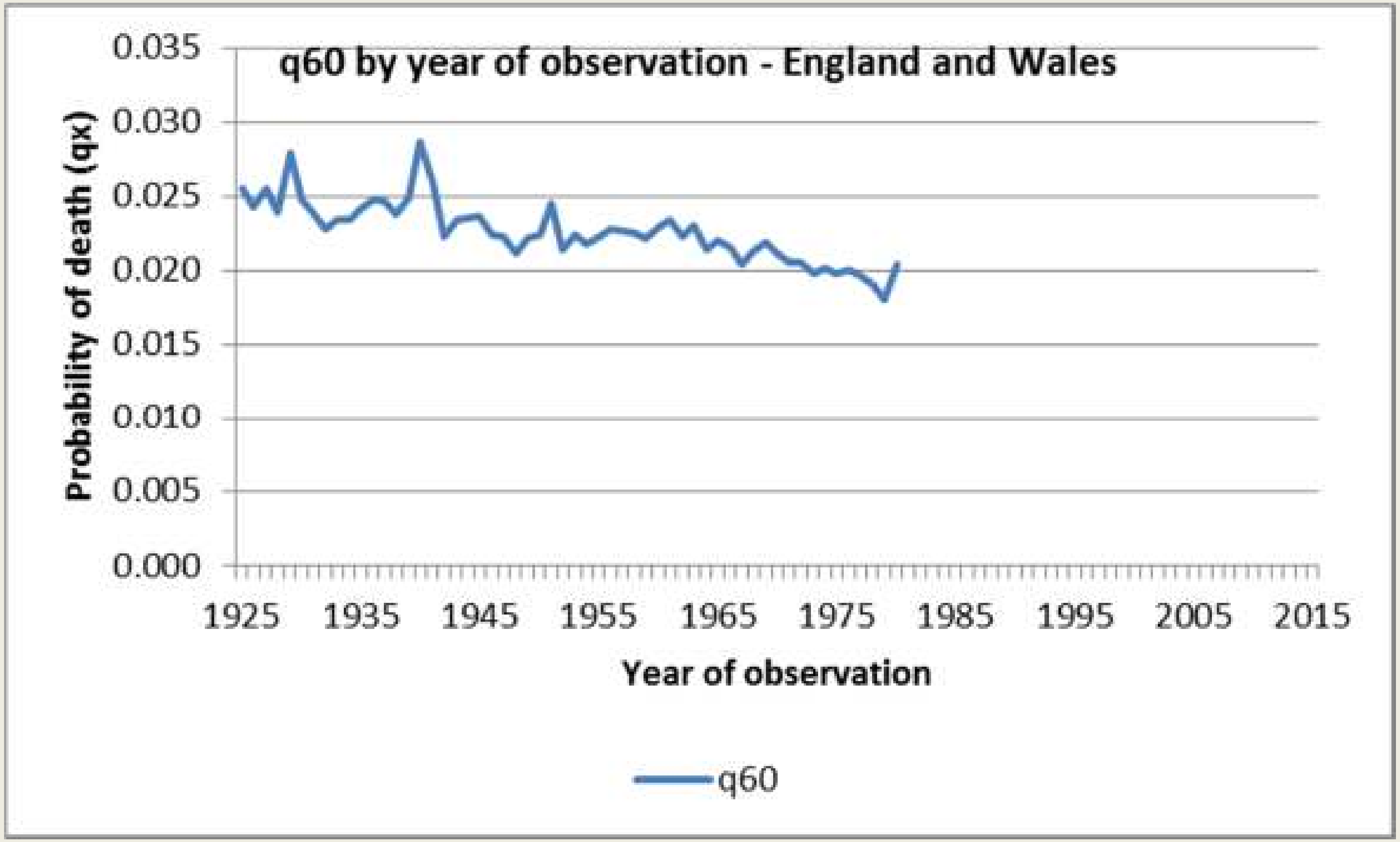
Calculations are based on data from the Human Mortality Database (www.mortality.org) updated to February 2017.

The cohort effect: international comparisons and parameterization

- Demonstrations of the “cohort effect”
- Data sources and smoothing
- International comparisons
- Parameterization
- Results
- Ageing of the cohorts
- What can we learn from this?

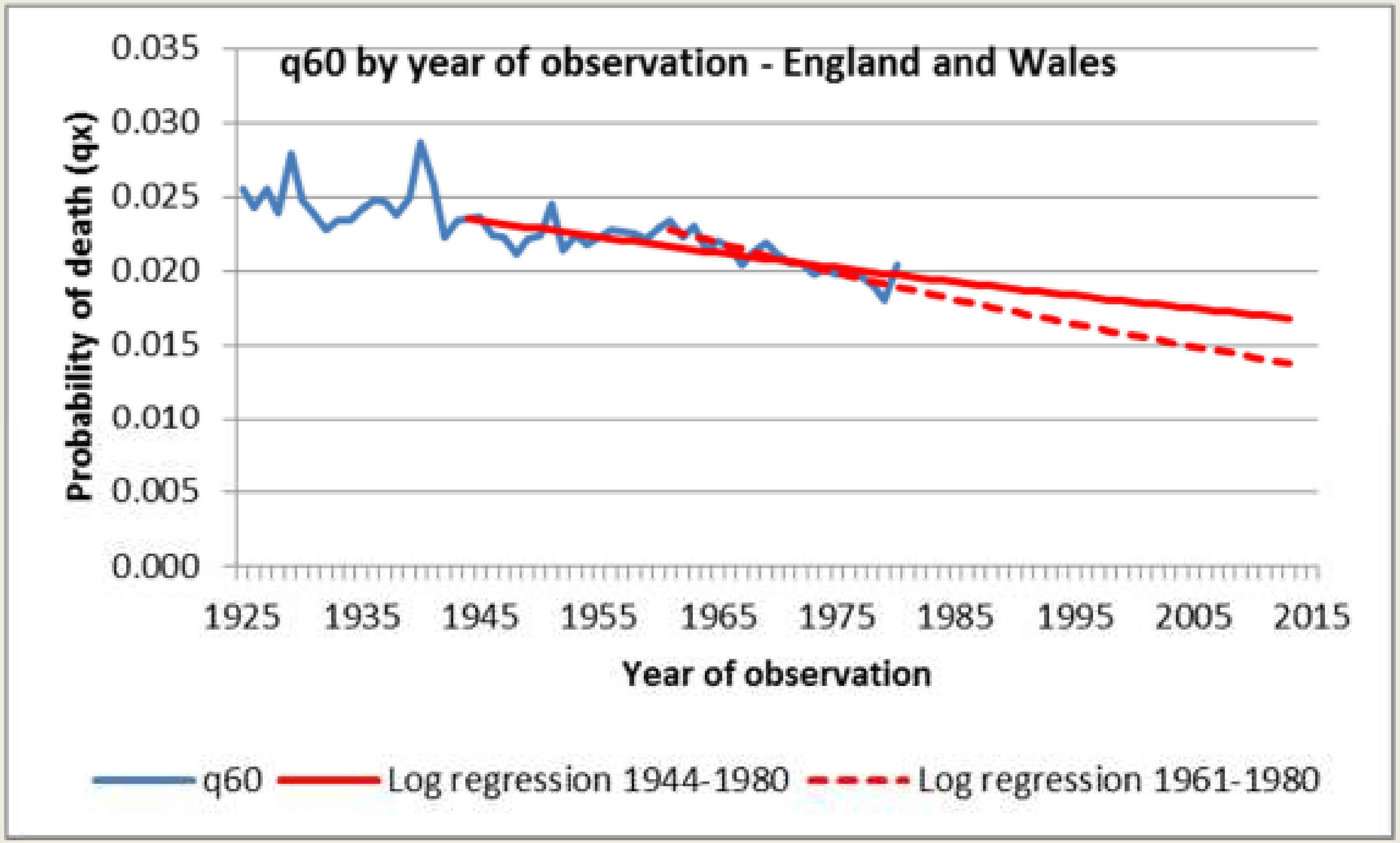
Mortality forecasting – what went wrong?

Suppose we are back in 1980, trying to forecast mortality rates in 35 years' time.



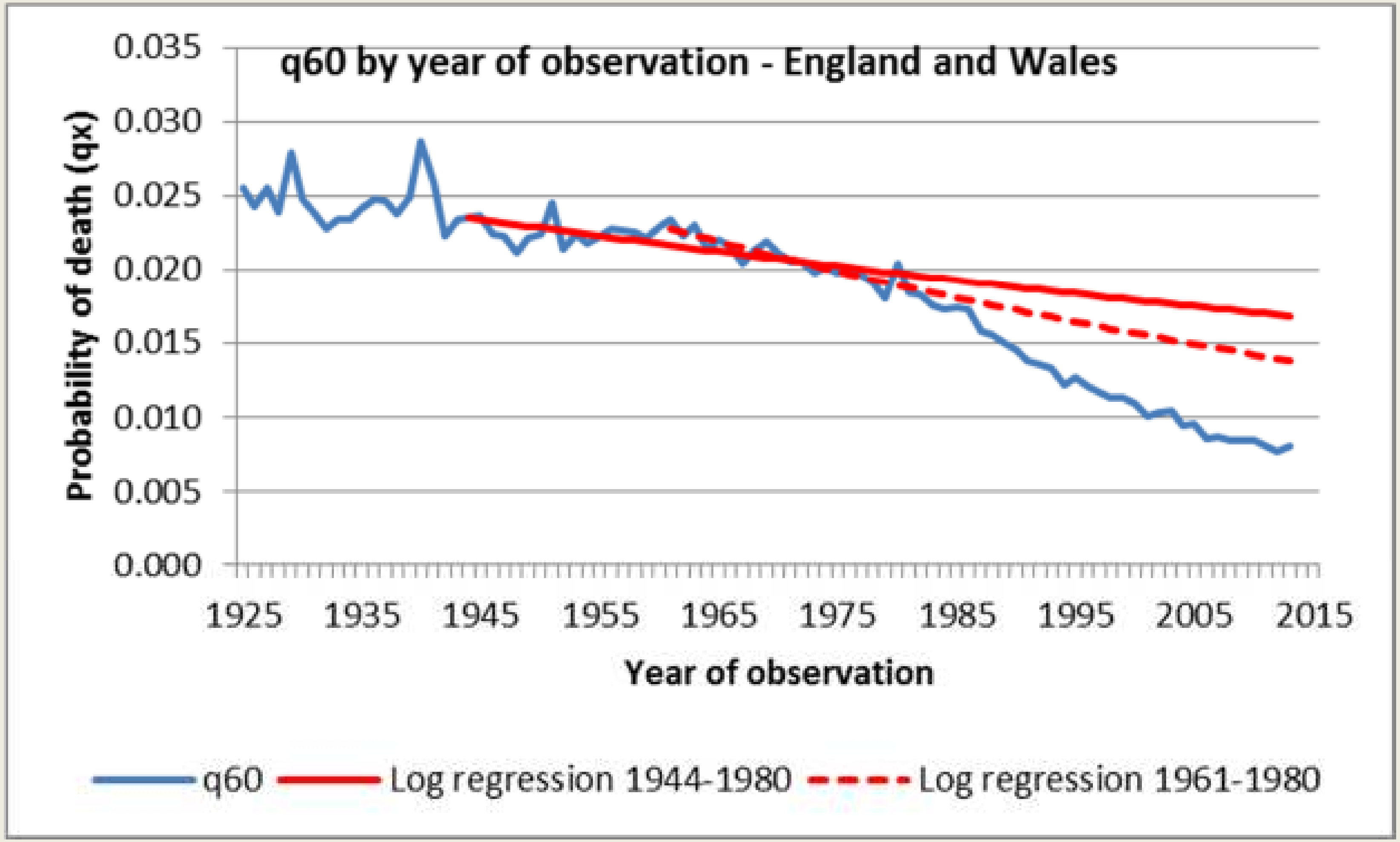
Mortality forecasting – what went wrong?

A simple log-regression model would suggest 17 per mille – perhaps 14 if we are cautious



Mortality forecasting – what went wrong?

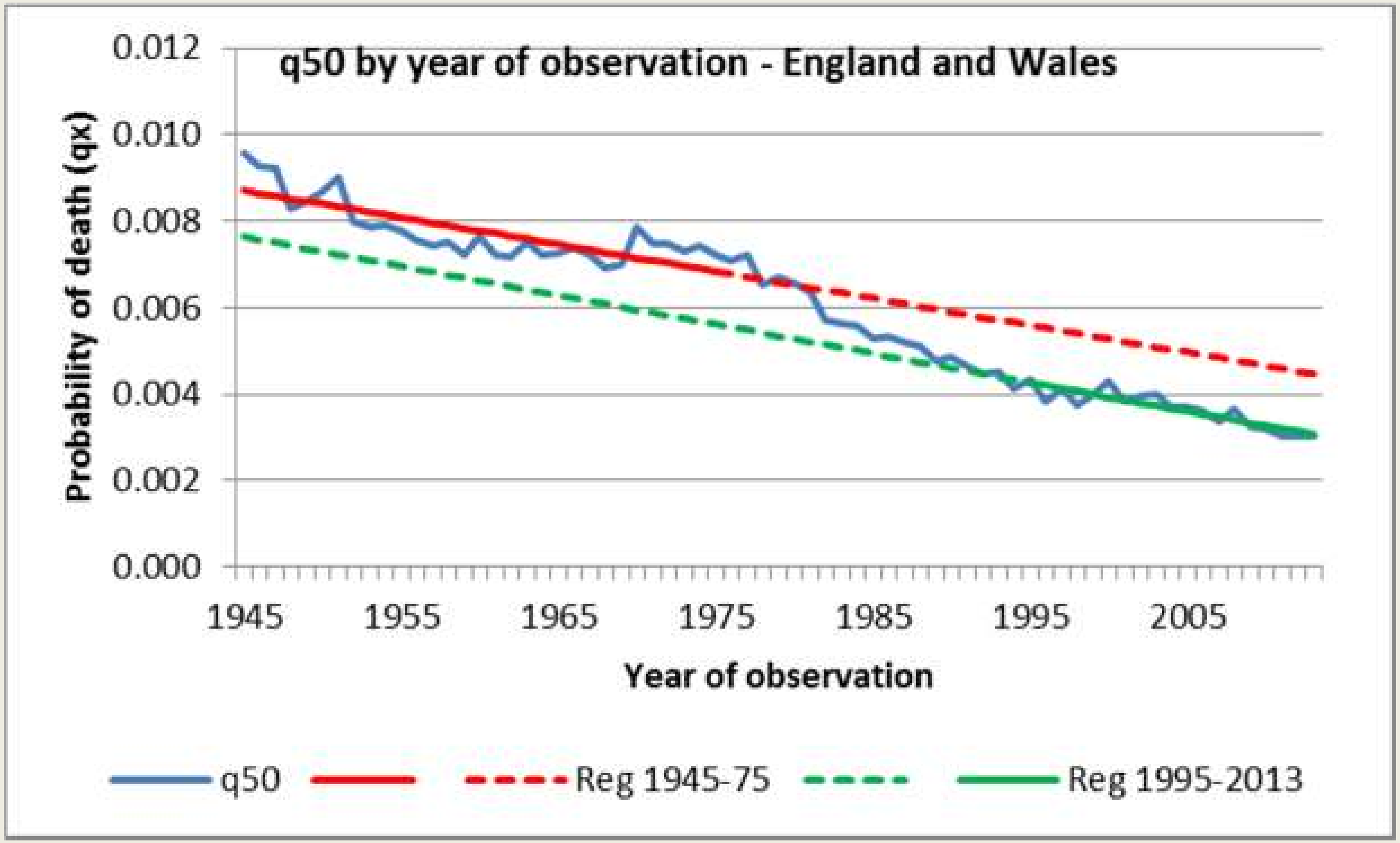
Oops! … q_{60} has actually dropped to 8 per mille in 2013!



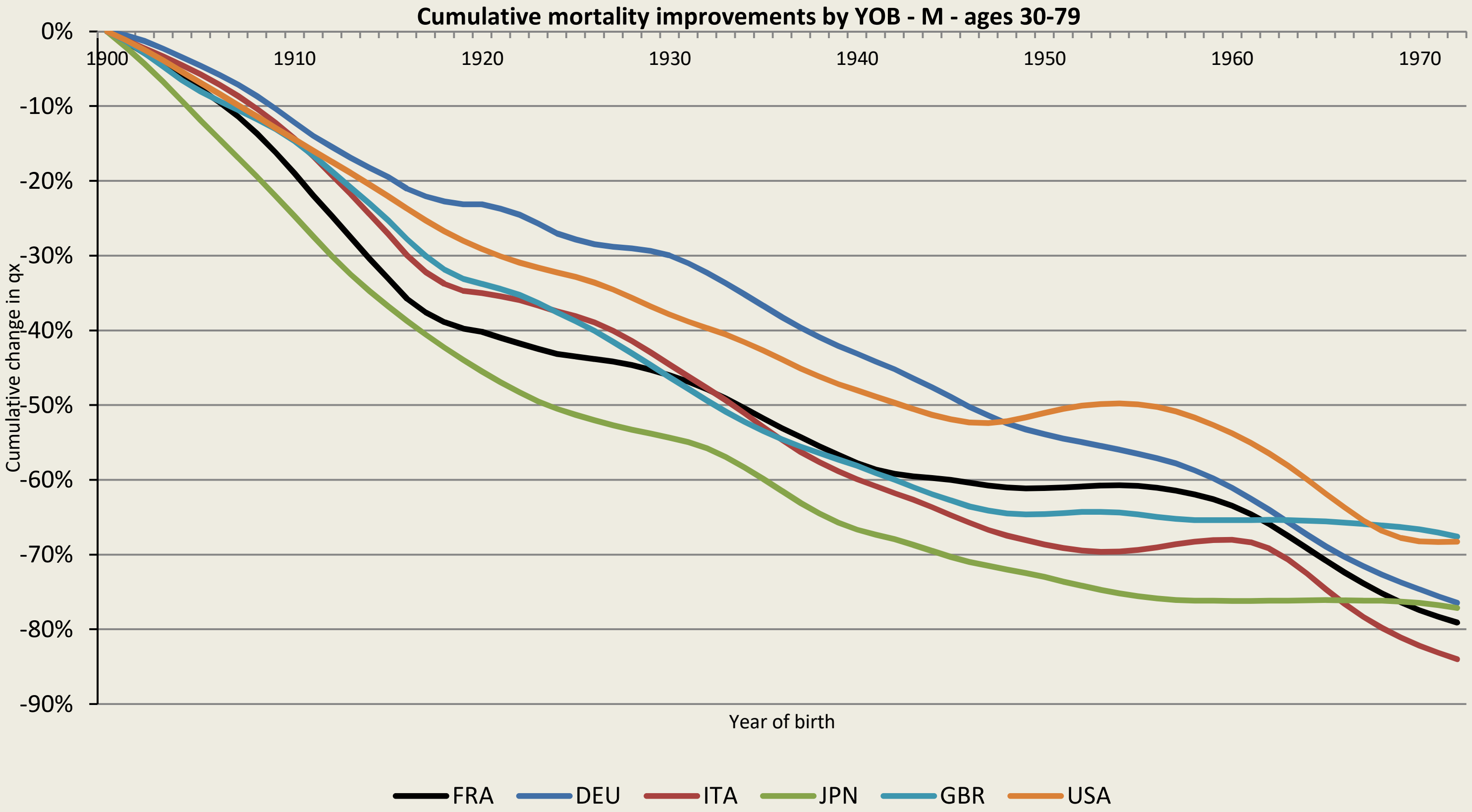
In 2013 in the UK, 2,050 males aged 60 died, much less than "expected" in 1980!

A quantum leap?

The mortality trend seems to have taken a quantum leap downwards – easier to see looking at q_{50}



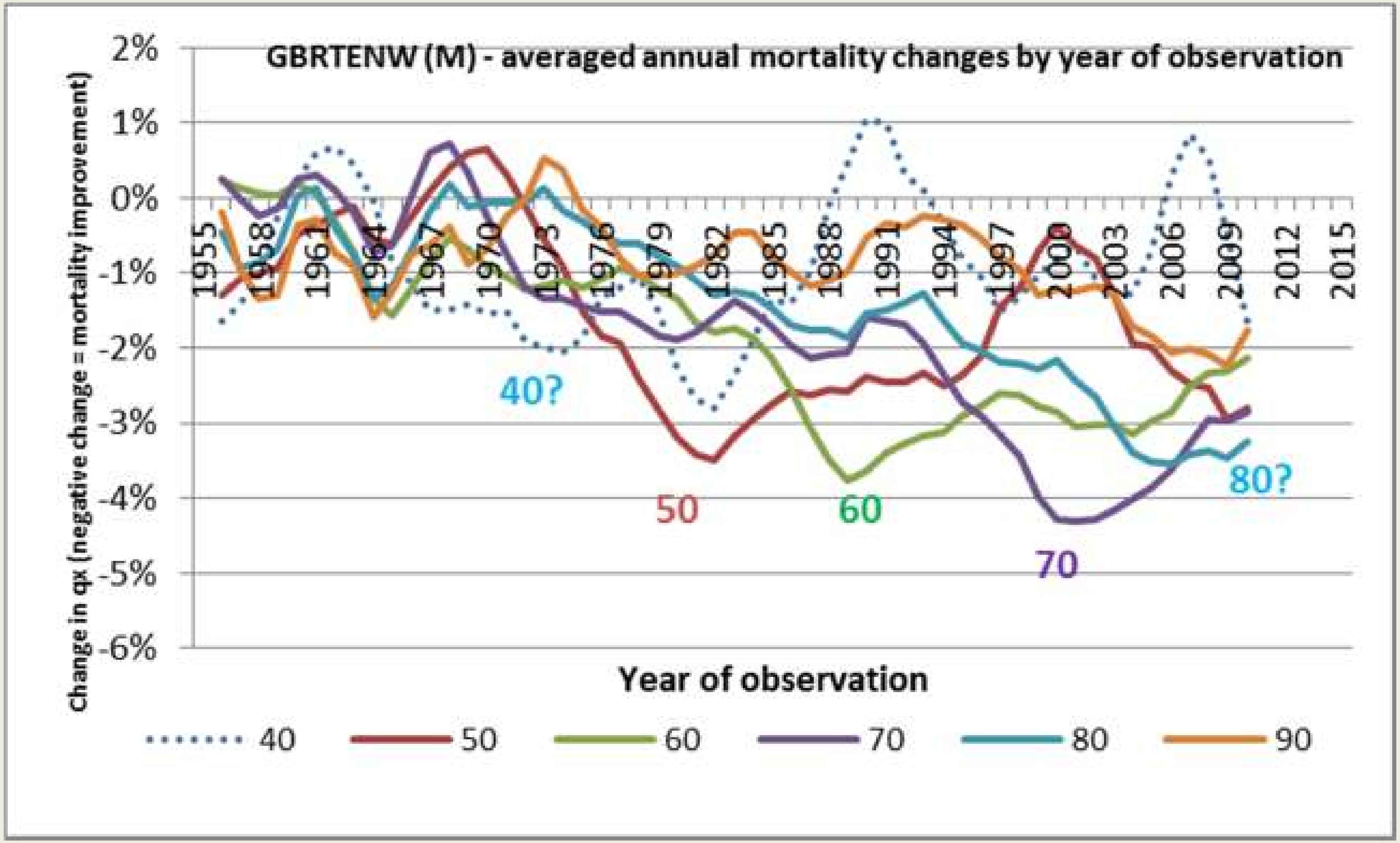
An amazing reduction in q_x over time…



but it is more useful to focus on the **annual change** i.e. $\Delta(\ln q_x)$

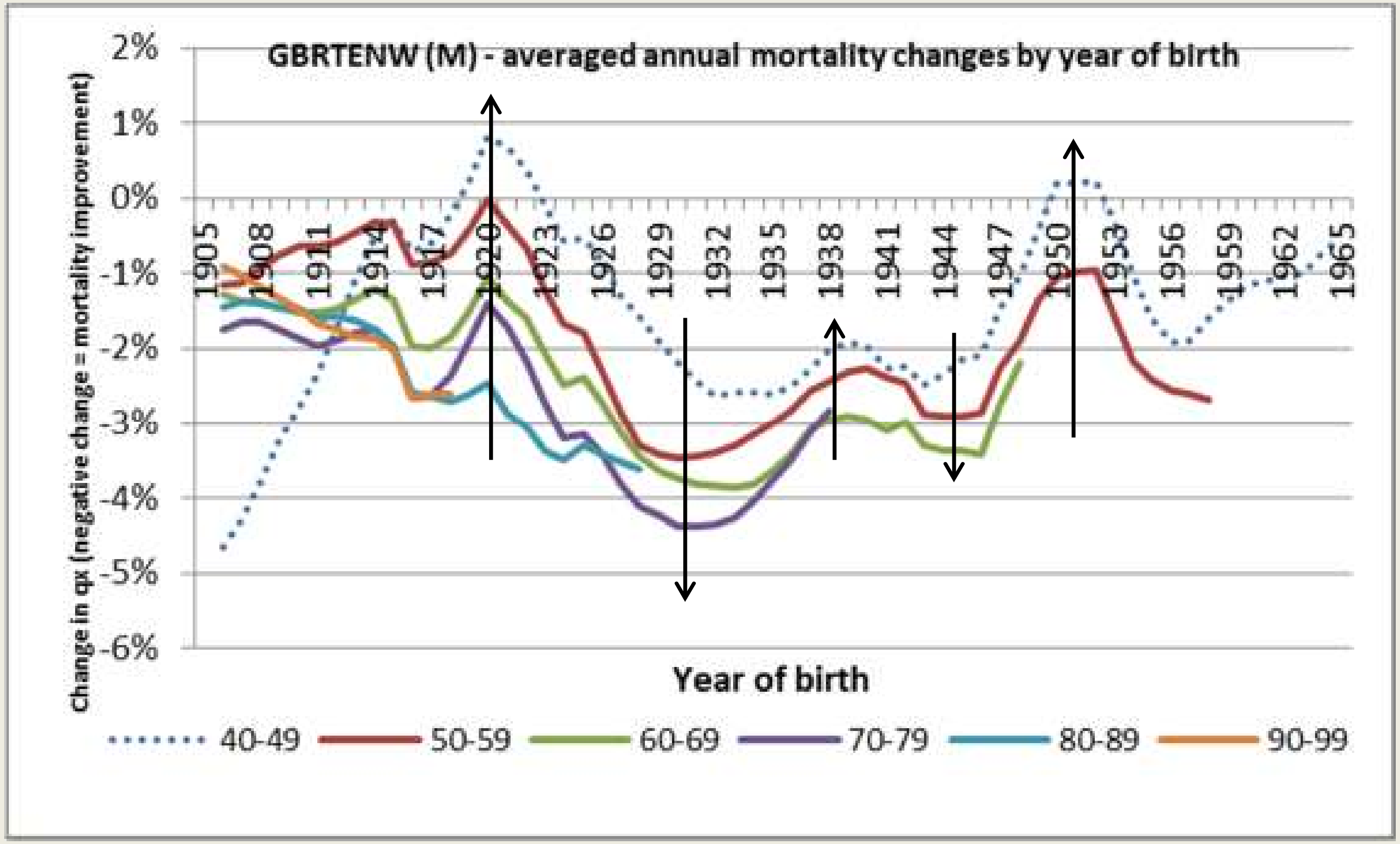
Graphical representations of the "cohort effect"

Willets (1999) pointed out that if we plot the annual change in q_x, we notice that the fastest improvement for lives born in the 1930s (i.e. at different points if the x-axis is year of observation).



Graphical representations of the "cohort effect"

By reorganizing the data by age and **year of birth**, the changes in q_x for different ages converge.



At ages below 35, the effect is not apparent – this makes sense because many deaths at these ages are from accidents or suicide (consistent with UK statistics on cause of death by age).

Questions?

- Why is there a "golden cohort"?
- Is this just a UK phenomenon?
- If it is international, how can we compare the characteristics of cohort effects in different countries?
- Could this be useful for analysing cohort effects at earlier or later dates?

A brief history of cohorts

- The first known demonstration of the cohort effect was by Derrick (1927): “Cohort rates (based on birth year) are more useful for mortality projections than period rates (based on observation year)”.
- Similar arguments were made by Kermack et al. (1934), who pointed out that in a matrix of mortality probabilities arranged by age and observation years, similar rates of improvement are apparent along **diagonal lines**.
- Subsequently, use of cohorts seems to have fallen from popularity until the end of the century. Hobcraft et al. (1982) were convinced that cohort effects had a minor influence on mortality changes.

Why is there a "golden cohort"?

Richard Willets (1999, 2004) noted that "For the past four decades, people [in England and Wales] born between 1925 and 1945 have benefited from faster mortality improvements than those born in adjacent generations".

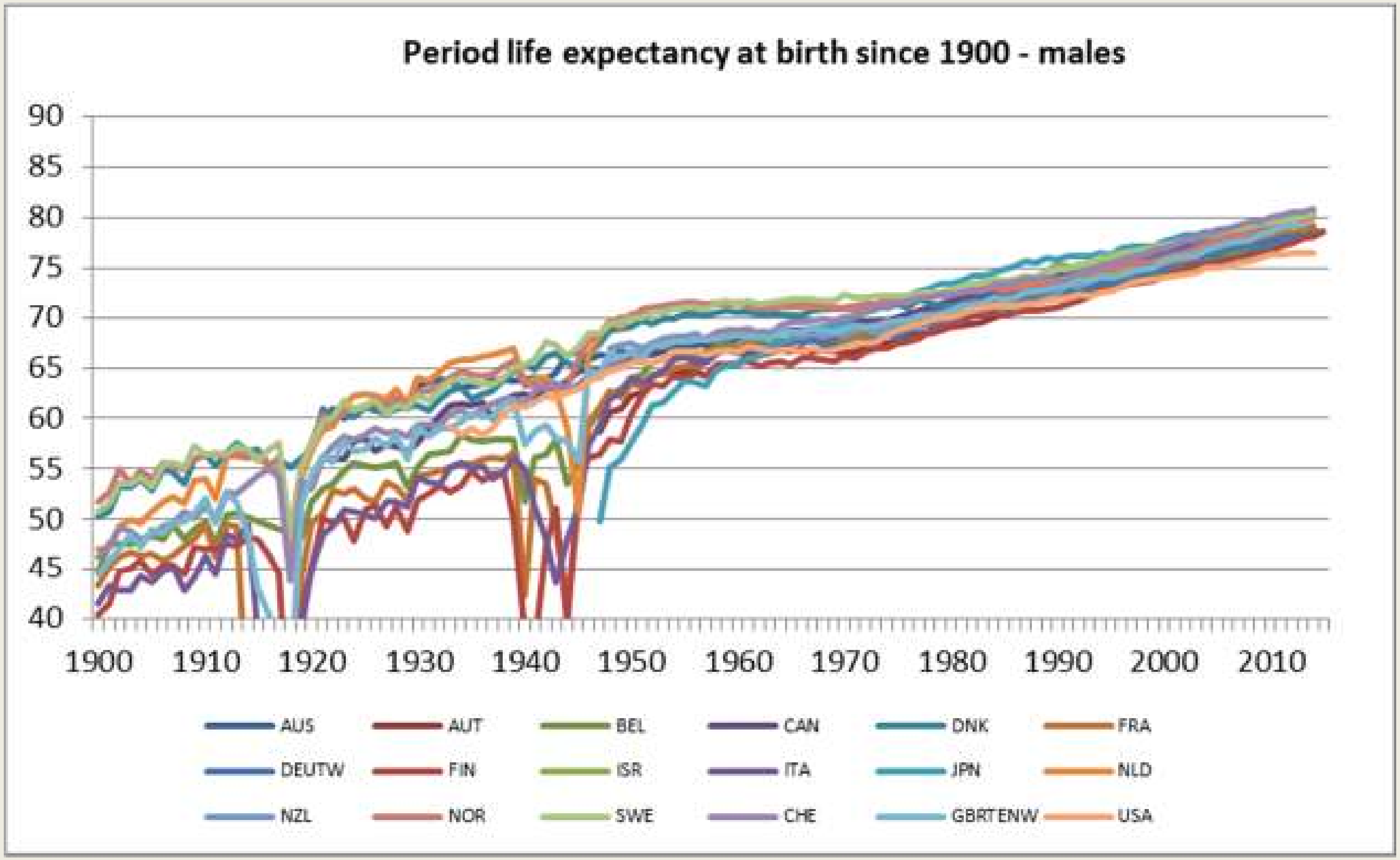
He also noted that mortality of lives under 40 behaved differently, e.g. because of increasing drug and alcohol abuse.

Why is there a “golden cohort”?

Possible reasons for the dramatic improvements for this cohort are:

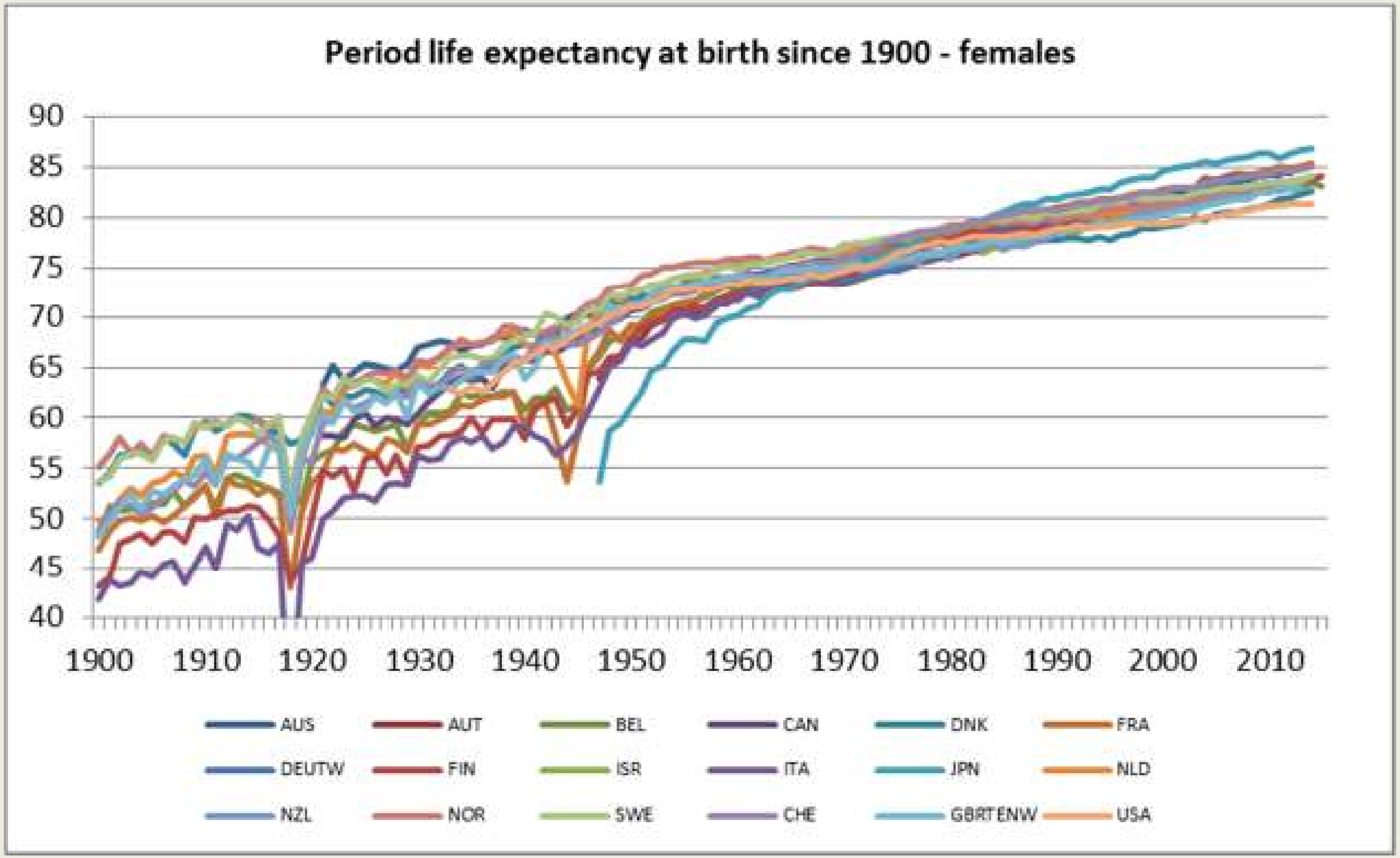
- better childhood health
- the conquest of infectious diseases
- a decline in smoking
- lower fertility
- a healthier diet during post-World War II rationing
- the welfare state
- screening for breast cancer (which became available in 1988, when the relevant cohorts would have benefited).

The actuarial global village



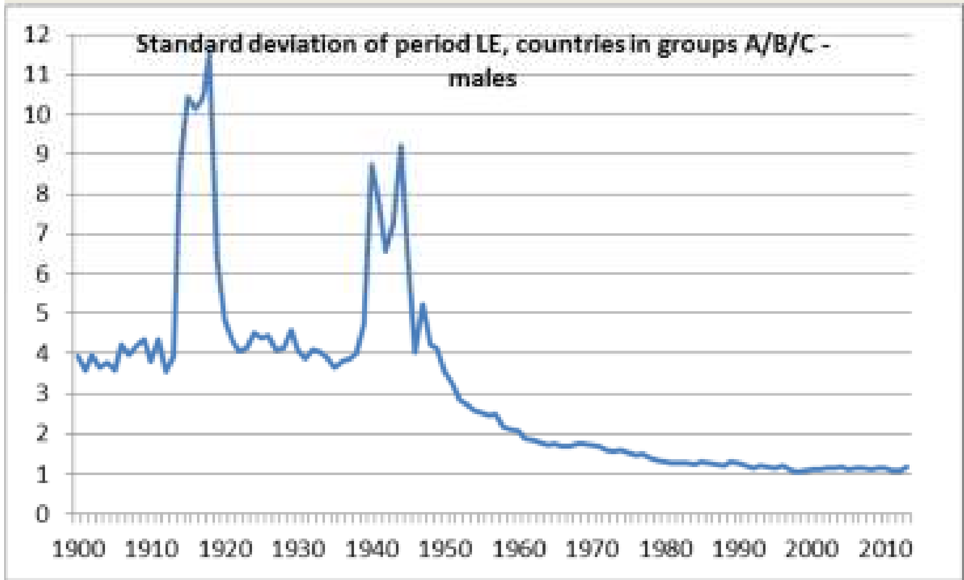
A comparison of life expectancy in 18 major countries (not including Eastern Europe) shows **convergence** over the course of the 20th century. (in the first half, only 10-13 countries are represented.)

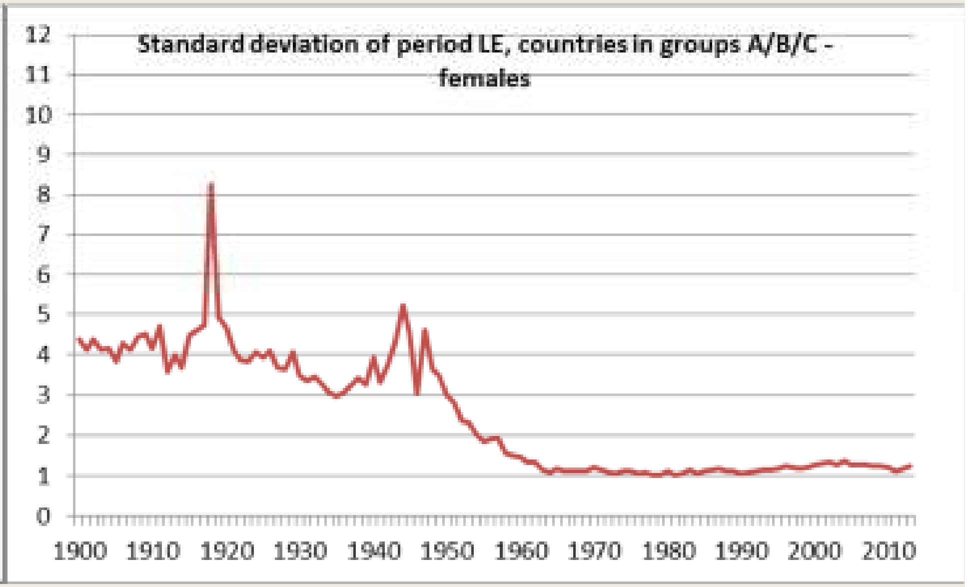
The actuarial global village



A comparison of life expectancy in 18 major countries (not including Eastern Europe) shows **convergence** over the course of the 20th century. (in the first half, only 10-13 countries are represented.)

The actuarial global village





The standard deviation of this group of countries has reduced from 4 to ~1, both for males and females. → similarities between countries? (although even within the same country there can be significant differences based on ethnic origin, socio-economic status etc.)

Data sources and smoothing

- The Human Mortality Database (HMD) provides population data by sex, age and observation year for 38 countries. We have reorganized the data by sex, age and birth year.
- In order to smooth out random fluctuations between ages and birth years, we use a weighted 7x7 two-dimensional moving average, where the weight of each cell is determined by its distance from the central cell. (Other choices are possible, but this seems to give the best mix of smoothing without damping real changes.)

0.00	**0.39**	**0.84**	**1.00**	**0.84**	**0.39**	**0.00**
0.39	**1.17**	**1.76**	**2.00**	**1.76**	**1.17**	**0.39**
0.84	**1.76**	**2.59**	**3.00**	**2.59**	**1.76**	**0.84**
1.00	**2.00**	**3.00**	**4.00**	**3.00**	**2.00**	**1.00**
0.84	**1.76**	**2.59**	**3.00**	**2.59**	**1.76**	**0.84**
0.39	**1.17**	**1.76**	**2.00**	**1.76**	**1.17**	**0.39**
0.00	**0.39**	**0.84**	**1.00**	**0.84**	**0.39**	**0.00**

International comparisons

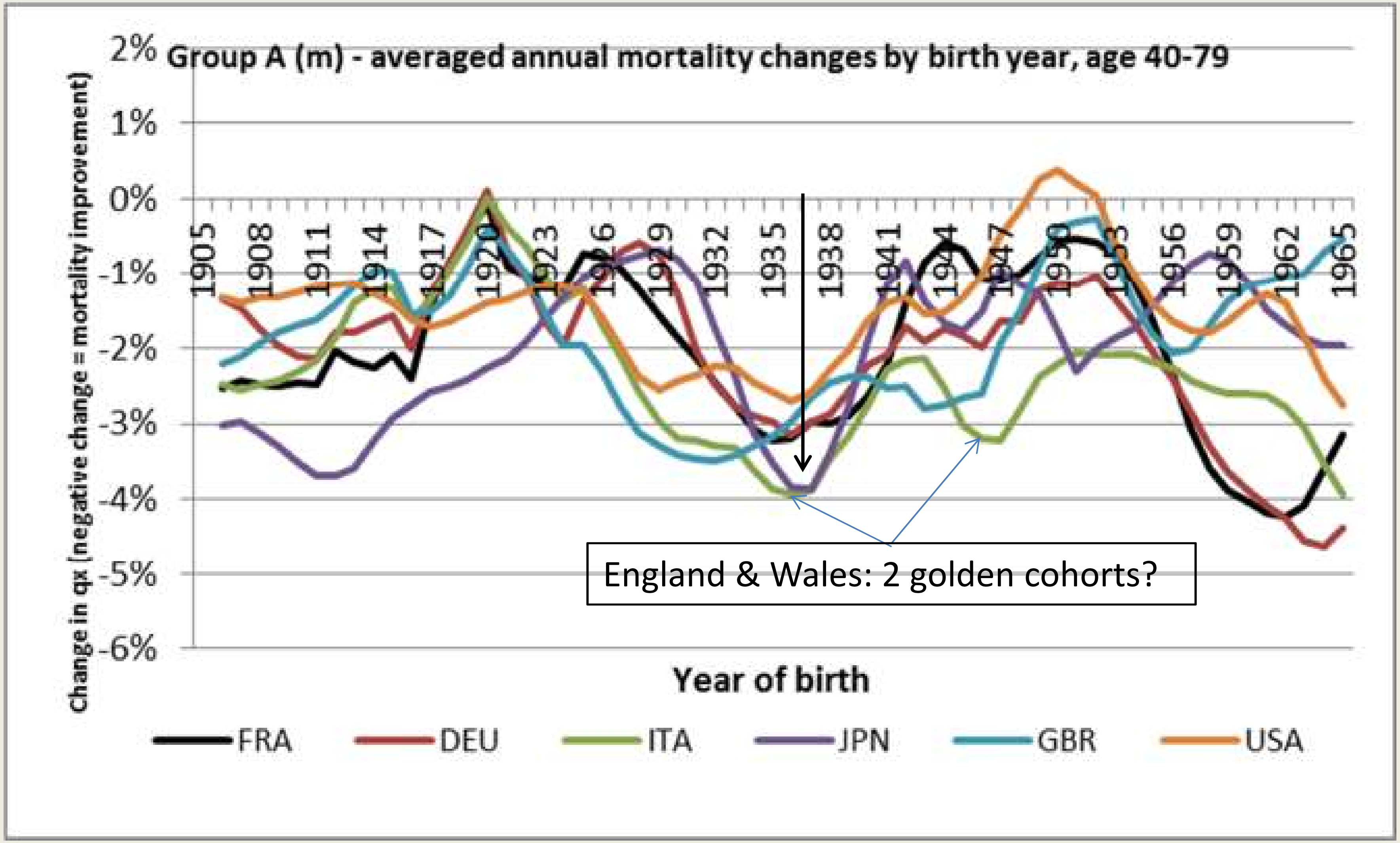
We compared annual mortality changes between countries, grouped as follows:

A	FRA	DEU	ITA	JPN	GBR	USA			Population over 50m
B	AUS	BEL	CAN	NLD	SWE				Population 10-50m
C	AUT	DEN	FIN	ISR	IRL	NOR	NZL	CHE	Population less than 10m
E	CZE	HUN	POL	RUS	UKR				Eastern Europe
X	Others								Too small / data queries

The study relates to the 19 countries in groups A/B/C for males and females – a total of 38 "data sets".

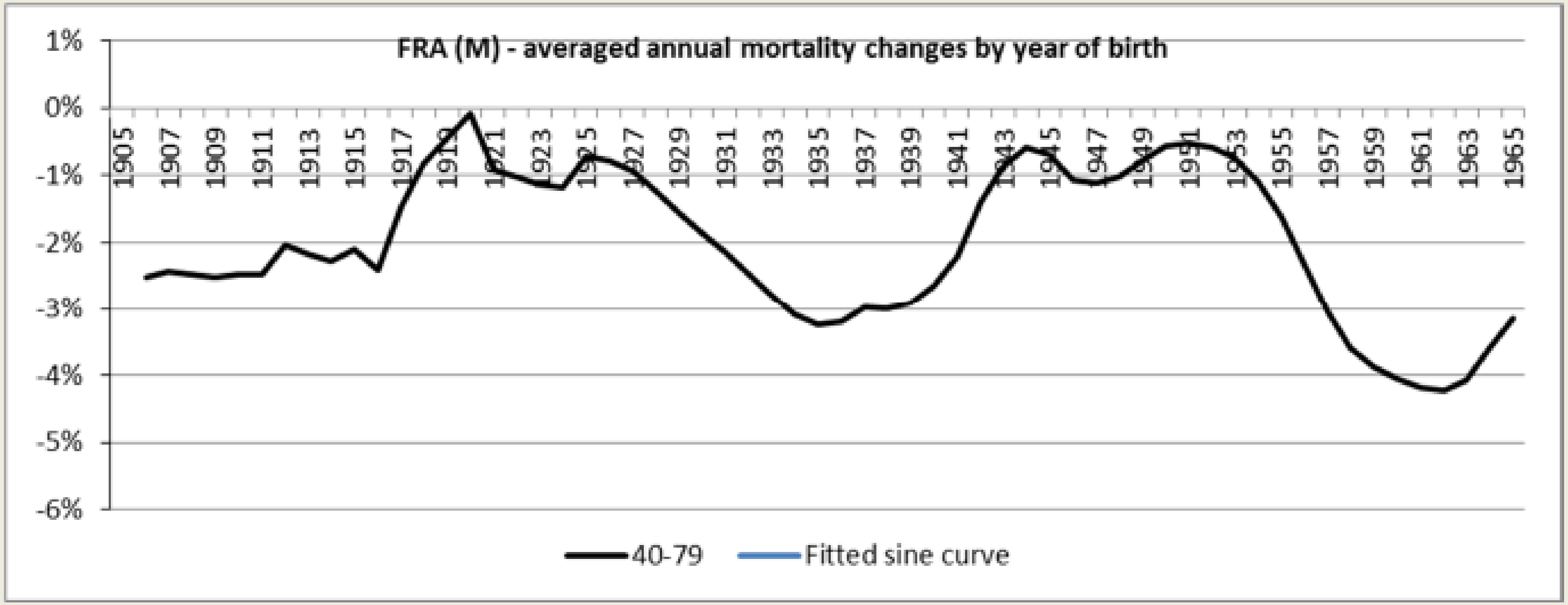
International comparisons

Here are the mortality changes for males in “group A” (the 6 largest countries) by year of birth, averaged over ages 40 to 79:



International comparisons

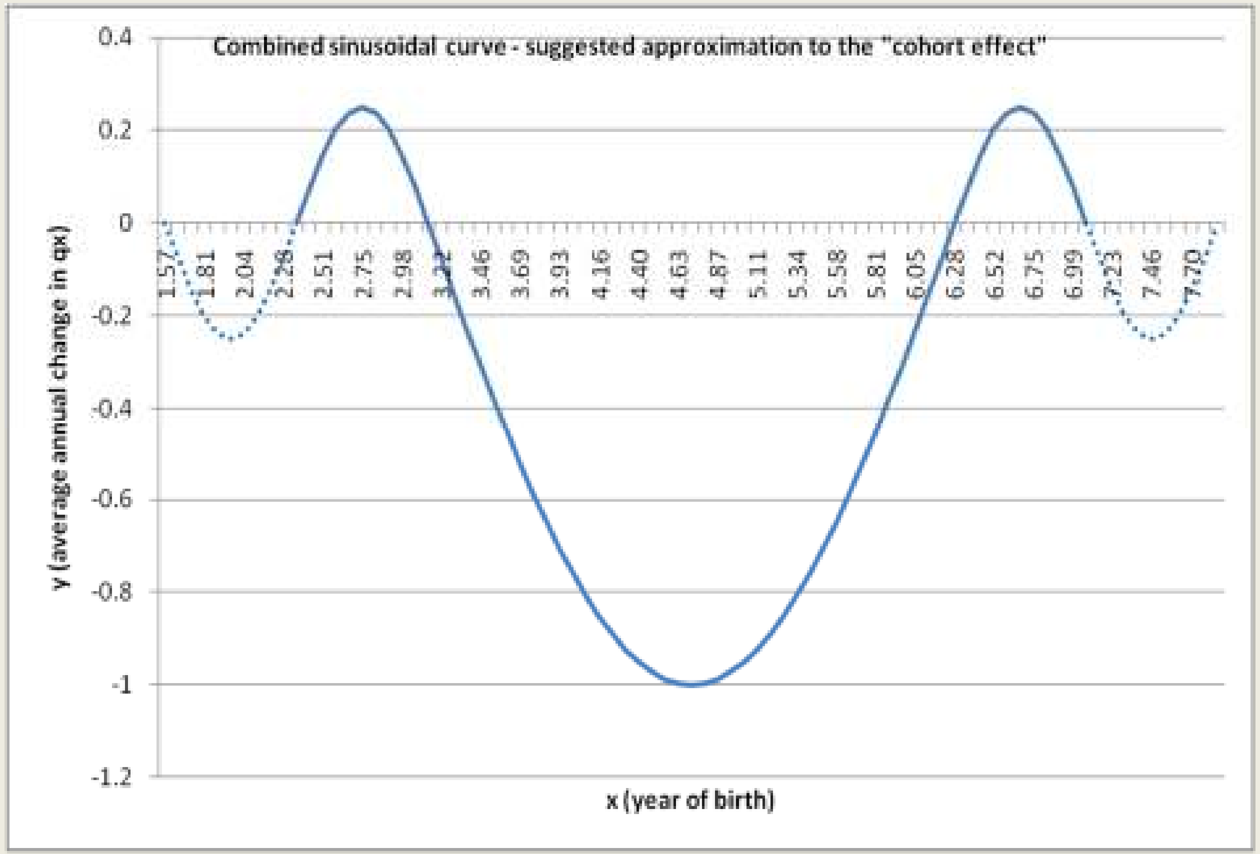
Let's take France as an example:



How can we describe and compare these graphs mathematically?

Parameterization

Each cohort effect appears on the graph of Δqx as a sine curve, usually with two smaller peaks in the opposite direction at each end (=<u>less</u> improvement before and after the cohort period)



Parameterization

Formula for combined sinusoidal curve:

Segment 1 ($0.5\pi<x<\pi$): $y= -\sin(4x)/4$

Segment 2 ($\pi<x<2\pi$): $y=\sin(x)$

Segment 3 ($2\pi<x<2.5\pi$): $y= \sin(4x)/4$

This modified sine curve needs **four parameters** to make it conform to the graph of a specific data set:

The **shape** of the curve – defined by

“**length**” – the period in years of the “positive cohort”

“**depth**” – the maximum mortality improvement relative to the long-term rate

and its **coordinates** – defined by

“**norm**” – the assumed long-term rate of improvement

“**midpoint**” – the middle year of the positive cohort

Parameterization

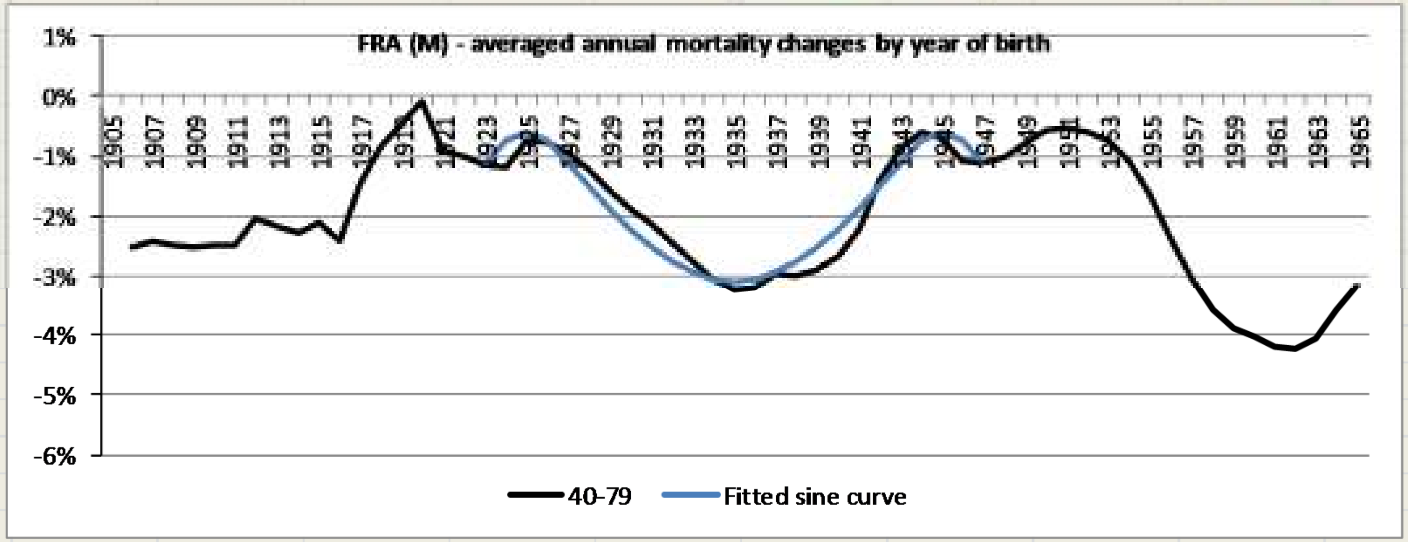
- **Goodness of fit** is described by the sum of the squared deviation of the fitted curve from actual data (minimize!)
- We use the curve-fitting to **compare** different countries, and also age-groups within the same country.
- A measure which combines length and amplitude is the "**area**" (integral).
- A genuine effect should appear at consecutive age groups with similar characteristics.
- In many cases, the cohort effect seems to "wear off" as the cohort ages (the amplitude decreases)

Parameterization

For each data set (cohort/country/sex/age-group) we find the curve which minimizes the least-square deviation, and note its parameters.

FIT CURVE   Reset

Cohort	Main	
	Identify first peak	
Automatic	1925	
	1944	
Override		
Final	1925	
	1944	
midpoint	1935	
length	16	
Parameter for weighted m.a.		
	4	



		Base		Norm	Midpoint	Length	Depth	ean LS deviatio	Integral
Adjusted curve				-1.1%	1935	16	2.0%	0.223%	20.0%
Effect from	to	Adj		0			0		
1925	1945	Optimal		-1.1%	1935	16	2.0%	0.223%	

Extract of results – France (M)

	Norm	Midpoint	Length	Depth	Mean LS d	Integral
25-29	None					
30-34	None					
35-39	-0.7%	1937	12	1.7%	0.274%	13.0%
40-44	-0.6%	1937	12	2.2%	0.120%	16.7%
45-49	-0.9%	1937	12	2.4%	0.224%	18.6%
50-54	-1.3%	1937	12	2.2%	0.305%	16.9%
55-59	-1.5%	1935	14	1.7%	0.219%	15.9%
60-64	-1.8%	1935	14	1.2%	0.223%	10.9%
65-69	-1.5%	1935	14	2.0%	0.182%	17.7%
70-74	Possible					

Extract of results – England & Wales (M)

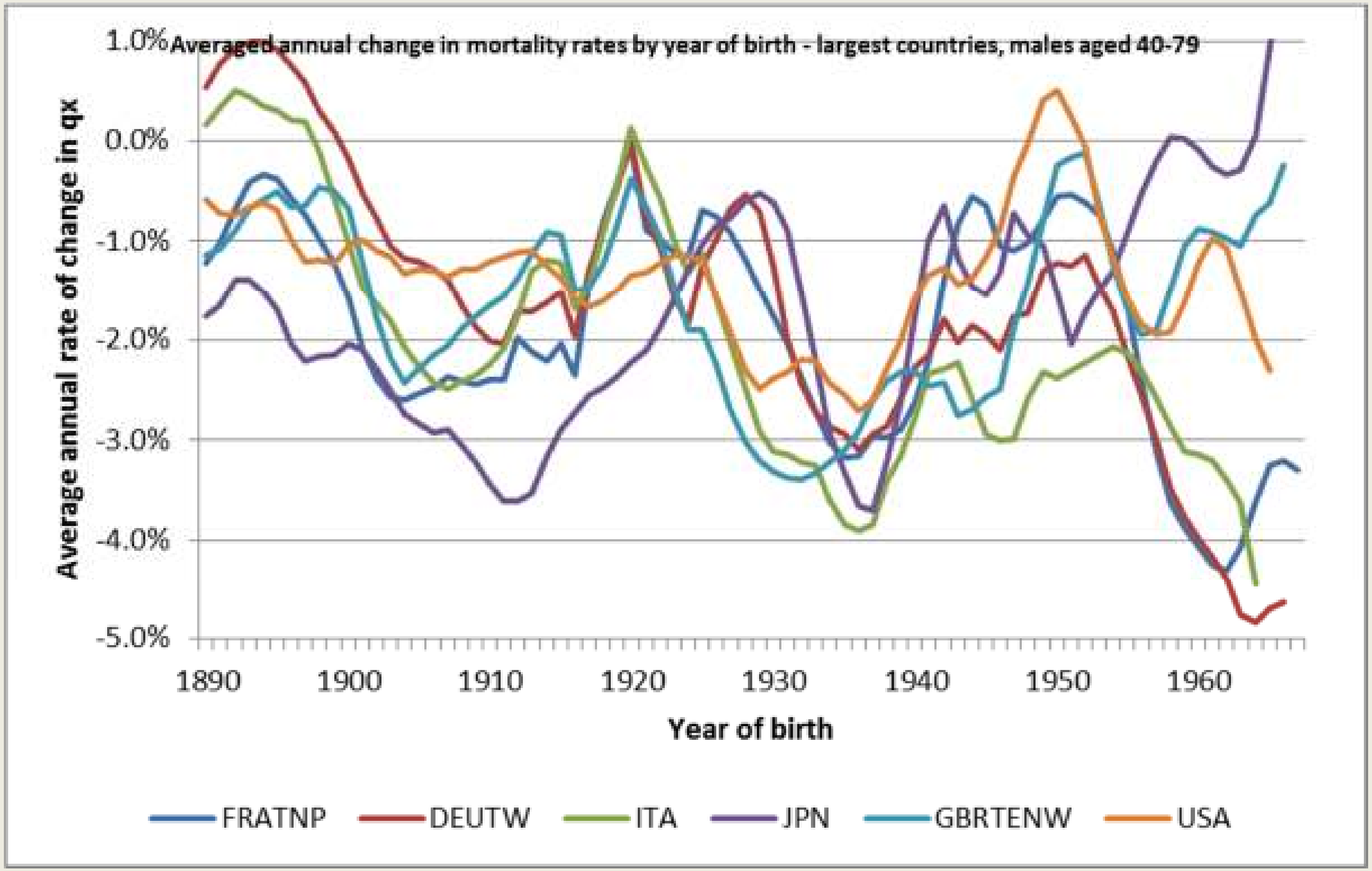
	Norm	Midpoint	Length	Depth	Mean LS dev	Integral
25-29	None					
30-34	None					
35-39	Double trough - no sine fit					
40-44	-0.8%	1937	22	1.6%	0.323%	23.2%
45-49	-1.2%	1937	22	1.7%	0.379%	25.6%
50-54	-1.4%	1936	24	1.8%	0.495%	29.5%
55-59	-1.7%	1936	26	1.6%	0.460%	28.7%
60-64	-2.5%	1934	22	0.9%	0.433%	13.9%
65-69	-2.7%	1932	16	1.3%	0.349%	12.7%
70-74	Possible					

Here, the sinusoidal fit is less exact because of the double trough, but the overall effect of the golden cohort period (=integral) is much greater than France.
Unlike France, the effect seems to wear off after age 60.

Extract of results – Group A countries

		Main cohort age 40-69														
		Norm	Midpoint	Length	Depth	Mean LS deviation	Integral	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69
GROUP A																
FRA	M	-1.1%	1935	14	2.0%	0.358%	18.0%			*	*	*	*	*	*	*
	F	-1.4%	1934	16	1.0%	0.376%	9.8%			*	*	*	*	*	*	*
DEU	M	-1.4%	1936	12	1.6%	0.296%	12.6%					*	*	*	*	*
	F	-1.6%	1934	12	1.2%	0.261%	9.6%			*	*	*	*	*	*	*
ITA	M	-2.5%	1935	12	1.3%	0.171%	9.8%				*	*	*	*	*	*
	F	-2.0%	1935	24	0.5%	0.384%	10.0%				*	*	*	*	*	*
JPN	M	-1.1%	1936	10	2.7%	0.197%	16.8%			*	*	*	*	*	*	*
	F	*-2.1%*	*1936*	*10*	*0.9%*	*0.266%*	*5.7%*									
GBR	M	-1.1%	1936	26	2.1%	0.361%	36.9%				*	*	*	*	*	*
	F	-0.9%	1936	26	1.9%	0.306%	31.6%				*	*	*	*	*	*
USA	M	-1.4%	1936	18	1.0%	0.342%	12.2%					*	*	*	*	*
	F	*-1.4%*	*1937*	*18*	*0.5%*	*0.191%*	*6.2%*									

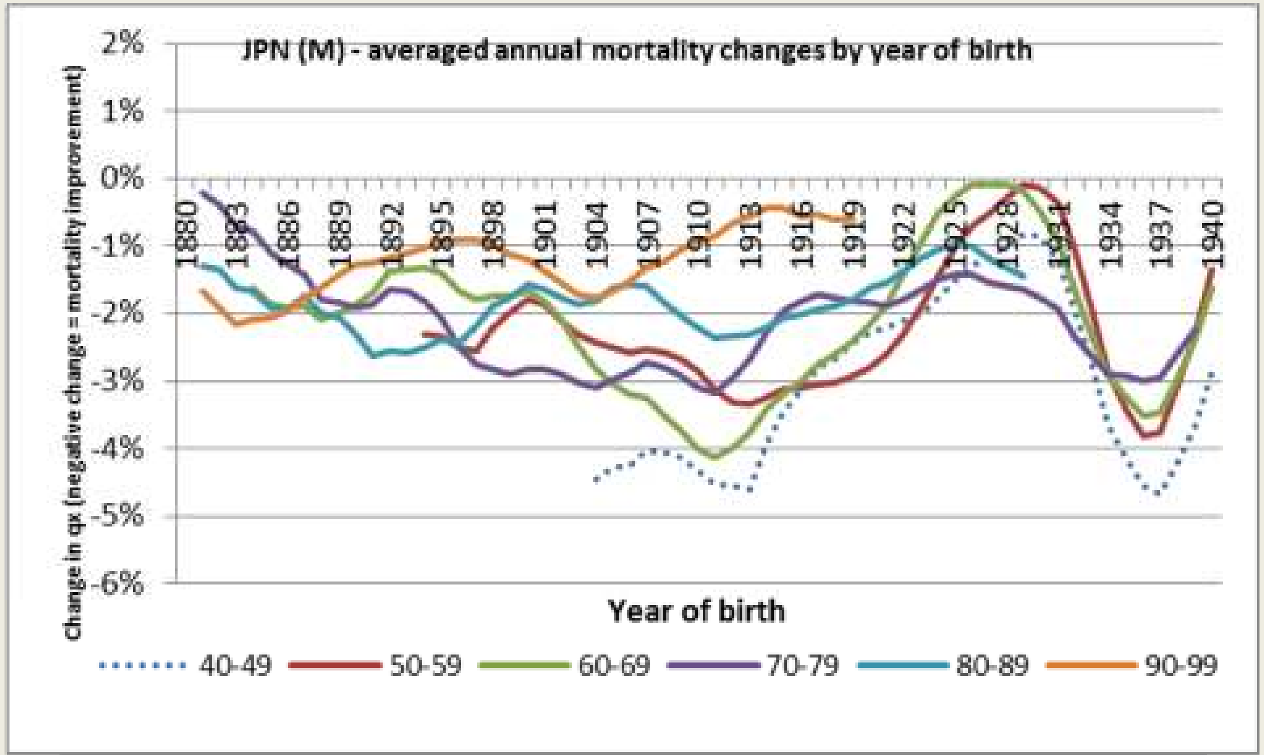
Expanding the view

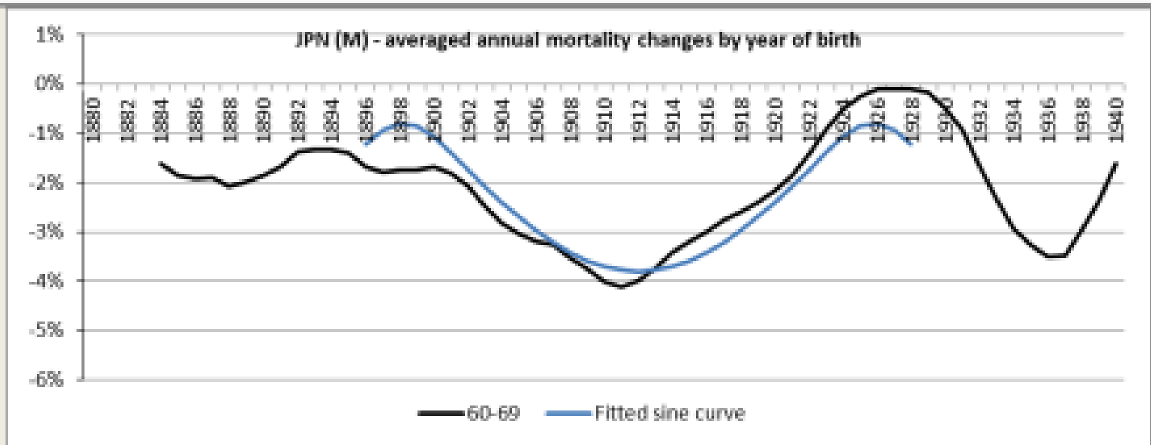


Expanding the view – earlier years

Willets (1999, 2003) noted a prominent cohort effect in Japan in 1910-1915. The previous graph shows that a similar effect may exist, albeit less prominently, in France, Germany and Italy. We can identify this as the "early cohort". However caution is needed, because an additional requirement is consistency between different age groups which may be obscured in the above graph.

The early cohort - Japan





The early cohort - Japan

	Early cohort					
	Norm	Midpoint	Length	Depth	Mean LS d	Integral
45-49	Possible					
50-54	-2.6%	1913	12	0.3%	0.131%	2.6%
55-59	-1.7%	1913	20	1.8%	0.286%	24.2%
60-64	-1.7%	1912	20	2.1%	0.217%	27.2%
65-69	-1.8%	1911	20	2.0%	0.326%	25.8%
70-74	-2.1%	1909	20	1.2%	0.451%	17.0%
75-79	-2.4%	1908	16	0.2%	0.369%	3.0%
80-84	-1.6%	1916	14	0.9%	0.126%	8.3%
85-89	-1.6%	1911	10	0.8%	0.082%	5.1%
90-94	-1.2%	1907	10	0.9%	0.138%	6.0%
95-99	-0.9%	1902	10	0.9%	0.121%	5.4%

The effect wears off at age 75, and in any case the regression of the midpoint points to an observation year effect (~1998/9) and not a cohort effect!

The early cohort – other countries

The “main cohort” (midpoint year ~ 1935) appears in 31 of the 38 datasets of groups A/B/C (18 countries). This includes all Group A datasets except Japan(F) and USA(F).

The “early cohort” (midpoint year ~ 1911) appears in about 11 datasets and in many cases is less consistent across ages. Group A countries exhibiting an early cohort effect: France(M), W. Germany (M+F), Japan(M+F). From age 80+, there are no excess mortality improvements by birth year.

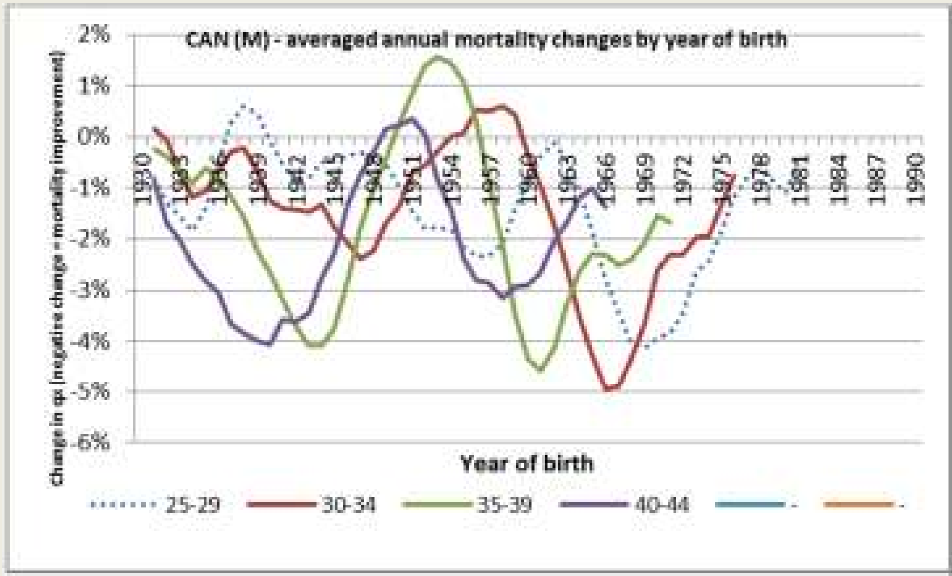
Is there a late cohort?

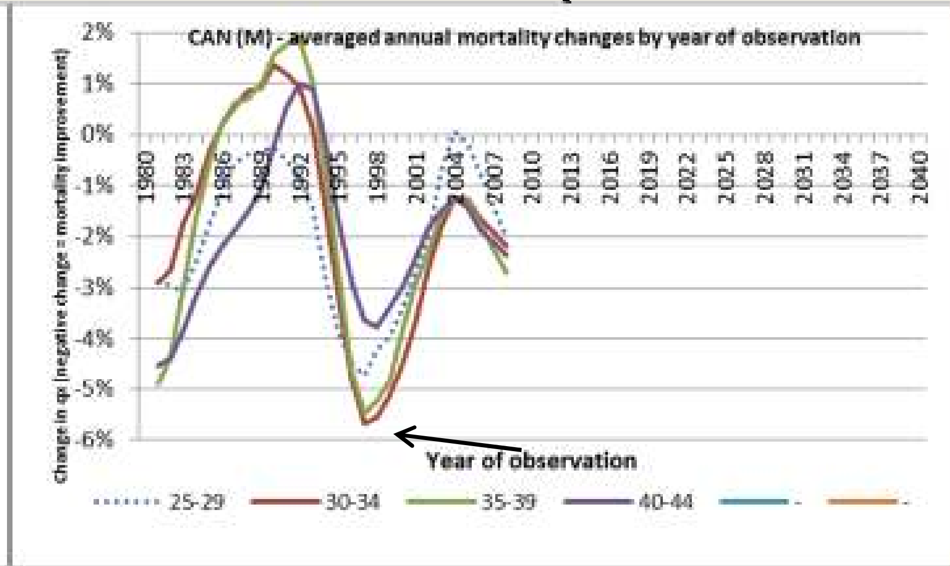
Birth years ~1950 show a slowdown in mortality improvements, an in the US even a deterioration

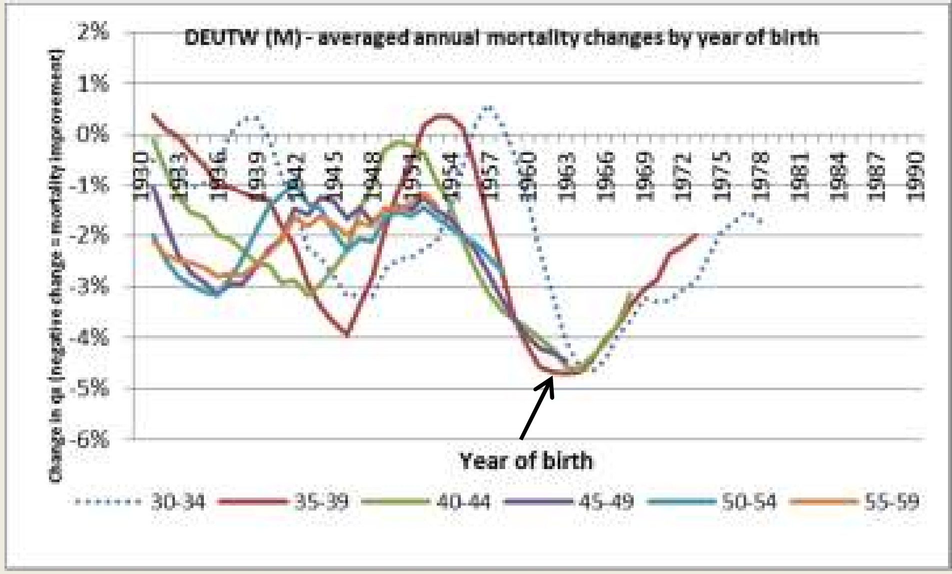
For birth years in the 1960s, there may be signs of a new “golden cohort” in some countries (10 datasets out of 38, including W. Germany and Italy in group A). Other countries e.g. France and Canada, show improvements related to observation year.

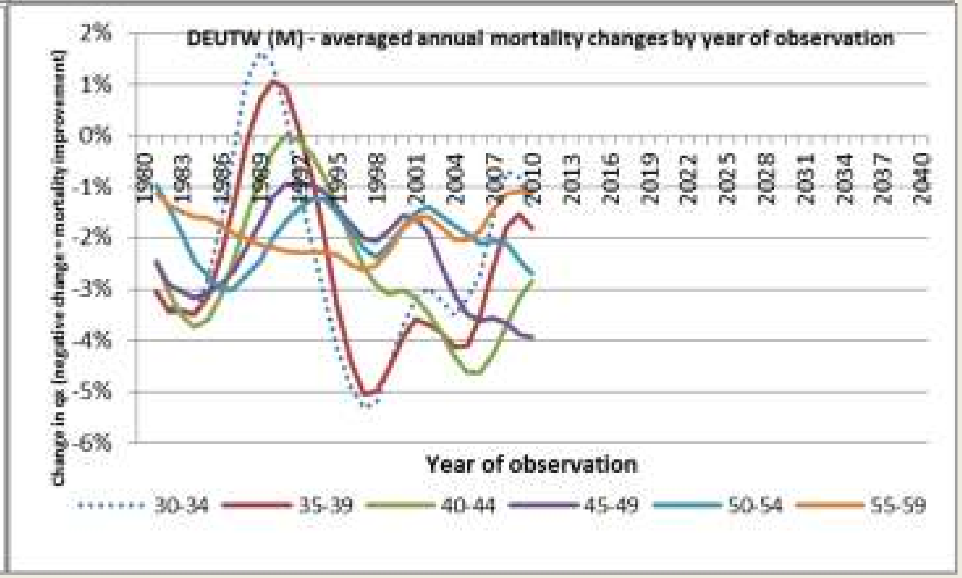
At present, data are only available up to about age 45 - so difficult to be sure!

Is there a late cohort? – some examples









Cohorts in modelling projections

An age period cohort model (APC model) uses the equation

$$logit(q_{x,t}) = \beta_x^1 + \kappa_t^2 + \gamma_{t-x}^3$$

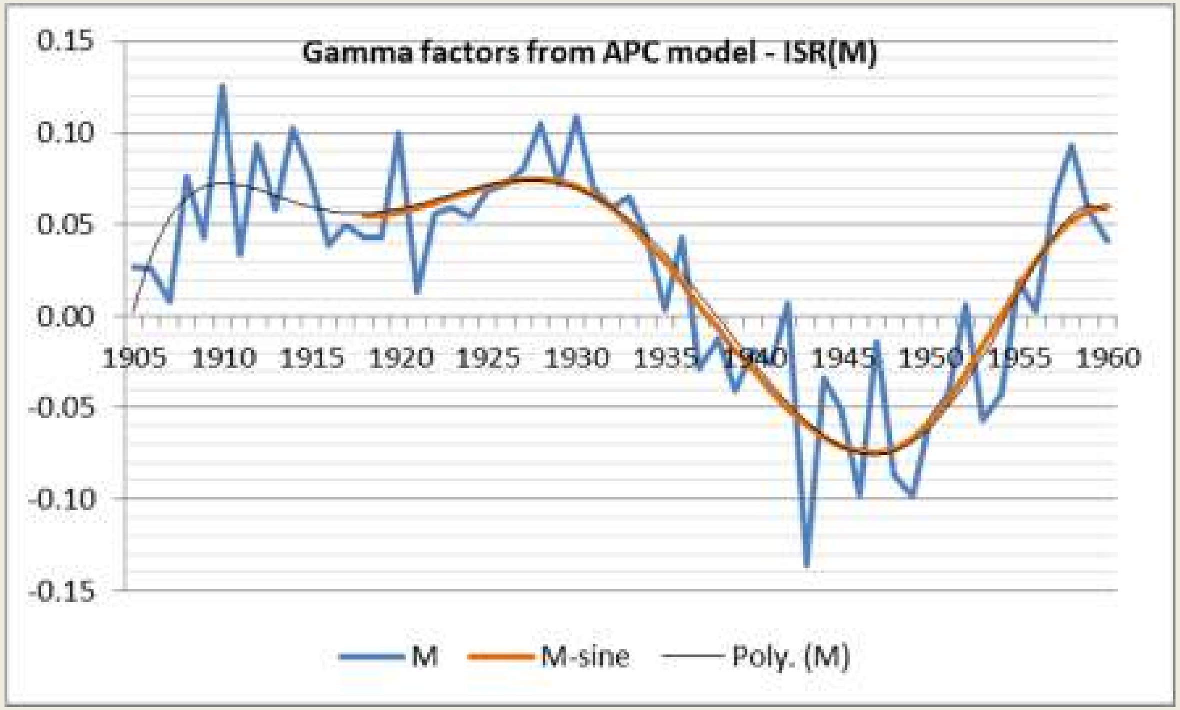
where β depends on age, κ on observation year and γ on year of birth. The gamma factors reflect the relative cohort effect at each year of birth – positive and negative, averaging to zero.

The model implies that the "cohort adjustment" applies uniformly at all ages.
However, we know that it should not apply before age 35-40, and seems to wear off at older ages.

Room for improvement?

Cohorts in modelling projections

$$logit(q_{x,t}) = \beta_x^1 + \kappa_t^2 + \gamma_{t-x}^3$$



This represents the component of logit($q_{x,t}$) resulting from the cohort effect. The "golden cohort" is the period where the differential of the curve is negative (~1929-1946). These factors can also be approximated by a series of sine curves.

What can we learn from all this?

- The cohort effect exhibits similarity, but not uniformity, across countries.
- The effect is usually seen only starting from age 35 or 40.
- The "main cohort" (central year ~ 1935) exists in most data sets in W. Europe, USA , Japan and Australasia.
- The "early cohort" (~1911) exists in some countries, but appears to "wear off" at advanced ages.
- Parameterization enables helps us to understand the effect and to compare between countries and age groups.
- This could be useful in refining projection techniques such as APC (age-period-cohort), which implicitly assumes that the cohort effect applies uniformly over age.
- Such models could be used to assess the effect of a possible positive cohort in birth years around 1965.

Thank you for your attention!

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