Why are northern Europeans falling behind in life expectancy? An international comparison of age and cause of death, 1970-2009

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Abstract

In 1970, Sweden, Norway and Denmark (males only) had the highest known period life expectancy in the world. By 2009 the life expectancy of the three countries had fallen to average or below average among western developed countries, with Denmark having fallen way behind. This decline in rankings occurred alongside the development of generous and universalistic social welfare policies, which are often thought to be the most beneficial to population health. In this paper we analyze the age and cause of death patterns behind these changes with life table analyses and newly developed decomposition techniques. The hypotheses that we investigate, which are not mutually exclusive, include: (1) a failure to reduce mortality at older ages, (2) a move toward a comparatively shorter-lived cause of death structure than in comparison countries, (3) cohort effects from the survival of frail or less selected individuals due to a less lethal early life environment, and (4) cohort effects from smoking. The objective is to uncover whether there is a common narrative to the decline in rankings among the four countries, albeit to different final levels, or whether the three countries have followed different pathways.

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Introduction

In 1970, the top three female countries for life expectancy were Norway, Sweden, and the Netherlands (females), while the top male countries were Sweden, Norway, and Denmark (HMD 2015). By 2009, all of these countries had dropped in the rankings, especially Norway and Denmark. If mortality declines from the last 40 years are extrapolated forward in a Lee-Carter forecast (Lee and Carter 1992), within 20 years Sweden, Norway and Denmark could expect to be overtaken by most western and southern European countries (Figure 1).

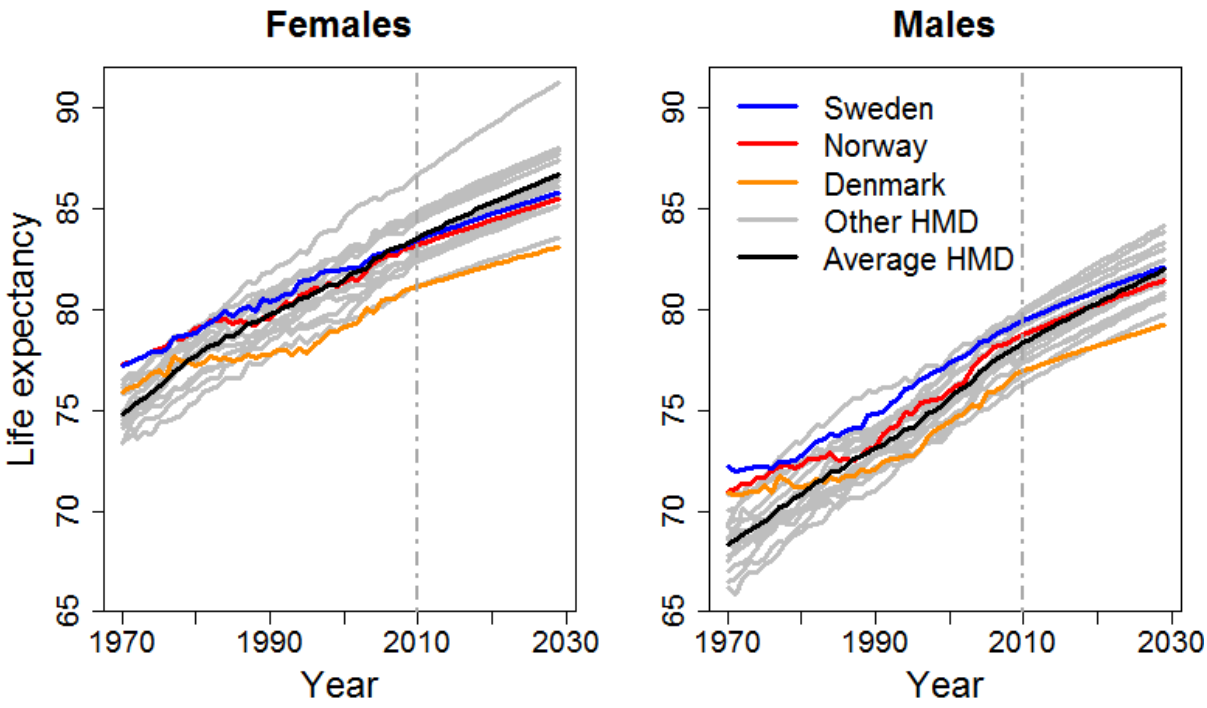

Figure 1: Observed and forecasted period life expectancy at birth. Forecast was made with the R-package Demography (Hyndman 2014), using fitted jump-off rates and adjustment to e_0 (Lee and Miller 2001). The forecast was built on HMD data from 1970-2009. "Other HMD" is comprised of Australia, Austria, Belgium, Canada, Finland, France, Ireland, Italy, Japan, the Netherlands, Spain, Switzerland, UK and the USA.

This decline in rankings is perhaps surprising as it first appeared alongside the development of generous and universalistic social welfare policies, which are often thought to be the most beneficial to overall population health (Lundberg et al. 2008).

In this paper we undertake a comprehensive investigation into the age- and cause-of-death patterns that led to the decline in rankings. We aim to determine whether a common narrative or country-specific circumstances drove these declines. A common narrative would force us to question the overall validity of 'social policy as health policy', while country-specific circumstances might point to vulnerabilities within the scope of a universalistic social welfare system that could benefit from targeted health policies.

Specifically, we will investigate four hypotheses for each country's decline, which are not mutually exclusive: (1) a failure to reduce mortality at older ages as rapidly as other countries, (2) a move toward a shorter-lived cause-of-death structure compared to other countries, (3) cohort effects from the survival of frail or less selected individuals due to a healthier early-life environment in the early 20th Century, and (4) cohort effects from smoking.

To investigate these hypotheses we compare the age and cause-specific mortality development of Norway, Sweden and Denmark against a composite made up of 14 other western high income populations since 1970, using life table analyses and newly developed decomposition techniques. Our preliminary findings show no clear common narrative emerging between the three northern countries but rather country-specific circumstances affecting mortality patterns for different periods and cohorts.

Data

Death and exposure counts for all countries come from the Human Mortality Database (HMD). The cause of death distribution comes from the World Health Organization (WHO) mortality database. For the moment, no modifications were made to the WHO data to smooth over ICD revisions, but causes were grouped into 9 meaningful and broad causes of death where time series ruptures are less evident. The cause of death groupings include external mortality, heart disease, other circulatory disease, ill-defined causes, infancy-related causes, mental causes, smoking-related cancers, other cancers, and other causes. Smoking-related cancers were defined by having more than 50% of deaths attributable to smoking according to the American CPS-II survey (1989). The ICD codes can be found in the Appendix.

A composite population was created from medium to large, high income countries with a long time series of mortality and cause of death data. Eastern European countries were excluded because of their very different age- and cause-of-death structures, particularly over the mortality crisis years associated with transition to market economies. The composite population included: Australia, Austria, Belgium, Canada, Finland, France, Ireland, Italy, Japan, the Netherlands, Spain, Switzerland, UK and the USA. Since we are interested in population- rather than individual-level health, we gave each population equal weight in the composite regardless of size. Specifically we calculated the average death rate for each of the 9 causes of death, and summed these to get the all-cause mortality rates.

Section 1: Age patterns of mortality decline

In this section we investigate the age patterns of mortality decline of the northern European countries in comparison to the composite population. Our premise is that the northern European countries were once leaders because they were very effective at reducing mortality over infancy and early adulthood. However as the age pattern of mortality decline has shifted to older ages worldwide (Horiuchi and Wilmoth 1995), we hypothesize that northern Europe has not made the same comparative progress at reducing old age mortality as comparison countries.

First we tested this with a SVD decomposition of mortality change 1970-2009 into the known Lee-Carter ax, bx and kt parameters for the northern European countries compared to the composite population (Figure 2). This analysis was done to test whether the northern European countries indeed experienced life expectancy gains over the period from a younger age pattern of mortality decline, seen from the bx parameter. Comparing bx parameters, it is obvious that Danish females have experienced very different mortality patterns from Norwegian and Swedish females, with life

expectancy gains coming more strongly from younger ages than in other countries. Swedish females experienced life expectancy gains from a younger age pattern of mortality decline than other HMD countries, and Norwegian females made few gains over early adulthood, but strong gains from mortality decline at young and old ages. Among males, all of the northern European countries experienced life expectancy increases from a younger age pattern of mortality decline than the average HMD country.

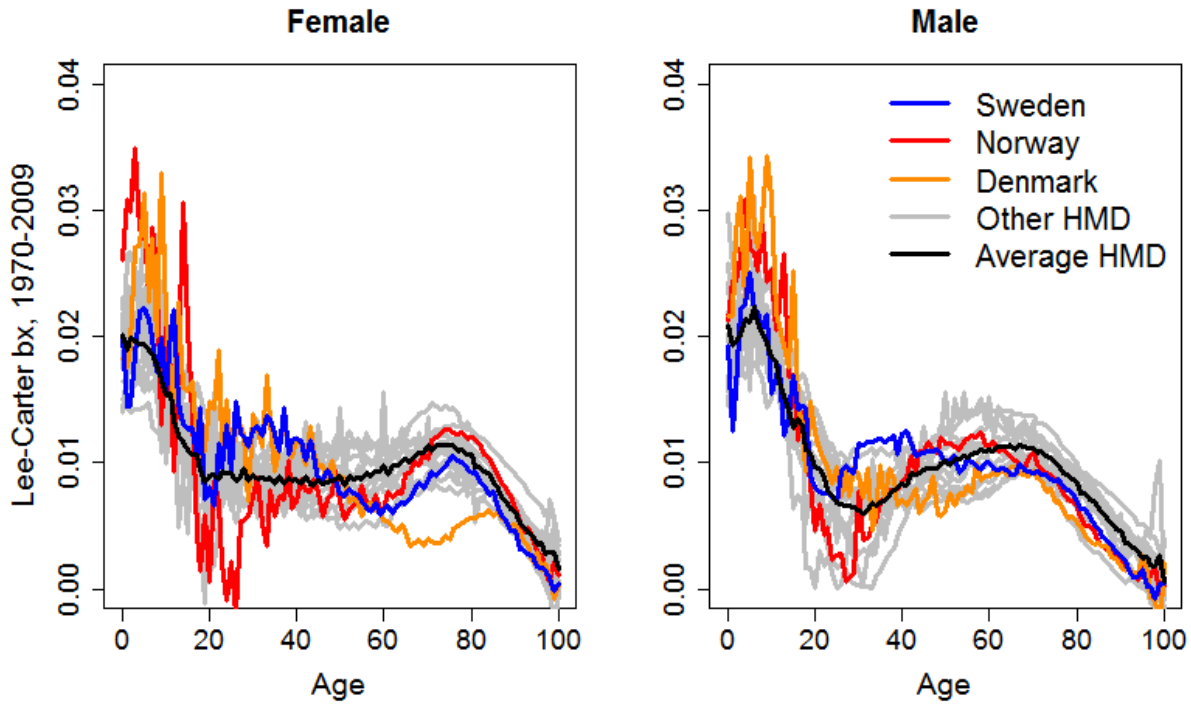

Figure 2: The bx parameter from fitting a Lee-Carter model, 1970-2009. Average HMD is the composite population described in the data section.

Although the bx parameter is informative about the importance of mortality decline at different ages over a given period, it can be misleading to compare across countries because of different initial levels of mortality and different rates of change. For instance, it could be that at some ages mortality decline was weaker in northern Europe because initial levels were already comparatively low. Until recently there has been no easy way to attribute current between-population differences in life expectancy to contributions from past life expectancy differences and differences in age-specific mortality trends. Summing the decompositions of the past gap in life expectancy between countries A and B and within-population decompositions of life expectancy trends for A and B do not sum to the current gap in life expectancy. This is because temporal change in life expectancy is path dependent (Horiuchi, Wilmoth and Pletcher 2008).

To disentangle the effects of initial differences in the age-specific mortality from differences in age-specific mortality change, we used a newly developed contour replacement decomposition algorithm (Jdanov et al. 2015) which is an extension of the classic step-wise decomposition method (Andreev, Shkolnikov and Begun 2002). Essentially this method step-wise replaces the death rates for each age category along an age-period demographic contour, and recalculates the life expectancy after each replacement step to determine intermediate contributions. Replacements were made from population A in 2009 to population A in 1970 to population B in 1970 to population B in 2009, from

youngest to oldest ages. Since there was no preference in designating either the northern European country or the composite as population A or B, the same procedure was performed in reverse and contributions averaged.

The end result was two terms: an initial conditions term (1970) and a trend term (1970-2009), both of which are vectors of age-specific contributions to the 2009 life expectancy difference. These two terms exactly sum to a classic between-population age decomposition of life expectancy in 2009, which could be obtained by any of the three independently developed but equivalent decomposition methods for discrete data (Andreev 1982; Arriaga 1984; Pressat 1985).

We applied the contour decomposition method to age-specific mortality differences (1970-2009) between each of the three northern European countries and the composite (Figure 3). Among females, Sweden and Norway had similar results: both countries had a strong advantage in life expectancy in 1970, primarily owing to lower mortality in infancy and over ages 40-79. Both countries experienced weaker mortality decline than the HMD composite over all ages, especially ages 60-79. By 2009 the average HMD country had caught up and overtaken Sweden and Norway in remaining life expectancy at ages above around 60 (check). A similar story could be told among Swedish and Norwegian men, however the crossover age where mortality among northern Europeans becomes higher than average is older than among females, which in part explains their continued higher than average life expectancy. In Denmark, the initial lower mortality advantage over the average HMD country was less than in Sweden and Norway, and trends were substantially worse, particularly at ages over 60.

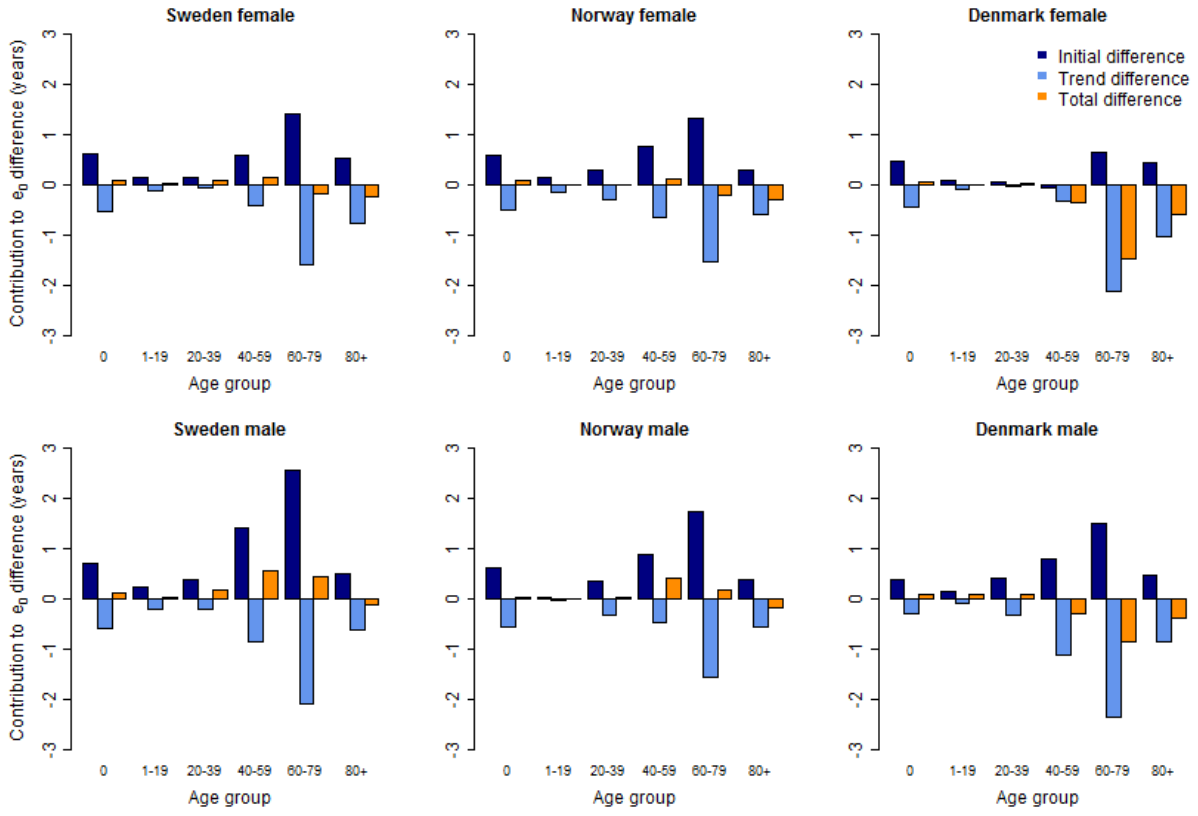

Figure 3: Contour decomposition of the northern European populations compared to the HMD composite for the period 1970 to 2009.

From the results in this section, it appears that much of the decline in rankings occurred because of a failure to keep pace in mortality reduction at ages above 60.

Section 2: Differences in the cause-of-death composition

In this section we investigate the hypothesis that mortality differentials between Sweden, Norway and Denmark are emerging against the composite population because of differences in the cause-of-death composition. We expect to find that the northern Europeans die on average at an older age from most causes of death, but have begun to die more often from shorter-lived causes of death than the composite population.

To test this hypothesis, we use the Firebaugh et al. (2014) cause-of-death decomposition which separates the life expectancy gap between Sweden, Norway and Denmark and the HMD composite into age and composition components by cause. A positive age component means that the northern European country died at an older age than the composite population for the given cause of death. If the cause of death has a higher than average age at death, the composition effect is positive when the country was dying from this cause at a higher proportion than the composite, and vice versa.

The change in the life expectancy gap between the three northern European countries and the composite is overwhelmingly attributable to age rather than compositional effects (Figure 4). Nevertheless, interesting country differences can be seen. In Sweden the composition component has been positive and increasing over much of the time period. By 2009 the two components were in

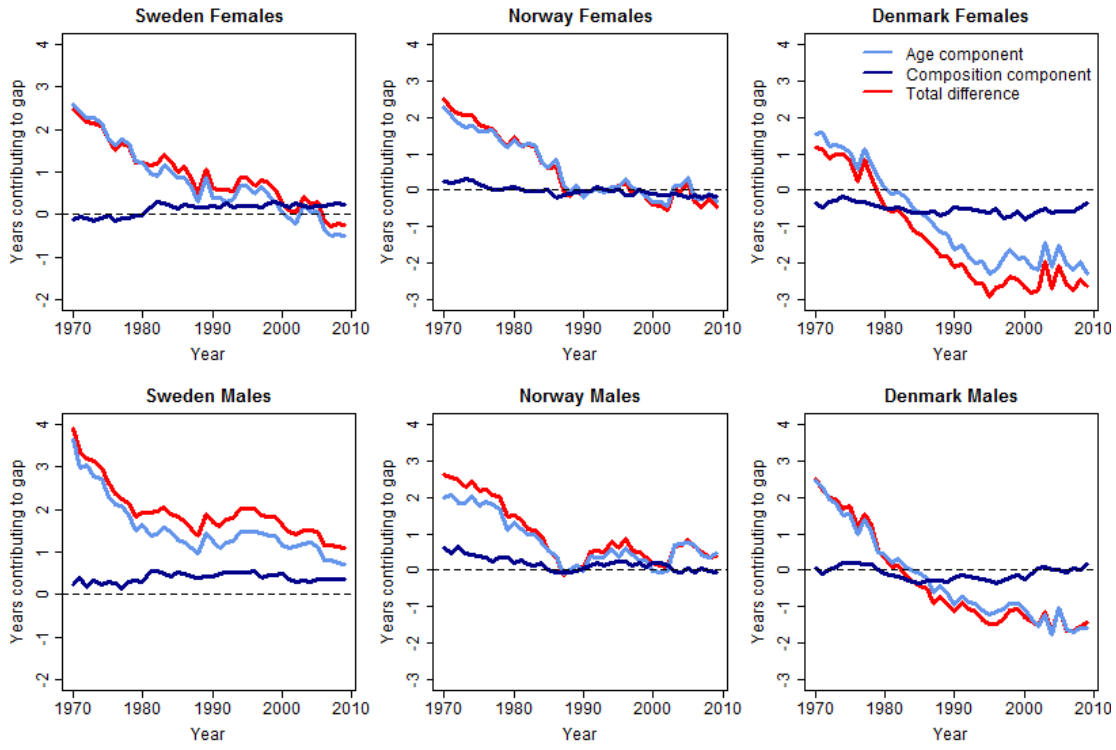

Figure 4: Yearly decomposition of the gap in life expectancy between northern European countries and the HMD composite into age and composition effects.

opposite directions for females, i.e. for any given cause of death Swedish women were dying at a younger age at death than the composite on average, however, they were dying more often from causes with older average ages at death. Danish females on the other hand have died from a younger cause of death structure over the entire time period. In Norway and among Danish males, the cause of death composition has closely tracked the average.

To see which causes were responsible for these between-country differences in the age and compositional components, we more closely examined the decomposition of the most recent year (2009, Table 1). The age component was responsible for about 2/3 of the total difference in life expectancy in Sweden and among Norwegian females, and for most of the difference in Denmark and among Norwegian men. Different causes of death were responsible for the life expectancy

Men

	Sweden			Norway			Denmark		
Cause of death	Composition	Age	Total	Composition	Age	Total	Composition	Age	Total
External	0.02	0.16	0.18	-0.06	0.12	0.06	0.24	-0.09	0.15
Heart Disease	0.14	0.27	0.41	-0.03	0.09	0.06	-0.13	-0.21	-0.34
Other Circulatory	0.06	0.03	0.09	0.03	0.01	0.04	0.00	-0.14	-0.15
Ill-Defined	-0.01	0.08	0.06	-0.05	0.03	-0.02	-0.09	0.04	-0.05
Infancy	0.07	0.03	0.10	0.01	0.01	0.02	0.10	0.03	0.13
Mental	0.03	-0.03	0.00	-0.04	-0.13	-0.17	0.00	-0.47	-0.47
Smoking-related Cancer	0.17	0.03	0.20	0.10	-0.03	0.07	0.02	-0.07	-0.05
Other Cancer	-0.01	0.09	0.08	-0.01	0.13	0.12	0.00	-0.24	-0.24
Other Causes	-0.09	0.07	-0.03	0.00	0.24	0.23	0.02	-0.35	-0.33
Total	**0.36**	**0.73**	**1.09**	**-0.06**	**0.47**	**0.41**	**0.15**	**-1.59**	**-1.44**

Women

	Sweden			Norway			Denmark		
Cause of death	Composition	Age	Total	Composition	Age	Total	Composition	Age	Total
External	0.01	0.01	0.01	-0.07	0.10	0.03	0.06	-0.02	0.04
Heart Disease	0.07	-0.05	0.02	-0.07	-0.02	-0.09	-0.26	-0.35	-0.61
Other Circulatory	0.03	-0.05	-0.01	0.00	-0.03	-0.03	-0.03	-0.28	-0.32
Ill-Defined	0.04	0.02	0.06	0.05	-0.02	0.02	0.10	-0.20	-0.10
Infancy	0.08	0.02	0.10	0.05	0.03	0.07	0.10	0.01	0.11
Mental	0.02	-0.12	-0.10	-0.08	-0.21	-0.29	-0.11	-0.41	-0.53
Smoking-related Cancer	0.02	-0.05	-0.03	-0.01	-0.04	-0.05	-0.21	-0.10	-0.31
Other Cancer	-0.01	-0.11	-0.12	-0.03	-0.08	-0.10	-0.04	-0.36	-0.40
Other Causes	-0.01	-0.16	-0.17	0.00	-0.02	-0.02	0.02	-0.54	-0.52
Total	**0.24**	**-0.49**	**-0.24**	**-0.16**	**-0.30**	**-0.46**	**-0.37**	**-2.26**	**-2.63**

Table 1: Decomposition of the 2009 gap between the country and the 9-country composite population into an "composition" component– the effect of dying more or less from that cause of death compared to the composite and an "age" component – the effect of dying from the given cause of death at a younger or older age.

advantage or disadvantage in the three countries with gains and losses relatively spread out over the 9 causes. Causes that are closely related to the smoking epidemic were contributing positively for Swedish men, but negatively for all women and Danish men. Denmark also lost close to a half year of life expectancy from having a lower average age at death from mental causes of death.

The composition component was overall less important than the age component, however often went in different directions for the three countries pointing to differences in the cause of death composition. Heart disease, which had a lower than average age at death, was positive for Sweden, close to zero for Norway and negative for Denmark. Thus Swedes benefitted from having relatively fewer heart disease deaths while Danes lost life expectancy by having a higher proportion of heart disease deaths. Differences in the proportion of deaths from smoking-related cancers were also a strong contributor to the composition component of life expectancy differences. Having a lower proportion of deaths from smoking-related cancers contributed 0.17 years of the life expectancy advantage of Swedish men, while its high proportion among Danish women cost them 0.21 years of life expectancy compared to the HMD composite.

Overall, we did not find evidence that northern Europeans are increasingly dying from causes with younger ages at death. Rather we found that the gradual loss in life expectancy rankings has been dominated by 'age effects'. The cause of death composition was only moderately helping Swedish males to maintain higher than average life expectancy and hurting the Danish female life expectancy rankings.

Section 3: Mortality decline and frail cohorts

In this section we investigate a cohort-driven theory for the mortality slowdowns. We theorize that in the past when mortality was high, frail individuals had lower chances to survive, leaving a more robust group of survivors to older ages. As large early reductions in infectious disease took hold in society, the frail survived alongside the more robust. Northern Europeans were among the first to experience mortality decline from reductions in infectious disease in the early 20th Century. Thus we expect to find that the lower was the cohort mortality at early ages, the frailer was the cohort at later ages in a country-comparative perspective.

In the first instance, we look within cohorts (Figure 4A). A within-cohort association between survival to age 5 and survival from 80 to 100 shows that the northern European cohorts have among the lowest survival from ages 80 to 100 for any given level of early cohort survival. A top-left bottom right pattern consistent with frailty being the main driver of mortality patterns is not evident. Next we look at period death rates at older ages given different early cohort survival probabilities (Figure 5B). For all levels of cohort early mortality, the period death rates at older ages were higher in the northern European countries than in other HMD countries.

Both Figures 5A and 5B are dominated by the gradually improving period death rates at old ages for all countries—the northern European countries are at the far right of both panels since they were the first to reduce early mortality. From this figure there does not appear to be any general mortality disadvantage from higher early cohort survival probabilities. Thus the general period improvement in mortality was far more important in driving old age mortality patterns than selection effects.

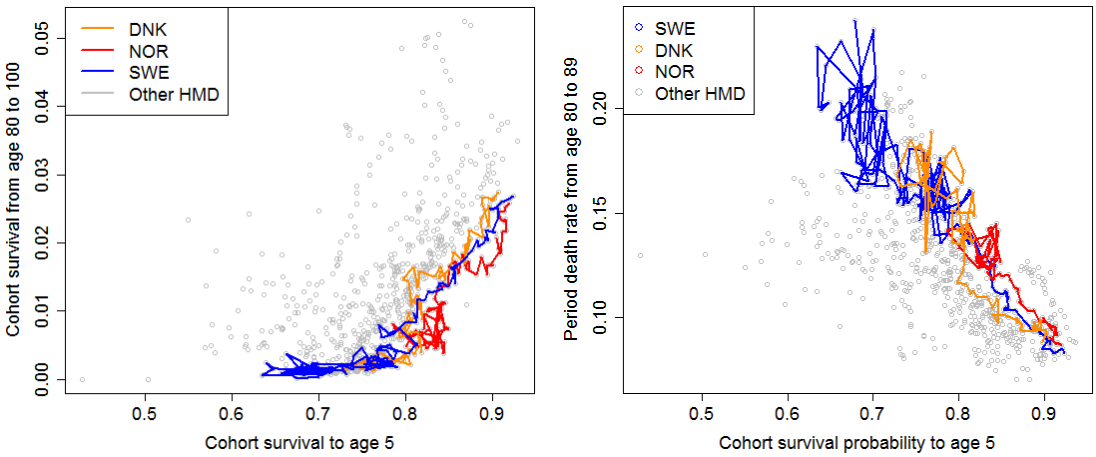

Figure 5: A within-cohort association between survival to age 5 and survival probabilities from ages 80 to 100 (Panel A). The association between cohort survival to age 5 and period death rates from ages 80 to 89 when the cohort was aged 85 (Panel B). Included are all HMD countries with cohort data for all available cohorts.

Finally in Figure 6 we looked at the association between early cohort survival and period rates of mortality improvement (see Kannisto et al. 1994), the idea being that highly selected cohorts might experience rapid rates of mortality improvement that could not be seen by looking at the level alone. The reality is less clear. All countries went through periods with faster and slower rates of mortality improvement at old age, seen by the upward and downward moving curves. Importantly, these movements do not appear to be related to the degree of early cohort survival and show no common pattern over the three countries.

From Figures 5 and 6 we cannot conclusively dismiss the idea that early cohort selection is not playing a role in late life mortality patterns, however we would argue that such a role, if present, is small and less important than other factors. Between now and EPC we will use more sophisticated statistical models to quantify these effects.

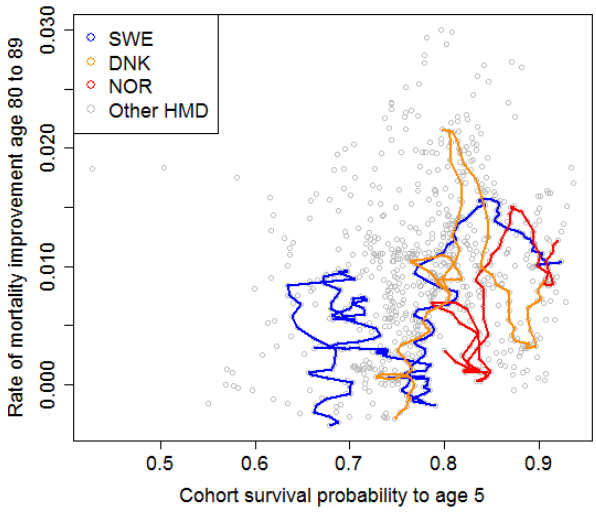

Figure 6: the association between early cohort survival probabilities and smoothed period rates of mortality improvement aged 80 to 89 from when the cohort was 85.

Section 4: Smoking and mortality slowdowns

In this final section we investigate whether smoking-attributable mortality can explain the decline in life expectancy rankings. We compare Sweden, Norway and Denmark to the HMD composite population used in sections 2 and 3. Since smoking-attributable mortality is low below age 50, we limit our analysis to remaining life expectancy at age 50. We apply the Preston-Glei-Wilmoth method to remove smoking-attributable mortality (Preston, Glei and Wilmoth 2010; Preston, Glei and Wilmoth 2011) and compare observed e_{50} and e_{50} in the absence of smoking for the 4 populations.

For women, removing smoking had no noticeable effect on the gap between Sweden and Norway to the composite. For Denmark, the difference in e_{50} to the HMD composite narrowed from 2.7 to 2.3 years, but the trends remained largely the same. For men removing smoking caused a deterioration in rankings for Sweden and Norway, suggesting that the smoking epidemic has been less harmful there than elsewhere over the period in question. For Denmark, though the levels were different, the gap to the average was similar for observed e_{50} and e_{50} in the absence of smoking.

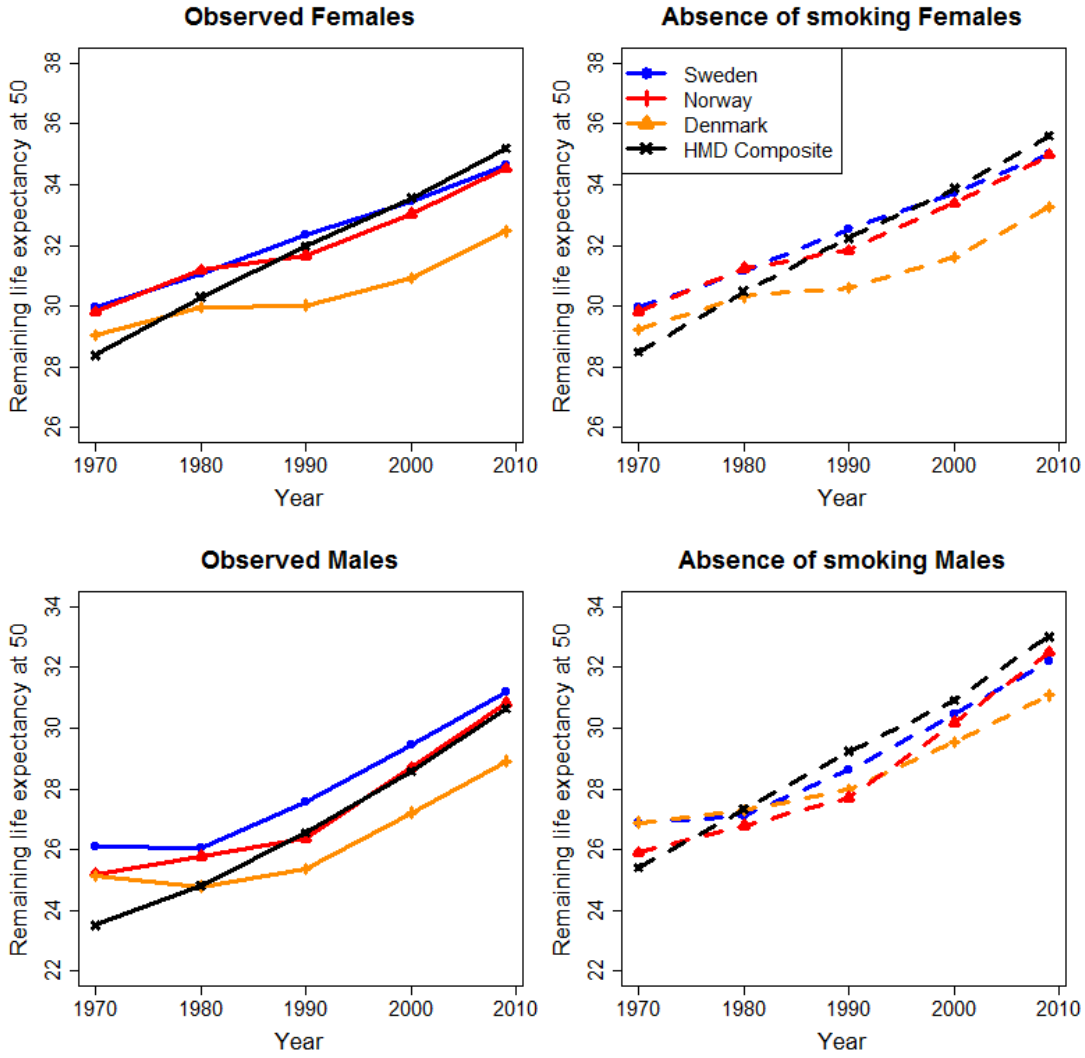

Figure 7: Remaining life expectancy at age 50 observed and in the absence of smoking.

Conclusion

Summary of initial results:

Though once leaders, Sweden, Norway and Denmark have all fallen in life expectancy rankings at some point during the 1970 to 2009 period. This drop in rankings is owing to slower mortality decline at ages above 60, from a multitude of causes of death. While the general age pattern of mortality decline has followed similar patterns in the three countries, some differences were found in the timing of decline and in the causes of death. Cohort effects from survival of frail cohorts or from strong smoking epidemics do not appear to be the main driver of life expectancy slowdowns. We still do not have a conclusive answer as to whether the decline in life expectancy rankings is following a similar pattern across the three countries or owing to country-specific circumstances.

Future Outlook:

Until now, we have mostly investigated mortality decline between time periods 1970 and 2009, ignoring much of what happened in the middle. Between now and the EPC, we will more carefully investigate periods of stagnation and catching up, to see whether the same ages and cause are responsible, and whether this is likely a period- or cohort-driven phenomenon. We are limiting the overall discussion and conclusions at this time until we have a better idea of what has happened in northern Europe.

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Appendix: Cause of death groupings and ICD codes

Cause group	Subgroups included	ICD-7	ICD-8	ICD-9	ICD-10
Heart Disease	Heart Disease	400-447	390-429	390-429	1065-1068
Other Circulatory	Cerebrovascular	330-334	430-438	430-438	1069
	Other circulatory	450-468	440-458	440-459	1070-1071
Smoking cancers	Lung, trachea, bronchus	162-163	162	162	1034
	Esophagus	150	150	150	1028
	Lip/oral cavity/pharynx	140-148	140-149	140-149	1027
	Larynx	161	161	161	1033
Non-smoking cancer	All others	151-160, 164-239	151-160, 163, 170-239	151-157, 170-175, 179-239	1029-1032,1035-1047
External mortality	Transport accidents	E810-E835, E800-E802, E840-E866	E810-E823, E800-E807, E825-E845	E800-E848	1096
	Poisinings	E870-E895	E850-E877	E850-E869, E870-E879	1100
	Homicides & Accidents caused by firearms	E919, E964, E980-E985	E922, E960-E978, E980-E989	E922, E960-E969, E970-E999, E980-E989	1102
	Suicides	E963, E970-E979	E950-E959	E950-E959	1101
	Other external	E900-E904, E912, E916, E917, E918, E929, E910, E911, E913-E915, E920-E928, E930-E962, E965, E990-E999	E880-E887, E890-E899, E910, E916-E921, E923-E928, E900-E909, E911-E915, E929-E949, E990-E999	E880-E888, E890-E899, E900-E909, E910, E914, E915, E919, E920, E930-E949, E990-E999	1097-1099, 1103
Infancy-related		750-776	740-779	740-779	1092-1093
Mental disorders	Alzheimer's, Mental Disorders and diseases of the nervous system and sense organs	300-326, 340-398	290-389	290-389	1055, 1058, 1062-1063
Illdefined	Senility & Ill-defined	780-795	780-796	780-799	1094
Other causes	Other causes*	001-138, 240-245, 250-254, 260, 270-277, 280-299, 470-475, 480-483, 490-493, 500-502, 510-527, 530-545, 550-553, 560-561, 570-587, 590-594, 600-617, 620-637, 640-652, 650-651, 660, 670-698, 700-716, 720-727, 730-749	000-027, 030-046, 050-057, 060-068, 070-117, 120-136, 240-246, 250-258, 260-289, 460-466, 470-474, 480-486, 490-493, 500-508, 510-537, 540-543, 550-553, 560-577, 580-584, 590-607, 610-645, 650-662, 670-678, 680-686, 690-718, 720-738	B01, B02, B03, B04, B05, B06, B07, B180-B185, B189, B19, B20, B31, B32, B33, B34, B35, B36, B37, B38, B39, B40, B41, B42, B43	1001, 1049, 1050, 1052, 1054, 1072, 1078, 1082, 1083, 1084, 1087

* Big remaining cause groups are infectious disease, respiratory disease, and diabetes