Improving life expectancy: how many years behind has the US fallen?

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2013-002814
Article Type:	Research
Date Submitted by the Author:	01-Mar-2013
Complete List of Authors:	Verguet, Stephane; University of Washington, Global Health Jamison, Dean; University of Washington, Global Health
Primary Subject Heading:	Public health
Secondary Subject Heading:	Public health, Health services research
Keywords:	PUBLIC HEALTH, International health services < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

Title

Improving life expectancy: how many years behind has the US fallen?

Authors

Stéphane Verguet, Dean T Jamison

Affiliation

Department of Global Health, University of Washington, Seattle, WA, USA

Correspondence to

Stéphane Verguet, Department of Global Health, University of Washington, 325, 9th Avenue, Box 359931, Seattle, WA, 98104. Ph: +1-206-685-6845. Fax: +1-206-744-3694. Email: verguet@uw.edu.

Keywords

Life expectancy; population health; high-income countries; US; years behind.

Abstract

Objective: many studies have documented higher mortality levels in the United States compared to other high-income nations. We add to this discussion by quantifying how many years behind comparison countries the US has fallen and by identifying when US mortality rates began to diverge.

Design: We use full life tables, for males and females, for seventeen high-income countries including the US. We extract the life expectancy at birth and compute the mortality rates for each five-year age group from birth up to age 80. Using the metric of how many "years behind" a country has fallen, we compare US mortality levels with those in the other high-income countries ("comparators").

Results: We report life expectancy for seventeen high-income countries, for the period 1958-2007. Up to 1980, US men closely tracked comparators in life expectancy. In the late 1970s the US began to diverge from comparators so that the lower US male life expectancy in 2007 corresponded to that of the comparators' average 15 years earlier. Female life expectancy followed a similar pattern. The largest mortality gap was in the 15-49 age group, for both males and females, where the US had fallen about 40 years behind the comparators by 2007.

Conclusions: Some causes proposed for high relative US mortality today – racial differences, lack of universal health insurance – changed little while the mortality gap emerged and grew. Quantification of how many years behind the US has fallen can help provide clues about where to look for potential causes and remedies.

Article summary

Article focus

- Many studies have documented higher mortality levels in the US compared to other high-income nations of Europe and Australasia.
- This study quantifies how many years behind comparison countries the US has fallen and explores whether there was a particular time when US mortality rates began to diverge from comparators.

Key messages

- Since 1980, US life expectancy has fallen behind that of other high-income nations. The US male life expectancy in 2007 corresponded to that of the comparators' average 15 years earlier. Female life expectancy followed a similar pattern.
- The largest mortality gap was in the 15-49 age group, for both males and females, where by 2007 the US had fallen about 40 years behind the comparators.
- Identification of when US mortality rates began to diverge from comparators provides clues about where to look for potential causes and remedies.

Strengths and limitations of this study

- The strength of this study is that it uses full life tables, for males and females, for seventeen high-income countries for an extended time series. The detailed results allow for tracking the magnitude and timing of US divergence. This provides a specific criterion for assessing the explanatory power of causes proposed for poor performance, and narrows the range of potentially important determinants.

- The main limitation of this study is that it does not propose explanations for high relative US mortality today and why the mortality gap emerged and grew, as it is instead a tool for others making those assessments. Concern for the poor US performance on mortality prompted major investigations by the US National Academy of Sciences into its causes, and it was not our purpose to reiterate the conclusions of the US National Academies' assessments.

Introduction

Much has been said and debated about the differences in health outcomes among high-income countries. Using different measures of health, mortality and disability, many studies have documented that the population of the United States is less healthy than those of the high-income nations in Europe and Australasia. This finding of poorer US health outcomes relative to other nations plays a significant part in public debate over improving US health outcomes.[1] This paper adds to the previous discussion by quantifying how many years behind its comparators the US has fallen and by exploring whether there was a particular time when US mortality rates began to diverge from the others. Identification of such a time would provide clues about where to look for potential causes and remedies.

The metric used to assess performance must be able to capture variation across countries and over time. In this paper we apply a long-established approach to performance measurement that lends itself readily to graphic depiction: the assessment of how many "years behind" a country has fallen, relative to other countries.[2,3] We compare the life expectancy (and age-specific mortality rates) for men and women in the US with the best country life expectancy ("leader") and figures from sixteen other high-income countries in the Organisation for Economic Co-operation and Development (OECD) ("comparators"), from 1958-2007, using data primarily from the Human Mortality Database.[4] This dynamic depiction also captures the magnitude of the effort needed to catch-up with other participants. Evolution over time of years behind enables sensitive identification of divergent and convergent trends, and the ability to flag rapid changes on the path to improvement in life expectancy. This capacity underpins an important purpose

of this paper, which is to identify whether there is a point in time marking the beginning of US deterioration relative to its comparators.

Design

Data

We use full life tables encompassing the years 1850 through 2007,[4] for males and females, for the following seventeen countries: Australia, Austria, Canada, Denmark, Finland, France, Germany (West Germany), Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States. This set of countries is a subset of high-income OECD countries chosen for best comparability to the US. The selection criteria were sufficient population size to ensure stability of estimates, high development achieved for a long time period, data quality and availability, and were described elsewhere.[5] We extract the life expectancy at birth for males and females, and the mortality rates for each five-year age group from birth up to age 80 (0-4, 5-9, 10-14,…, 70-74, 75-79), and additionally for the specific age ranges 0-14 and 15-49.

Approach

We report life expectancy at birth for males and females for all seventeen countries, for the period 1958-2007.[a] In keeping with published methodology, for each year we identify the highest recorded life expectancy i.e. the leader.[1,6,7] These point estimates define a 'maximum frontier.' We also estimate the average life expectancy recorded for the

[a] The latest year available for the United States was 2007. The earliest available year for West Germany was 1956. We retained the years 1958 to 2007 in order to have five 10-year periods.

sixteen countries (arithmetic average), besides the US, i.e. the comparators. Finally, we compare the US life expectancy to both the leader and the comparators. We do this by calculating how many years behind the leader the US and the comparators fall in a given year. For instance, if in 2007 the US had a life expectancy which was closest to the life expectancy of the leader in 1986, then the US is said to have been 21 years behind the leader in 2007.

In order to investigate to what extent the health gap varies across different age groups, we analyze mortality rates for males and females for the age groups described above, for the period 1958-2007. Similarly, we identify the leader of the lowest recorded mortality rates in a given year, which define a 'minimum frontier,' and compute the comparators' average observed mortality rates per age group. Note that this leader is not necessarily the same as the leader in life expectancy. Finally, we calculate how many years behind the US and the comparators are for each age group and each year of the period 1958-2007.

Results

Years behind for life expectancy

Figure 1.a shows, over the period 1958-2007, for male and female life expectancy, the evolution of the leader, the US and the comparators. In any given year, the leader, the US and the comparators had higher life expectancies for females than for males. The US life expectancy for males was lower than the comparators' life expectancy for males; the differential of life expectancy between the US and the leader diminished from the late 1950s to the late 1970s, and then stayed about the same after the late 1970s. For females,

the US life expectancy was about the same as the comparators from the late 1950s to the late 1970s, and both converged slightly toward the leader. Notably, after the late 1970s, the life expectancy for US females started to diverge substantially from both the leader and the comparators; the US presented a rate of increase of about 1 year per decade, far below the 2-3 years per decade of the leader. Tables A.1 and A.2 in the Supplementary Appendix show, for males and females, the life expectancy across countries for each decade from 1958.

FIGURE 1 AROUND HERE

The number of years behind the leader, for male and female life expectancy, for the US and the comparators, is presented in figure 1.b. Over the period 1958-2007, the US fell between 15 and 35 years behind the leader for male life expectancy, and was also always behind the comparators. Up to about the late 1970s, both the US and the comparators presented a similar trend in increasing years behind the leader. Then, over the course of only a few years, the comparators narrowed the distance from 25 to 10 years behind, followed by a slightly decreasing trend until 2007 where it was about 5 years behind the leader. In contrast, the US narrowed the distance with the leader abruptly in the late 1980s (slightly delayed relative to the comparators), and then remained at about the same level of 20 years behind the leader through 2007 leading to substantial divergence from the comparators. In the first two decades (1958-67 and 1968-77), Sweden was the leader (with mean life expectancy of 71.6 and 72.1 years), but its advance on Japan diminished (14th and 6th positions with mean life expectancy of 66.7 and 70.7 years) (Supplementary Appendix, table A.1). Japanese male life expectancy

increased dramatically from 1958-67 to 1978-87, at about 4 years per decade, about 4 times Sweden's rate of increase. Japan has been the leader for the last three decades, although, Sweden and a few other countries kept very close pace behind. Australia and Italy have substantially closed the gap in recent decades, moving from 8th and 9th positions behind Japan in 1978-87, to 2nd and 5th in 1998-07, respectively.

Over the period 1958-2007, the life expectancy for US females was between 10 and 20 years behind the leader, which was better than US male life expectancy but hid a disturbing trend (figure 1.b). Up to about the late 1970s, US females and the comparators presented similar trajectories: starting around 10 years behind the leader, they trailed to around 20, but made a comeback to where they were, again, about 10 years behind the leader. Then, the US substantially diverged from the comparators, falling further and further behind at a steady pace (figure 1.b). In 1998-07, the US was about 19 years behind the leader, with a life expectancy of 79.9 years (Supplementary Appendix, table A.2). Over the last three decades, Japan has been the leader, and its distance ahead of the comparators has increased. In 1978-87 the 2nd best country (Switzerland) had life expectancy of 0.2 years less than Japan's, whereas in 1998-07 the 2nd (France) had life expectancy of 1.8 years less than Japan's. Japanese female life expectancy increased dramatically from 1958-67 to 1978-87: Japanese were 16th behind the leader (Norway) in 1958-67 with a life expectancy of 71.7 years, before taking the lead in 1978-87 with a life expectancy of 79.8 years, a rate of increase of 4 years per decade. Norway and Denmark lost ground from 1968-77 onward. Norway led in 1968-77 but ranked 9th in 1998-07, a rate of increase of only 1.5 years per decade. Denmark was 8th in 1968-77 but fell to last in 1998-07, with a rate of increase of only 1 year per decade.

Years behind in age-specific mortality rates.

Figure 2 shows the number of years behind the leader the US and the comparators were for 5-year age groups, for males and females and two time periods, the early 1960s (1958-67) and the early 2000s (1998-07). In the early 1960s, the US and the comparators presented similar age distributions for the number of years behind the leader, for males and females. Males presented a larger number of years behind than females across almost all age groups; females in both the US and the comparators presented almost identical age distributions for years behind the leader. The situation in the early 2000s was very different for the US. For females, the comparators presented a pattern similar to the early 1960s, between 10 and 20 years behind the leader across all age groups; the US presented a larger number of years behind the leader but most significantly the number of years behind the leader had increased substantially between age 15 and age 50. For males, the comparators had substantially reduced the number of years behind the leader beyond age 45, but increased the number of years behind the leader from age 15 to age 40; the US had also substantially reduced the number of years behind the leader after age 45, and like the comparators, had increased the number of years behind the leader between age 10 and age 45.

FIGURE 2 AROUND HERE

Figure 3.a shows time trends in the probability of dying between age birth and age 15 (15q0) for the leader, the US and the comparators. Tables A.3 and A.4 in the Supplementary Appendix show values for 15q0 across countries. In a given year, the leader, the US and the comparators had higher mortality rates for males than for females.

For both males and females, the differential of 15q0 between the US and the leader stayed somewhat similar from the early 1960s to the early 2000s. The US 15q0 started lower than the comparators' 15q0 for both males and females; in the 1970s, the leader, the US and the comparators crossed. For both males and females, the comparators' 15q0 was converging toward the leader throughout the entire time period.

FIGURE 3 AROUND HERE; FIGURE 4 AROUND HERE

Figure 4.a shows time trends for the probability of dying between age 15 and age 50 (35q15) for the leader, the US and the comparators. Tables A.5 and A.6 in the Supplementary Appendix show values for 35q15 across countries. In a given year, the leader, the US and the comparators had substantially higher mortality rates for males than for females. For both males and females, the US 35q15 was always higher than the comparators' 35q15; the differential of 35q15 between the US and the leader stayed about the same from 1958 to 2007, for males. However, for females, the US was slightly diverging from the leader from 1980 onward.

Figures 3.b and 4.b show the number of years behind the leader the US and the comparators were for the 0-14 and 15-49 age groups, for males and females, over the 1958-2007 period. For the 0-14 age group, up to the late 1970s, the US and the comparators showed similar trajectories, between 10 and 20 years behind the leader (both males and females); on average, the US was slightly ahead of the comparators then. Afterwards, while the comparators consistently kept pace about 10 years behind the leader, the US saw an increase up to between 20 and 30 years behind the leader through 2007 (both males and females). For the 15-49 age group, the US was always behind the

comparators over the whole period; the US consistently diverged from the leader. The male trajectory, for the US and the comparators, was similar until the early 1990s, when the comparators started converging on the leader, dropping from about 40 to 15 years behind the leader in 2007; meanwhile, the US kept diverging with years behind the leader increasing from about 45 years in 1990 to about 55 years in 2007. The female trajectory, for the US and the comparators, was somewhat similar until the mid-1970s (20-25 years behind the leader then), when the comparators kept the distance behind the leader below 20 years behind the leader (below 10 years behind the leader in 2007), while the US continued diverging, being about 50 years behind the leader in 2007.

Discussion

This paper applies a sensitive measure of national performance – years behind – to comparison of US mortality rates with those of other high-income countries. As has been well documented,[1,8] US life expectancy is lower and mortality rates are higher than in other high-income or comparator countries. Most strikingly, for both males and females, the typical high-income country had achieved, by the 1970s, a mortality rate in the age group 15-49 that the US failed to achieve until about 2007: i.e., the US, in 2007 fell about 40 years behind the average (and 50 years behind the leader). A similar if less pronounced pattern appears for life expectancy and for mortality under age 15.

The US now lies far behind other high-income countries, but this was not always so. The detailed results of this paper allow for tracking the magnitude of US divergence and for (approximate) timing of when it began. Although our results contain noise a key result emerges: sometime in the late 1970s the US stopped tracking its comparators and

began to fall behind (table 1). At different rates for different indicators the US fell further and further behind over subsequent three decades.

TABLE 1 AROUND HERE

Concern for the poor US performance on mortality prompted major investigations by the US National Academy of Sciences[1,8] into its nature (in terms of age groups and conditions) and its causes. Major potential causes that have been explored include cross-country differences in the level and equality of income, in level of education, in social cohesion, in a broad range of specific risk factors, and in the level and quality of expenditures on the health care system. It is not our purpose to reiterate the conclusions of the National Academies' assessments. Rather our conclusions point to an additional and quite specific criterion for judging the explanatory power of potential explanations for poor performance in the US. Since we conclude divergence to have begun in the late 1970s, potential explanations like racial diversity, lack of health insurance and high income inequality in the US become less plausible. Racial diversity and income inequality were high, and insurance coverage low in the US in the 1970s when the US was performing well on health. Establishing a time for the beginning of the US divergence helps in identifying the effects of the broader social policy arena on health,[9] and in narrowing the range of potentially important determinants, and remedies.

Acknowledgements

The authors gratefully acknowledge funding from the Bill & Melinda Gates Foundation through the Disease Control Priorities Network grant to the University of Washington

and from the National Research Council of the United States National Academies. The authors received valuable comments from Laudy Aron.

Contributors

SV and DTJ designed the study, conducted the analysis, interpreted the data and drafted the original manuscript. Both authors fulfill the ICMJE guidelines for authorship.

Funding

This work was supported by the Bill & Melinda Gates Foundation through the Disease Control Priorities Network grant to the University of Washington, and by the National Research Council of the United States National Academies.

Competing interests

None declared

Data sharing statement

There is no additional data available.

References

1. Crimmins EM, Preston SH, Cohen B, editors. *Explaining divergent levels of longetivity in high-income countries*. Washington, DC: National Academies Press, 2011.

2. Sicherl P. Time-distance as a dynamic measure of disparities in social and economic development. *Kyklos* 1973; 26(3):559-575.

3. Kulkarni SC, Levin-Rector A, Ezzati M, Murray CJL. Falling behind: life expectancy in US counties from 2000 to 2007 in an international context. *Population Health Metrics* 2011; 9(1):16.

4. Human Mortality database. http://www.mortality.org/ (accessed 30 Aug 2011).

5. Ho JH, Preston SH. US mortality in an international context: age variations. *Population and Development Review* 2010; 36(4):749-773.

6. Oeppen J, Vaupel JW. Broken limits to life expectancy. *Science* 2002; 296:1029-31.

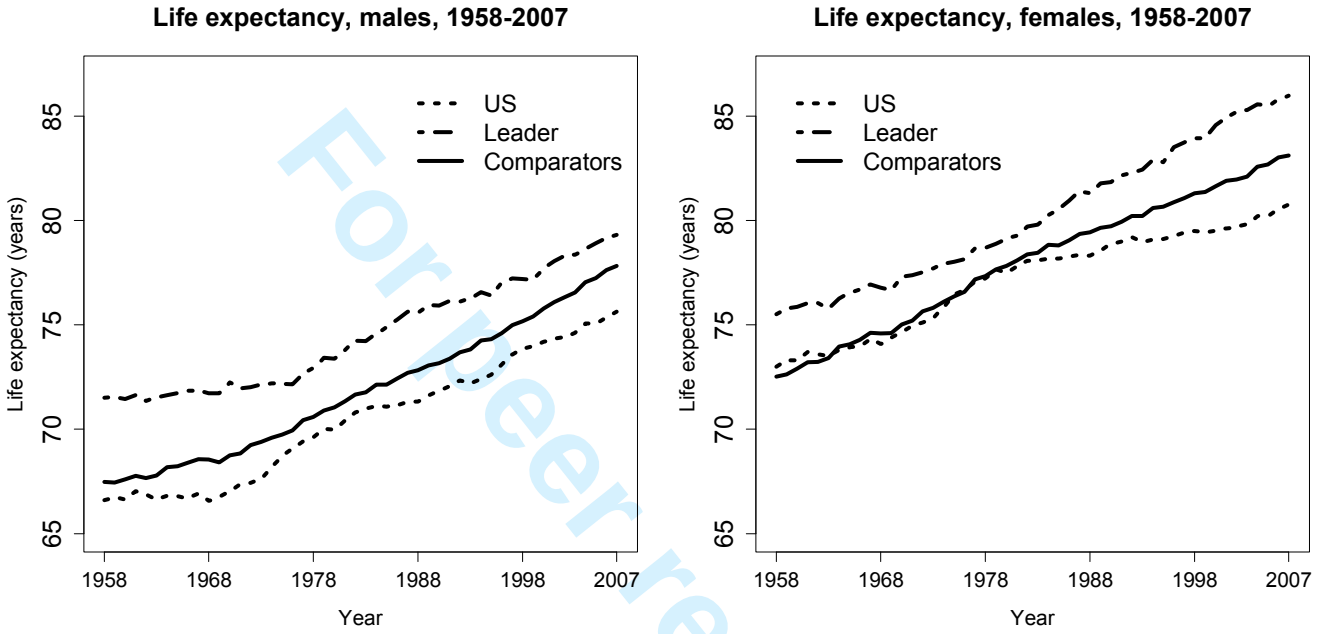
7. Vallin J, Meslé F. The segmented trend line of highest life expectancies, *Population and Development Review* 2009; 35(1):159-187.

8. Woolf S, Aron L, editors. *US health in international perspectives: shorter lives, poorer health*. Washington, DC: National Academies Press, 2013.

9. Dow WH, Rehkopf DH. Socioeconomic gradients in health in international and historical context. *Annals of the New York Academy of Sciences* 2010; 1186:24-36.

Figure 1. Evolution of life expectancy and years behind the leader for the leader, the US, and the average of sixteen comparator high-income countries, males and females, 1958-2007

(a) Life expectancy



(b) Years behind the leader

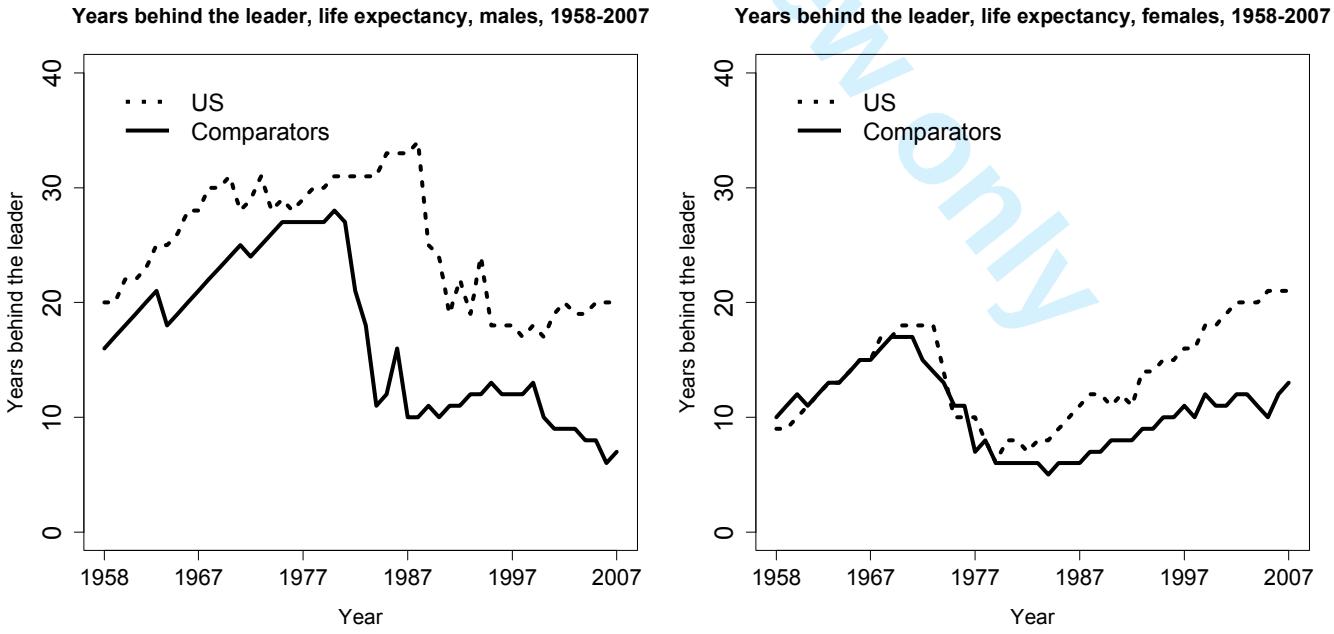
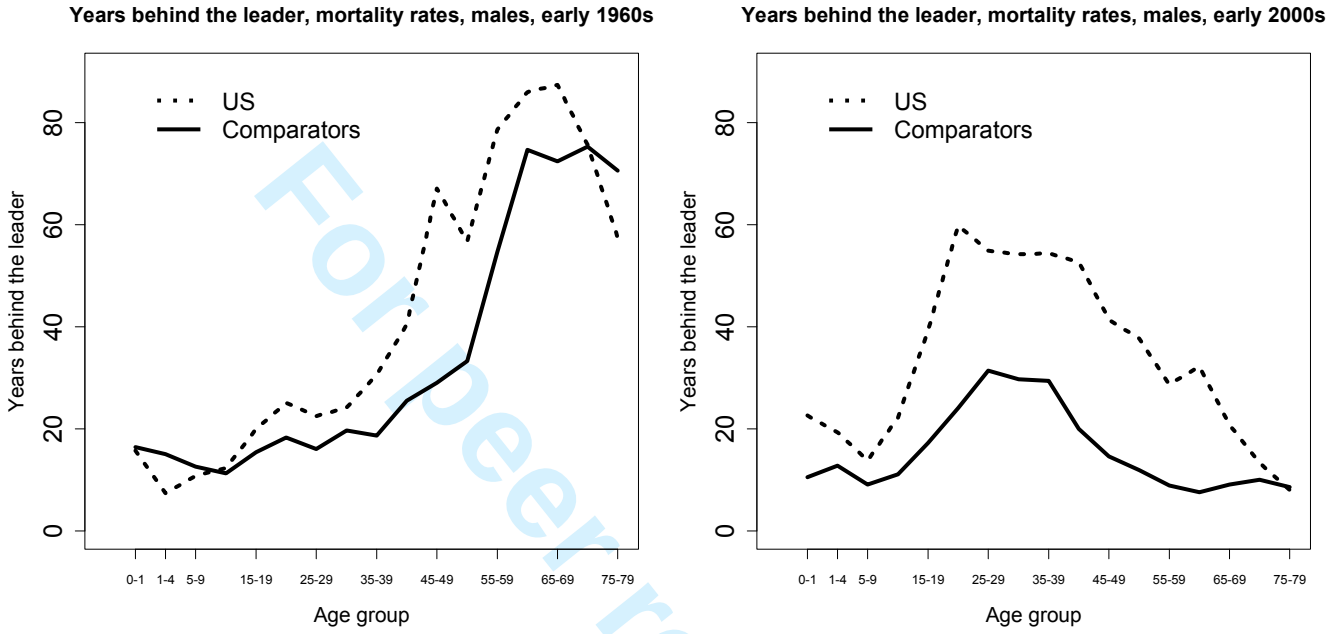
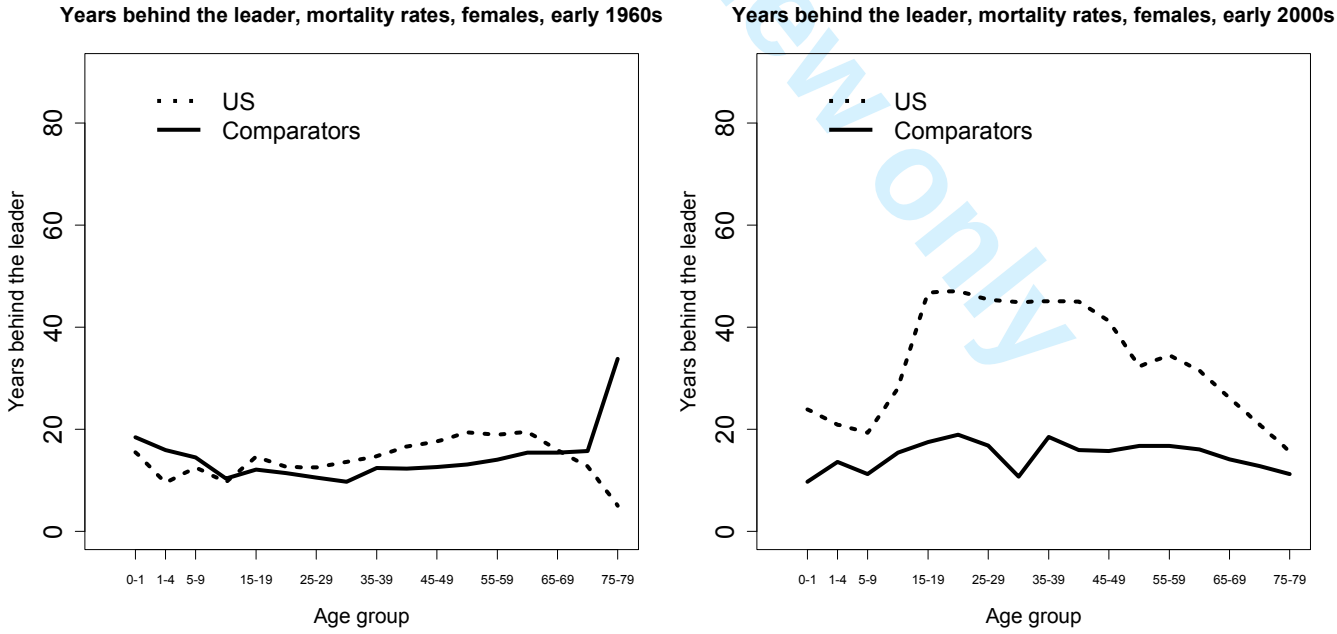


Figure 2. Number of years behind the leader for mortality rates across age groups, for the US and the average of sixteen comparator high-income countries, males and females, early 1960s and early 2000s

(a) Males



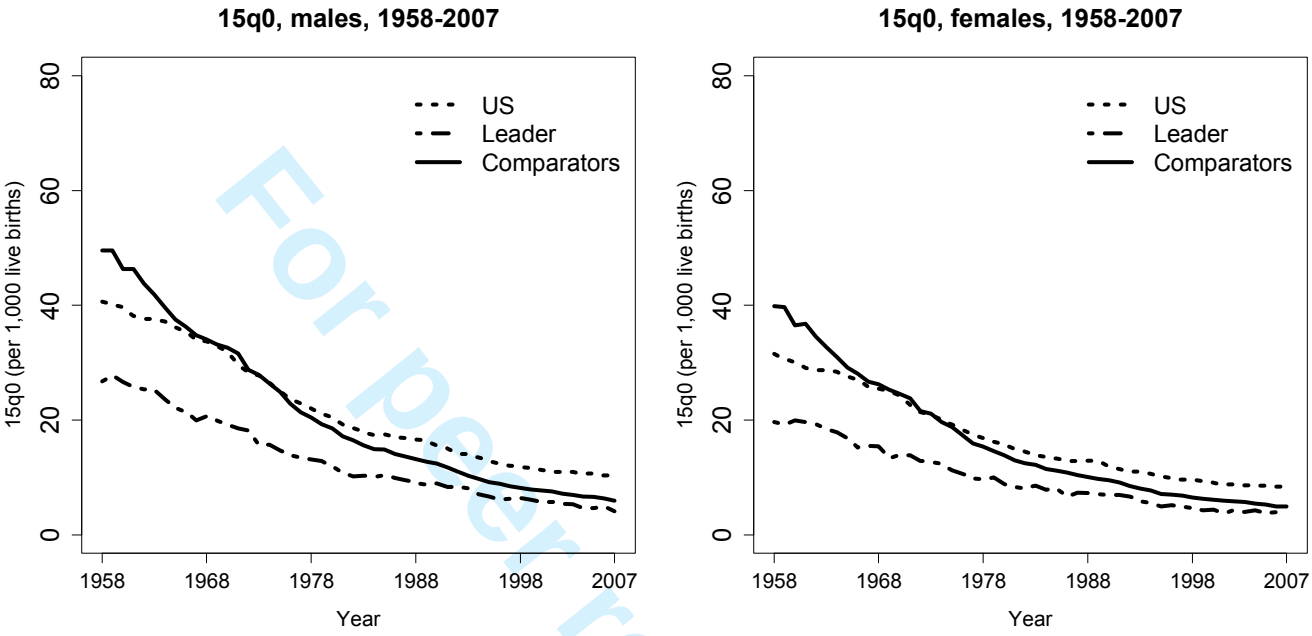
(b) Females



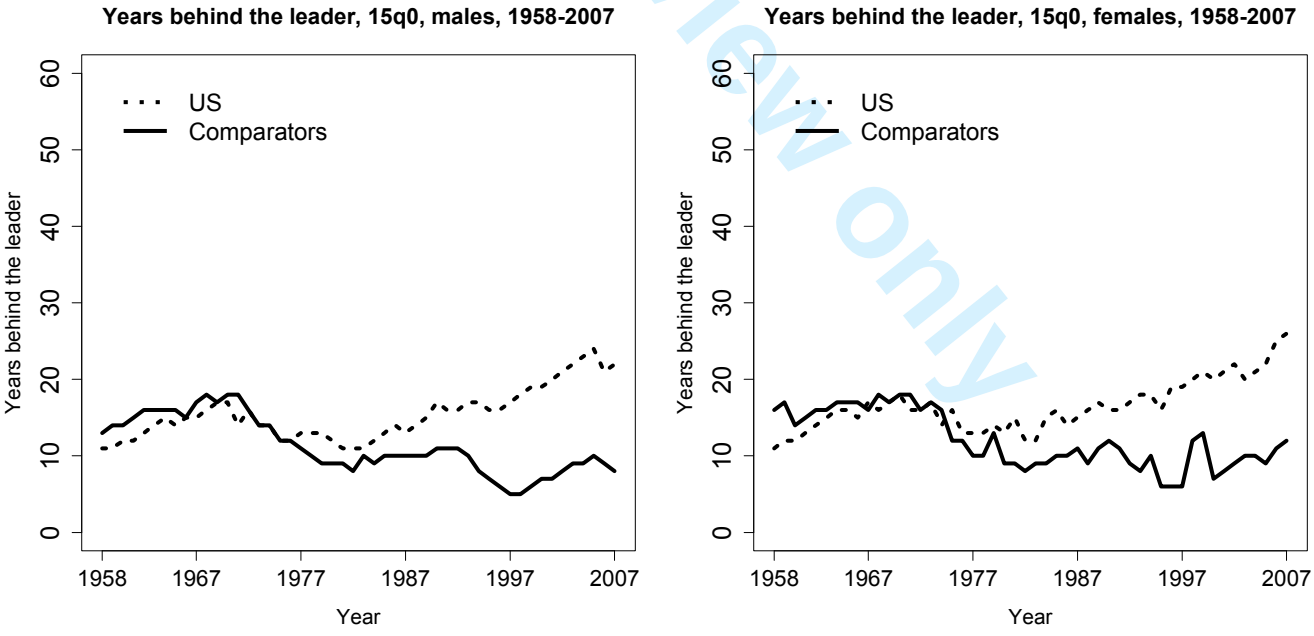
Note: Early 1960s refers to the period 1958-67 and early 2000s refers to 1998-2007.

Figure 3. Evolution of mortality rates and years behind the leader in the 0-14 age group, for the leader, the US, and the average of sixteen comparator high-income countries, males and females, 1958-2007

(a) Mortality rates



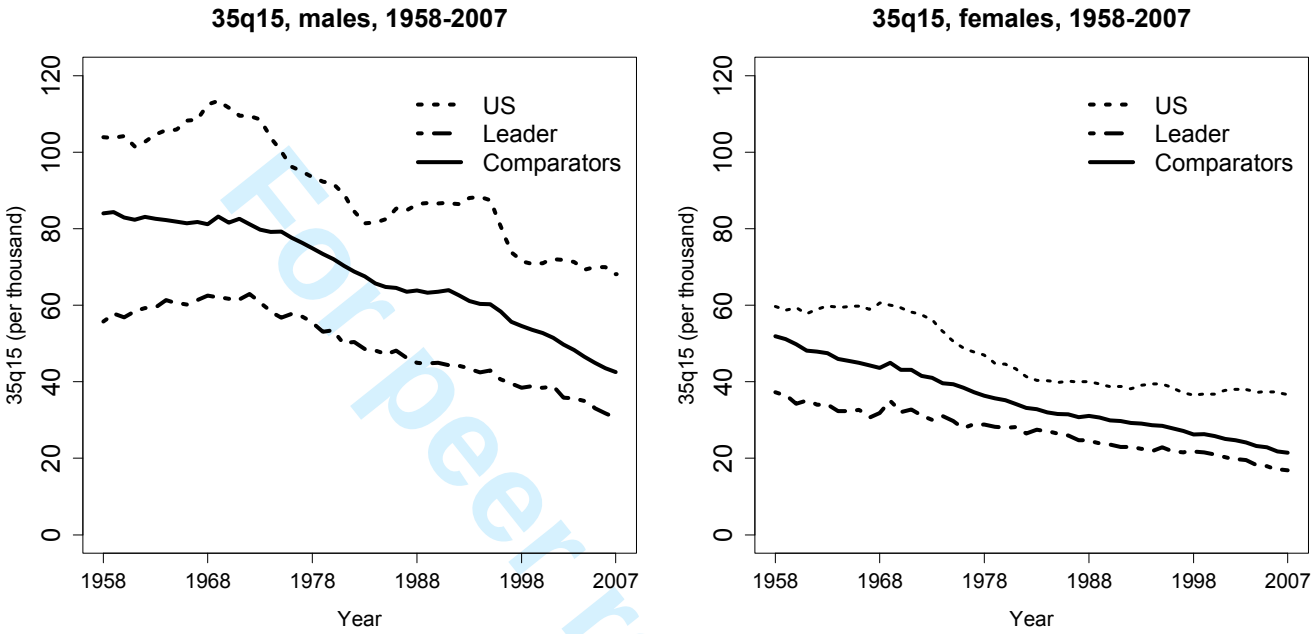
(b) Years behind the leader



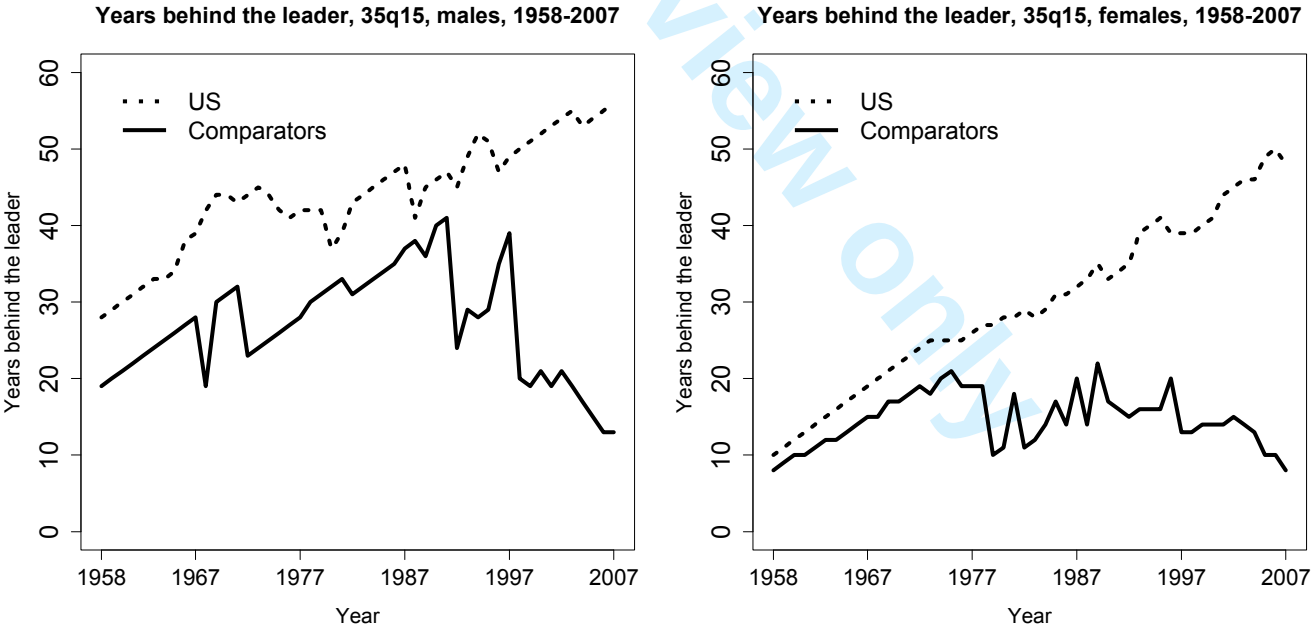
Note: 15q0 is defined as the probability of dying from birth through age 14 at then prevailing age-specific mortality rates.

Figure 4. Evolution of mortality rates and years behind the leader in the 15-49 age group, for the leader, the US, and the average of sixteen comparator high-income countries, males and females, 1958-2007

(a) Mortality rates



(b) Years behind the leader



Note: 35q15 is defined as the probability of dying from age 15 through age 49 at then prevailing age-specific mortality rates.

Table 1. Timing of US divergence from the average of sixteen comparator high-income countries, for life expectancy, 15q0, and 35q15, males and females, 1958-2007

Indicator	Males	Females
Life expectancy	Late 1970s (temporary reconvergence late '80s to late '90s)	Late 1970s
15q0	Late 1970s (US had lower mortality than comparators before 1965)	Late 1970s (US had lower mortality than comparators before 1965)
35q15	About 1990 (US already substantially behind comparators before divergence)	Late 1970s (more rapid divergence after about 1990)

Note: 15q0 is defined as the probability of dying from birth through age 14 at then prevailing age-specific mortality rates; 35q15 is defined as the probability of dying from age 15 through age 49 at then prevailing age-specific mortality rates.

Supplementary Appendix

Table A.1. Evolution of male life expectancy for the US, and sixteen other high-income countries, 1958-67 to 1998-2007

Table A.2. Evolution of female life expectancy for the US, and sixteen other high-income countries, 1958-67 to 1998-2007

Table A.3. Evolution of male 15q0 for the US, and sixteen other high-income countries, 1958-67 to 1998-2007

Table A.4. Evolution of female 15q0 for the US, and sixteen other high-income countries, 1958-67 to 1998-2007

Table A.5. Evolution of male 35q15 for the US, and sixteen other high-income countries, 1958-67 to 1998-2007

Table A.6. Evolution of female 35q15 for the US, and sixteen other high-income countries, 1958-67 to 1998-2007

Table A.1. Evolution of male life expectancy for the US, and sixteen other high-income countries, 1958-67 to 1998-2007

Life expectancy (years)	1958-67	1966-77	1978-87	1988-97	1998-07
Above 80					
75 to 80				JPN (76.3)	JPN (78.2) AUS (77.9) SWE (77.9) CHE (77.9) ITA (77.3) CAN (77.2) NOR (76.8) ESP (76.4) NLD (76.4) UK (76.1) FRA (76.0) DEU (76.0) AUT (75.9) DNK (75.0)
70 to 75	SWE (71.6) NLD (71.2) NOR (71.2) DNK (70.4)	SWE (72.1) NOR (71.4) NLD (71.3) DNK (71.0) CHE (70.8) JPN (70.7)	JPN (74.2) SWE (73.4) CHE (72.9) NLD (72.8) ESP (72.7) NOR (72.5) CAN (72.4) AUS (71.8) ITA (71.6) DNK (71.5) UK (71.1) FRA (70.8) DEU (70.7) USA (70.7)	SWE (75.5) CHE (74.8) AUS (74.6) CAN (74.6) NLD (74.2) NOR (74.2) ITA (74.2) ESP (74.0) UK (73.5) FRA (73.3) DEU (73.2) AUT (72.8) DNK (72.6) USA (72.3) FIN (72.0) PRT (71.3)	FIN (74.8) USA (74.7) PRT (74.1)
65 to 70	CHE (68.9) CAN (68.4) UK (68.1) AUS (67.8) ESP (67.4) FRA (67.3) ITA (67.2) DEU (67.2) USA (66.8) JPN (66.7) AUT (66.2) FIN (65.5)	ESP (69.8) CAN (69.7) ITA (69.1) UK (69.1) FRA (68.6) AUS (68.5) DEU (67.9) USA (67.8) AUT (67.3) FIN (66.7)	FIN (69.9) AUT (69.7) PRT (69.0)		
Below 65	PRT (61.6)	PRT (64.9)			

AUS = Australia, AUT = Austria, CAN = Canada, CHE = Switzerland, DEU = West Germany, DNK = Denmark, ESP = Spain, FIN = Finland, FRA = France, ITA = Italy, JPN = Japan, NLD = Netherlands, NOR = Norway, PRT = Portugal, SWE = Sweden, UK = United Kingdom, USA = United States.
Source: Human Mortality Database.

Table A.2. Evolution of female life expectancy for the US, and sixteen other high-income countries, 1958-67 to 1998-2007

Life expectancy (years)	1958-67	1968-77	1978-87	1988-97	1998-07
Above 80				JPN (82.5)	JPN (85.1)
				FRA (81.4)	FRA (83.3)
				CHE (81.4)	CHE (83.2)
				ESP (81.2)	ESP (83.2)
				SWE (80.9)	ITA (83.1)
				CAN (80.8)	AUS (82.9)
				ITA (80.8)	SWE (82.4)
				AUS (80.6)	CAN (82.2)
				NLD (80.2)	NOR (81.9)
				NOR (80.2)	FIN (81.8)
					AUT (81.7)
					DEU (81.6)
					NLD (81.1)
					PRT (80.9)
					UK (80.7)
75 to 80	NOR (76.1)	NOR (77.6)	JPN (79.8)	DEU (79.6)	USA (79.9)
	NLD (75.8)	SWE (77.5)	CHE (79.6)	FIN (79.6)	DNK (79.7)
	SWE (75.6)	NLD (77.2)	SWE (79.4)	AUT (79.4)	
		CHE (77.0)	NLD (79.4)	USA (79.0)	
		CAN (76.8)	CAN (79.3)	UK (78.9)	
		DNK (76.4)	NOR (79.2)	PRT (78.5)	
		FRA (76.3)	ESP (79.0)	DNK (77.9)	
		JPN (75.9)	FRA (79.0)		
		ESP (75.5)	AUS (78.6)		
		USA (75.5)	FIN (78.3)		
		AUS (75.4)	ITA (78.2)		
		UK (75.3)	USA (77.9)		
		ITA (75.2)	DNK (77.5)		
		FIN (75.1)	DEU (77.3)		
			UK (77.0)		
			AUT (76.7)		
			PRT (75.9)		
70 to 75	CAN (74.6)	DEU (74.3)			
	CHE (74.6)	AUT (74.2)			
	DNK (74.5)	PRT (71.5)			
	FRA (74.2)				
	AUS (74.2)				
	UK (74.1)				
	USA (73.6)				
	DEU (72.8)				
	FIN (72.6)				
	ITA (72.5)				
	AUT (72.5)				
	ESP (72.5)				
	JPN (71.7)				
65 to 70	PRT (67.5)				

AUS = Australia, AUT = Austria, CAN = Canada, CHE = Switzerland, DEU = West Germany, DNK = Denmark, ESP = Spain, FIN = Finland, FRA = France, ITA = Italy, JPN = Japan, NLD = Netherlands, NOR = Norway, PRT = Portugal, SWE = Sweden, UK = United Kingdom, USA = United States.
Source: Human Mortality Database.

Table A.3. Evolution of male 15q0 for the US, and sixteen other high-income countries, 1958-67 to 1998-2007 (per 1,000 live births)

1958-67	1968-77	1978-87	1988-97	1998-07
SWE (24)	SWE (17)	SWE (11)	SWE (8)	SWE (5)
NLD (28)	NLD (21)	FIN (12)	JPN (8)	JPN (6)
NOR (29)	NOR (21)	JPN (12)	FIN (9)	FIN (6)
DNK (31)	FIN (21)	DNK (14)	DEU (10)	NOR (6)
AUS (31)	DNK (21)	CHE (14)	NOR (10)	ITA (6)
FIN (32)	JPN (22)	NOR (14)	CHE (10)	DEU (7)
UK (32)	CHE (23)	NLD (14)	NLD (10)	AUT (7)
CHE (33)	FRA (25)	CAN (16)	CAN (11)	FRA (7)
FRA (37)	UK (26)	FRA (16)	DNK (11)	ESP (7)
USA (38)	AUS (26)	AUS (17)	AUT (11)	DNK (7)
CAN (39)	CAN (27)	UK (17)	FRA (11)	CHE (7)
JPN (43)	USA (28)	DEU (18)	AUS (11)	NLD (8)
DEU (43)	DEU (32)	ESP (18)	UK (11)	AUS (8)
AUT (47)	ESP (34)	USA (19)	ESP (11)	CAN (8)
ITA (56)	AUT (34)	ITA (19)	ITA (11)	UK (8)
ESP (59)	ITA (36)	AUT (20)	USA (14)	PRT (9)
PRT (116)	PRT (69)	PRT (33)	PRT (18)	USA (11)

AUS = Australia, AUT = Austria, CAN = Canada, CHE = Switzerland, DEU = West Germany, DNK = Denmark, ESP = Spain, FIN = Finland, FRA = France, ITA = Italy, JPN = Japan, NLD = Netherlands, NOR = Norway, PRT = Portugal, SWE = Sweden, UK = United Kingdom, USA = United States.
Source: Human Mortality Database.
Note: 15q0 is defined as the probability of dying from birth through age 14 at then prevailing age-specific mortality rates.

Table A.4. Evolution of female 15q0 for the US, and sixteen other high-income countries, 1958-67 to 1998-2007 (per 1,000 live births)

1958-67	1968-77	1978-87	1988-97	1998-07
SWE (18)	SWE (13)	FIN (9)	SWE (6)	SWE (4)
NLD (21)	NOR (15)	SWE (9)	JPN (7)	FIN (5)
NOR (21)	DNK (15)	JPN (9)	FIN (7)	JPN (5)
DNK (22)	FIN (15)	CHE (10)	NOR (8)	NOR (5)
FIN (24)	NLD (15)	DNK (10)	DEU (8)	FRA (5)
AUS (24)	JPN (16)	NOR (11)	CHE (8)	ITA (6)
CHE (24)	CHE (17)	NLD (11)	NLD (8)	DEU (6)
UK (25)	FRA (19)	FRA (12)	FRA (8)	AUT (6)
FRA (29)	UK (19)	CAN (12)	DNK (8)	DNK (6)
USA (29)	AUS (20)	AUS (13)	CAN (8)	CHE (6)
CAN (30)	CAN (20)	UK (13)	AUT (9)	ESP (6)
DEU (33)	USA (21)	DEU (13)	UK (9)	NLD (6)
JPN (34)	DEU (24)	ESP (14)	AUS (9)	AUS (6)
AUT (37)	AUT (25)	USA (14)	ESP (9)	UK (7)
ITA (47)	ESP (26)	AUT (15)	ITA (9)	CAN (7)
ESP (47)	ITA (28)	ITA (15)	USA (11)	PRT (7)
PRT (100)	PRT (55)	PRT (25)	PRT (13)	USA (9)

AUS = Australia, AUT = Austria, CAN = Canada, CHE = Switzerland, DEU = West Germany, DNK = Denmark, ESP = Spain, FIN = Finland, FRA = France, ITA = Italy, JPN = Japan, NLD = Netherlands, NOR = Norway, PRT = Portugal, SWE = Sweden, UK = United Kingdom, USA = United States.
Source: Human Mortality Database.
Note: 15q0 is defined as the probability of dying from birth through age 14 at then prevailing age-specific mortality rates.

Table A.5. Evolution of male 35q15 for the US, and sixteen other high-income countries, 1958-67 to 1998-2007 (per 1,000)

1958-67	1968-77	1978-87	1988-97	1998-07
NLD (59)	NLD (60)	NLD (50)	JPN (44)	SWE (36)
SWE (62)	SWE (66)	JPN (55)	NLD (44)	NLD (37)
DNK (63)	NOR (66)	UK (57)	SWE (47)	JPN (40)
NOR (66)	UK (67)	SWE (59)	UK (51)	CHE (41)
UK (71)	DNK (68)	NOR (61)	NOR (53)	ITA (41)
CHE (78)	CHE (69)	ITA (61)	AUS (55)	CAN (44)
ESP (79)	ESP (67)	CHE (62)	CAN (56)	NOR (45)
ITA (79)	JPN (73)	ESP (64)	ITA (56)	AUS (46)
CAN (84)	ITA (75)	AUS (66)	CHE (60)	DEU (46)
DEU (85)	CAN (84)	CAN (66)	DEU (60)	UK (47)
AUS (87)	AUS (84)	DNK (69)	DNK (64)	AUT (50)
AUT (94)	DEU (87)	DEU (73)	AUT (69)	DNK (52)
JPN (95)	AUT (97)	FIN (85)	ESP (72)	ESP (53)
FRA (97)	FRA (97)	USA (87)	FRA (79)	FRA (62)
USA (105)	PRT (104)	FRA (87)	FIN (81)	FIN (64)
PRT (106)	USA (106)	AUT (87)	USA (85)	USA (71)
FIN (115)	FIN (113)	PRT (93)	PRT (90)	PRT (76)

AUS = Australia, AUT = Austria, CAN = Canada, CHE = Switzerland, DEU = West Germany, DNK = Denmark, ESP = Spain, FIN = Finland, FRA = France, ITA = Italy, JPN = Japan, NLD = Netherlands, NOR = Norway, PRT = Portugal, SWE = Sweden, UK = United Kingdom, USA = United States.
Source: Human Mortality Database.
Note: 35q15 is defined as the probability of dying from age 15 through age 49 at then prevailing age-specific mortality rates.

Table A.6. Evolution of female 35q15 for the US, and sixteen other high-income countries, 1958-67 to 1998-2007 (per 1,000)

1958-67	1968-77	1978-87	1988-97	1998-07
NOR (34)	NOR (31)	NOR (28)	JPN (23)	ITA (20)
NLD (37)	CHE (35)	JPN (28)	ITA (25)	JPN (20)
SWE (39)	NLD (36)	ESP (29)	SWE (26)	SWE (20)
CHE (41)	SWE (36)	ITA (29)	NOR (27)	CHE (21)
DNK (45)	ITA (39)	NLD (30)	AUS (27)	ESP (22)
CAN (46)	ESP (39)	SWE (30)	ESP (27)	AUS (23)
UK (46)	FIN (40)	FIN (31)	CAN (28)	AUT (24)
ITA (48)	JPN (42)	CHE (31)	CHE (28)	NOR (24)
FIN (50)	UK (42)	AUS (33)	NLD (28)	DEU (24)
DEU (51)	CAN (43)	CAN (34)	UK (29)	CAN (24)
AUT (51)	DNK (44)	UK (34)	FIN (30)	NLD (26)
AUS (51)	AUT (45)	DEU (36)	DEU (31)	UK (26)
ESP (51)	FRA (46)	FRA (37)	AUT (31)	FIN (26)
FRA (51)	AUS (46)	AUT (38)	FRA (32)	FRA (27)
PRT (59)	DEU (46)	PRT (41)	PRT (36)	DNK (28)
USA (59)	PRT (50)	DNK (41)	DNK (37)	PRT (29)
JPN (65)	USA (55)	USA (42)	USA (39)	USA (37)

AUS = Australia, AUT = Austria, CAN = Canada, CHE = Switzerland, DEU = West Germany, DNK = Denmark, ESP = Spain, FIN = Finland, FRA = France, ITA = Italy, JPN = Japan, NLD = Netherlands, NOR = Norway, PRT = Portugal, SWE = Sweden, UK = United Kingdom, USA = United States.
Source: Human Mortality Database.
Note: 35q15 is defined as the probability of dying from age 15 through age 49 at then prevailing age-specific mortality rates.

BMJ open

Improving life expectancy: how many years behind has the US fallen? A cross-national comparison among high-income countries, 1958-2007

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2013-002814.R1
Article Type:	Research
Date Submitted by the Author:	08-May-2013
Complete List of Authors:	Verguet, Stephane; University of Washington, Global Health Jamison, Dean; University of Washington, Global Health
Primary Subject Heading:	Public health
Secondary Subject Heading:	Public health, Health services research
Keywords:	PUBLIC HEALTH, International health services < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

Title

Improving life expectancy: how many years behind has the US fallen? A cross-national comparison among high-income countries, 1958-2007

Authors

Stéphane Verguet, Dean T Jamison

Affiliation

Department of Global Health, University of Washington, Seattle, WA, USA

Correspondence to

Stéphane Verguet, Department of Global Health, University of Washington, 325, 9th Avenue, Box 359931, Seattle, WA, 98104. Ph: +1-206-221-2147. Fax: +1-206-744-3694. Email: verguet@uw.edu.

Keywords

Life expectancy; population health; high-income countries; US; years behind.

Abstract

Objective: many studies have documented higher mortality levels in the United States compared to other high-income nations. We add to this discussion by quantifying how many years behind comparison countries the US has fallen and by identifying when US mortality rates began to diverge.

Design: We use full life tables, for males and females, for seventeen high-income countries including the US. We extract the life expectancy at birth and compute the mortality rates for each five-year age group from birth up to age 80. Using the metric of how many "years behind" a country has fallen, we compare US mortality levels with those in the other high-income countries ("comparators").

Results: We report life expectancy for seventeen high-income countries, for the period 1958-2007. Up to the late 1970s, US men and especially women closely tracked comparators in life expectancy. In the late 1970s the US, most strikingly women, began to diverge from comparators so that the US female life expectancy in 2007 corresponded to that of the comparators' average 10 years earlier. Mortality rates also began to diverge from the late 1970s, and the largest mortality gap was in the 15-49 age group, for both males and females, where the US had fallen about 40 years behind the comparators by 2007.

Conclusions: Some causes proposed for high relative US mortality today – racial differences, lack of universal health insurance, US exceptionalism – changed little while the mortality gap emerged and grew. This suggests that explanations for the growing gap lie elsewhere. Quantification of how many years behind the US has fallen can help provide clues about where to look for potential causes and remedies.

Article summary

Article focus

- Many studies have documented higher mortality levels in the US compared to other high-income nations of Europe and Australasia.
- This study quantifies how many years behind comparison countries the US has fallen and explores whether there was a particular time when US mortality rates began to diverge from comparators.

Key messages

- Since the late 1970s, the US life expectancy, most strikingly women's, began to diverge from comparators so that the US female life expectancy in 2007 corresponded to that of the comparators' average 10 years earlier.
- Mortality rates also began to diverge from the late 1970s, and the largest mortality gap was in the 15-49 age group, for both males and females, where by 2007 the US had fallen about 40 years behind the comparators.
- Identification of when US mortality rates began to diverge from comparators provides clues about where to look for potential causes and remedies.

Strengths and limitations of this study

- The strength of this study is that it uses full life tables, for males and females, for seventeen high-income countries for an extended time series. The detailed results allow for tracking the magnitude and timing of US divergence. This provides a specific criterion for assessing the explanatory power of causes proposed for poor performance, and narrows the range of potentially important determinants.

- The main limitation of this study is that it does not propose comprehensive explanations for high relative US mortality today and why the mortality gap emerged and grew, as it is instead a tool for others making those assessments. Concern for the poor US performance on mortality prompted major investigations by the US National Academy of Sciences into its causes, and it is not our purpose to reiterate the conclusions of the US National Academies' assessments.
- This paper adds to the National Academies' assessments by identifying rapid changes on the path to improvement in life expectancy and a particular point in time marking the US deterioration relative to its comparators.

Introduction

Much has been said and debated about the differences in health outcomes among high-income countries. Using different measures of health, mortality and disability, many studies have documented that the population of the United States is less healthy than those of the high-income nations in Europe and Australasia. This finding of poorer US health outcomes relative to other nations plays a significant part in public debate over improving US health outcomes.[1] This paper adds to the previous discussion by quantifying how many years behind its comparators the US has fallen and by exploring whether there was a particular time when US mortality rates began to diverge from the others. Identification of such a time would provide clues about where to look for potential causes and remedies.

The metric used to assess performance must be able to capture variation across countries and over time. In this paper we apply a long-established approach to performance measurement that lends itself readily to graphic depiction: the assessment of how many "years behind" a country has fallen, relative to other countries.[2,3] We compare the life expectancy (and age-specific mortality rates) for men and women in the US with the best country life expectancy ("leader") and figures from sixteen other high-income countries in the Organisation for Economic Co-operation and Development (OECD) ("comparators"), from 1958-2007, using data primarily from the Human Mortality Database.[4] This dynamic depiction also captures the magnitude of the effort needed to catch-up with other participants. Evolution over time of years behind enables sensitive identification of divergent and convergent trends, and the ability to flag rapid changes on the path to improvement in life expectancy. This capacity underpins an important purpose

of this paper, which is to identify whether there is a point in time marking the beginning of US deterioration relative to its comparators.

Design

Data

We use full life tables encompassing the years 1850 through 2007,[4] for males and females, for the following seventeen countries: Australia, Austria, Canada, Denmark, Finland, France, Germany (West Germany), Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States. This set of countries is a subset of high-income OECD countries chosen for best comparability to the US. The selection criteria were of sufficient population size to ensure stability of estimates, high development achieved for a long time period, data quality and availability, and were described elsewhere.[5] We extract the life expectancy at birth for males and females, and the mortality rates for each five-year age group from birth up to age 80 (0-4, 5-9, 10-14,…, 70-74, 75-79), and additionally for the specific age ranges 0-14 and 15-49.

Approach

We report life expectancy at birth for males and females for all seventeen countries, for the period 1958-2007.[a] In keeping with published methodology, for each year we identify the highest recorded life expectancy i.e. the leader.[1,6,7] These point estimates define a

[a] The latest year available for the United States was 2007. The earliest available year for West Germany was 1956. We retained the years 1958 to 2007 in order to have five 10-year periods.

"maximum frontier." We also estimate the average life expectancy recorded for the sixteen countries (arithmetic average), besides the US, i.e. the comparators. Finally, we compare the US life expectancy to both the leader and the comparators. We do this by calculating how many years behind the leader the US and the comparators fall in a given year. For instance, if in 2007 the US had a life expectancy which was closest to the life expectancy of the leader in 1986, then the US is said to have been 21 years behind the leader in 2007.

In order to investigate to what extent the health gap varies across different age groups, we analyze mortality rates for males and females for the age groups described above, for the period 1958-2007. Similarly, we identify the country with the lowest recorded mortality rates in a given year (leader), which defines a "minimum frontier," and we compute the comparators' average observed mortality rates per age group. Note that this leader is not necessarily the same as the leader in life expectancy. Finally, we calculate how many years behind the US and the comparators are for each age group and each year of the period 1958-2007.

Results

Years behind for life expectancy

Figure 1.a shows, over the period 1958-2007, for male and female life expectancy, the evolution of the leader, the US and the comparators. In any given year, the leader, the US and the comparators had higher life expectancies for females than for males. The US life expectancy for males was lower than the comparators' life expectancy for males; the differential of life expectancy between the US and the leader diminished from the late

1950s to the late 1970s, and then stayed about the same after the late 1970s, while the differential of life expectancy between the US and the comparators slightly increased after the late 1970s. For females, the US life expectancy was about the same as the comparators from the late 1950s to the late 1970s, and both converged slightly toward the leader. Notably, after the late 1970s, the life expectancy for US females started to diverge substantially from both the comparators and the leader; the US presented a rate of increase of about 1 year per decade, far below the 2-3 years per decade of the leader. Tables A.1 and A.2 in the Supplementary Appendix show, for males and females, the life expectancy across countries for each decade from 1958.

FIGURE 1 AROUND HERE

The number of years behind the leader, for male and female life expectancy, for the US and the comparators, is presented in figure 1.b. In addition, the number of years behind the comparators for the US is also presented in figure A.1 (Supplementary Appendix). Because the same quantity of years behind may correspond to different absolute gaps in life expectancy depending on the trends in the comparator countries, figure A.5 (Supplementary Appendix) also reports, for males and females, the gap in life expectancy between the US and the comparators, and between the US and the leader. Over the period 1958-2007, for male life expectancy, the US always fell behind the comparators, up to 25 years behind the comparators (figure A.1), and fell between 15 and 35 years behind the leader. Up to about the late 1970s, both the US and the comparators presented a similar trend in increasing years behind the leader. Then, over the course of only a few years, the comparators narrowed the distance from 25 to 10 years behind,

followed by a slightly decreasing trend until 2007 where it was about 5 years behind the leader. In contrast, the US narrowed the distance with the leader abruptly in the late 1980s (slightly delayed relative to the comparators), and then remained at about the same level of 20 years behind the leader through 2007 leading to substantial divergence from the comparators (about 15 years behind the comparators in 2007).

Over the period 1958-2007, the life expectancy for US females was up to 10 years behind the comparators and between 10 and 20 years behind the leader, which was better than US male life expectancy but hid a disturbing trend (figure 1.b). Up to about the late 1970s, US females and the comparators presented similar trajectories: starting around 10 years behind the leader, they trailed to around 20, but made a comeback to where they were, again, about 10 years behind the leader. Then, the US substantially diverged from the comparators, falling further and further behind at a steady pace (figure 1.b; figure A.1). In 1998-07, the US was about 10 years behind the comparators and about 20 years behind the leader, with a life expectancy of 79.9 years (Supplementary Appendix, table A.2).

Years behind in age-specific mortality rates

Figure 2 shows the number of years behind the leader the US and the comparators were for five-year age groups, for males and females and two time periods, the early 1960s (1958-67) and the early 2000s (1998-07). The number of years behind the comparators the US was for five-year age groups is also presented in figure A.2 (Supplementary Appendix). In the early 1960s, the US and the comparators presented similar age distributions for the number of years behind the leader, for males and females. Males presented a larger number of years behind than females across almost all age groups;

females in both the US and the comparators presented almost identical age distributions for years behind the leader. The situation in the early 2000s was very different for the US. For females, the comparators presented a pattern similar to the early 1960s, between 10 and 20 years behind the leader across all age groups; the US presented a larger number of years behind the leader but most significantly the number of years behind the leader had increased substantially between age 15 and age 50 (about 30 years behind the comparators; figure A.2). For males, the comparators had substantially reduced the number of years behind the leader beyond age 45, but increased the number of years behind the leader from age 15 to age 40; the US had also substantially reduced the number of years behind the leader after age 45, and like the comparators, had increased the number of years behind the leader between age 10 and age 45 (about 30 years behind the comparators; figure A.2).

FIGURE 2 AROUND HERE

Figure 3.a shows time trends in the probability of dying between age birth and age 15 (15q0) for the leader, the US and the comparators. Tables A.3 and A.4 in the Supplementary Appendix show values for 15q0 across countries. In a given year, the leader, the US and the comparators had higher mortality rates for males than for females. For both males and females, from the early 1960s to the early 2000s, the differential of 15q0 between the US and the comparators stayed similar (slightly increasing), and the differential of 15q0 between the US and the leader also stayed similar (slightly decreasing). The US 15q0 started lower than the comparators' 15q0 for both males and females; in the 1970s, the US and the comparators crossed. For both males and females,

the comparators' 15q0 was converging toward the leader throughout the entire time period.

FIGURE 3 AROUND HERE

Figure 4.a shows time trends for the probability of dying between age 15 and age 50 (35q15) for the leader, the US and the comparators. Tables A.5 and A.6 in the Supplementary Appendix show values for 35q15 across countries. In a given year, the leader, the US and the comparators had substantially higher mortality rates for males than for females. For both males and females, the US 35q15 was always higher than the comparators' 35q15; the differential of 35q15 between the US and the comparators and between the US and the leader stayed about the same from 1958 to 2007, for males. However, for females, the US was slightly diverging from both the comparators and the leader from 1980 onward.

FIGURE 4 AROUND HERE

Figures 3.b and 4.b show the number of years behind the leader the US and the comparators were for the 0-14 and 15-49 age groups, for males and females, over the 1958-2007 period. The number of years behind the comparators the US was, for the mortality rates in the 0-14 and 15-49 age groups, is also presented in figures A.3 and A.4 (Supplementary Appendix). Figures A.6 and A.7 (Supplementary Appendix) also report, for males and females, the gap in 15q0 and 35q15 between the US and the comparators, and between the US and the leader. For the 0-14 age group, up to the late 1970s, the US

and the comparators showed somewhat similar trajectories, between 10 and 20 years behind the leader (both males and females); on average, the US was slightly ahead of the comparators then. Afterwards, while the comparators consistently kept pace about 10 years behind the leader, the US saw an increase up to 15 years behind the comparators (figure A.3) and up to between 20 and 30 years behind the leader through 2007 (both males and females). For the 15-49 age group, the US was always behind the comparators over the whole period; the US consistently diverged from the leader. The male trajectory, for the US and the comparators, was similar until the early 1990s, when the comparators started converging on the leader, dropping from about 40 to 15 years behind the leader in 2007; meanwhile, the US kept diverging with years behind the comparators increasing from about 10 years in 1990 to about 45 years in 2007 (figure A.4), a corresponding increase in years behind the leader from about 45 years in 1990 to about 55 years. The female trajectory, for the US and the comparators, was somewhat similar until the mid-1970s (20-25 years behind the leader then), when the comparators kept the distance behind the leader below 20 years (below 10 years behind the leader in 2007), while the US continued diverging, being about 40 years behind the comparators and about 50 years behind the leader in 2007.

Discussion

This paper applies a sensitive measure of national performance – years behind – to comparison of US mortality rates with those of other high-income countries. As has been well documented,[1,8] US life expectancy is lower and mortality rates are higher than in other high-income or comparator countries. Life expectancy results summarize and aggregate an heterogeneous combination of distinct age-specific mortality measures and

patterns, hence we further examined mortality rates across different age groups. Most strikingly, for both males and females, the typical high-income country had achieved, by the 1970s, a mortality rate in the age group 15-49 that the US failed to achieve until about 2007: i.e., the US, in 2007 fell about 40 years behind the average (and 50 years behind the leader). A similar if less pronounced pattern appears for life expectancy and for mortality under age 15. The US now lies far behind other high-income countries, but this was not always so. The detailed results of this paper allow for tracking the magnitude of US divergence and for (approximate) timing of when it began. Although our results contain noise a key result emerges: sometime in the late 1970s the US stopped tracking its comparators and began to fall behind (table 1). At different rates for different indicators the US fell further and further behind over subsequent three decades. The finding is remarkably striking for US females.

TABLE 1 AROUND HERE

The analysis presents several strengths. It uses full life tables, for males and females, for seventeen high-income countries for an extended time series, and it allows for tracking the timing of US divergence. This provides a specific criterion for assessing the explanatory power of causes proposed for poor performance, and narrows the range of potentially important determinants. In particular, trends in mortality rates provide a starting point for assessing the importance of the determinants of health.[9,10] The analysis also has limitations. For instance, it does not aim at fully explaining in detail why the US mortality gap emerged and grew, as it essentially proposes a tool for others making those assessments. In addition, while the results highlight a particular period in time when the

US fell behind other countries, one should be cautious in interpretation as there may be a lag time between any determinant change and its population-level effect on mortality. The timing of effects is delicate as different policies may have different temporal spans (e.g. tobacco control). It may take a long time to reduce mortality gaps, if appropriate interventions are not implemented rapidly. Some diseases may be amenable to both immediate curative and preventive interventions (e.g. reduction of blood pressure) whereas certain habits/conditions independent of the current state of things, such as tobacco consumption[11] and obesity,[12,13] can affect mortality many decades later. Finally, the years behind results may be more stable when the comparator is the average of all the other countries rather than the leading country as there may be rapid changes in the leading country (tables A.1-4, Supplementary Appendix). Hence, we also presented results for years behind the comparators (figures A.1-4; Supplementary Appendix).

Concern for the poor US performance on mortality prompted major investigations by the US National Academy of Sciences[1,8] into its nature (in terms of age groups and conditions) and its causes. Major potential causes that have been explored include cross-country differences in the level and equality of income, in level of education, in social cohesion, in a broad range of specific risk factors, and in the level and quality of expenditures on the health care system. The National Research Council (NRC) examined the diverging trends in mortality between the US and others with high income, looking at specific causes of deaths. NRC researchers estimated that a large part of the life expectancy difference was attributable to smoking, amounting to 80 and 40% of the difference for females and males, respectively.[11] Less dramatically, they suggested that 20 to 33% of the life expectancy gap could be attributable to higher rates of obesity.[12] They argued that smoking and obesity could well explain the rise of mortality recorded in

adult men and women over the last decades.[14] Other research has shown that chronically ill US patients tend to have less access to care, and benefit from less efficient and organized care, compared to counterparts in other high-income countries.[15] Beyond substantial healthcare spending, social welfare spending is a strong determinant for population health.[16] Overemphasizing individual risk factors can obscure the importance of key determinants of health such as financing and delivery.[17] Constructively, these determinants offer the possibility that political commitment inside and outside the health sector can make real improvements in population health.[16,17] Finally, the "compression" of older age mortality from 1958-67 to 1998-07 in the US may be attributable to the Medicare program introduced in 1965.

It is not our purpose to reiterate the conclusions of the National Academies' assessments. Rather our conclusions point to an additional and quite specific criterion for judging the explanatory power of potential explanations for poor performance in the US. Since we conclude divergence to have begun in the late 1970s, potential explanations like racial diversity, lack of health insurance and high income inequality in the US become less plausible. Racial diversity and income inequality were high, and insurance coverage low in the US in the 1970s when the US was performing well on health. Establishing a time for the beginning of the US divergence helps in identifying the effects of the broader social policy arena on health,[18] and in narrowing the range of potentially important determinants, and remedies.

Seeking potential explanations, we examined whether the more advantaged population groups presented similar trends to the average of comparator countries while looking at the maximum and minimum life expectancy (by county) and the average white and black life expectancy (by county) in the US[19] (figure A.8, Supplementary Appendix).

We found however that maximum male/female and white male/female life expectancy followed a somewhat distinct trajectory in recent decades. Likewise, the divergence from the 1970s could be related to a lack of universal coverage with unequal treatment access and coverage at a time when many treatments for cardiovascular disease (CVD) (e.g. anti-hypertensives, statins) became available. Using OECD data,[20] we examined whether this divergence was following declines in CVD mortality. We found on the contrary that US CVD mortality reduced more rapidly in the late 1970s compared to comparator countries (figure A.9, Supplementary Appendix). Recent research[21] showed that from 1983 to 1999, life expectancy declined significantly in 11 US counties for men and in 180 counties for women. These declines were caused by increased mortality from lung cancer, chronic obstructive pulmonary disease, diabetes, and were no longer compensated for by the CVD mortality decline.[21]

Measuring health system performance will remain difficult: health outcomes depend on the health system together with non-medical socio-economic and geographical determinants, and can be affected by favorable risk factors. Assessing performance in health in terms of "years behind" enables identifying trends and rapid changes in outcomes, for which researchers can then try to identify explanations. The years behind measure offers an intuitive and generalizable approach to measuring country performance in health, as well as convergent and divergent patterns, and can be readapted to various health indicators, for diverse disease- and condition-related outcomes. We suggest that this approach would also be valuable for the evaluation of US performance on specific causes of death and conditions, facilitating the design of policies that impact health and social risk factors for the most burdened populations.

Acknowledgements

The authors received valuable comments from Laudy Aron. We thank Anna Peeters and Goodarz Danaei for their constructive and valuable contributions on our work.

Contributors

SV and DTJ designed the study, conducted the analysis, interpreted the data and drafted the original manuscript.

Funding

This work was supported by the Bill & Melinda Gates Foundation through the Disease Control Priorities Network grant to the University of Washington, and by the National Research Council of the United States National Academies.

Competing interests

None declared

Data sharing statement

There is no additional data available.

References

1. Crimmins EM, Preston SH, Cohen B, editors. *Explaining divergent levels of longetivity in high-income countries*. Washington, DC: National Academies Press, 2011.

2. Sicherl P. Time-distance as a dynamic measure of disparities in social and economic development. *Kyklos* 1973; 26(3):559-575.

3. Kulkarni SC, Levin-Rector A, Ezzati M, et al. Falling behind: life expectancy in US counties from 2000 to 2007 in an international context. *Population Health Metrics* 2011; 9(1):16.

4. Human Mortality database. http://www.mortality.org/ (accessed 30 Aug 2011).

5. Ho JH, Preston SH. US mortality in an international context: age variations. *Population and Development Review* 2010; 36(4):749-773.

6. Oeppen J, Vaupel JW. Broken limits to life expectancy. *Science* 2002; 296:1029-31.

7. Vallin J, Meslé F. The segmented trend line of highest life expectancies, *Population and Development Review* 2009; 35(1):159-187.

8. Woolf S, Aron L, editors. *US health in international perspectives: shorter lives, poorer health*. Washington, DC: National Academies Press, 2013.

9. Verguet S, Jamison DT. Performance in rate of decline of adult mortality in the OECD, 1970-2010. *Health Policy* 2013; 109(2):137-42.

10. Verguet S, Jamison DT. Estimates of performance in the rate of decline of under-five mortality for 113 low- and middle-income countries, 1970-2010. *Health Policy and Planning* 2013; doi:10.1093/heapol/czs143.

11. Preston SH, Glei DA, Wilmoth JR. Contribution of smoking to international differences in life expectancy. In: Crimmins EM, Preston SH, Cohen B (eds). International Differences in Mortality at Older Ages: Dimensions and Sources. Washington, DC: The National Academies Press, 2010.

12. Alley DE, Lloyd J, Shardell M. Can obesity account for cross-national differences in life-expectancy trends? In: Crimmins EM, Preston SH, Cohen B (eds).

International Differences in Mortality at Older Ages: Dimensions and Sources. Washington, DC: The National Academies Press, 2010.

13. Comanor WS, Frech HE III, Miller RD Jr. Is the United States an outlier in health care and health outcomes? *International Journal of Health Care Finance and Economics* 2006; 6:3-23.

14. Preston S, Ho J. Low life expectancy in the United States: is the health care system at fault? In: Crimmins EM, Preston SH, Cohen B (eds). International Differences in Mortality at Older Ages: Dimensions and Sources. Washington, DC: The National Academies Press, 2010.

15. Schoen C, Osborn R, How SKH, et al. In chronic condition: experiences of patients with complex health care needs, in eight countries, 2008. *Health Affairs* 2009; 28(1):w1-w16.

16. Stuckler D, Basu S, McKee M. Budget crises, health, and social welfare programmes. *British Medical Journal* 2010; 340: doi.10.1136/bmj.c3311.

17. Geneau R, Stuckler D, Stachenko S, et al. Raising the priority of preventing chronic diseases: a political process. *Lancet* 2010; 376:1689-1698.

18. Dow WH, Rehkopf DH. Socioeconomic gradients in health in international and historical context. *Annals of the New York Academy of Sciences* 2010; 1186:24-36.

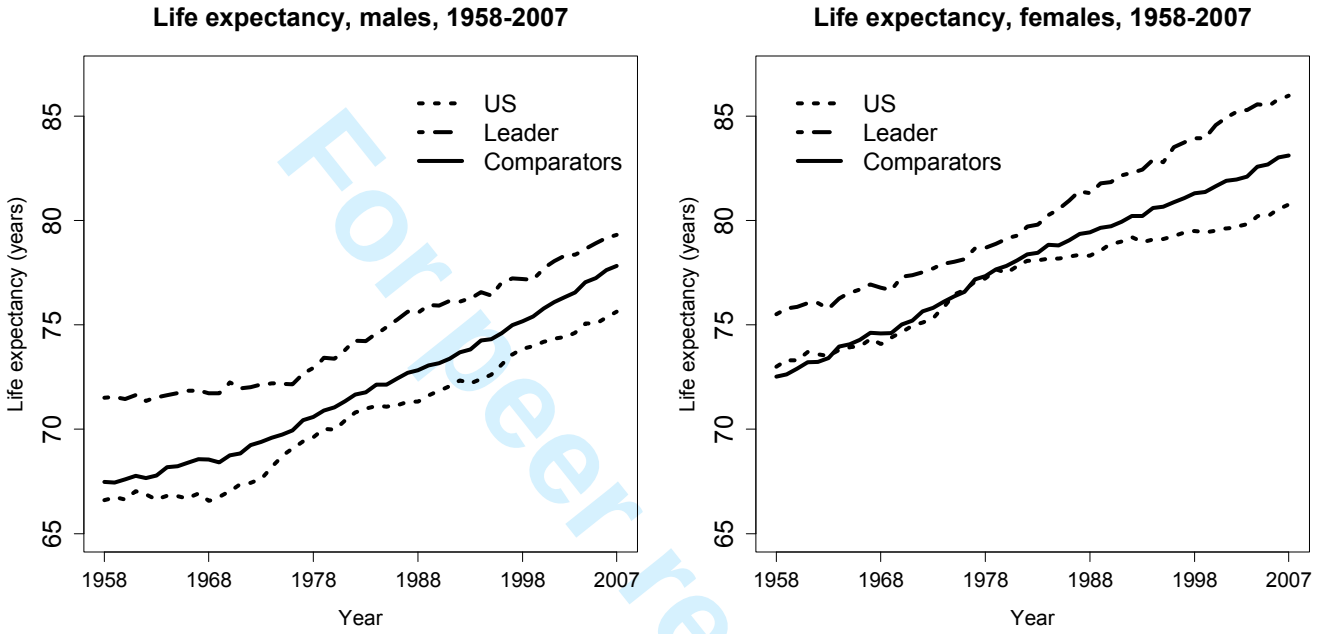
19. Institute for Health Metrics and Evaluation. Life expectancy in US counties 1989-2009. http://www.healthmetricsandevaluation.org/news-events/event/ihme-release-county-life-expectancy-results-14th-annual-health-journalism-conferen#/data-methods (accessed 30 Apr 2013).

20. Organisation for Economic Co-operation and Development. OECD.StatExctracts. http://stats.oecd.org/ (accessed 30 Apr 2013).

21. Ezzati M, Friedman AB, Kulkarni SC, et al. The reversal of fortunes: trends in county mortality and cross-county mortality disparities in the United States. *PloS Medicine* 2008; 5(4):e66.

Figure 1. Evolution of life expectancy and years behind the leader for the leader, the US, and the average of sixteen comparator high-income countries, males and females, 1958-2007

(a) Life expectancy



(b) Years behind the leader

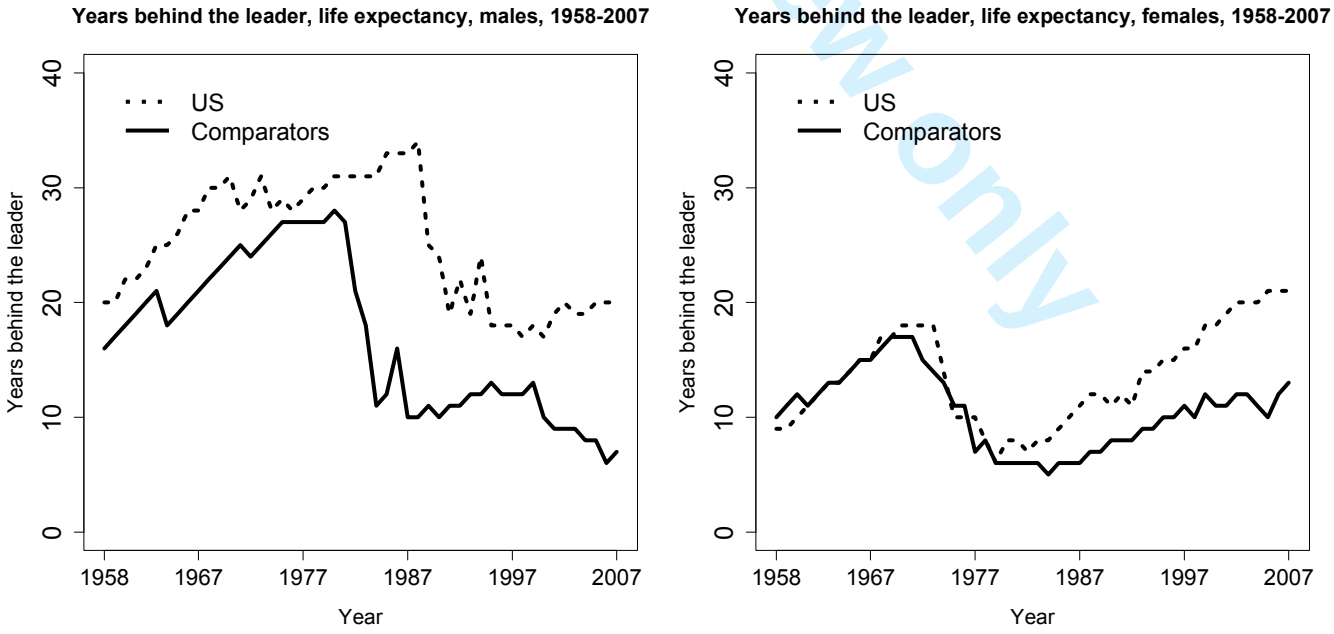
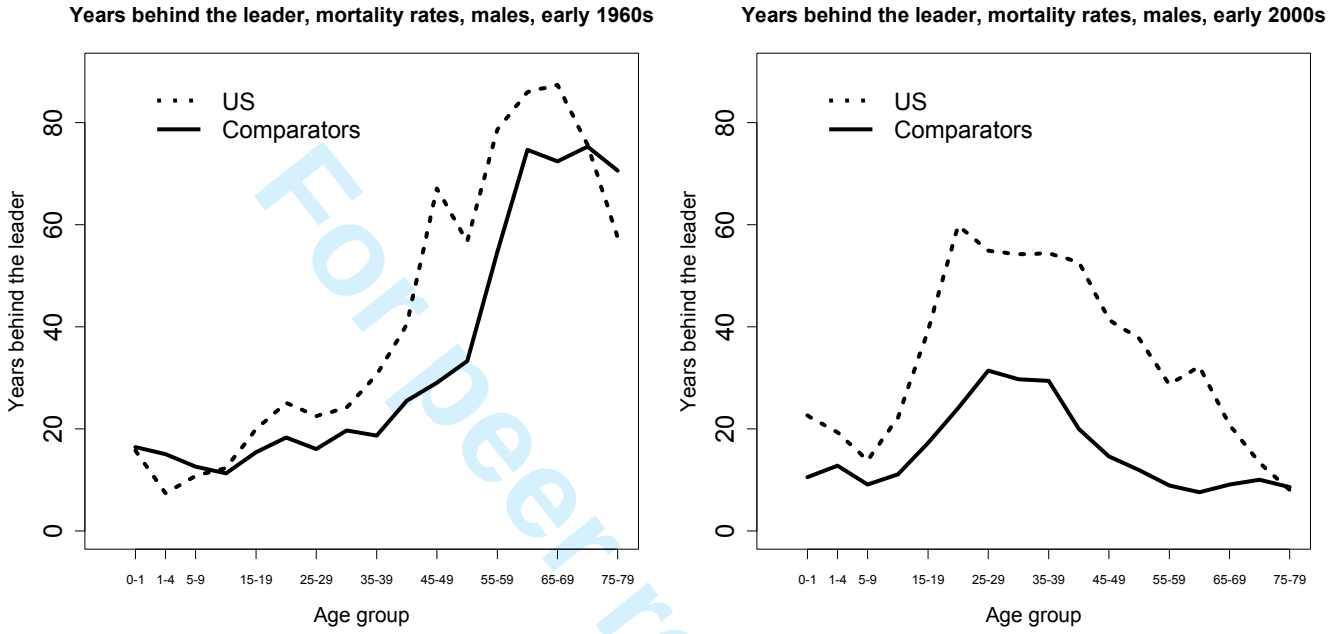
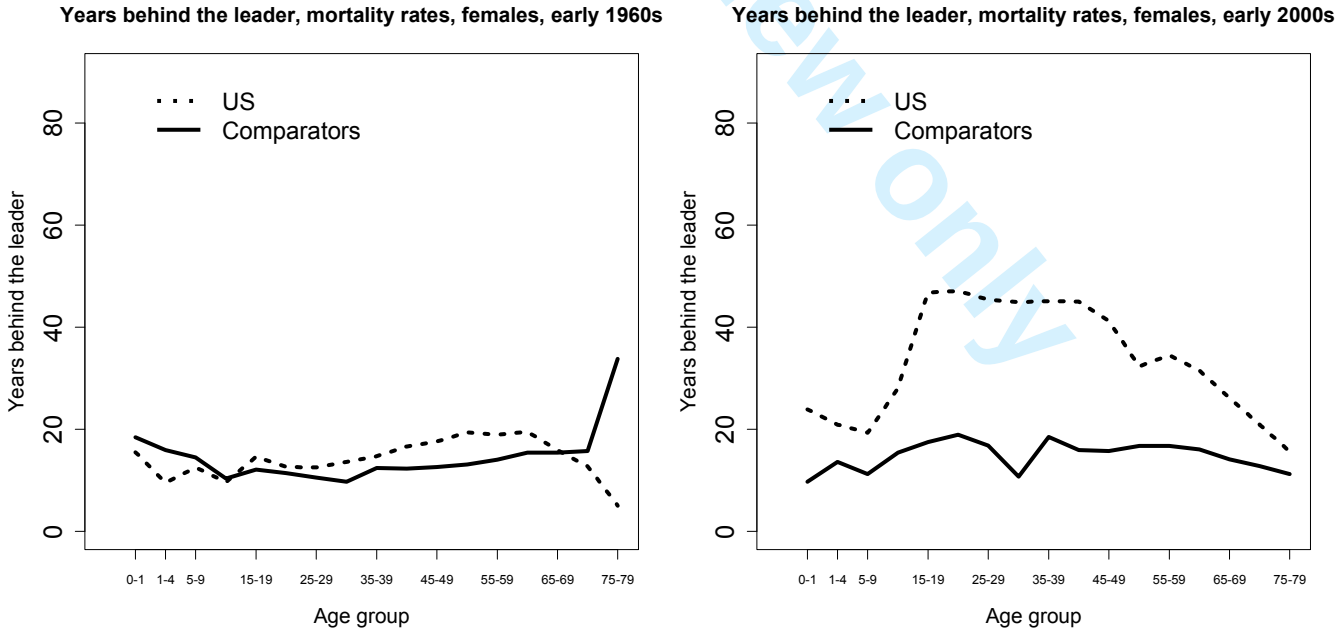


Figure 2. Number of years behind the leader for mortality rates across age groups, for the US and the average of sixteen comparator high-income countries, males and females, early 1960s and early 2000s

(a) Males



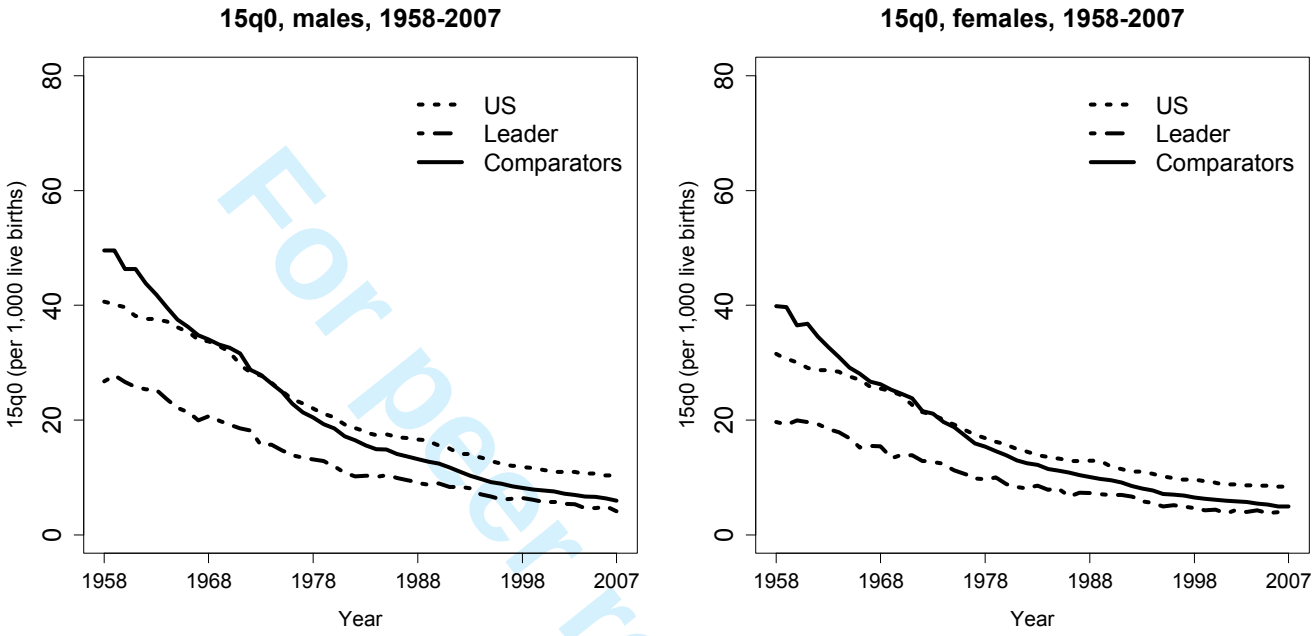
(b) Females



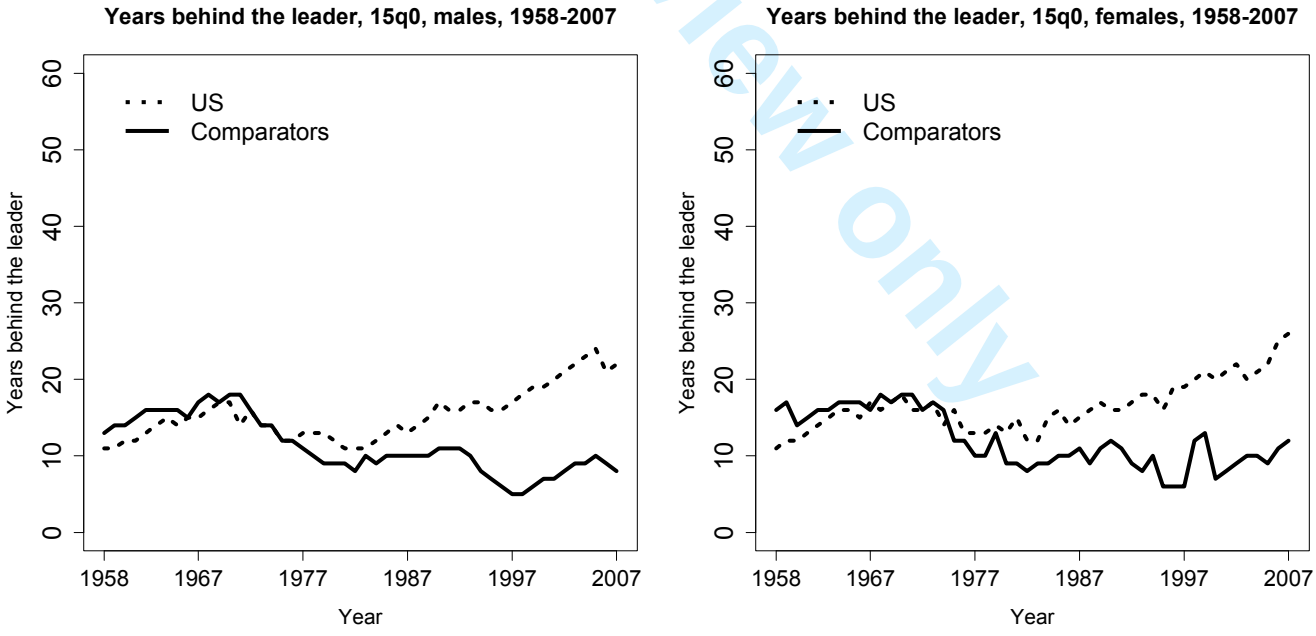
Note: Early 1960s refers to the period 1958-67 and early 2000s refers to 1998-2007.

Figure 3. Evolution of mortality rates and years behind the leader in the 0-14 age group, for the leader, the US, and the average of sixteen comparator high-income countries, males and females, 1958-2007

(a) Mortality rates



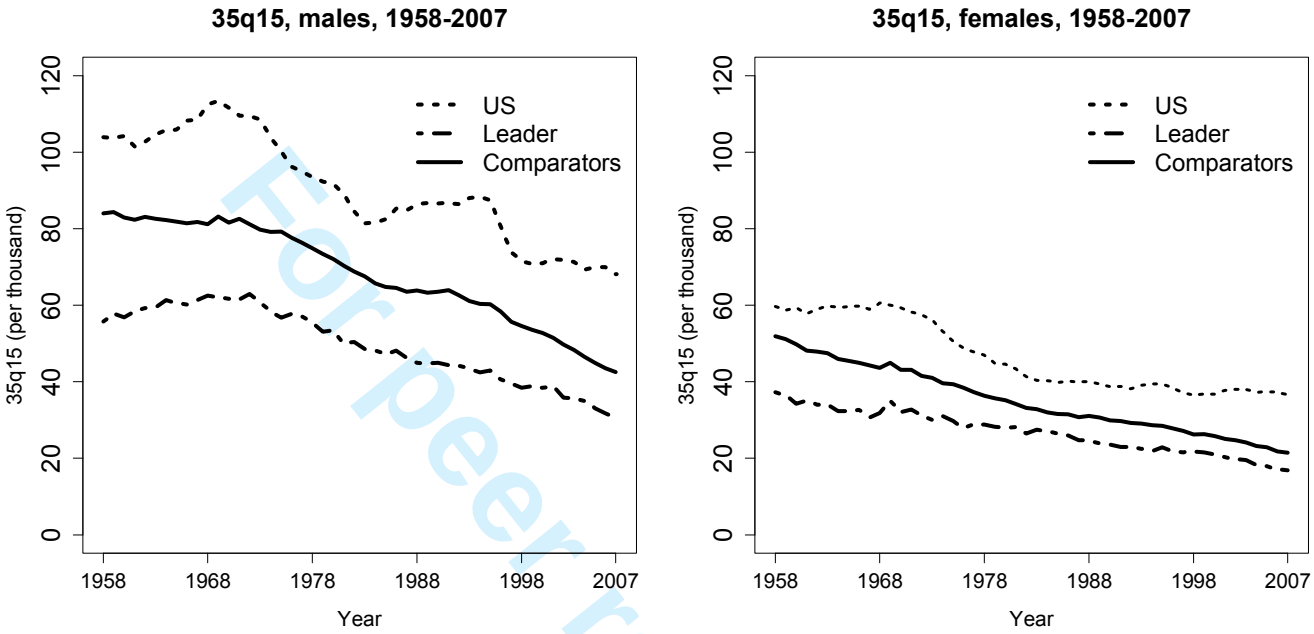
(b) Years behind the leader



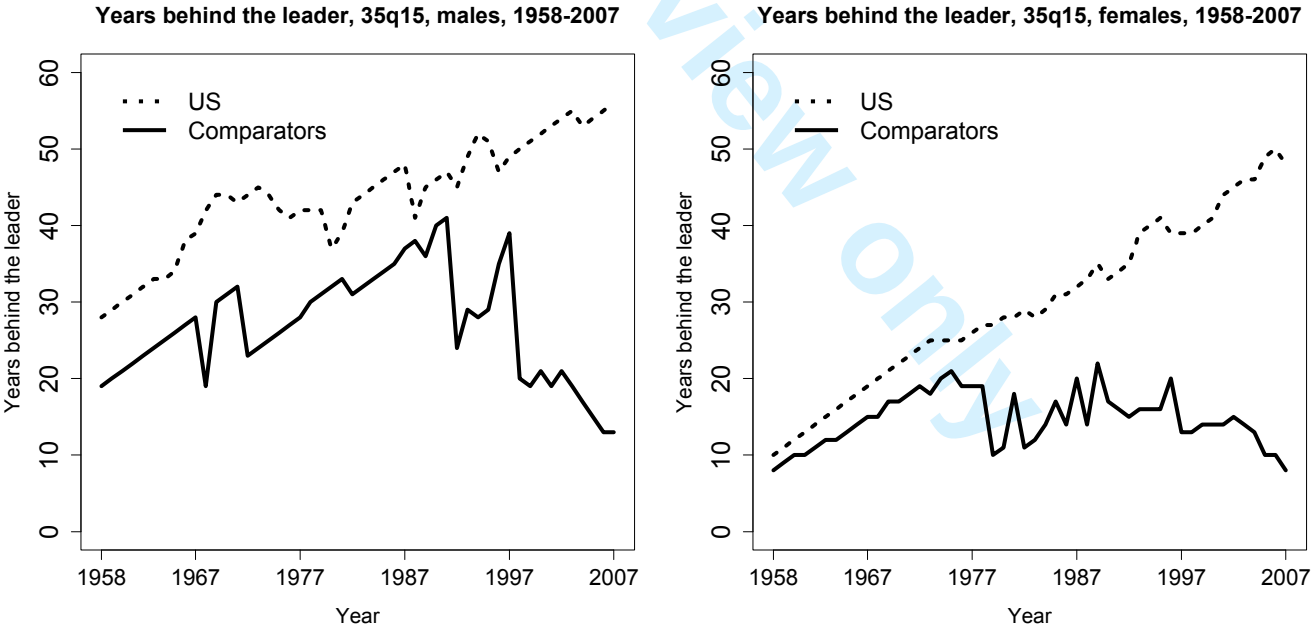
Note: 15q0 is defined as the probability of dying from birth through age 14 at then prevailing age-specific mortality rates.

Figure 4. Evolution of mortality rates and years behind the leader in the 15-49 age group, for the leader, the US, and the average of sixteen comparator high-income countries, males and females, 1958-2007

(a) Mortality rates



(b) Years behind the leader



Note: 35q15 is defined as the probability of dying from age 15 through age 49 at then prevailing age-specific mortality rates.

Table 1. Timing of US divergence from the average of sixteen comparator high-income countries, for life expectancy, 15q0, and 35q15, males and females, 1958-2007

Indicator	Males	Females
Life expectancy	Late 1970s (temporary reconvergence late '80s to late '90s)	Late 1970s
15q0	Late 1970s (US had lower mortality than comparators before 1965)	Late 1970s (US had lower mortality than comparators before 1965)
35q15	About 1990 (US already substantially behind comparators before divergence)	Late 1970s (more rapid divergence after about 1990)

Note: 15q0 is defined as the probability of dying from birth through age 14 at then prevailing age-specific mortality rates; 35q15 is defined as the probability of dying from age 15 through age 49 at then prevailing age-specific mortality rates.

Title

Improving life expectancy: how many years behind has the US fallen? A cross-national comparison among high-income countries, 1958-2007

Authors

Stéphane Verguet, Dean T Jamison

Affiliation

Department of Global Health, University of Washington, Seattle, WA, USA

Correspondence to

Stéphane Verguet, Department of Global Health, University of Washington, 325, 9th Avenue, Box 359931, Seattle, WA, 98104. Ph: +1-206-221-2147. Fax: +1-206-744-3694. Email: verguet@uw.edu.

Keywords

Life expectancy; population health; high-income countries; US; years behind.

Abstract

Objective: many studies have documented higher mortality levels in the United States compared to other high-income nations. We add to this discussion by quantifying how many years behind comparison countries the US has fallen and by identifying when US mortality rates began to diverge.

Design: We use full life tables, for males and females, for seventeen high-income countries including the US. We extract the life expectancy at birth and compute the mortality rates for each five-year age group from birth up to age 80. Using the metric of how many "years behind" a country has fallen, we compare US mortality levels with those in the other high-income countries ("comparators").

Results: We report life expectancy for seventeen high-income countries, for the period 1958-2007. Up to the late 1970s, US men and especially women closely tracked comparators in life expectancy. In the late 1970s the US, most strikingly women, began to diverge from comparators so that the US female life expectancy in 2007 corresponded to that of the comparators' average 10 years earlier. Mortality rates also began to diverge from the late 1970s, and the largest mortality gap was in the 15-49 age group, for both males and females, where the US had fallen about 40 years behind the comparators by 2007.

Conclusions: Some causes proposed for high relative US mortality today – racial differences, lack of universal health insurance, US exceptionalism – changed little while the mortality gap emerged and grew. This suggests that explanations for the growing gap lie elsewhere. Quantification of how many years behind the US has fallen can help provide clues about where to look for potential causes and remedies.

Article summary

Article focus

- Many studies have documented higher mortality levels in the US compared to other high-income nations of Europe and Australasia.
- This study quantifies how many years behind comparison countries the US has fallen and explores whether there was a particular time when US mortality rates began to diverge from comparators.

Key messages

- Since the late 1970s, the US life expectancy, most strikingly women's, began to diverge from comparators so that the US female life expectancy in 2007 corresponded to that of the comparators' average 10 years earlier.
- Mortality rates also began to diverge from the late 1970s, and the largest mortality gap was in the 15-49 age group, for both males and females, where by 2007 the US had fallen about 40 years behind the comparators.
- Identification of when US mortality rates began to diverge from comparators provides clues about where to look for potential causes and remedies.

Strengths and limitations of this study

- The strength of this study is that it uses full life tables, for males and females, for seventeen high-income countries for an extended time series. The detailed results allow for tracking the magnitude and timing of US divergence. This provides a specific criterion for assessing the explanatory power of causes proposed for poor performance, and narrows the range of potentially important determinants.

- The main limitation of this study is that it does not propose comprehensive explanations for high relative US mortality today and why the mortality gap emerged and grew, as it is instead a tool for others making those assessments. Concern for the poor US performance on mortality prompted major investigations by the US National Academy of Sciences into its causes, and it is not our purpose to reiterate the conclusions of the US National Academies' assessments.
- This paper adds to the National Academies' assessments by identifying rapid changes on the path to improvement in life expectancy and a particular point in time marking the US deterioration relative to its comparators.

Introduction

Much has been said and debated about the differences in health outcomes among high-income countries. Using different measures of health, mortality and disability, many studies have documented that the population of the United States is less healthy than those of the high-income nations in Europe and Australasia. This finding of poorer US health outcomes relative to other nations plays a significant part in public debate over improving US health outcomes.[1] This paper adds to the previous discussion by quantifying how many years behind its comparators the US has fallen and by exploring whether there was a particular time when US mortality rates began to diverge from the others. Identification of such a time would provide clues about where to look for potential causes and remedies.

The metric used to assess performance must be able to capture variation across countries and over time. In this paper we apply a long-established approach to performance measurement that lends itself readily to graphic depiction: the assessment of how many "years behind" a country has fallen, relative to other countries.[2,3] We compare the life expectancy (and age-specific mortality rates) for men and women in the US with the best country life expectancy ("leader") and figures from sixteen other high-income countries in the Organisation for Economic Co-operation and Development (OECD) ("comparators"), from 1958-2007, using data primarily from the Human Mortality Database.[4] This dynamic depiction also captures the magnitude of the effort needed to catch-up with other participants. Evolution over time of years behind enables sensitive identification of divergent and convergent trends, and the ability to flag rapid changes on the path to improvement in life expectancy. This capacity underpins an important purpose

of this paper, which is to identify whether there is a point in time marking the beginning of US deterioration relative to its comparators.

Design

Data

We use full life tables encompassing the years 1850 through 2007,[4] for males and females, for the following seventeen countries: Australia, Austria, Canada, Denmark, Finland, France, Germany (West Germany), Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States. This set of countries is a subset of high-income OECD countries chosen for best comparability to the US. The selection criteria were of sufficient population size to ensure stability of estimates, high development achieved for a long time period, data quality and availability, and were described elsewhere.[5] We extract the life expectancy at birth for males and females, and the mortality rates for each five-year age group from birth up to age 80 (0-4, 5-9, 10-14,…, 70-74, 75-79), and additionally for the specific age ranges 0-14 and 15-49.

Approach

We report life expectancy at birth for males and females for all seventeen countries, for the period 1958-2007.[a] In keeping with published methodology, for each year we identify the highest recorded life expectancy i.e. the leader.[1,6,7] These point estimates define a

[a] The latest year available for the United States was 2007. The earliest available year for West Germany was 1956. We retained the years 1958 to 2007 in order to have five 10-year periods.

"maximum frontier." We also estimate the average life expectancy recorded for the sixteen countries (arithmetic average), besides the US, i.e. the comparators. Finally, we compare the US life expectancy to both the leader and the comparators. We do this by calculating how many years behind the leader the US and the comparators fall in a given year. For instance, if in 2007 the US had a life expectancy which was closest to the life expectancy of the leader in 1986, then the US is said to have been 21 years behind the leader in 2007.

In order to investigate to what extent the health gap varies across different age groups, we analyze mortality rates for males and females for the age groups described above, for the period 1958-2007. Similarly, we identify the country with the lowest recorded mortality rates in a given year (leader), which defines a "minimum frontier," and we compute the comparators' average observed mortality rates per age group. Note that this leader is not necessarily the same as the leader in life expectancy. Finally, we calculate how many years behind the US and the comparators are for each age group and each year of the period 1958-2007.

Results

Years behind for life expectancy

Figure 1.a shows, over the period 1958-2007, for male and female life expectancy, the evolution of the leader, the US and the comparators. In any given year, the leader, the US and the comparators had higher life expectancies for females than for males. The US life expectancy for males was lower than the comparators' life expectancy for males; the differential of life expectancy between the US and the leader diminished from the late

1950s to the late 1970s, and then stayed about the same after the late 1970s, while the differential of life expectancy between the US and the comparators slightly increased after the late 1970s. For females, the US life expectancy was about the same as the comparators from the late 1950s to the late 1970s, and both converged slightly toward the leader. Notably, after the late 1970s, the life expectancy for US females started to diverge substantially from both the comparators and the leader; the US presented a rate of increase of about 1 year per decade, far below the 2-3 years per decade of the leader. Tables A.1 and A.2 in the Supplementary Appendix show, for males and females, the life expectancy across countries for each decade from 1958.

FIGURE 1 AROUND HERE

The number of years behind the leader, for male and female life expectancy, for the US and the comparators, is presented in figure 1.b. In addition, the number of years behind the comparators for the US is also presented in figure A.1 (Supplementary Appendix). Because the same quantity of years behind may correspond to different absolute gaps in life expectancy depending on the trends in the comparator countries, figure A.5 (Supplementary Appendix) also reports, for males and females, the gap in life expectancy between the US and the comparators, and between the US and the leader. Over the period 1958-2007, for male life expectancy, the US always fell behind the comparators, up to 25 years behind the comparators (figure A.1), and fell between 15 and 35 years behind the leader. Up to about the late 1970s, both the US and the comparators presented a similar trend in increasing years behind the leader. Then, over the course of only a few years, the comparators narrowed the distance from 25 to 10 years behind,

followed by a slightly decreasing trend until 2007 where it was about 5 years behind the leader. In contrast, the US narrowed the distance with the leader abruptly in the late 1980s (slightly delayed relative to the comparators), and then remained at about the same level of 20 years behind the leader through 2007 leading to substantial divergence from the comparators (about 15 years behind the comparators in 2007).

Over the period 1958-2007, the life expectancy for US females was up to 10 years behind the comparators and between 10 and 20 years behind the leader, which was better than US male life expectancy but hid a disturbing trend (figure 1.b). Up to about the late 1970s, US females and the comparators presented similar trajectories: starting around 10 years behind the leader, they trailed to around 20, but made a comeback to where they were, again, about 10 years behind the leader. Then, the US substantially diverged from the comparators, falling further and further behind at a steady pace (figure 1.b; figure A.1). In 1998-07, the US was about 10 years behind the comparators and about 20 years behind the leader, with a life expectancy of 79.9 years (Supplementary Appendix, table A.2).

Years behind in age-specific mortality rates

Figure 2 shows the number of years behind the leader the US and the comparators were for five-year age groups, for males and females and two time periods, the early 1960s (1958-67) and the early 2000s (1998-07). The number of years behind the comparators the US was for five-year age groups is also presented in figure A.2 (Supplementary Appendix). In the early 1960s, the US and the comparators presented similar age distributions for the number of years behind the leader, for males and females. Males presented a larger number of years behind than females across almost all age groups;

females in both the US and the comparators presented almost identical age distributions for years behind the leader. The situation in the early 2000s was very different for the US. For females, the comparators presented a pattern similar to the early 1960s, between 10 and 20 years behind the leader across all age groups; the US presented a larger number of years behind the leader but most significantly the number of years behind the leader had increased substantially between age 15 and age 50 (about 30 years behind the comparators; figure A.2). For males, the comparators had substantially reduced the number of years behind the leader beyond age 45, but increased the number of years behind the leader from age 15 to age 40; the US had also substantially reduced the number of years behind the leader after age 45, and like the comparators, had increased the number of years behind the leader between age 10 and age 45 (about 30 years behind the comparators; figure A.2).

FIGURE 2 AROUND HERE

Figure 3.a shows time trends in the probability of dying between age birth and age 15 (15q0) for the leader, the US and the comparators. Tables A.3 and A.4 in the Supplementary Appendix show values for 15q0 across countries. In a given year, the leader, the US and the comparators had higher mortality rates for males than for females. For both males and females, from the early 1960s to the early 2000s, the differential of 15q0 between the US and the comparators stayed similar (slightly increasing), and the differential of 15q0 between the US and the leader also stayed similar (slightly decreasing). The US 15q0 started lower than the comparators' 15q0 for both males and females; in the 1970s, the US and the comparators crossed. For both males and females,

the comparators' 15q0 was converging toward the leader throughout the entire time period.

FIGURE 3 AROUND HERE

Figure 4.a shows time trends for the probability of dying between age 15 and age 50 (35q15) for the leader, the US and the comparators. Tables A.5 and A.6 in the Supplementary Appendix show values for 35q15 across countries. In a given year, the leader, the US and the comparators had substantially higher mortality rates for males than for females. For both males and females, the US 35q15 was always higher than the comparators' 35q15; the differential of 35q15 between the US and the comparators and between the US and the leader stayed about the same from 1958 to 2007, for males. However, for females, the US was slightly diverging from both the comparators and the leader from 1980 onward.

FIGURE 4 AROUND HERE

Figures 3.b and 4.b show the number of years behind the leader the US and the comparators were for the 0-14 and 15-49 age groups, for males and females, over the 1958-2007 period. The number of years behind the comparators the US was, for the mortality rates in the 0-14 and 15-49 age groups, is also presented in figures A.3 and A.4 (Supplementary Appendix). Figures A.6 and A.7 (Supplementary Appendix) also report, for males and females, the gap in 15q0 and 35q15 between the US and the comparators, and between the US and the leader. For the 0-14 age group, up to the late 1970s, the US

and the comparators showed somewhat similar trajectories, between 10 and 20 years behind the leader (both males and females); on average, the US was slightly ahead of the comparators then. Afterwards, while the comparators consistently kept pace about 10 years behind the leader, the US saw an increase up to 15 years behind the comparators (figure A.3) and up to between 20 and 30 years behind the leader through 2007 (both males and females). For the 15-49 age group, the US was always behind the comparators over the whole period; the US consistently diverged from the leader. The male trajectory, for the US and the comparators, was similar until the early 1990s, when the comparators started converging on the leader, dropping from about 40 to 15 years behind the leader in 2007; meanwhile, the US kept diverging with years behind the comparators increasing from about 10 years in 1990 to about 45 years in 2007 (figure A.4), a corresponding increase in years behind the leader from about 45 years in 1990 to about 55 years. The female trajectory, for the US and the comparators, was somewhat similar until the mid-1970s (20-25 years behind the leader then), when the comparators kept the distance behind the leader below 20 years (below 10 years behind the leader in 2007), while the US continued diverging, being about 40 years behind the comparators and about 50 years behind the leader in 2007.

Discussion

This paper applies a sensitive measure of national performance – years behind – to comparison of US mortality rates with those of other high-income countries. As has been well documented,[1,8] US life expectancy is lower and mortality rates are higher than in other high-income or comparator countries. Life expectancy results summarize and aggregate an heterogeneous combination of distinct age-specific mortality measures and

patterns, hence we further examined mortality rates across different age groups. Most strikingly, for both males and females, the typical high-income country had achieved, by the 1970s, a mortality rate in the age group 15-49 that the US failed to achieve until about 2007: i.e., the US, in 2007 fell about 40 years behind the average (and 50 years behind the leader). A similar if less pronounced pattern appears for life expectancy and for mortality under age 15. The US now lies far behind other high-income countries, but this was not always so. The detailed results of this paper allow for tracking the magnitude of US divergence and for (approximate) timing of when it began. Although our results contain noise a key result emerges: sometime in the late 1970s the US stopped tracking its comparators and began to fall behind (table 1). At different rates for different indicators the US fell further and further behind over subsequent three decades. The finding is remarkably striking for US females.

TABLE 1 AROUND HERE

The analysis presents several strengths. It uses full life tables, for males and females, for seventeen high-income countries for an extended time series, and it allows for tracking the timing of US divergence. This provides a specific criterion for assessing the explanatory power of causes proposed for poor performance, and narrows the range of potentially important determinants. In particular, trends in mortality rates provide a starting point for assessing the importance of the determinants of health.[9,10] The analysis also has limitations. For instance, it does not aim at fully explaining in detail why the US mortality gap emerged and grew, as it essentially proposes a tool for others making those assessments. In addition, while the results highlight a particular period in time when the

US fell behind other countries, one should be cautious in interpretation as there may be a lag time between any determinant change and its population-level effect on mortality. The timing of effects is delicate as different policies may have different temporal spans (e.g. tobacco control). It may take a long time to reduce mortality gaps, if appropriate interventions are not implemented rapidly. Some diseases may be amenable to both immediate curative and preventive interventions (e.g. reduction of blood pressure) whereas certain habits/conditions independent of the current state of things, such as tobacco consumption[11] and obesity,[12,13] can affect mortality many decades later. Finally, the years behind results may be more stable when the comparator is the average of all the other countries rather than the leading country as there may be rapid changes in the leading country (tables A.1-4, Supplementary Appendix). Hence, we also presented results for years behind the comparators (figures A.1-4; Supplementary Appendix).

Concern for the poor US performance on mortality prompted major investigations by the US National Academy of Sciences[1,8] into its nature (in terms of age groups and conditions) and its causes. Major potential causes that have been explored include cross-country differences in the level and equality of income, in level of education, in social cohesion, in a broad range of specific risk factors, and in the level and quality of expenditures on the health care system. The National Research Council (NRC) examined the diverging trends in mortality between the US and others with high income, looking at specific causes of deaths. NRC researchers estimated that a large part of the life expectancy difference was attributable to smoking, amounting to 80 and 40% of the difference for females and males, respectively.[11] Less dramatically, they suggested that 20 to 33% of the life expectancy gap could be attributable to higher rates of obesity.[12] They argued that smoking and obesity could well explain the rise of mortality recorded in

adult men and women over the last decades.[14] Other research has shown that chronically ill US patients tend to have less access to care, and benefit from less efficient and organized care, compared to counterparts in other high-income countries.[15] Beyond substantial healthcare spending, social welfare spending is a strong determinant for population health.[16] Overemphasizing individual risk factors can obscure the importance of key determinants of health such as financing and delivery.[17] Constructively, these determinants offer the possibility that political commitment inside and outside the health sector can make real improvements in population health.[16,17] Finally, the "compression" of older age mortality from 1958-67 to 1998-07 in the US may be attributable to the Medicare program introduced in 1965.

It is not our purpose to reiterate the conclusions of the National Academies' assessments. Rather our conclusions point to an additional and quite specific criterion for judging the explanatory power of potential explanations for poor performance in the US. Since we conclude divergence to have begun in the late 1970s, potential explanations like racial diversity, lack of health insurance and high income inequality in the US become less plausible. Racial diversity and income inequality were high, and insurance coverage low in the US in the 1970s when the US was performing well on health. Establishing a time for the beginning of the US divergence helps in identifying the effects of the broader social policy arena on health,[18] and in narrowing the range of potentially important determinants, and remedies.

Seeking potential explanations, we examined whether the more advantaged population groups presented similar trends to the average of comparator countries while looking at the maximum and minimum life expectancy (by county) and the average white and black life expectancy (by county) in the US[19] (figure A.8, Supplementary Appendix).

We found however that maximum male/female and white male/female life expectancy followed a somewhat distinct trajectory in recent decades. Likewise, the divergence from the 1970s could be related to a lack of universal coverage with unequal treatment access and coverage at a time when many treatments for cardiovascular disease (CVD) (e.g. anti-hypertensives, statins) became available. Using OECD data,[20] we examined whether this divergence was following declines in CVD mortality. We found on the contrary that US CVD mortality reduced more rapidly in the late 1970s compared to comparator countries (figure A.9, Supplementary Appendix). Recent research[21] showed that from 1983 to 1999, life expectancy declined significantly in 11 US counties for men and in 180 counties for women. These declines were caused by increased mortality from lung cancer, chronic obstructive pulmonary disease, diabetes, and were no longer compensated for by the CVD mortality decline.[21]

Measuring health system performance will remain difficult: health outcomes depend on the health system together with non-medical socio-economic and geographical determinants, and can be affected by favorable risk factors. Assessing performance in health in terms of "years behind" enables identifying trends and rapid changes in outcomes, for which researchers can then try to identify explanations. The years behind measure offers an intuitive and generalizable approach to measuring country performance in health, as well as convergent and divergent patterns, and can be readapted to various health indicators, for diverse disease- and condition-related outcomes. We suggest that this approach would also be valuable for the evaluation of US performance on specific causes of death and conditions, facilitating the design of policies that impact health and social risk factors for the most burdened populations.

Acknowledgements

The authors received valuable comments from Laudy Aron. We thank Anna Peeters and Goodarz Danaei for their constructive and valuable contributions on our work.

Contributors

SV and DTJ designed the study, conducted the analysis, interpreted the data and drafted the original manuscript.

Funding

This work was supported by the Bill & Melinda Gates Foundation through the Disease Control Priorities Network grant to the University of Washington, and by the National Research Council of the United States National Academies.

Competing interests

None declared

Data sharing statement

There is no additional data available.

References

1. Crimmins EM, Preston SH, Cohen B, editors. *Explaining divergent levels of longetivity in high-income countries*. Washington, DC: National Academies Press, 2011.

2. Sicherl P. Time-distance as a dynamic measure of disparities in social and economic development. *Kyklos* 1973; 26(3):559-575.

3. Kulkarni SC, Levin-Rector A, Ezzati M, Murray CJL. Falling behind: life expectancy in US counties from 2000 to 2007 in an international context. *Population Health Metrics* 2011; 9(1):16.

4. Human Mortality database. http://www.mortality.org/ (accessed 30 Aug 2011).

5. Ho JH, Preston SH. US mortality in an international context: age variations. *Population and Development Review* 2010; 36(4):749-773.

6. Oeppen J, Vaupel JW. Broken limits to life expectancy. *Science* 2002; 296:1029-31.

7. Vallin J, Meslé F. The segmented trend line of highest life expectancies, *Population and Development Review* 2009; 35(1):159-187.

8. Woolf S, Aron L, editors. *US health in international perspectives: shorter lives, poorer health*. Washington, DC: National Academies Press, 2013.

9. Verguet S, Jamison DT. Performance in rate of decline of adult mortality in the OECD, 1970-2010. *Health Policy* 2013; 109(2):137-42.

10. Verguet S, Jamison DT. Estimates of performance in the rate of decline of under-five mortality for 113 low- and middle-income countries, 1970-2010. *Health Policy and Planning* 2013; doi:10.1093/heapol/czs143.

11. Preston SH, Glei DA, Wilmoth JR. Contribution of smoking to international differences in life expectancy. In: Crimmins EM, Preston SH, Cohen B (eds). International Differences in Mortality at Older Ages: Dimensions and Sources. Washington, DC: The National Academies Press, 2010.

12. Alley DE, Lloyd J, Shardell M. Can obesity account for cross-national differences in life-expectancy trends? In: Crimmins EM, Preston SH, Cohen B (eds).

International Differences in Mortality at Older Ages: Dimensions and Sources. Washington, DC: The National Academies Press, 2010.

13. Comanor WS, Frech HE III, Miller RD Jr. Is the United States an outlier in health care and health outcomes? *International Journal of Health Care Finance and Economics* 2006; 6:3-23.

14. Preston S, Ho J. Low life expectancy in the United States: is the health care system at fault? In: Crimmins EM, Preston SH, Cohen B (eds). International Differences in Mortality at Older Ages: Dimensions and Sources. Washington, DC: The National Academies Press, 2010.

15. Schoen C, Osborn R, How SKH, Doty MM, Peugh J. In chronic condition: experiences of patients with complex health care needs, in eight countries, 2008. *Health Affairs* 2009; 28(1):w1-w16.

16. Stuckler D, Basu S, McKee M. Budget crises, health, and social welfare programmes. *British Medical Journal* 2010; 340: doi.10.1136/bmj.c3311.

17. Geneau R, Stuckler D, Stachenko S, et al. Raising the priority of preventing chronic diseases: a political process. *Lancet* 2010; 376:1689-1698.

18. Dow WH, Rehkopf DH. Socioeconomic gradients in health in international and historical context. *Annals of the New York Academy of Sciences* 2010; 1186:24-36.

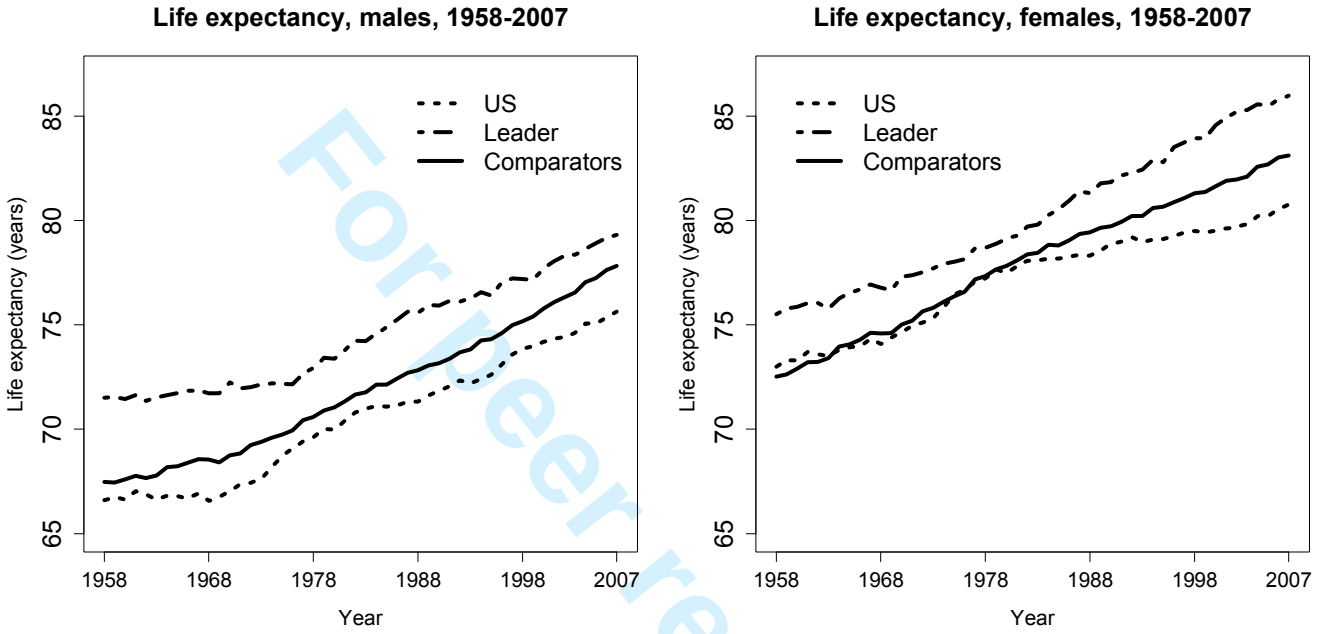
19. Institute for Health Metrics and Evaluation. Life expectancy in US counties 1989-2009. http://www.healthmetricsandevaluation.org/news-events/event/ihme-release-county-life-expectancy-results-14th-annual-health-journalism-conferen#/data-methods (accessed 30 Apr 2013).

20. Organisation for Economic Co-operation and Development. OECD.StatExctracts. http://stats.oecd.org/ (accessed 30 Apr 2013).

21. Ezzati M, Friedman AB, Kulkarni SC, Murray CJL. The reversal of fortunes: trends in county mortality and cross-county mortality disparities in the United States. *PloS Medicine* 2008; 5(4):e66.

Figure 1. Evolution of life expectancy and years behind the leader for the leader, the US, and the average of sixteen comparator high-income countries, males and females, 1958-2007

(a) Life expectancy



(b) Years behind the leader

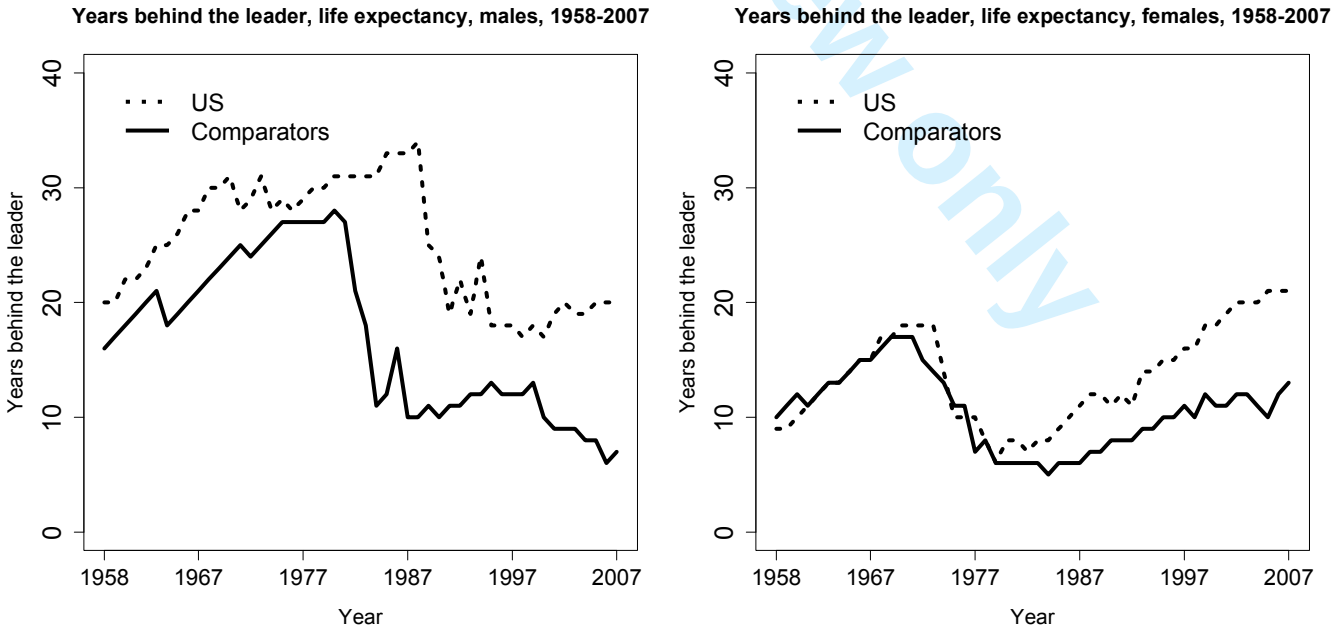
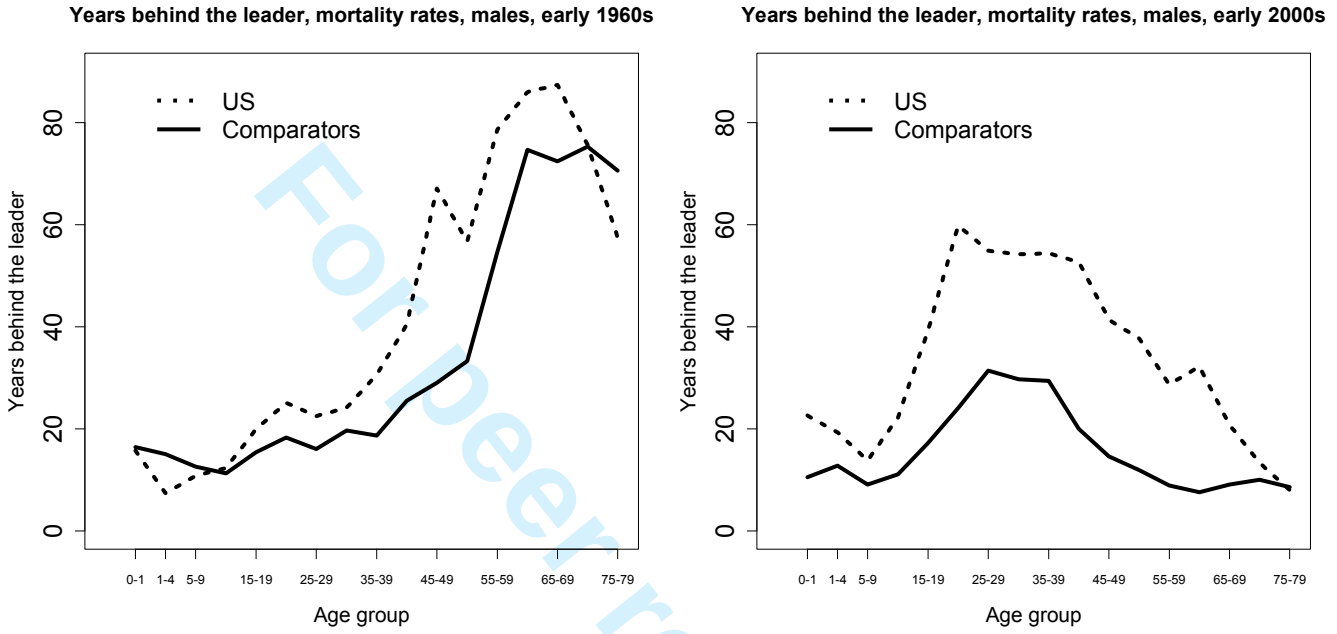
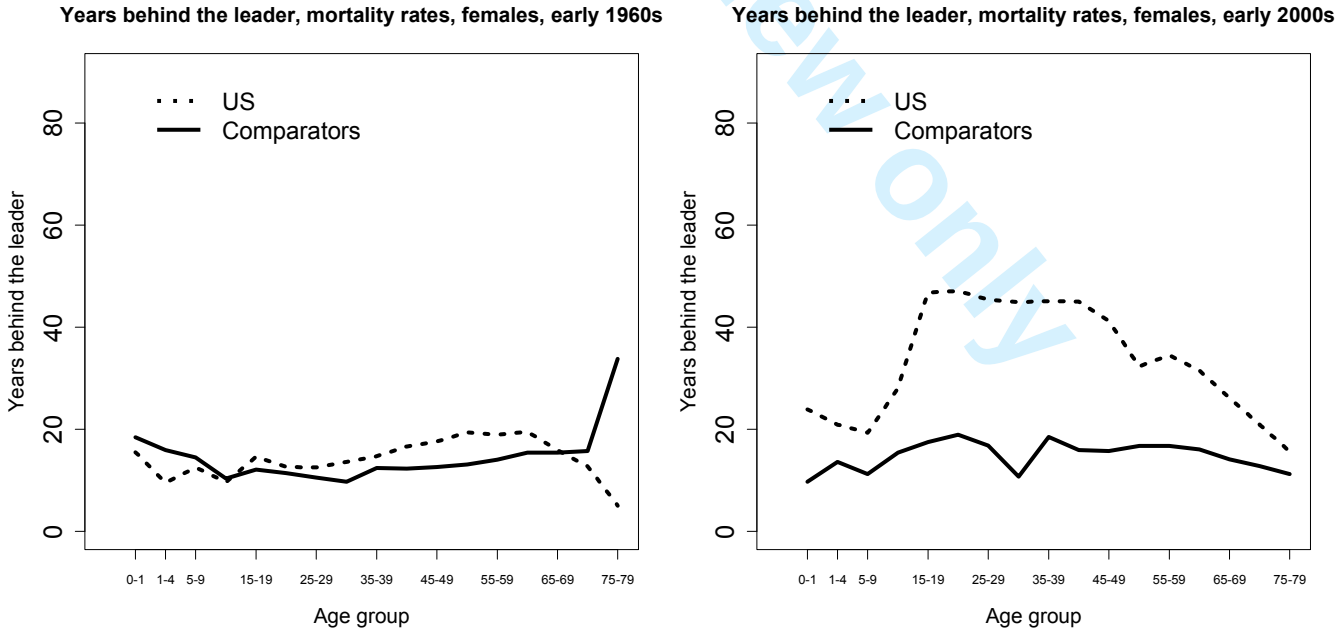


Figure 2. Number of years behind the leader for mortality rates across age groups, for the US and the average of sixteen comparator high-income countries, males and females, early 1960s and early 2000s

(a) Males



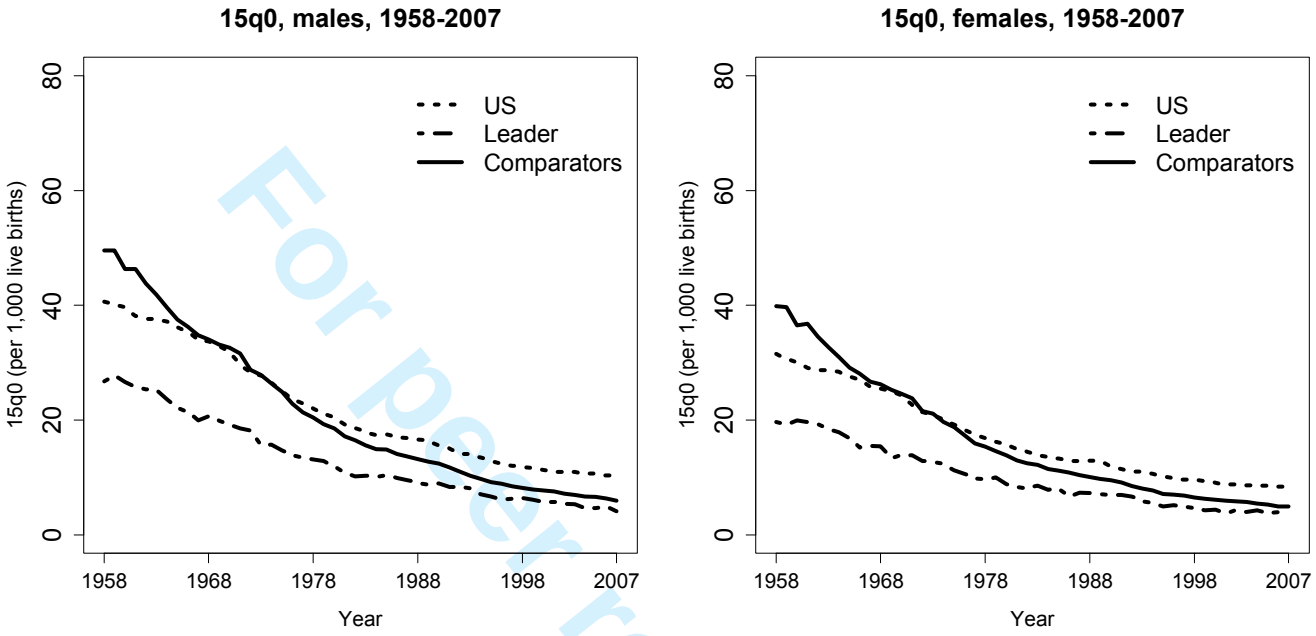
(b) Females



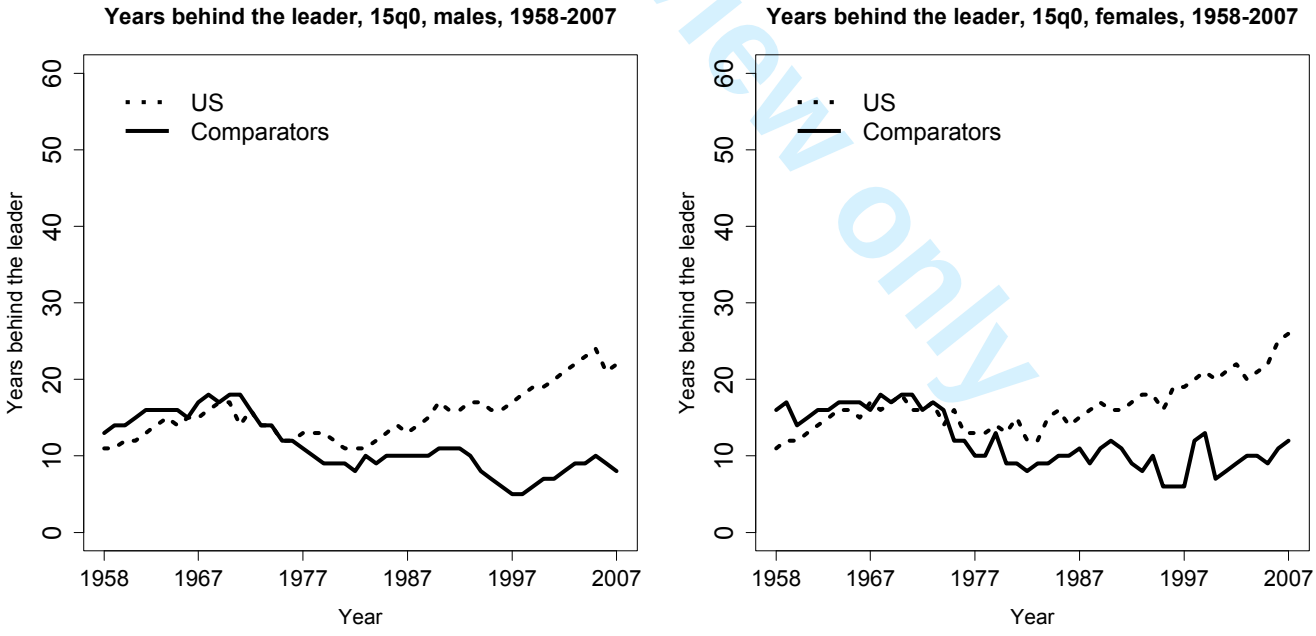
Note: Early 1960s refers to the period 1958-67 and early 2000s refers to 1998-2007.

Figure 3. Evolution of mortality rates and years behind the leader in the 0-14 age group, for the leader, the US, and the average of sixteen comparator high-income countries, males and females, 1958-2007

(a) Mortality rates



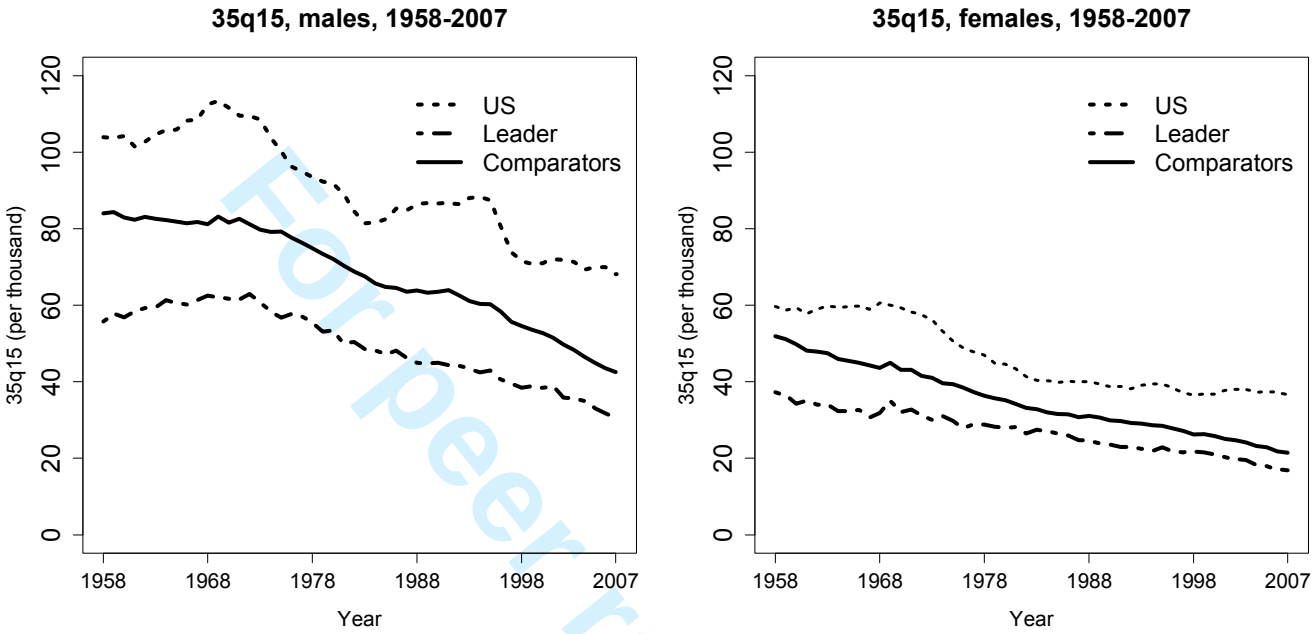
(b) Years behind the leader



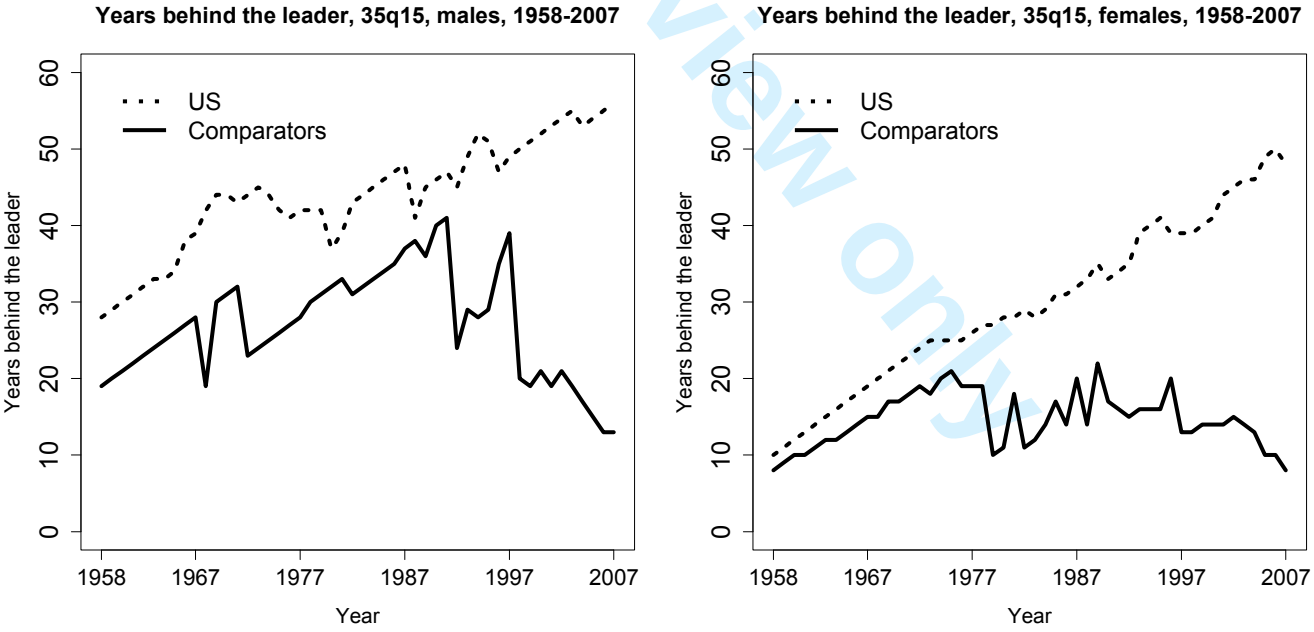
Note: 15q0 is defined as the probability of dying from birth through age 14 at then prevailing age-specific mortality rates.

Figure 4. Evolution of mortality rates and years behind the leader in the 15-49 age group, for the leader, the US, and the average of sixteen comparator high-income countries, males and females, 1958-2007

(a) Mortality rates



(b) Years behind the leader



Note: 35q15 is defined as the probability of dying from age 15 through age 49 at then prevailing age-specific mortality rates.

Table 1. Timing of US divergence from the average of sixteen comparator high-income countries, for life expectancy, 15q0, and 35q15, males and females, 1958-2007

Indicator	Males	Females
Life expectancy	Late 1970s (temporary reconvergence late '80s to late '90s)	Late 1970s
15q0	Late 1970s (US had lower mortality than comparators before 1965)	Late 1970s (US had lower mortality than comparators before 1965)
35q15	About 1990 (US already substantially behind comparators before divergence)	Late 1970s (more rapid divergence after about 1990)

Note: 15q0 is defined as the probability of dying from birth through age 14 at then prevailing age-specific mortality rates; 35q15 is defined as the probability of dying from age 15 through age 49 at then prevailing age-specific mortality rates.

Supplementary Appendix

Figure A.9. Evolution of mortality rates (per 100,000) for diseases of the circulatory system and ischemic heart disease for the US, and the average of sixteen comparator high-income countries, males and females, 1960-2010

Table A.1. Evolution of male life expectancy for the US, and sixteen other high-income countries, 1958-67 to 1998-2007

Life expectancy (years)	1958-67	1966-77	1978-87	1988-97	1998-07
Above 80					
75 to 80				JPN (76.3)	JPN (78.2) AUS (77.9) SWE (77.9) CHE (77.9) ITA (77.3) CAN (77.2) NOR (76.8) ESP (76.4) NLD (76.4) UK (76.1) FRA (76.0) DEU (76.0) AUT (75.9) DNK (75.0)
70 to 75	SWE (71.6) NLD (71.2) NOR (71.2) DNK (70.4)	SWE (72.1) NOR (71.4) NLD (71.3) DNK (71.0) CHE (70.8) JPN (70.7)	JPN (74.2) SWE (73.4) CHE (72.9) NLD (72.8) ESP (72.7) NOR (72.5) CAN (72.4) AUS (71.8) ITA (71.6) DNK (71.5) UK (71.1) FRA (70.8) DEU (70.7) USA (70.7)	SWE (75.5) CHE (74.8) AUS (74.6) CAN (74.6) NLD (74.2) NOR (74.2) ITA (74.2) ESP (74.0) UK (73.5) FRA (73.3) DEU (73.2) AUT (72.8) DNK (72.6) USA (72.3) FIN (72.0) PRT (71.3)	FIN (74.8) USA (74.7) PRT (74.1)
65 to 70	CHE (68.9) CAN (68.4) UK (68.1) AUS (67.8) ESP (67.4) FRA (67.3) ITA (67.2) DEU (67.2) USA (66.8) JPN (66.7) AUT (66.2) FIN (65.5)	ESP (69.8) CAN (69.7) ITA (69.1) UK (69.1) FRA (68.6) AUS (68.5) DEU (67.9) USA (67.8) AUT (67.3) FIN (66.7)	FIN (69.9) AUT (69.7) PRT (69.0)		
Below 65	PRT (61.6)	PRT (64.9)			

AUS = Australia, AUT = Austria, CAN = Canada, CHE = Switzerland, DEU = West Germany, DNK = Denmark, ESP = Spain, FIN = Finland, FRA = France, ITA = Italy, JPN = Japan, NLD = Netherlands, NOR = Norway, PRT = Portugal, SWE = Sweden, UK = United Kingdom, USA = United States.
Source: Human Mortality Database.

Table A.2. Evolution of female life expectancy for the US, and sixteen other high-income countries, 1958-67 to 1998-2007

Life expectancy (years)	1958-67	1968-77	1978-87	1988-97	1998-07
Above 80				JPN (82.5)	JPN (85.1)
				FRA (81.4)	FRA (83.3)
				CHE (81.4)	CHE (83.2)
				ESP (81.2)	ESP (83.2)
				SWE (80.9)	ITA (83.1)
				CAN (80.8)	AUS (82.9)
				ITA (80.8)	SWE (82.4)
				AUS (80.6)	CAN (82.2)
				NLD (80.2)	NOR (81.9)
				NOR (80.2)	FIN (81.8)
					AUT (81.7)
					DEU (81.6)
					NLD (81.1)
					PRT (80.9)
					UK (80.7)
75 to 80	NOR (76.1)	NOR (77.6)	JPN (79.8)	DEU (79.6)	USA (79.9)
	NLD (75.8)	SWE (77.5)	CHE (79.6)	FIN (79.6)	DNK (79.7)
	SWE (75.6)	NLD (77.2)	SWE (79.4)	AUT (79.4)	
		CHE (77.0)	NLD (79.4)	USA (79.0)	
		CAN (76.8)	CAN (79.3)	UK (78.9)	
		DNK (76.4)	NOR (79.2)	PRT (78.5)	
		FRA (76.3)	ESP (79.0)	DNK (77.9)	
		JPN (75.9)	FRA (79.0)		
		ESP (75.5)	AUS (78.6)		
		USA (75.5)	FIN (78.3)		
		AUS (75.4)	ITA (78.2)		
		UK (75.3)	USA (77.9)		
		ITA (75.2)	DNK (77.5)		
		FIN (75.1)	DEU (77.3)		
			UK (77.0)		
			AUT (76.7)		
			PRT (75.9)		
70 to 75	CAN (74.6)	DEU (74.3)			
	CHE (74.6)	AUT (74.2)			
	DNK (74.5)	PRT (71.5)			
	FRA (74.2)				
	AUS (74.2)				
	UK (74.1)				
	USA (73.6)				
	DEU (72.8)				
	FIN (72.6)				
	ITA (72.5)				
	AUT (72.5)				
	ESP (72.5)				
	JPN (71.7)				
65 to 70	PRT (67.5)				

AUS = Australia, AUT = Austria, CAN = Canada, CHE = Switzerland, DEU = West Germany, DNK = Denmark, ESP = Spain, FIN = Finland, FRA = France, ITA = Italy, JPN = Japan, NLD = Netherlands, NOR = Norway, PRT = Portugal, SWE = Sweden, UK = United Kingdom, USA = United States.
Source: Human Mortality Database.

Table A.3. Evolution of male 15q0 for the US, and sixteen other high-income countries, 1958-67 to 1998-2007 (per 1,000 live births)

1958-67	1968-77	1978-87	1988-97	1998-07
SWE (24)	SWE (17)	SWE (11)	SWE (8)	SWE (5)
NLD (28)	NLD (21)	FIN (12)	JPN (8)	JPN (6)
NOR (29)	NOR (21)	JPN (12)	FIN (9)	FIN (6)
DNK (31)	FIN (21)	DNK (14)	DEU (10)	NOR (6)
AUS (31)	DNK (21)	CHE (14)	NOR (10)	ITA (6)
FIN (32)	JPN (22)	NOR (14)	CHE (10)	DEU (7)
UK (32)	CHE (23)	NLD (14)	NLD (10)	AUT (7)
CHE (33)	FRA (25)	CAN (16)	CAN (11)	FRA (7)
FRA (37)	UK (26)	FRA (16)	DNK (11)	ESP (7)
USA (38)	AUS (26)	AUS (17)	AUT (11)	DNK (7)
CAN (39)	CAN (27)	UK (17)	FRA (11)	CHE (7)
JPN (43)	USA (28)	DEU (18)	AUS (11)	NLD (8)
DEU (43)	DEU (32)	ESP (18)	UK (11)	AUS (8)
AUT (47)	ESP (34)	USA (19)	ESP (11)	CAN (8)
ITA (56)	AUT (34)	ITA (19)	ITA (11)	UK (8)
ESP (59)	ITA (36)	AUT (20)	USA (14)	PRT (9)
PRT (116)	PRT (69)	PRT (33)	PRT (18)	USA (11)

AUS = Australia, AUT = Austria, CAN = Canada, CHE = Switzerland, DEU = West Germany, DNK = Denmark, ESP = Spain, FIN = Finland, FRA = France, ITA = Italy, JPN = Japan, NLD = Netherlands, NOR = Norway, PRT = Portugal, SWE = Sweden, UK = United Kingdom, USA = United States.
Source: Human Mortality Database.
Note: 15q0 is defined as the probability of dying from birth through age 14 at then prevailing age-specific mortality rates.

Table A.4. Evolution of female 15q0 for the US, and sixteen other high-income countries, 1958-67 to 1998-2007 (per 1,000 live births)

1958-67	1968-77	1978-87	1988-97	1998-07
SWE (18)	SWE (13)	FIN (9)	SWE (6)	SWE (4)
NLD (21)	NOR (15)	SWE (9)	JPN (7)	FIN (5)
NOR (21)	DNK (15)	JPN (9)	FIN (7)	JPN (5)
DNK (22)	FIN (15)	CHE (10)	NOR (8)	NOR (5)
FIN (24)	NLD (15)	DNK (10)	DEU (8)	FRA (5)
AUS (24)	JPN (16)	NOR (11)	CHE (8)	ITA (6)
CHE (24)	CHE (17)	NLD (11)	NLD (8)	DEU (6)
UK (25)	FRA (19)	FRA (12)	FRA (8)	AUT (6)
FRA (29)	UK (19)	CAN (12)	DNK (8)	DNK (6)
USA (29)	AUS (20)	AUS (13)	CAN (8)	CHE (6)
CAN (30)	CAN (20)	UK (13)	AUT (9)	ESP (6)
DEU (33)	USA (21)	DEU (13)	UK (9)	NLD (6)
JPN (34)	DEU (24)	ESP (14)	AUS (9)	AUS (6)
AUT (37)	AUT (25)	USA (14)	ESP (9)	UK (7)
ITA (47)	ESP (26)	AUT (15)	ITA (9)	CAN (7)
ESP (47)	ITA (28)	ITA (15)	USA (11)	PRT (7)
PRT (100)	PRT (55)	PRT (25)	PRT (13)	USA (9)

AUS = Australia, AUT = Austria, CAN = Canada, CHE = Switzerland, DEU = West Germany, DNK = Denmark, ESP = Spain, FIN = Finland, FRA = France, ITA = Italy, JPN = Japan, NLD = Netherlands, NOR = Norway, PRT = Portugal, SWE = Sweden, UK = United Kingdom, USA = United States.
Source: Human Mortality Database.
Note: 15q0 is defined as the probability of dying from birth through age 14 at then prevailing age-specific mortality rates.

Table A.5. Evolution of male 35q15 for the US, and sixteen other high-income countries, 1958-67 to 1998-2007 (per 1,000)

1958-67	1968-77	1978-87	1988-97	1998-07
NLD (59)	NLD (60)	NLD (50)	JPN (44)	SWE (36)
SWE (62)	SWE (66)	JPN (55)	NLD (44)	NLD (37)
DNK (63)	NOR (66)	UK (57)	SWE (47)	JPN (40)
NOR (66)	UK (67)	SWE (59)	UK (51)	CHE (41)
UK (71)	DNK (68)	NOR (61)	NOR (53)	ITA (41)
CHE (78)	CHE (69)	ITA (61)	AUS (55)	CAN (44)
ESP (79)	ESP (67)	CHE (62)	CAN (56)	NOR (45)
ITA (79)	JPN (73)	ESP (64)	ITA (56)	AUS (46)
CAN (84)	ITA (75)	AUS (66)	CHE (60)	DEU (46)
DEU (85)	CAN (84)	CAN (66)	DEU (60)	UK (47)
AUS (87)	AUS (84)	DNK (69)	DNK (64)	AUT (50)
AUT (94)	DEU (87)	DEU (73)	AUT (69)	DNK (52)
JPN (95)	AUT (97)	FIN (85)	ESP (72)	ESP (53)
FRA (97)	FRA (97)	USA (87)	FRA (79)	FRA (62)
USA (105)	PRT (104)	FRA (87)	FIN (81)	FIN (64)
PRT (106)	USA (106)	AUT (87)	USA (85)	USA (71)
FIN (115)	FIN (113)	PRT (93)	PRT (90)	PRT (76)

AUS = Australia, AUT = Austria, CAN = Canada, CHE = Switzerland, DEU = West Germany, DNK = Denmark, ESP = Spain, FIN = Finland, FRA = France, ITA = Italy, JPN = Japan, NLD = Netherlands, NOR = Norway, PRT = Portugal, SWE = Sweden, UK = United Kingdom, USA = United States.
Source: Human Mortality Database.
Note: 35q15 is defined as the probability of dying from age 15 through age 49 at then prevailing age-specific mortality rates.

Table A.6. Evolution of female 35q15 for the US, and sixteen other high-income countries, 1958-67 to 1998-2007 (per 1,000)

1958-67	1968-77	1978-87	1988-97	1998-07
NOR (34)	NOR (31)	NOR (28)	JPN (23)	ITA (20)
NLD (37)	CHE (35)	JPN (28)	ITA (25)	JPN (20)
SWE (39)	NLD (36)	ESP (29)	SWE (26)	SWE (20)
CHE (41)	SWE (36)	ITA (29)	NOR (27)	CHE (21)
DNK (45)	ITA (39)	NLD (30)	AUS (27)	ESP (22)
CAN (46)	ESP (39)	SWE (30)	ESP (27)	AUS (23)
UK (46)	FIN (40)	FIN (31)	CAN (28)	AUT (24)
ITA (48)	JPN (42)	CHE (31)	CHE (28)	NOR (24)
FIN (50)	UK (42)	AUS (33)	NLD (28)	DEU (24)
DEU (51)	CAN (43)	CAN (34)	UK (29)	CAN (24)
AUT (51)	DNK (44)	UK (34)	FIN (30)	NLD (26)
AUS (51)	AUT (45)	DEU (36)	DEU (31)	UK (26)
ESP (51)	FRA (46)	FRA (37)	AUT (31)	FIN (26)
FRA (51)	AUS (46)	AUT (38)	FRA (32)	FRA (27)
PRT (59)	DEU (46)	PRT (41)	PRT (36)	DNK (28)
USA (59)	PRT (50)	DNK (41)	DNK (37)	PRT (29)
JPN (65)	USA (55)	USA (42)	USA (39)	USA (37)

AUS = Australia, AUT = Austria, CAN = Canada, CHE = Switzerland, DEU = West Germany, DNK = Denmark, ESP = Spain, FIN = Finland, FRA = France, ITA = Italy, JPN = Japan, NLD = Netherlands, NOR = Norway, PRT = Portugal, SWE = Sweden, UK = United Kingdom, USA = United States.
Source: Human Mortality Database.
Note: 35q15 is defined as the probability of dying from age 15 through age 49 at then prevailing age-specific mortality rates.

Figure A.1. Evolution of years behind the average of sixteen comparator high-income countries for US life expectancy, males and females, 1958-2007

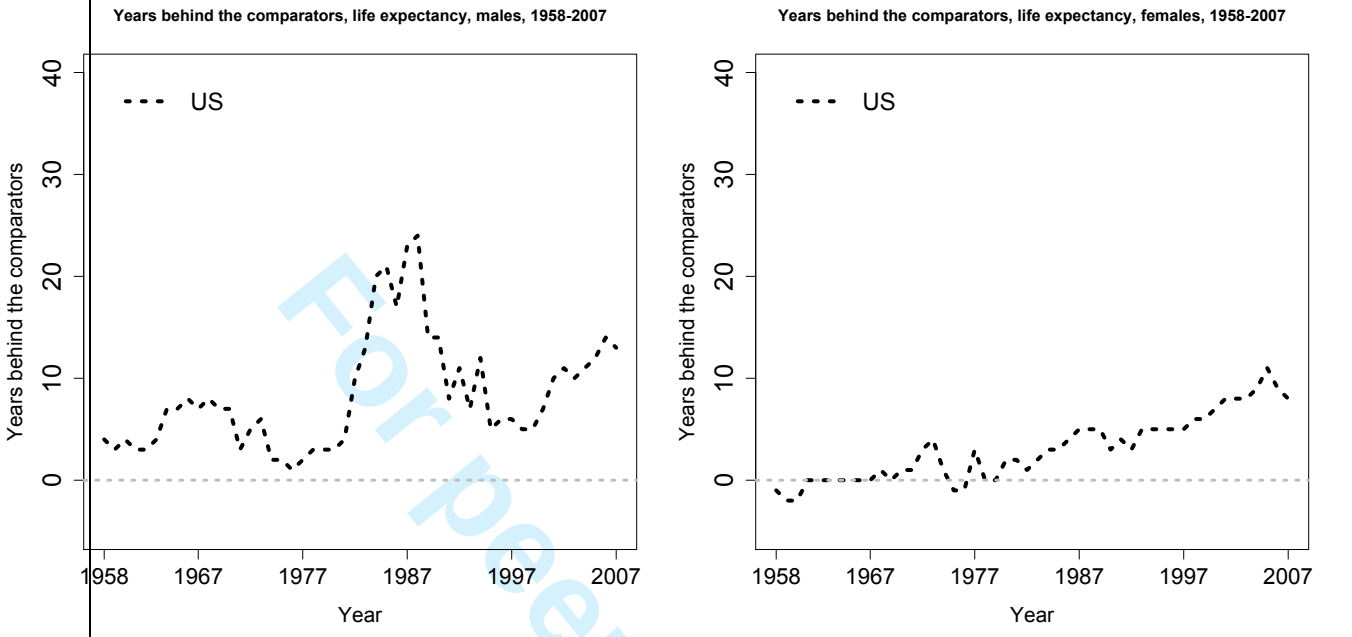
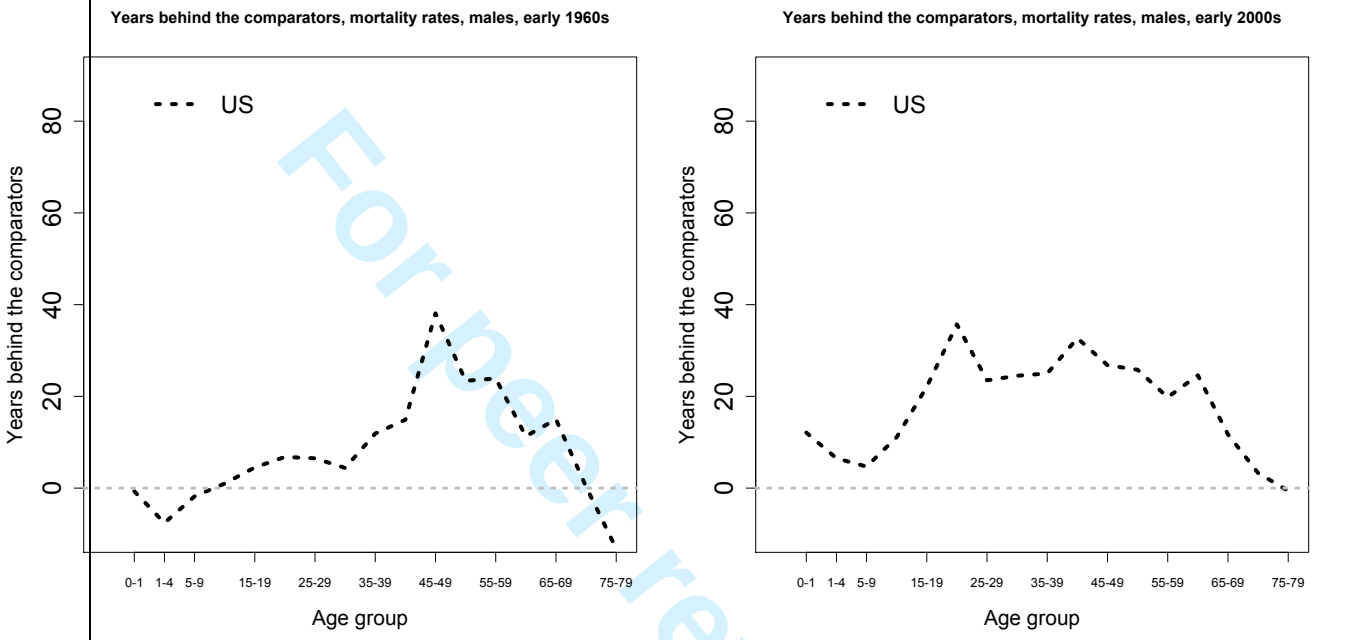
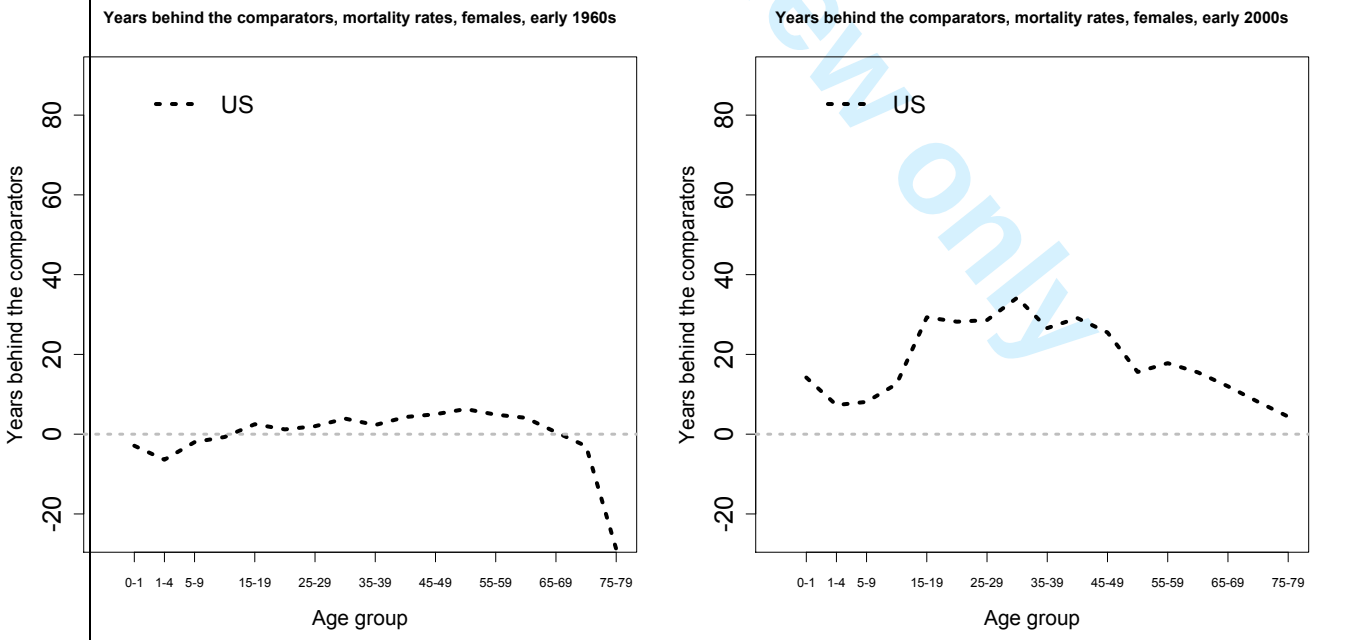


Figure A.2. Evolution of years behind the average of sixteen comparator high-income countries for US mortality rates across age groups, males and females, early 1960s and early 2000s

(a) Males

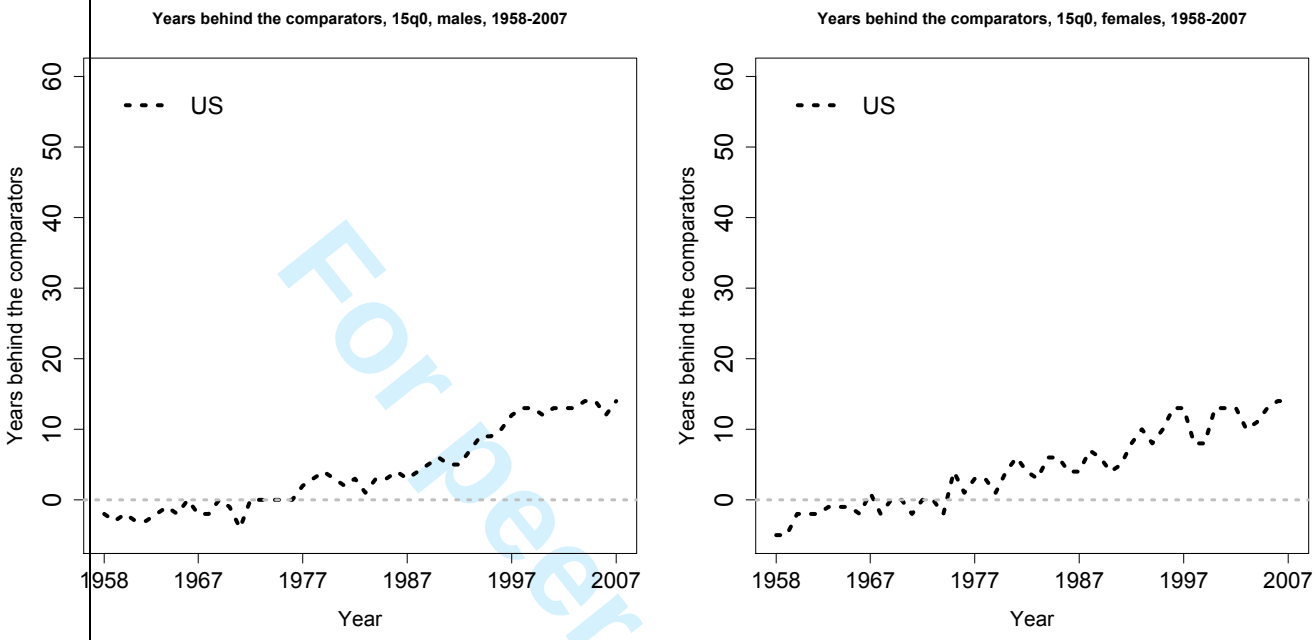


(b) Females



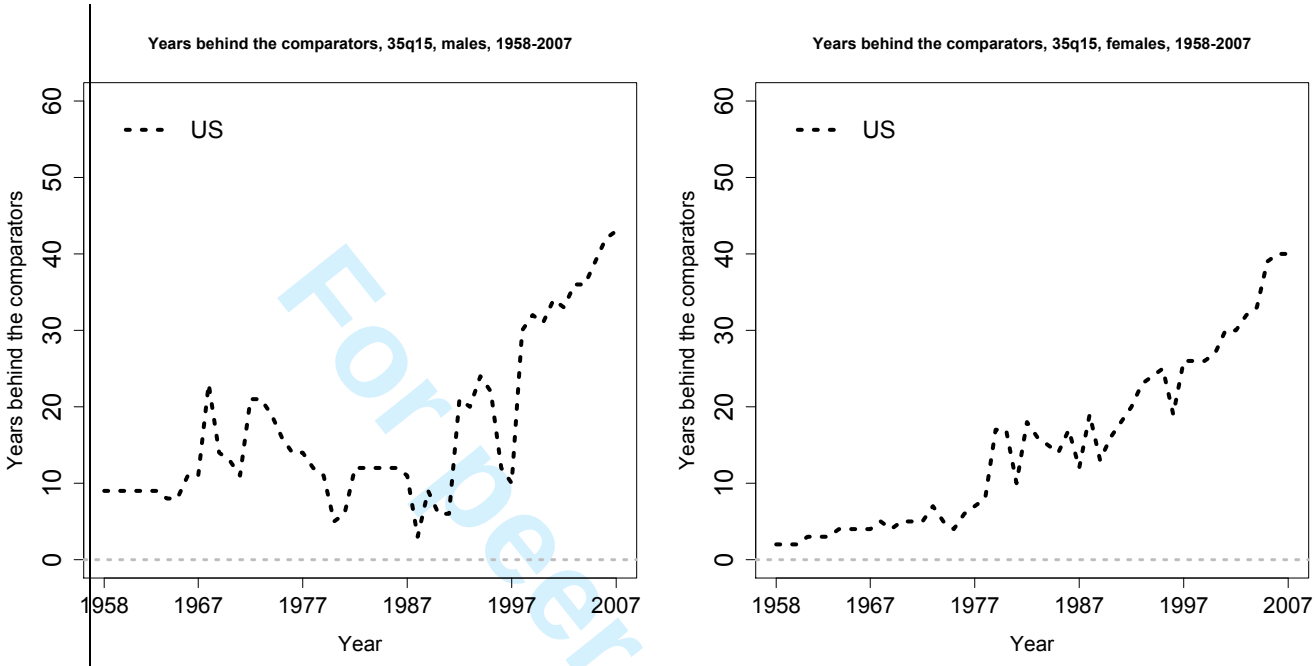
Note: Early 1960s refers to the period 1958-67 and early 2000s refers to 1998-2007.

Figure A.3. Evolution of years behind the average of sixteen comparator high-income countries for US mortality rates in the 0-14 age group, males and females, 1958-2007



Note: 15q0 is defined as the probability of dying from birth through age 14 at then prevailing age-specific mortality rates.

Figure A.4. Evolution of years behind the average of sixteen comparator high-income countries for US mortality rates in the 15-49 age group, males and females, 1958-2007



Note: 35q15 is defined as the probability of dying from age 15 through age 49 at then prevailing age-specific mortality rates.

Figure A.5. Gap in life expectancy between the US and the leader, and between the US and the average of sixteen comparator high-income countries, males and females, 1958-2007

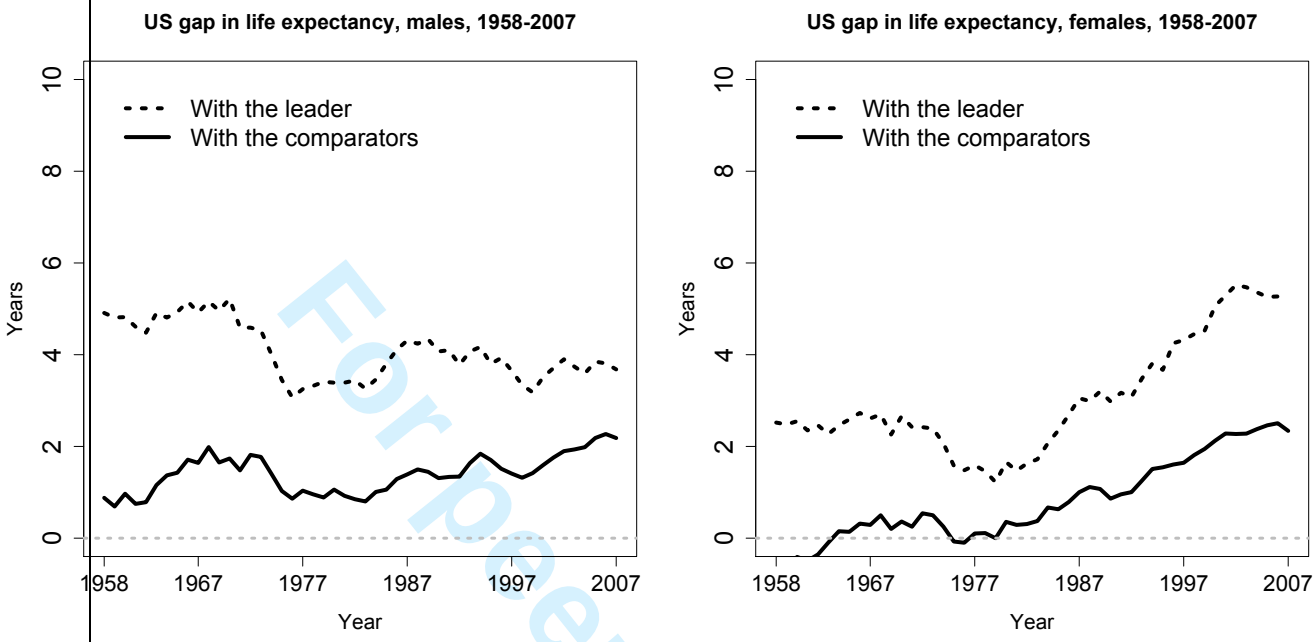
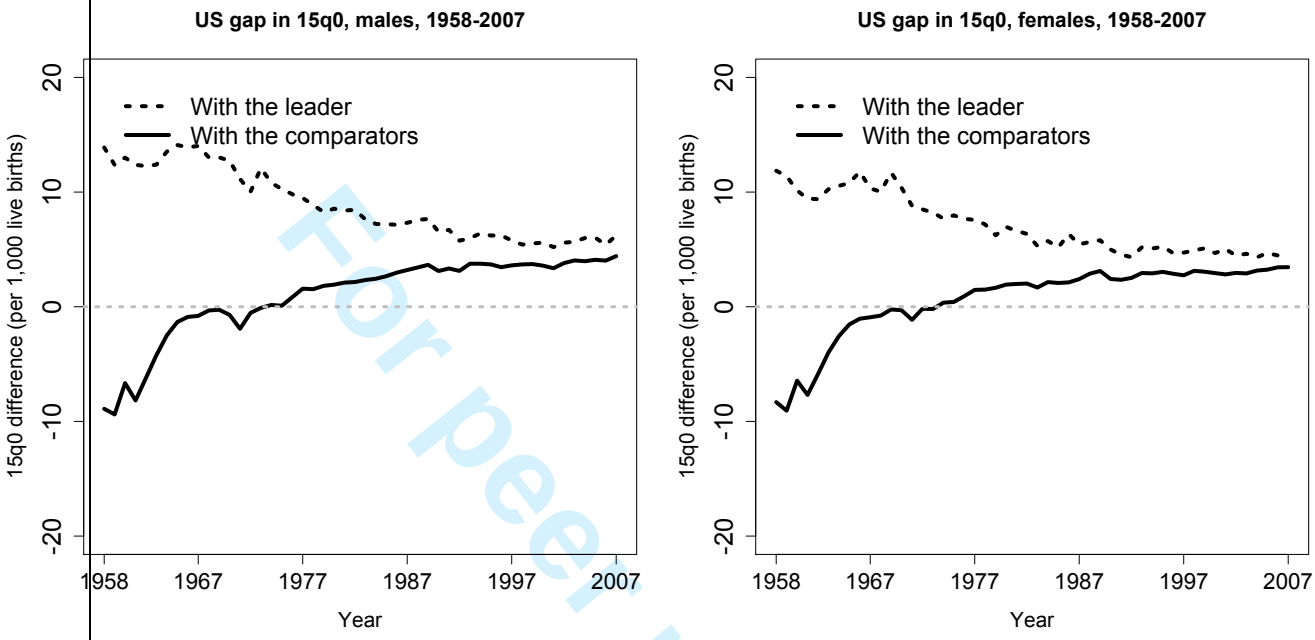
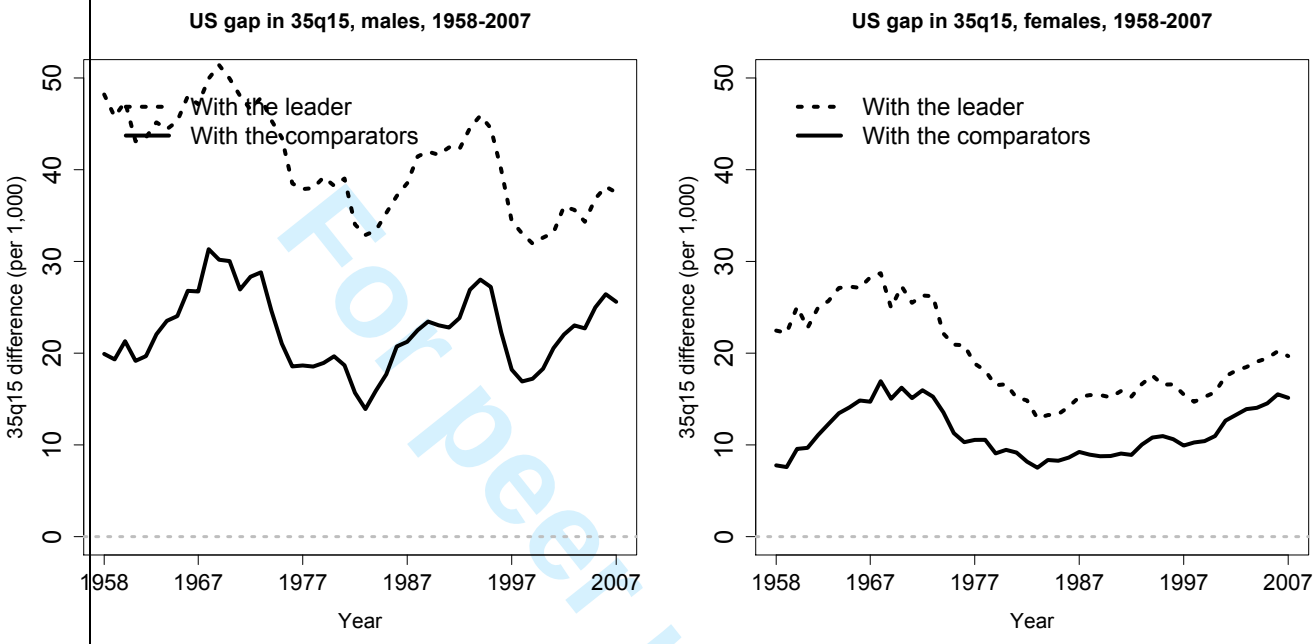


Figure A.6. Gap in mortality rates in the 0-14 age group between the US and the leader, and between the US and the average of sixteen comparator high-income countries, males and females, 1958-2007



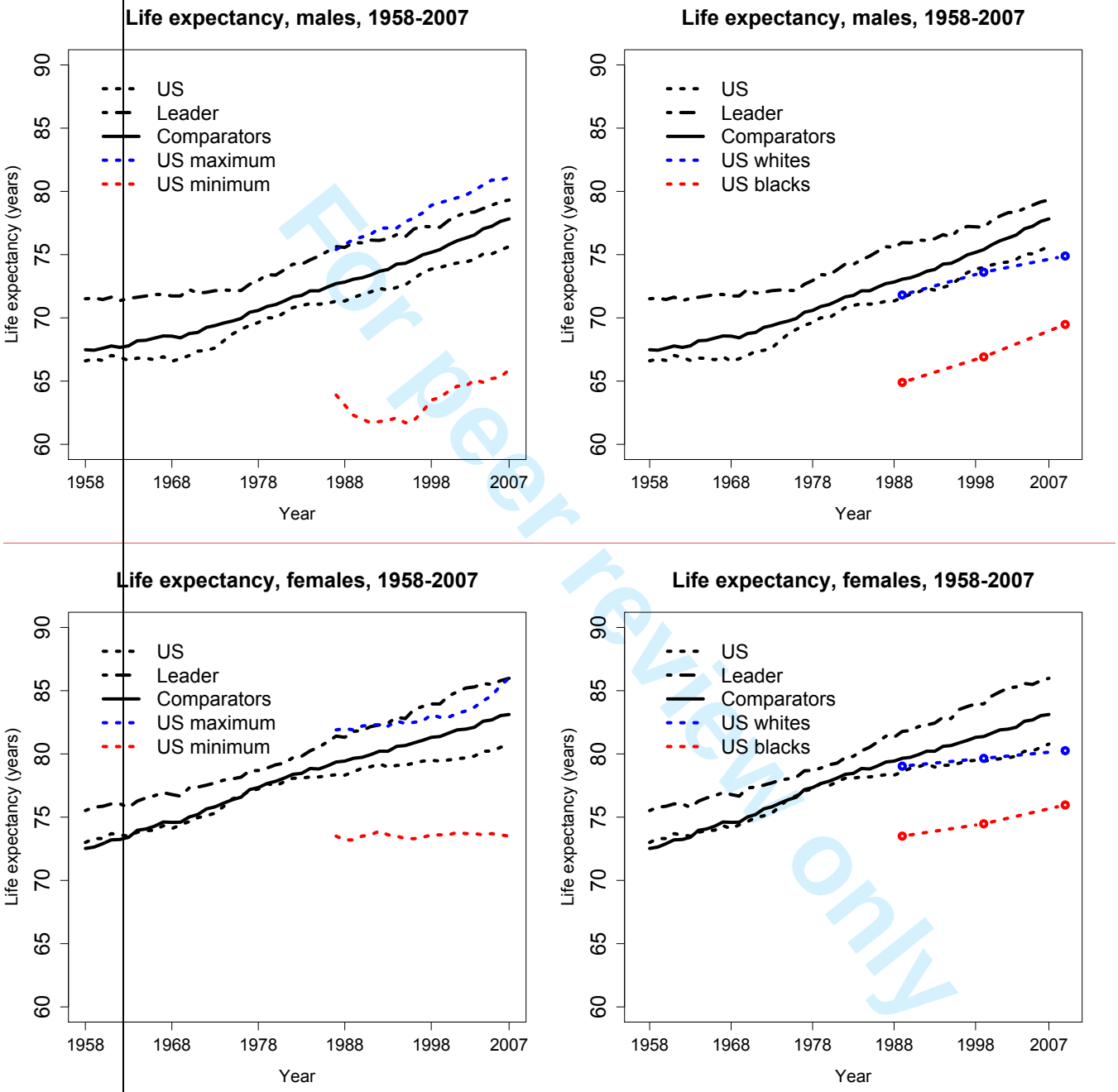
Note: 15q0 is defined as the probability of dying from birth through age 14 at then prevailing age-specific mortality rates.

Figure A.7. Gap in mortality rates in the 15-49 age group between the US and the leader, and between the US and the average of sixteen comparator high-income countries, males and females, 1958-2007



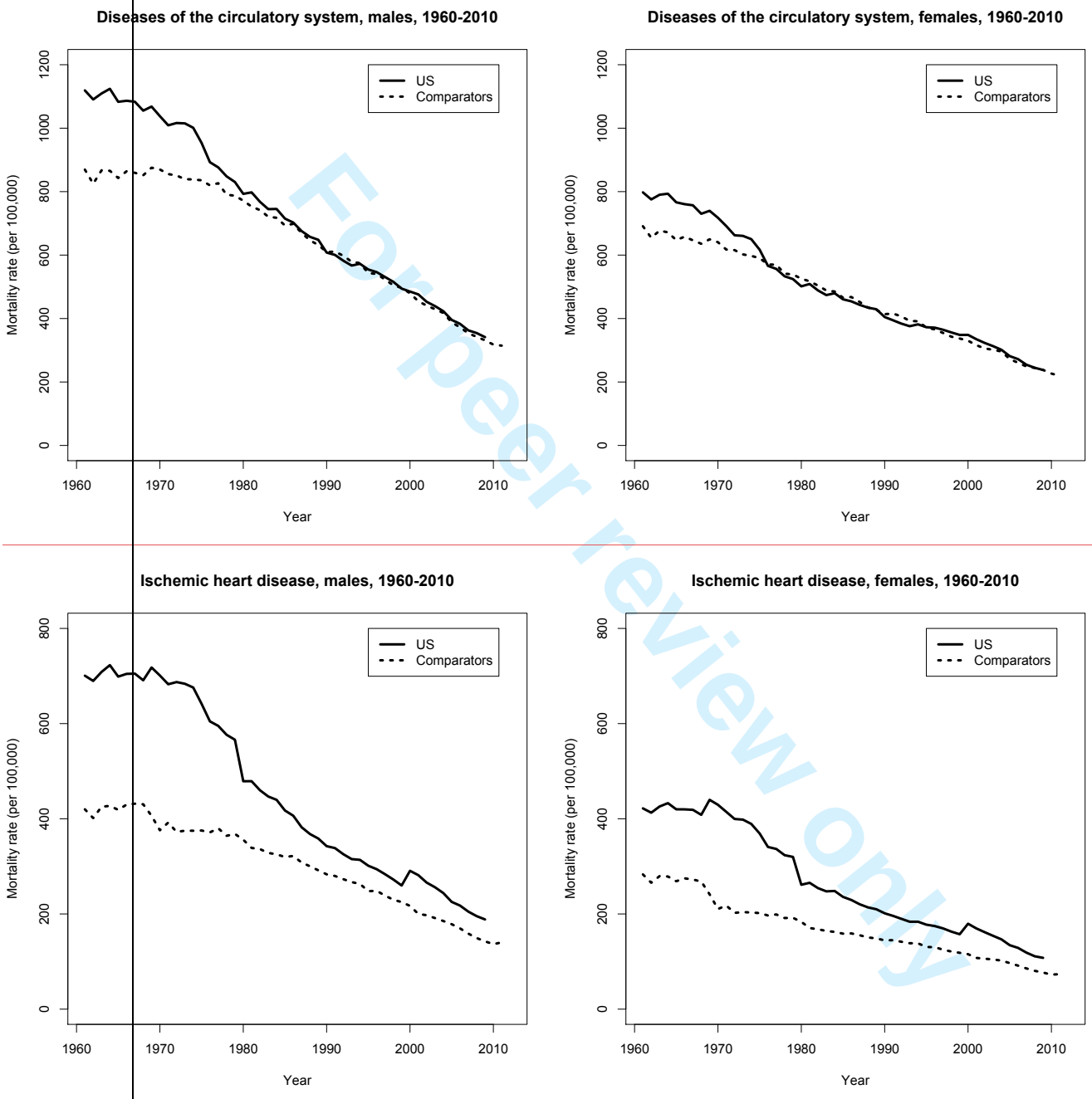
Note: 35q15 is defined as the probability of dying from age 15 through age 49 at then prevailing age-specific mortality rates.

Figure A.8. Evolution of life expectancy for the leader, the US, and the average of sixteen comparator high-income countries, males and females, 1958-2007



US maximum = maximum life expectancy (by county); US minimum = minimum life expectancy (by county); US whites = average life expectancy for white individuals (by county); US blacks = average life expectancy for black individuals (by county).
Source: Institute for Health Metrics and Evaluation, University of Washington.

Figure A.9. Evolution of mortality rates (per 100,000) for diseases of the circulatory system and ischemic heart disease for the US and the average of sixteen comparator high-income countries, males and females, 1960-2010



Source: Organisation for Economic Co-operation and Development.
Note: Diseases of the circulatory system include: acute rheumatic fever; chronic rheumatic heart diseases; hypertensive diseases; ischemic heart diseases; pulmonary heart disease and diseases of pulmonary circulation; other forms of heart disease; cerebrovascular diseases; diseases of arteries, arterioles, and capillaries; diseases of veins, lymphatic veissels and lymph nodes, not elsewhere classified; other unspecified diseases of the circulatory system.