Differential Mortality: Estimation and Implications for Pension Systems

FACTAGE – WP 4
Deliverable 4.2

Edited by Johannes Klotz and Tobias Göllner
Statistics Austria

March 2019

FACTAGE is a project coordinated in the Joint Programming Initiative: More Years, Better Lives. The Austrian contributions, such as this, are funded by the Federal Ministry of Education, Science and Research

Preface

This report is a joint work of Senior Researchers of Statistics Austria, which is one of five members of the FACTAGE project consortium, and an external contractor from the central bank of Austria, who served as an advisor to the FACTAGE project. FACTAGE is a project funded in the framework of the first call of the Joint Programming Initiative ‘More Years, Better Lives’ (‘Extended Working Life and its Interaction with Health, Wellbeing and beyond’). FACTAGE is funded nationally by the Austrian Federal Ministry of Science, Research and Economics. Details regarding the project can be found at www.factage.eu . Details regarding the Joint Programming Initiative can be found at www.jp-demographic.eu.

This report is the second in a series of three reports to be produced in FACTAGE Work Package 4. In its core, it contains two papers. The first paper by Markus Knell is on theoretical and mathematical considerations on fairness in pension systems when one accounts for systematic variation in mortality risk between population subgroups. The second is on the actual mortality disadvantage of Europeans classified as ‘severely materially deprived’. A final detailed technical report is to be produced in mid-2019.

This report was reviewed within the FACTAGE project consortium by the National Institute of Economic and Social Research (NIESR, London) as well as externally by Bernard Casey (SOCECONRES, Frankfurt). Of course, any errors are solely the authors’ responsibility.

Suggested citation: Klotz, J., and Göllner, T. (eds.): Differential Mortality: Estimation and Implications for Pension Systems. FACTAGE Project Report, Deliverable 4.2, March 2019.

Authors (in alphabetical order)

Tobias Göllner

Statistik Austria

Direktion Bevölkerung

Guglgasse 13

1110 Wien

Austria

Tobias.Goellner@statistik.gv.at

Johannes Klotz

Statistik Austria

Direktion Bevölkerung

Guglgasse 13

1110 Wien

Austria

Johannes.Klotz@statistik.gv.at

Markus Knell

Oesterreichische Nationalbank

Economic Studies Division

Otto-Wagner-Platz 3

1011 Wien

Austria

Markus.Knell@oenb.at

Matthias Till

Statistik Austria

Direktion Bevölkerung

Guglgasse 13

1110 Wien

Austria

Matthias.Till@statistik.gv.at

Contents

Introduction

Johannes Klotz

50 years ago the long-run increases in life expectancy in developed societies appeared to have come to a halt. This was not seen as surprising, because the life expectancy gains observed since the 19th century had been predominantly caused by a steep reduction in infant mortality rates and in deaths from infectious diseases, which were already at a low level, so the potential for further improvement was small (Vallin et al. 2001). The belief that developed societies had more or less reached the limits of the possible can easily be shown by the typical assumptions made in population projections at that time. To quote just from the United Nations' "Concise Report on the World Population Situation in 1970-1975 and Its Long-Range Implications": "There is the possibility expectation of life may rise still further though, with presently available means and resources, perhaps not very much further. (…) An eventual life expectancy of 72.5 years for males and 77.5 years for females has been assumed" (United Nations 1974: p. 41).

A second assumption which some scholars mention to have been prevailing around 1970 (although there is in fact not much hard evidence on it) was that mortality disparities between socio-economic groups would eventually disappear, as a result of the expansion of social services provided by modern welfare states.[1] As we know today, both propositions broke down shortly afterwards. The "cardiovascular revolution" driven by lifestyle changes has since the 1970's (in Eastern Europe only since the fall of the Communist regimes) brought life expectancy to unprecedented levels in developed societies (Vallin and Meslé 2004), and this trend has continued even in the most recent years, albeit at a smaller pace and not uniformly between countries (Case and Deaton 2015). Moreover, the cardiovascular revolution was by no means accompanied by a closing in the socio-economic gap in mortality, and for many countries even the reverse has been observed (Mackenbach et al. 2016).

The rise in life expectancy is clearly a great societal achievement, in particular as it was essentially brought about by an increase in healthy or only mildly ill years, whereas the expected number of years with severe illness or disability has remained essentially unchanged (Robine et al. 2003) —even if this may not hold for the more recent past, especially in the United States (Crimmins and Beltrán-Sánchez 2010, Case and Deaton 2017). This progress notwithstanding, pension systems have come under pressure as a result of changing old-age dependency ratios[2] (which were further inflated by falling birth rates). Many countries have thus reformed their pension systems over the last 20 years or so, and although design of pension system and pension reform vary substantially between countries (Carone et al. 2016),

[1] This is mentioned for instance by Zarulli et al. (2012), however, without providing any evidence. In fact, very few countries had any data on socio-economic mortality differences then. This data scarcity was not, as one may speculate, evidence of the subject's unimportance (Feichtinger 1973: p. 80).
[2] This is not restricted, as it is sometimes believed, to public pay-as-you-go systems. It should be clear that any system which redistributes from the working to the retired population is sensitive to changes in age structure.

it is clear that in one way or the other most reforms aim at increasing the effective retirement age.

From an insurance mathematics perspective, a rise in the effective retirement age in times of rising life expectancy can be justified by the criterion of actuarial fairness, meaning that expected discounted contributions to the pension system should be equal to expected discounted pension payments. And although actuarial fairness may not be the only criterion in designing a pension system,[3] its importance is evident both on fiscal grounds as well as for the pension system's social acceptance. The crucial question is however whether actuarial fairness is somehow violated in light of substantial socio-economic differences in mortality, when the pension system does not take account of them.

There is of course variation in individual lifespans. On an individual level, if one does not die exactly at the age of average life expectancy, he or she inevitably ends up either as a net contributor or as a net receiver in the pension system. Net contributors pay in more money than they receive back in form of a pension, while net receivers get more money than they actually contributed. So, assuming two persons contributed the same amount, person X who dies at age 70 subsidizes the lifetime pension of person Y who dies at age 90. [4] But such redistribution on an individual level does not violate actuarial fairness on an aggregate level. As long as we do not know in advance one's individual lifespan, actuarial fairness can only be implemented in terms of mathematical expectation in a large population, and individual gains and losses are perfectly consistent with it.[5]

The question is rather whether actuarial fairness is violated by known and substantial mortality differences between large subpopulations. Suppose the entire population can be partitioned into two pre-identifiable groups L and H, with low and high life expectancy, respectively, and that a uniform pension formula is applied to both groups. Then clearly group L on the whole subsidizes the pensions of group H.[6]

Now from an overall perspective such redistribution between subpopulations would still be consistent with a balanced system if the distinction between L and H were unrelated to income level. But the point is that life expectancy and income[7] are positively correlated. This has a profound impact on the pension system in general, as Markus Knell demonstrates in the first paper of this report. It results in a deficit of the overall system, because what the system saves from the short-living poor is not enough to cover the extra payments to the long-living rich. In other words, life expectancy differences between socio-economic groups in combination with uniform pension formulas violate actuarial fairness on an aggregate level,

[3] Other possible criteria are the avoidance of old-age poverty, implemented by some minimum pension, and compensation for workers in hazardous occupations.

[4] Note that here we implicitly assume a homogeneous workforce in terms of employment history. In reality, the personal gains or losses in the pension system depend of course on many more variables than just the age of death.

[5] What is, after all, the mere purpose of a pension system, if not insurance against the risk of longevity?

[6] Again, this does not at all rule out that some members of L end up as net receivers and some members of H as net contributors.

[7] Socio-economic position can be used as a more general indicator.

and incorporating them into the design of the pension system is not merely an ethical, but also a fiscal issue.[8]

In the simplified example of two pre-identifiable high and low life expectancy groups, actuarial fairness can be easily arranged by altering certain parameters of the pension system such as the retirement age or the replacement rate. In practice, things are not that straightforward because firstly such groups are not pre-identifiable and have to be approximated by socio-economic variables such as income or occupational class, and secondly actuarial fairness is only one of many possible fairness dimensions. If, for example, the lower life expectancy in group L compared to group H were merely a result of a higher cigarette smoking prevalence in L, with all other factors of influence on mortality risk being equally distributed among the two groups, then a lower retirement age for L would still be actuarially fair, but clearly unfair from a more general understanding of fairness and of course unacceptable on political grounds.

To give another example, although pension systems redistribute from men to women (mainly because of higher female life expectancy, in some cases also because of lower retirement ages for women and/or higher replacement rates for low earners), this transfer is hardly seen as a call for political action. For some redistribution is usually seen as a justified compensation for the uneven distribution of unpaid work (housework, raising children, and domestic elderly care) between the sexes. Furthermore, only a small portion of the female life expectancy advantage is caused by biological factors, whereas the lion's share results from gender-specific behaviors and lifestyles (Luy 2003).

To conclude, actuarial fairness may not be actual fairness. Thus, Markus Knell discusses various normative fairness concepts which have been established in academic and philosophical discourse, and how they relate to socio-economic mortality differences. He also mentions several international examples of how socio-economic mortality differences were actually considered in the design of public pension systems.

Clearly, country-specific arrangements play an important role in social policy and its support among the population. In the past decades, it has become customary to classify (European) countries according to welfare state types. Esping-Andersen's (1990) three types of welfare capitalism is the most prominent approach, but not necessarily the most promising in explaining health inequalities (Bergqvist et al. 2013). When it comes to pension systems, a distinction is usually drawn between flat-rate, defined-contribution and defined-benefit schemes, as well as between pay-as-you-go and pre-funded systems (Carone et al. 2016: p. 16).

However, countries differ not only in their pension systems, but also in their health care systems, labour market policies, child care and many more policies which matter for and are

[8] It is clear that accounting for socio-economic mortality differences in the pension system can only be the second-best solution and it would be much better to find a way to actually close the mortality gap between social groups (Kroh 2012). However, altering a formula is arguably easier and quicker to achieve than closing the mortality gap.

influenced by social inequality. An excess of, say, fatal heart diseases in a poor population may be caused by an excess diseases incidence in this population, but also by a lower survival rate in case of illness. Although both may result in the same life expectancy gap, possible political remedies would be very much different. The problem for the actual politician is of course that we often do not know the social determinants of differential mortality and how much each of these factors matters. So in a general sense, international comparisons may serve as an important tool in assessing the importance of different factors.

A major hurdle in that respect is that mortality by socio-economic status is not part of the European Statistical System (ESS). As of 2018, some European countries still cannot provide any figures on socio-economic differences in mortality. Among those which can, figures are not easily comparable, for they differ in terms of data source (unlinked cross-sectional vs. linked longitudinal data), period of analysis, population covered, socio-economic stratification variables, and mortality indicator. Details on comparability issues and possible remedies are discussed by Klotz and Göllner (2017).

One of the core outputs of the FACTAGE project was to develop a standardized methodology for comparative European estimation of socio-economic mortality differences. For that purpose, longitudinal information from the harmonized European-wide EU-SILC sample survey is extracted from Eurostat's User Database and then processed in such a way that the final dataset allows for standard applications of differential mortality estimators like Cox's Proportional Hazards Regression. The method was developed in 2016-2017 and is described in detail in Klotz and Göllner (2017). The algorithm is now available in SAS (Göllner and Klotz 2018) as well as in R.

An application of the FACTAGE method is the work of Johannes Klotz, Tobias Göllner and Matthias Till in the second paper of this report. They estimate relative mortality risk for Europeans facing severe material deprivation, an absolute poverty indicator which to date has not been investigated in differential mortality research. Their findings indicate that absolute poverty clearly damages longevity chances, and that this is only partially a consequence of higher morbidity levels among the poor population. Excess mortality of the deprived compared to the non-deprived is observed at all morbidity levels, but the relative hazard ratios are largest among those in good health.

Interestingly, the substantial gap in deprivation levels between Western and Eastern Europe is not at all reflected in different excess mortality of the severely materially deprived. Rather it is the Mediterranean countries which stand out in such a way that the deprived are relatively better off than in non-Mediterranean countries. A greater disadvantage of the poor is found among men than women, which is the usual finding of studies on differential mortality.

References

Bergqvist, K., Yngwe, M.Å., and Lundberg, O. (2013): Understanding the role of welfare state characteristics for health and inequalities – an analytical review. *BMC Public Health*, 13: 1234.

Carone, G., Eckefeldt, P., Giamboni, L., Laine, V., and Pamies Sumner, S. (2016): Pension reforms in the EU since the early 2000's. Achievements and challenges ahead. Luxembourg: Publications Office of the European Union.

Case, A., and Deaton, A. (2015): Rising morbidity and mortality in midlife among white non-Hispanic Americans in the 21st century. Proceedings of the National Academy of Sciences 112(49): 15078-15083.

Case, A., and Deaton, A. (2017): Mortality and morbidity in the 21st century. Brookings Papers on Economic Activity, Spring 2017: 397-476.

Crimmins, E.M., and Beltrán-Sánchez, H. (2010): Mortality and morbidity trends: is there compression of morbidity? *The Journals of Gerontology* Series B: Psychological Sciences and Social Sciences 66B(1): 75-86.

Esping-Andersen, G. (1990): *The Three Worlds of Welfare Capitalism*. Princeton University Press.

Feichtinger, Gustav (1973): *Bevölkerungsstatistik*. De Gruyter Lehrbuch. Berlin-New York.

Göllner, T., and Klotz, J. (2018): Editing EU-SILC UDB Longitudinal Data for Differential Mortality Analyses. SAS code and documentation. FACTAGE project report, May 2018.

Klotz, J., and Göllner, T. (2017). Estimating Differential Mortality from EU–SILC Longitudinal Data. A Feasibility Study. Vienna: Statistics Austria (FACTAGE research report WP4).

Kroh, M. (2012): Lebenserwartung von Menschen mit geringen Einkommen erhöhen. Interview, *DIW Wochenbericht* Nr. 38.2012, p. 16.

Luy, M. (2003): Causes of male excess mortality: insights from cloistered populations. *Population and Development Review* 29(4): 647-676.

Mackenbach, J.P., Kulhánová, I., Artnik, B., Bopp, M., Borrell, C., Clemens, T., Costa, G., Dibben, C., Kalediene, R., Lundberg, O., Martikainen, P., Menvielle, G., Östergren, O., Prochorskas, R., Rodriguez-Sanz, M., Strand, B.H., Looman, C.W.N., and de Gelder, R. (2016): Changes in mortality inequalities over two decades: register based study of European countries. *BMJ* 353: i1732.

Robine, J.-M., Jagger, C., Mathers, C.D., Crimmins, E.M., and Suzman, R.M. (eds.) (2003): *Determining Health Expectancies*. Chichester/UK: John Wiley and Sons.

United Nations (1974): *Concise Report on the World Population Situation in 1970-75 and Its Long-Range Implications*. Department of Economic and Social Affairs, Population Studies, No. 56, New York.

Vallin, J., and Meslé, F. (2004): Converges and diverges in mortality. A new approach to health transition. *Demographic Research,* Special Collection 2, Article 2, 11-44.

Vallin, J., Meslé, F., and Valkonen, T. (2001): *Trends in mortality and differential mortality*. Population studies No. 36, Council of Europe Publishing.

Zarulli, V., Jasilionis, D., and Jdanov, D.A. (2012): Changes in educational differentials in old-age mortality in Finland and Sweden between 1971-75 and 1996-2000. *Demographic Research*, Volume 26, Article 19, 489-510.

Fair Pension Systems and Differential Mortality

Markus Knell[9]

1. Introduction

Pension systems have a number of goals (see e.g. Barr and Diamond, 2009). The two most important ones are consumption smoothing (i.e. the provision of adequate levels of retirement income that preserve the standard of living in old age) and the prevention of old age poverty. These goals have to be fulfilled while obeying a number of constraints: fiscal sustainability, efficiency (minimizing the distortions for savings and labor supply) and the design of a fair and equitable system (if this is not the case then the system lacks acceptance and the backing of the general public).

In this paper[10] we deal with the latter aspect and analyze how the phenomenon of differential mortality might have an effect on the "fairness" of pension systems, in particular on systems that are organized on a pay-as-you-go (PAYG) basis. We choose this focus for two reasons. First, in a majority of countries public PAYG pension systems are the most important pillar of old-age security. Second, a focus on these systems allows to discuss the interplay of fairness and differential mortality in a concise and transparent manner. It has to be stressed at the outset, however, that differential mortality also represents a considerable challenge for private insurance markets and for pension systems that are dominated by a funded pillar (as is the case for countries like Australia, the Netherlands, Switzerland and the United Kingdom). Furthermore, the question of a fair pension design is of course not only related to differential mortality but entails other dimensions. These have, e.g., to do with the size and conditionality of the minimum pension, the eligibility criteria for acquiring pension rights, the treatment of non-contributory periods (for unemployment, sickness, care etc.), the determination of deductions/supplements for early/late retirement, regulations concerning gender equality, the reaction to demographic and (in the case of funded systems) asset-price fluctuations etc. For the sake of brevity, we have to abstract from these additional aspects in this paper and we focus on the direct effect of differential mortality on the fairness of pensions systems.

We start our analysis with simple numerical examples that are valuable to discuss the meaning of "fairness" in the presence of socio-economic differences in life expectancy. These examples are then used to introduce two different concepts of fairness. On the one hand the notion of "actuarial fairness" as it is often used in the insurance industry and, on the other hand, normative concepts of fairness (utilitarianism, egalitarianism) that have been proposed

[9] The views expressed in this paper reflect the private opinion of the author.
[10] The paper is partly based on Knell (2016) (in German) which contains additional considerations and results.

in political philosophy and welfare economics. In the last section we discuss how a "fair" policy could be implemented by using differentiated pension formulas.

2. Examples for the distributional impact of socio-economic mortality differences

There exist numerous studies for different countries and different periods showing that life expectancy of low-income individuals is considerably lower than the one of high-income individuals. Chetty et al. (2016), for example, have documented in a recent study that the life expectancy gap between the richest and the poorest percent of the American population is 14.6 years (for men) and 10.1 years (for women). Von Gaudecker and Scholz (2007), on the other hand, analyzed German data and found differences in residual life expectancy at age 65 between those with the highest and the lowest pension of almost 6 years. The first paper of this report also confirms these results for a large number of European countries. For an identical retirement age this life expectancy gap implies considerable differences in the expected number of pension payments and thus in the net expected present value of pension benefits for the two groups.

This can be illustrated most easily by the use of a specific numerical example (as shown in Table 1). The public PAYG pension system is modeled as an "accrual rate system" similar to the German earnings point and the Austrian pension account models.[11] It is assumed that the contribution rate is 25% and that the accrual rate for each year of work is given by 1.67%. After 45 years of contributions with a retirement at the age of 65 the replacement rate thus amounts to 75%. We focus on a stylized society in which there are only two types of people: an H-type and a L-type (see description in Table 1). One can either think of these types as being the only individuals in an illustrative example or – preferably – as representing the average values of large groups of people. Both types are assumed to enter the labor market at the age of 20, to be continuously employed and to retire at the age of 65. For sake of simplicity it is assumed that earnings remain constant and that the same is true for pension payments. Table 1 shows three scenarios for the case that H and L receive an identical annual income of 40,000.

In cases A and B, the pension is calculated according to a conventional accrual rate scheme, where the same formula is used for both types. In the reference case A types H and L have the same life expectancy of 80 years, whereas case B is based on the assumption of differences in life expectancy (82 years for type H and 78 years for type L). In case C it is assumed that the pension formulas differ for types H and L. It is thus implicitly assumed that the system can identify the two types and that it can therefore condition the pension calculation on the different lifespans. These formulas are now determined in such a way that the replacement rate of type L is 87% if he works until the age of 65 (an annual accrual rate of 1.93%) while type H will only receive 66% at the same age (an accrual rate of 1.47%). Table 2 is

[11] For a constant life expectancy and appropriate choice of parameter values it is also analogous to a Swedish notional defined contribution (NDC) model.

completely analogous to Table 1 only that H and L now differ in their incomes. The long-lived H has an annual income of 60,000 while the short-lived L only earns 20,000. There is thus a positive correlation between longevity and income.

Table 1: Different Life Expectancies, Identical Incomes

	Case A		Case B		Case C	
	Uniform Life Expectancy		Different Life Expectancy			
	Uniform Replacement Rates		Uniform Replacement Rates		Different Replacement Rates	
	H	L	H	L	H	L
Life Expectancy	80	80	82	78	82	78
Retirement Age	65	65	65	65	65	65
Replacement Rate	75 %	75 %	75 %	75 %	66 %	87 %
Annual Income	40,000	40,000	40,000	40,000	40,000	40,000
Annual Pension	30,000	30,000	30,000	30,000	26,471	34,615
Lifetime Contributions	450,000	450,000	450,000	450,000	450,000	450,000
Lifetime Pension Benefits	450,000	450,000	510,000	390,000	450,000	450,000
Subsidy	0	0	60,000	-60,000	0	0
Subsidy (in %)	0.00 %	0.00 %	13.33 %	-13.33 %	0.00 %	0.00 %
Revenues	900,000		900,000		900,000	
Expenditures	900,000		900,000		900,000	
Deficit	0		0		0	
Deficit (in %)	0.00%		0.00%		0.00%	

Note: The table illustrates various cases of an “accrual rate pension system” with two types H and L. The two types have identical incomes, but different life expectancies (except in case A). It is assumed that there exists an equal fraction of each type and that this distribution remains constant over time. Furthermore, it is assumed that the contribution rate is 25% and that both types enter the labor market at the age of 20. For simplicity we assume a discount rate of 0%.
Source: Own calculations.

Table 2: Different Life Expectancies, Different Incomes

	Case A		Case B		Case C	
	Uniform Life Expectancy		Different Life Expectancy			
	Uniform Replacement Rates		Uniform Replacement Rates		Different Replacement Rates	
	H	L	H	L	H	L
Life Expectancy	80	80	82	78	82	78
Retirement Age	65	65	65	65	65	65
Replacement Rate	75 %	75 %	75 %	75 %	66 %	87 %
Annual Income	60,000	20,000	60,000	20,000	60,000	20,000
Annual Pension	45,000	15,000	45,000	15,000	39,706	17,308
Lifetime Contributions	675,000	225,000	675,000	225,000	675,000	225,000
Lifetime Pension Benefits	675,000	225,000	765,000	195,000	675,000	225,000
Subsidy	0	0	90,000	-30,000	0	0
Subsidy (in %)	0.00 %	0.00 %	13.33 %	-13.33 %	0.00 %	0.00 %
Revenues	900,000		900,000		900,000	
Expenditures	900,000		960,000		900,000	
Deficit	0		60,000		0	
Deficit (in %)	0%		6,67%		0%	

Note: The table illustrates various cases of an "accrual rate pension system" with two types H and L. The two types are assumed to differ both in their life expectancies and in their incomes. The remaining parameter values are the same as in Table 1.
Source: Own calculations.

Tables 1 and 2 contain a number of key figures both for the two types and for the aggregate: annual income, annual pension, lifetime contributions, lifetime pension payments, the implicit "subsidy" of the system (i.e. total pension payments minus total contributions) and this subsidy as a percentage of total contributions. The results of the individual and aggregate balances can be summarized as follows:

For the assumption of identical incomes (Table 1) the total budget of the PAYG system is balanced in each of the three cases. On the individual level the picture is, however, different. In case B type H has a longer life and the total sum of his pension benefits exceeds his total contribution payments by 60,000 (or 13.33%). The mirror image occurs for type L, whose pension payments fall short of his total contributions by the same percentage. The case C has been designed in such a way that despite different life expectancies the total contributions are exactly equal to the total pension benefits for each of the two types.

For the example in which types H and L earn different incomes (Table 2) the budget remains balanced if both types have an identical life expectancy (case A). For different life expectancies, however, the picture changes. In the conventional case with identical accrual rates (case B) the total pension benefits of type H exceed his total contributions by 13.33% (while for type L benefits are lower by 13.33%). Although this is the same percentage as for case B in Table 1, the budget of the entire system is no longer in balance but rather runs an annual deficit of 6.67%. This follows from the fact that the long-lived type H also has higher pension claims. By the premature death of type L the pension system has smaller expenses, but these savings are not enough to cover the higher pension payments to type H. The progressive system C in turn has the property that total contributions correspond to total pension benefits for each of the two types. This helps to avoid a budget deficit in this case.

These considerations lead to the question which of the allocations reported in Tables 1 and 2 could be regarded as fair. Opinions on this topic will most likely be quite diverse depending on individual principles, perspectives and perceptions.[12] In order to discuss these conflicting views, we call on the existing literature in the fields of insurance, political philosophy and welfare economics. The natural starting point for this discussion is the concept of "actuarial fairness", as laid out in the next section. In the following section we go beyond this popular, although somewhat narrow concept and discuss various normative theories of equity and fairness that have been proposed in the related literature.

3. Actuarial fairness

In the insurance industry the notion of fairness is commonly used almost synonymously with "actuarial fairness" which stipulates that "premiums paid by policyholders should match as closely as possible their risk exposure" (Landes, 2015, 519).[13] For the topic of pension policy this would mean that the "premiums" (i.e. the contribution rates) or the "indemnifications" (i.e. the pension payments) should match the exposure to longevity risk. In other words, long-lived people should either pay higher contribution rates or receive lower annual pensions such that the sum of expected discounted pension payments corresponds to the sum of expected discounted contributions.

The logic of the argument can be illustrated by example B of Table 1. Both types H and L pay the same sum of contributions (450,000) but receive over the course of retirement a different sum of pension benefits (510,000 vs. 390,000). At first sight this does not look equitable and it is certainly not "actuarially fair" (by the definition of this term). Case C, on the other hand,

[12] There exists an interesting literature on "empirical justice" that uses questionnaires and experiments to explore the ideas of justice of the respondents. A survey of the literature is offered by Konow (2003) and Gaertner & Schokkaert (2012). The examples of tables 1 and 2 could also be used as the basis for such a study.

[13] Meyers and Van Hoyweghen (2018, p.11) document similar definitions from insurance textbooks. They also report that the term "actuarial fairness" has been coined by K. Arrow (1963) in his seminal article on the "economics of medical care".

shows that the use of differentiated replacement rates restores the property of actuarial fairness. Equivalently (although not shown in Table 1) one could also stipulate differentiated contribution rates in order to arrive at the same result (which would imply contribution rates of 28.33% and 21.67% for types H and L, respectively). Differentiation (i.e. risk classification) is thus essential to guarantee actuarial fairness.

3.1 Main arguments for the use of differentiated pension formulas

In the literature one can find two main justifications for the use of actuarially fair insurance policies. The first consist in the belief that it is a simple and almost self-evident "command of fairness" to determine risk premia in accordance with individual risk profiles.[14] In section 4 we will discuss whether this intuitive fairness concept can be grounded in more fundamental principles. The second reason for an actuarially fair insurance is related to the phenomenon of "adverse selection". Community ratings (i.e. undifferentiated insurance policies) imply that the "good risks" pay premia that are above their expected losses which might induce them to leave the insurance market (if possible). Furthermore, the "bad risks" who pay too low premia might have an incentive to engage in riskier behavior ("moral hazard") thus further aggravating the situation. This potential breakdown of the insurance market thus vindicates that use of an actuarially fair structure. "Given that the insurance market is characterized by asymmetric information, its efficiency has traditionally been based on risk classification, which can be seen as a virtuous process designed to achieve the narrowest possible definition of a risk pool" (Porrini, 2015, p. 445).

Although the arguments for differentiated insurance policies and pension formulas look prima facie rather convincing there exists a long debate about the practical feasibility and ethical justifiability of this approach.

3.2 Admissibility

A major objection against the use of actuarial differentiation is the belief that certain risk classifications have to be regarded as inadmissible or discriminatory. "Some variables with predictive power may be socially, legally, or morally inadmissible for use in constructing risk classes. For example, race, sex, or age may be good predictors of certain kinds of loss experience. Race, however, is almost always an inadmissible consideration, and both sex and age are sometimes objectionable, depending on the kind of insurance involved" (Abraham, 1985, p. 419). The concern about inadmissible classifications and unacceptable discrimination is also reflected in a number of widely debated and sometimes controversial court rulings that prohibit the use of certain variables (e.g. gender or genetic information) for insurance (see Thiery and Van Schoubroeck, 2006; Landes, 2015). In fact, it has been argued that there exist different views on the "concept of fairness in insurance classification. These different views on fairness boil down to a different approach to equality: an 'individualistic' human rights approach and an insurance 'group' approach" (Thiery and Van Schoubroeck, 2006, p. 191) where the former is mostly upheld by lawyers and legislators and the latter by insurers. The

[14] "Actuarial fairness is the guiding principle of the insurance industry. [...] The fundamental idea is that 'fairness means equal treatment for equal risks'" (Landes, 2015, p. 521).

individualistic approach is concerned about illegitimate discrimination and based on the view that individuals should not be treated differently based on their membership to a specific group. The group approach, on the other hand, emphasizes that insurance is only possible if individuals are treated as members of groups, i.e. of specific risk pools. The tension between illegitimate discrimination and efficiency-enhancing risk classification involves deep questions that cannot be dealt with in this report (see, e.g., Heath, 2007). Leaving this issue of admissibility aside there exist, however, a number of additional objections that have been raised against the use of actuarially fair, differentiated systems.

3.3 Missing necessity

A regularly used counterargument against the use of adjustments for heterogenous life expectancy in pension system is that such an approach is simply “overdone”. The occurrence of redistributions in undifferentiated systems, it is argued, is no matter of concern but rather a characteristic of every insurance contract in which resources are transferred from the whole to the damaged, the healthy to the sick or the unburnt to the fire victims. The pension insurance, the argument continues, is no exception as it simply redistributes from the short-lived to the long-lived in an analogous manner.

This argument is not convincing. First, it is certainly true that every insurance leads to *ex-post* redistributions (i.e. after the damage has happened). The same, however, is not true from an *ex-ante* perspective. In fact, the endorsement of actuarially fair systems is exactly based on the principle that the ex-ante net benefits should be the same for all insured groups.

In the case of pension systems there exists an additional argument that provides further support for the use of differentiated rules. This argument is related to the fact that pension payments are mostly related to income and the neglect of a differentiation will cause fiscal imbalances if there exists a correlation between mortality and income. This point is perhaps best illustrated by means of an example.

One can start with the case of a pension system that is based on flat (i.e. income-independent) contributions and pension benefits. In fact, one could adapt the example of case B in Table 2 to illustrate this. In particular, assume that type H has a higher income (60,000) than type L (20,000) but that both pay an annual contribution of 10,000 and receive an annual pension of 30,000. If the system sticks to uniform pension formulas then the system would not be actuarially fair in the normal sense since the expected benefits of the H-type exceed his expected contributions (and vice versa for type L). Nevertheless, the advantages of H are offset by the losses of L and the budget of the system stays balanced.

The picture changes if one considers income-related pensions (which are used by the majority of OECD countries). This is illustrated by case B in Table 2. The positive correlation of income and life expectancy together with the income-related pension leads to a situation where the budget of the system is no longer balanced. The cost savings due to the early death of the low-income individuals no longer counterbalance the higher costs due to the longer retirement period of the high-income persons. Individuals with a short lifespan pay insurance premiums that are too high while the premiums of long-lived individuals are too low. As a result, the system is unbalanced and runs an annual deficit of 6.67%, which it needs for pension subsidies to type H. For an ultimate assessment it would thus be necessary to know how the costs of these annual deficits are allocated. If the deficit is financed by a proportional tax on income (for the example this would require a tax rate of 1.67%), then type H would bear only three-quarters of the costs for their own subsidies. This would mean that the system not only fails to be actuarially fair it would even be additionally unfair as the long-lived individuals who are responsible for the deficit do not shoulder the entire costs of the additional burden.[15]

The latter argument is highly relevant for the PAYG system of many countries that do not use differentiated pension formulas. Even if the system were designed in such a way that it were actuarially fair for the representative individual with average characteristics, deficits would nevertheless arise due to the fact that life expectancy and income are positively correlated. Subsidies to the system thus favor the long-lived with high incomes.

3.4 Behavioral responses

As stated in section 3.1 it is frequently argued that the possibility of adverse section is a major argument for the installation of an actuarially fair system. In the presence of a uniform system the “good risk” might prefer to stay without an insurance which might endanger the existence of the entire insurance market. This argument, however, has itself been challenged. First, it does not apply to mandatory insurance systems as is typically the case for publicly organized PAYG pensions systems. Second, the net benefits of risk pooling might still be positive for “good risks” even in the presence of an undifferentiated system (cf. Heath, 2007). Even if adverse selection alone is not a compelling reason to implement an actuarially fair system, the second major justification remains in place, i.e. that it is simple a principle of fairness that risk premia should be commensurate with the risk that individuals bring to the risk pool.

On a general note, the argument of behavioral responses can cut both ways and both an actuarial and a non-actuarial system might give rise to unintended behavioral effects. For example, it has also been argued that the use of a differentiated pension system might lead to moral hazard. In particular, if life expectancy is not directly observable (see section 3.5) and the differentiation has to be based on indicator variables that are not immutable factors (like gender, birthplace or genetic predisposition) then individuals could act in a way such as to fall into a more favorable category. To give an extreme example, people might pretend to be smokers (or actually start to smoke) in order to receive a more favorable treatment in case smoking is used as a marker for longevity in the pension calculation. Similarly, higher replacement rates for lower-educated people might be a disincentive to complete higher

[15] It should be repeated that this argument requires both the income-dependence of pension formulas *and* the correlation between income and life expectancy. If income and mortality were completely uncorrelated, then the life expectancy of every insured person would be exactly the same – regardless of the income level. This situation corresponds to case A in Table 2. For each income group the sum of expected pension payments is equal to the sum of expected contributions and this system could be regarded as actuarially (or ex-ante) fair. Ex-post there will be transfers between different individuals, but since from the outset it is not clear who will come to enjoy a longer life, these differences do not change the ex-ante assessment. The assumption of uncorrelated income and mortality rates is, however, at odds with the empirical evidence.

education. Ultimately, it is a matter of both empirical magnitudes and political considerations which behavioral effects are regarded as acceptable.[16]

3.5 Imperfect observability

As a further argument against the use of actuarial rates it has also been mentioned that risk classifications might be infeasible in practice even if reasonable, legitimate and socially acceptable in theory. This is due to the fact that crucial variables on which the differentiation should be based are not directly observable and the use of proxy variables might be problematic.

For the issue of differential mortality this is immediately evident. Individual longevity is unobservable and it is only possible to measure and document statistical correlations between life expectancy and various socio-economic or lifestyle factors. Brown and Scahill (2010, p. 3), e.g., refer to a study that has "found twelve variables that were significant in the analysis of post-retirement mortality. The twelve variables were (in alphabetical order): Age, Alcohol, Education, Gender, Health Behavior (lifestyle and use of health services), Income, Marital Status, Obesity, Occupation, Race and Ethnicity, Religion (participation) and Smoking". In addition, other studies have documented that life expectancy is lower for individuals who live in cities, have parents who died young, have medical preconditions etc. Given the myriad of influencing factors, it has been argued that it is a hopeless endeavour to try to determine the causes of longevity and to consider them in the pension calculation.

As a response to this objection it has to be stressed that one should not throw out the baby with the bathwater. On the one hand, it is true that there exists an abundance of factors that are statistically correlated with life expectancy. On the other hand, however, this "embarrassment of riches" is not per se a reason to abandon all attempts of differentiation. In the case of car insurance, e.g., the insurance industry has developed rather sophisticated and fine-tuned models in order to capture the risk-profile of different socio-demographic groups. Also in some countries, in particular in the United Kingdom, the insurance industry has successfully introduced "impaired annuities" which offer higher annual payments for individuals with specific medical conditions that reduce life expectancy. Details on these schemes can be found in Brown and Scahill (2010).

The abundance of (potential) factors means that one has to be careful to provide a reasonable and reliable statistical model and to choose those factors that are the most important correlates with life expectancy. One might think of a "checklist" that a correlate has to fulfil in order to be considered as a potential basis of differentiation. For the issue of life expectancy, e.g., one could demand that the eligible characteristic: (i) should have a statistically significant, quantitatively relevant and intertemporally stable correlation with life expectancy; (ii) should be measurable in an accurate and cost-effective manner and not be easily manipulable by the insured; (iii) should not cause considerable changes in behavior ("moral hazard") when used as a policy. This checklist is well-known to the insurance industry and is taken into account in

[16] In fact, it is sometimes even argued (Abraham, 1985) that risk classification should only be based on variables that are within the control of the insured in order to induce to more diligent behavior and loss prevention.

underwriting and the classification of risks.[17] The request for stability, non-manipulability and behavioral neutrality is one reason why insurance risks are often classified according to unalterable characteristics like age, location or origin. This current practice does not mean, however, that in the future and with the advance of big data and new statistical tools it would not be possible to use a larger number of factors. This is, e.g., suggested by Brown and Scahill (2010) and it is already partly practiced in the context of impaired and enhanced annuities as mentioned above. The construction of a reliable statistical model might, however, be quite challenging. For example, many of the factors have strong cross correlations (e.g. education and income, but also income and all kinds of life-style choices like smoking, body weight and risky leisure-time activities etc.). This might lead to problems with small cell sizes, low statistical significance and instabilities over time.

As a general rule it might thus be recommendable to focus on a small number of important and sizable correlates. Various potential indicators exist that could be used. Considering the literature on the determinants of life expectancy (Cutler et al., 2006, Christensen et al., 2006), it might be feasible to revert to individual data on education, health status or employment history. None of these variables, however, seems perfectly suited for different reasons. The level of formal education is highly correlated with individual life expectancy. The main problem with this approach, however, is that the share of the population in different educational categories is changing over time (see Dowd and Hamoudi, 2014 or the references in Currie and Schwandt, 2016). The same also applies for the use of occupational categories, e.g. the years of heavy, physically or mentally strenuous work (Pestieau and Racionero, 2013). Comprehensive health checks in turn could probably provide meaningful results although only at considerable costs in terms of financial resources, time and administrative burden. Altogether, individual, lifetime income looks like the preferred indicator for the assessment of individual life expectancy (as is also emphasized by Brown and Scahill, 2010). Relevant studies (Chetty et al., 2016) show an economically and statistically highly significant correlation, the income data permit accurate differentiation and the negative incentive effects are probably manageable. In particular, the existing empirical literature suggests that the elasticities of labor supply decrease with income levels for most countries (Bargain et al., 2014) which suggests that aggregate labor supply might even increase with progressive pension formulas.

4. Normative concept of fairness

In section 3 we have only looked at the concept of “actuarial fairness” that is popular in the field of insurance and also often used in discussions about pension systems and longevity insurance. It has been emphasized, however, that this is a rather narrow concept of fairness and furthermore a concept that has emerged from the practical tasks of the insurance industry

[17] A list of important features of risk classification schemes has, e.g., been provided by Abraham (1985). He refers, e.g., to “separation” (different risk classes should have sufficiently different expected losses), “reliability” (the characteristics on which the classification is based should be easily measurable such as to minimize administrative error and fraud) and “homogeneity” (expected losses within a class should be similar).

and that is not really based on “first principles”. There exist requirements of fair systems that go beyond the scope of actuarial fairness. One might, for example, approach the question from a different angle and ask how a just longevity insurance should distribute a given amount of resources in order to maximize welfare. Or one might find it important to take the ultimate causes for differences in life expectancy into account when designing a fair system.

In this section we broaden the view on fairness along these and related lines. In order to do so we will use the assumption that individual lifespans are deterministically given, perfectly observable and therefore also generally known. We do so in order to be able to focus on the main issues and not be distracted by question of measurability etc. The assumption is, however, less restrictive than it might seem since one could alternatively interpret this assumption as referring to specific groups of people that have a stable and generally known correlation between income and life expectancy. In the examples of Table 1 and 2 this would mean that L and H stand for a large group of individuals associated with different lifespans and that the values in the table correspond to group averages. The question now is which of the pension schemes shown in Tables 1 and 2 could be considered as fair based on general considerations. The answer to this question is not obvious since it depends – inter alia – on assumptions about individual utility functions, social welfare functions, principles of justice and implementation constraints (Ponthiére, 2003).

The reference case A in Table 1 requires no further discussion, since in this case types H and L are the same in all of the listed dimensions. For case B of Table 1, however, the picture is different. Now types H and L share the same level of income while they differ in their lifespan. As argued in section 3 this situation can be regarded as problematic since it is not actuarially fair: the total sum of pension benefits of type L is smaller than the sum of total contributions, while for type H total pension payments exceed the contributions. As it turns out, however, there exist other definitions of fairness that picture this allocation in a more positive light. In fact, it can be shown that case B corresponds exactly to the socially optimal allocation, which would be chosen by a utilitarian social planner. This will be discussed in more detail below.

4.1 Principles of utilitarianism

A utilitarian (Benthamian) social planner wants to allocate existing resources such that the total utility is maximized. Under the usual utilitarian assumption of identical utility functions with decreasing marginal utility of consumption the utilitarian planner will equate the consumption levels of all individuals in each period. Any other allocation is suboptimal, because total utility could be increased by shifting resources from an individual with higher consumption and lower marginal utility to an individual with lower consumption and higher marginal utility. In the example of Table 1 an identical consumption level of 30,000 corresponds to the utilitarian optimum. As can be seen, this optimum can just be implemented by the pension account system with a uniform replacement rate of 75% (case B). This allocation involves a transfer from type L to type H. The total pension benefits of type H exceed his total contributions by 13.33%, while for type L the opposite is the case. This property of utilitarianism has been criticized: “Short-lived people are penalized twice: once by nature and once by Bentham” (Leroux and Ponthiére 2013).

Various suggestions exist as to how this doubtful result could be avoided. These alternative approaches remain, however, within the utilitarian framework and maintain a consequentialist yardstick. The respective initial situation is taken for granted and the quality of an allocation is only evaluated by the consequences for total utility. These problems with the utilitarian approach surface even more clearly when considering the examples of Table 2, in which the individuals differ in their life expectancy and in their income. In this case, the pension account system B no longer corresponds to the utilitarian optimum. The utilitarian planner would still strive for a level of consumption that is equal for both types in all periods (again given by 30,000). This implies, however, that the utilitarian planner would also equalize all income differences. In the specific example of case B this would mean that type L would receive a pension of 86,538 while type H would even have to pay an amount of 13,236. This redistribution seems excessive. Many observers will probably regard differences in life expectancy as worthy of compensation (at least to a certain degree), but would not want to eliminate differences in lifetime income via pension policy (or at least not entirely).

4.2 Principles of responsibility-sensitive egalitarianism

As mentioned above, a key objection against the utilitarian approach is that it redistributes the initial endowment in order to equalize levels of marginal utility without asking how the initial endowment came into existence. This, however, seems problematic since in its common usage fairness has to do with the background and the genesis of a particular initial situation. Furthermore, for an accurate assessment many people might also take the intentions of the actors into account. For example, it is commonly regarded as acceptable that some individuals are rewarded for special efforts while others are compensated for disadvantages that are not caused by individual choices. The use of compensations and rewards implies, however that one has to question why in a particular situation, the initial endowment of one person is higher than that of another.

This idea forms the basis of the normative concept of a "responsibility-sensitive egalitarianism" (RSE) as has been proposed by Marc Fleurbaey (2008). A central distinction of the RSE is the one between "(responsibility) characteristics" (for which the individual can be held responsible) and "circumstances" (also termed "luck characteristics") which are not the responsibility of the individuals (because they are due to innate characteristic, or to pure chance). According to Marc Fleurbaey one cannot justify welfare differences that are due to "circumstances", while inequalities that occur as a result of individual "characteristics" (i.e. due to a particular effort, but also due to specific preferences) are ethically acceptable. For the latter inequalities the "principle of reward" applies ("same responsibility characteristics, same welfare") while for the first-mentioned inequalities the "compensation principle" ("same luck characteristics, same welfare") is relevant. This particular role of responsibility distinguishes the RSE of alternative versions of egalitarianism like social contract theories (Rawls, 1971) or resource-based egalitarianism (Dworkin, 1981). A position similar to the RSE has been proposed by the "equality of opportunity" approach due to John Roemer (2012).

The concept of the RSE seems to be particularly suitable for the area of pension policy, since it is relevant for both the phenomenon of longevity and for the choice of the retirement age. As far as longevity is concerned, it has to be noted that longevity is related both to individual characteristics (for which the individual can be held responsible) and to circumstances (that are beyond the individual sphere of influence). On the one hand, it can arise from different lifestyle choices (smoking, lack of exercise, etc.), on the other hand, however, there are also a considerable genetic component (Christensen et al., 2006). Following the arguments of RSE, a pension system should therefore offset innate differences (compensation principle) while at the same time respecting differences due to individual efforts (reward principle).

In practice, the dividing line is often not clear-cut, especially since it can be argued that even individual characteristics (such as preferences) are controlled by factors, which themselves have a genetic origin.[18] Another challenge when using the RSE as a normative assessment criterion is that there may be situations where it is impossible to satisfy both principles – the "compensation principle" and the "reward principle" – at the same time. In such a situation, one must therefore decide which of the two principles shall be prioritized (see Fleurbaey, 2008). After these general considerations it is now possible to apply the criteria of the RSE in order to evaluate the allocations of the pension systems in Tables 1 and 2.

We start with the assumption that mortality differences are responsibility characteristics and look first at Table 1, in which the two types H and L differ only in their individual lifespans. If we take the view that these differences are only due to "characteristics" (e.g. due to lifestyle choices) then the "reward principle" is relevant and the pension system should not lead to any transfer payments between the two types. More specifically, in this case the optimal allocation corresponds to the private laissez-faire equilibrium ("no intervention for characteristics"). Case B (the "utilitarian optimum") is therefore ruled out. For case C, however, there are no transfers between the two types, thereby providing the necessary condition of a RSE optimum. Moreover, it can be calculated that in this case the lifetime income coincides with the laissez-faire situation without a pension system. This then implies that case C can in fact be regarded as a RSE fair allocation. The pension system depicted in case C has different replacement rates for L and H, thereby correcting for the differences in lifespan of the two types. More specifically, the system determines these replacement rates in such a way that total contributions are exactly equal to total pension payments. In fact, this is also the allocation that fulfills the criterion of "actuarial fairness" (see section 3) or "distributional neutrality" (see Breyer & Hupfeld, 2009). Furthermore, it corresponds to a property which is called *Teilhabeäquivalenz* ("participatory equivalence" or "proportionality principle") in German policy discussions. It is noteworthy that a system with differentiated replacement rates appears morally justified, even if the mortality differences are regarded as pure responsibility characteristics that do not require any compensation.

We now turn to the other extreme case and assume that the differences in life expectancy are seen as accidental, i.e. as a "circumstance" for which the individual cannot be held responsible. In this case, a RSE planner would stipulate transfers in order to equalize the utility levels of the two types. The exact size of those transfers depends on the shape of the

[18] "The intuition for compensation may also be strong even when longevity differentials are partly endogenous. For instance, shorter lives due to a strong taste for sin goods, or a large disutility from physical activity may be also regarded as caused by factors that are exogenous to the agent, and, as such, which would support some compensation" (Leroux & Ponthiére 2013, S.888).

individual utility functions. The extent of redistribution from H to L will increase in the concavity of these utility functions.

If one assumes that income differences are themselves responsibility characteristics then the considerations get more complicated, because the two types in Table 2 now differ in both their lifespans and in their incomes. To make things simple assume that incomes are treated as "characteristics", i.e. as factors for which the individuals are held responsible and for which a pension system should not carry out any compensations. If the different lifespans are again treated as characteristics one arrives at a similar conclusion as above. A RSE fair system should correspond to the laissez-faire equilibrium which is true for case C. If, however, the different lifespans are regarded as the consequence of external circumstances for which the individual cannot be held responsible, then the compensation principle comes into play. The challenge is now how to combine the responsibility characteristics (in incomes) with the external circumstances (in lifespans). Fleurbaey (2008) offers some suggestions for this problem but a thorough treatment of these issues is beyond the scope of this report.

Summing up, one can note that the use of normative concepts of fairness gives support for the view that it is justified to take the correlation between life expectancy and income into account when designing a pension system. The considerations also offer a theory-based justification for the concept of "actuarial fairness" that is prominent in the insurance literature. "Actuarial fairness", however, appears to be a "minimal requirement" and even more extensive redistributive actions might be defended if the distinction between "characteristics" and "circumstances" is taken into account.

5. Design of a differentiated pension system

In the previous sections we have provided a number of arguments why a pension system that is based on differentiated pension formulas could be regarded as "actuarially fair" or "distribution neutral" in the presence of socio-economic differences in life expectancy. In this section we discuss briefly how such a pension system could be implemented.

5.1 Three ways to implement a differentiated system

The starting point for these considerations is again the basic definition of actuarial fairness that the sum of expected discounted benefits should be equal to the sum of expected discounted contributions. If individuals differ in their life expectancy, then this requirement suggests that short-lived individuals should either pay lower contributions or receive higher benefits than long-lived individuals. This, however, is only a very general description of an actuarially fair approach and there exist various possibilities as to how to actually implement such a policy.

The arguably most straightforward policy is the use of progressive pension formulas, i.e. higher replacement rates for low-income individuals and lower replacement rates for high incomes. For some observers this approach might not look straightforward especially if one comes from a country with a strong Bismarckian tradition (i.e. with strict proportionality between contributions and benefits and uniform pension formulas). This impression is, however, deceptive since 26 of 37 OECD countries currently use differentiated replacement rates (see OECD, 2015). A prominent example for such a policy is the US Social Security system that uses two bendpoints in order to achieve a progressive pattern (Geanakoplos and Zeldes, 2009). In particular, the Social Security benefits replace 90% of the average lifetime earnings for individuals in the bottom 20% of the earnings distribution, but only between 40 and 50% for individuals with above-average earnings. It has been shown, however, that the positive correlation between lifetime earnings and life expectancy considerably reduces the degree of progressivity of this non-linear benefit-earnings rule (Coronado et al., 2011, National Academies of Sciences, Engineering, and Medicine, 2015). Breyer and Hupfeld (2009), on the other hand, have made a proposal as to how the German earnings point system could be adapted in order to better reflect differential mortality and to move the system towards actuarial fairness. Their proposed formula is proportional in the years of contributions but concave in average lifetime earnings and "looks similar to the corresponding function in the U.S. social security system. The main difference lies in the justification: while the U.S. system pretends to be redistributive in favor of low-income people, our formula explicitly tries to avoid any income redistribution on a lifetime basis" (Breyer and Hupfeld, 2009, 378). Knell (2016) contains a parallel analysis for the Austrian pension account system based on replacement rates that are conditioned on average lifetime income. In contrast to other papers it also discusses how the pension system can combine interpersonal differentiation and intertemporal variation in order to remain actuarially fair across members and fiscally stable over time.

An alternative to differentiated pension formulas would be a differentiation of contribution rates. This sounds rather unusual, but it is a completely parallel way to achieve the same goal of equalizing the sum of expected contributions and the sum of expected pension payments. In fact, this approach is also in line with public discussions where it is frequently argued that social security contributions should be lowered for individuals with low earnings. Furthermore, a policy with differentiated contribution rates is not completely unknown. In Sweden, employers pay contributions for all earnings above the ceiling on insurable earnings although these contributions do not increase the pension claims of the insured persons (see Swedish Pension Agency, 2015). In other words, these contributions function like a normal tax. One could argue, however, that differentiated pension formulas are superior to differentiated contribution rates since they can be better fine-tuned and based more easily on lifetime income.

Finally, one could also use the statutory retirement age in order to implement an actuarially fair system. In particular, the system could stipulate different, income-related statutory retirement ages at which a person can start to draw a pension without facing additional deductions. In fact, the statutory retirement age is already regarded as an important policy variable and "around half of OECD countries have elements in their mandatory retirement-income provision that provide an automatic link between pensions and a change in life expectancy" (OECD 2011, p. 81). These automatic adjustments, however, only refer to average values and they do not involve any interpersonal differentiation. The only element of differentiation that can already be observed in some countries is the permission of early retirement without deductions or with reduced deductions for special groups of employees (e.g. for the insured with especially long contributions periods). We know of no countries that currently follow a policy of differentiated statutory retirement ages in a systematic manner.

5.2 Further issues

The previous section has suggested that an (actuarially) fair pension system could be achieved in the presence of socio-economic differences in life expectancy by using differentiated pension formulas based on lifetime earnings. In closing this paper, we note a couple of issues that also have to be considered when designing a differentiated pension system and that have been neglected so far.

First, the devil is often in the details. If one uses lifetime income in order to differentiate pension payments it has to be decided, for example, which income concept to use. It is not clear whether individual or household income is the better measure for dealing with part-time work or patchy employment histories. Second, an encompassing assessment of actuarial fairness should probably also take social programs into account that are related to the pension system. This concerns in particular disability insurance and the regulation of subsistence income. Third, it is also important to consider political economy issues. Some reforms will be easier to communicate than others and some measures might be met with particular resistance. These considerations are a further reason to design a simple and transparent system with a one-dimensional differentiation such as to prevent lengthy political negotiations over seemingly technical issues (e.g. bargaining over correlates with life expectancy that are most palatable for the own constituency).

6. Summary

In this part of the report we have discussed the impact of socio-economic differences in life expectancy on the fairness of pension systems. The starting point of the considerations was the notion of actuarial fairness that requires – loosely speaking – a correspondence between total contributions and total benefits. Short-lived individuals should thus be treated differently from long-lived individuals and either pay less contributions or receive higher benefits. Normative concepts of fairness based, for example, on responsibility-sensitive egalitarianism confirm this conclusion. The strong, stable and highly significant correlation between lifetime income and life expectancy could therefore be used to implement a fair pension system. We have discussed a number of possibilities how this could be done in practice and we have compared these approaches to real-world systems and to existing proposals. In the end we have also sketched a number of challenges that remain in designing and implementing such a differentiated system.

References

Abraham, K. (1985): Efficiency and Fairness in Insurance Risk Classification. *Virginia Law Review*, 71(3), 403-451.

Arrow, K. J. (1963): Uncertainty and the Welfare Economics of Medical Care. *The American Economic Review*, 53: 941-973.

Bargain, O., Orsini, K. and Peichl A. (2014): Comparing Labor Supply Elasticities in Europe and the United States. *The Journal of Human Resources*, 49(3): 723-838.

Barr, N. and Diamond, P. (2009): *Pension Reform: A Short Guide*, Oxford University Press, Oxford, New York.

Breyer, F. and Hupfeld, S. (2009): Fairness of Public Pensions and Old-Age Poverty. *FinanzArchiv: Public Finance Analysis*, 65(3): 358-380.

Brown, R.L. and Scahill, P.L. (2010): Issues in the Issuance of Enhanced Annuities. Social and Economic Dimensions of an Aging Population Program: Research Paper No. 265, McMaster University.

Chetty, R., Stepner, M., Abraham, S. et al. (2016): The Association between Income and Life Expectancy in the United States, 2001-2014. *Journal of the American Medical Association*, 315(16): 1750-66.

Christensen, K., Johnson, T. E. and Vaupel, J. W. (2006): The Quest for Genetic Determinants of Human Longevity: Challenges and Insights. *Nature Reviews Genetics*, 7(6):436-448.

Coronado, J. L., Fullerton, D. and Glass, T. (2011): The Progressivity of Social Security. *The B.E. Journal of Economic Analysis & Policy*, 11(1): 1-45.

Currie, J. and Schwandt, H. (2016): Mortality Inequality: The Good News from a County-Level Approach. *Journal of Economic Perspectives*, 30(2): 29–52.

Cutler, D., Deaton, A. and Lleras-Muney, A. (2006): The Determinants of Mortality. *Journal of Economic Perspectives*, 20(3): 97–120.

Dowd, J. B. and Hamoudi, A. (2014): Is Life Expectancy Really Falling for Groups of Low Socio-Economic Status? Lagged Selection Bias and Artefactual Trends in Mortality. *International Journal of Epidemiology*, 43(4): 983–88.

Dworkin, R. (1981): What is Equality? Part 2: Equality of Resources. *Philosophy and Public Affairs*, 10(4): 283–345.

Fleurbaey, M. (2008): *Fairness, Responsibility, and Welfare*, Oxford University Press. Oxford, New York.

Fleurbaey, M., Leroux, M.-L., Pestieau, P. and Ponthiére, G. (2016): Fair Retirement under Risky Lifetime. *International Economic Review*, 57(1): 177-210.

Gaertner, W. and Schokkaert, E. (2012): *Empirical Social Choice: Questionnaire-Experimental Studies on Distributive Justice*, Cambridge University Press Cambridge.

Geanakoplos, J. and Zeldes, S. (2009): Reforming Social Security with Progressive Personal Accounts. in: *Social Security Policy in a Changing Environment*, National Bureau of Economic Research: 73–121.

Heath, J. (2007): Reasonable Restrictions on Underwriting. in: *Insurance Ethics for a More Ethical World*, Emerald Group Publishing Limited: 127-159.

Knell, M. (2016): Grundlagen eines Soliden und Solidarischen Pensionskontensystems. *Wirtschaft und Gesellschaft*, 2016(3): 465-496.

Konow, J. (2003): Which is the Fairest One of All? Positive Analysis of Justice Theories. *Journal of Economic Literature*, 41:1188-1239.

Landes, X. (2015): How Fair Is Actuarial Fairness? *Journal of Business Ethics*, 128(3): 519-533.

Leroux, M.-L. and Ponthiére, G. (2013): Utilitarianism and Unequal Longevities: A Remedy?. *Economic Modelling*, 30(C): 888-899.

Meyers, G., and Van Hoyweghen, I. (2018): Enacting Actuarial Fairness in Insurance: From Fair Discrimination to Behaviour-based Fairness. *Science as Culture*, 27: 413-438.

National Academies of Sciences, Engineering, and Medicine (2015). *The Growing Gap in Life Expectancy by Income: Implications for Federal Programs and Policy Responses*, Washington, DC: The National Academies Press

OECD (2011). *Pensions at a Glance*, OECD, Paris.

OECD (2015). *Pensions at a Glance*, OECD, Paris.

Pestieau, P. and Racionero, M. (2013). Harsh Occupations, Life Expectancy and Social Security. CEPR Discussion Papers 678, Centre for Economic Policy Research.

Ponthiére, G. (2003). Utilitarian Population Ethics: A Survey. Technical report, Centre de Recherche en Economie Publique et de la Population (CREPP), HEC-Management School, University of Liége.

Porrini, D. (2015): Risk Classification Efficiency and the Insurance Market Regulation. *Risks*, *3*(4): 445-454.

Rawls, J. (1971). *A Theory of Justice*, Oxford University Press, Oxford, England.

Roemer, J. E. (2012). On Several Approaches to Equality Of Opportunity. *Economics and Philosophy*, 28(02): 165-200.

Swedish Pension Agency (2015). *Orange Report. Annual Report of the Swedish Pension System 2014*, Technical report.

Thiery, Y. and Van Schoubroeck, C. (2006). Fairness and Equality in Insurance Classification. *The Geneva Papers on Risk and Insurance-Issues and Practice*, 31:190-211.

von Gaudecker, H.-M. and Scholz, R. D. (2007). Differential Mortality by Lifetime Earnings in Germany. *Demographic Research*, 17(4): 83–108.

Relationships between morbidity, mortality and severe material deprivation in Europe

Johannes Klotz, Tobias Göllner and Matthias Till

Introduction

The past years have seen increasing interest in mortality differentials by socio-economic status,[19] for several reasons. Firstly, social inequality in general has resurged as a major topic in public discourse and mortality differentials may be seen as its ultimate outcome. Secondly, high-status groups are usually "vanguard groups" in terms of adoption of lifestyles (Shkolnikov et al. 2009), so their mortality developments are important benchmarks for overall population outcomes in the future. Finally, demographic ageing is challenging social security systems and socio-economic differences may be essential policy pointers for reform.

Besides persistently low fertility rates, the main driver of demographic ageing is the long-term decline in mortality risk among the elderly. Mortality rates at advanced ages have fallen dramatically in Western Europe since around 1970 (in Eastern Europe only since the fall of the Iron Curtain), which is usually attributed to a "cardiovascular revolution" based on changes in lifestyles. Sample survey data on health status indicate that the additional years of life expectancy are usually years in good or only mildly ill health, whereas the average number of years in bad health has remained relatively unchanged (see also the introduction to this report). It is thus likely that demographic ageing will put pension systems under even more financial pressure than health care systems.

An obvious response to increasing costs in the pension system as a result of more years in good health would be to extend working lives, and many European countries have already adopted measures to do so (Carone et al. 2016). However, the evidence on which such policies are based often refers to population averages, neglecting social inequalities in life expectancy and healthy life expectancy. To quote from Majer et al. (2011): "Discussions on raising pension eligibility age focus more on improvement in life expectancy (LE) and health expectancy measures than on socioeconomic differences in these measures".

[19] As evidenced by, for example, the introduction of a Eurostat Task Force in 2009 and the inclusion of life expectancy differences by educational level in the OECD's "Health at a Glance" publication (OECD 2017: p. 51).

It is a fact that the substantial life expectancy gains since the 1970s have in general not been accompanied by a decline in socio-economic disparities,[20] although there is some variation by country (Valkonen et al. 1993, Kunst 1997, Huisman 2004, Mackenbach et al. 2016). Moreover, socio-economic disparities in healthy life expectancy are usually found to be even larger than in overall life expectancy (Mosquera et al. 2018).

A prominent argument is that extending working lives is unfair towards poor population groups which are thus disadvantaged. While this discussion on fairness is ongoing, the much bigger issue is that a uniform extension of working lives makes political actions ineffective. Extending the legal retirement age will not suffice without Europeans actually spending more years in employment. If among certain groups health deteriorates and death comes early, this presents very practical limitations to increasing the actual retirement age and a challenge for designing fair pension systems.

Many studies on differences in mortality (sometimes including morbidity) by socio-economic status in European countries are now available (see Mackenbach et al. 2016 and Mosquera et al. 2018 and the references given therein). However, it is noteworthy to mention two main caveats which apply to the existing literature.

Firstly, most studies have focused on relatively broad populations to identify socio-economic groups such as distinguishing between individuals with high, medium and low education level, manual vs. non-manual occupational classes, or income quintiles. Although such distinctions are appropriate to describe the general extent of socio-economic mortality disparities in a society, they may not be the best approach to investigate specific health and mortality risks of poor population groups (for instance, if the "low" educational group covers more than 50 percent of the entire population, see Östergren et al. 2017). Little is known so far on the association between mortality risk and absolute poverty in Europe, apart from specific investigations on extremely poor populations such as the homeless (Nielsen et al. 2011, Thomas 2012).

Secondly, the available findings do not cover all European countries (as of 2019, some European countries still cannot provide any figures on the subject) and published figures are not easily comparable between countries because of different data sources, time periods and socio-economic breakdowns (Klotz and Göllner 2017). Moreover, even if the socio-economic breakdowns are technically comparable, their social meaning may be different. As a result of the educational expansion over the last decades educational levels are especially difficult to compare over generations. Occupational classes are often inadequate for the female population because women who are stay-at-home mothers are excluded and today's female workforce is highly concentrated on white-collar employees in the service sector. And although the first income quintile by definition separates the poorest 20 percent from the rest

[20] In fact, socio-economic inequalities in mortality are not just about different life expectancies, but also—perhaps even more important—about different variation in lifespan and proneness to premature death, see van Raalte et al. (2011).

of the population in any country, belonging to the poorest 20 percent obviously has a very different real meaning in Sweden or Switzerland than in Romania or Bulgaria.[21]

This paper aims to contribute to filling gaps in previous research by scrutinizing the association between mortality risk and severe material deprivation from a European perspective. To the best of our knowledge, this is the first comparative analysis on the impact of absolute poverty on mortality risk, covering 26 countries. We also investigate the relationship between excess mortality and differences in morbidity and test for effect modification by sex and by groups of countries.

The correlation of severe material deprivation and mortality

Severe material deprivation (SMD) refers to a state of economic strain defined as the enforced lack of items considered by most people as necessities. The SMD rate is one of three indicators to monitor poverty and social exclusion in the Europe 2020 strategy and has been defined by the Social Protection Committee (SPC) on the basis of normative considerations. Unlike relative income poverty, SMD is an absolute poverty measure.

A person is defined to be severely materially deprived if he or she lives in a private household which cannot afford at least four out of the following nine items:

- mortgage or rent payments, utility bills, hire purchase instalments or other loan payments;
- one week's holiday away from home;
- a meal with meat, chicken, fish or vegetarian equivalent every second day;
- unexpected financial expenses;
- a telephone (including mobile telephone);
- a color TV;
- a washing machine;
- a car; and
- heating to keep the home adequately warm.

Over time, three of these items have become considered less relevant. In fact, the European Community Survey on Income and Living Conditions (EU-SILC) hardly captures households in the EU Member States which are lacking a washing machine, a color TV or a telephone because they cannot afford it. Effectively the scale is used without those items and the yearly EU-SILC survey from 2016 onwards collect items for a revised deprivation scale to be used in the future, which considers individual as well as household level questions. A detailed discussion of the indicators and their revision is given by Guio et al. (2016).

The SMD indicator has the same definition across all European countries and over time (here we focus on 2003 to 2015); its definition does not depend on the average standard of living in a society. It should be noted that there are people who do not want, for instance, a color TV,

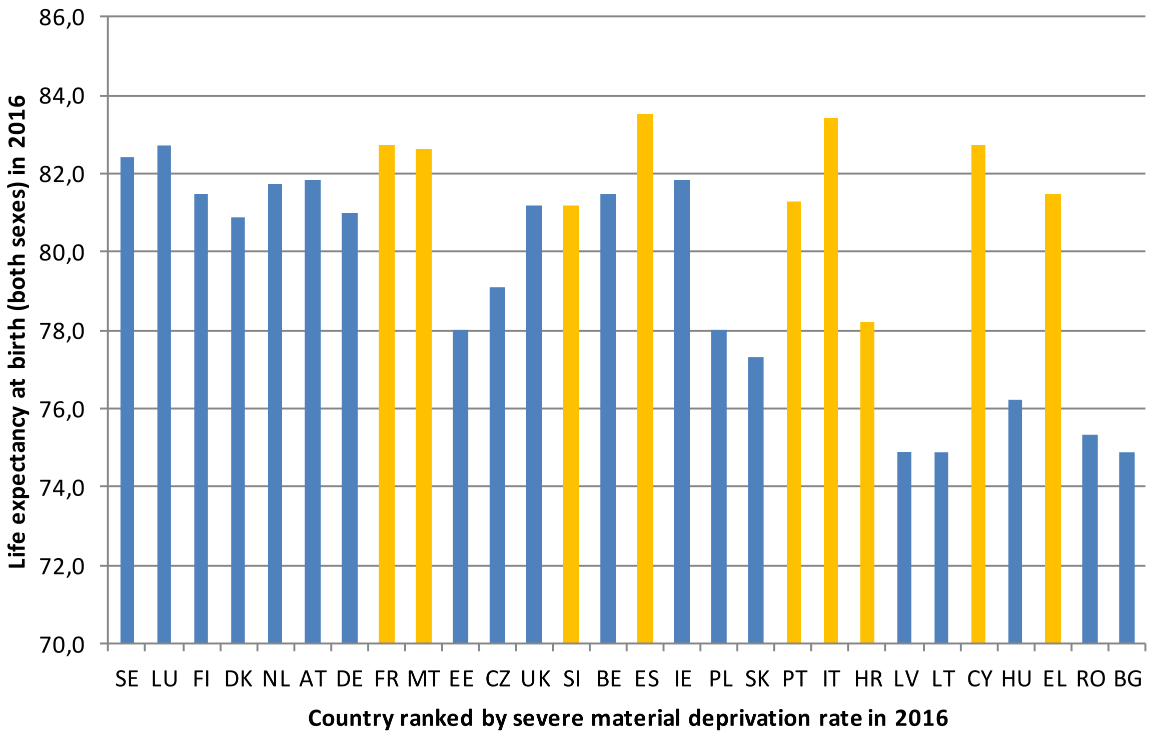
[21] We do not claim here that absolute poverty measures are somewhat superior to relative poverty measures in explaining social behavior (cf. Runciman 1966). The point is that comparative analyses of European populations should not be based solely on country-specific relative deprivation measures (see also Goedemé et al. 2017).

but this is not what the SMD indicator covers. It measures affordability and not actual possession.[22]

Also, one can reasonably assume a broad political consensus that SMD should be eliminated or at least reduced in Europe. Whereas redistribution in general is a highly controversial subject in the European policy discourse, avoiding and combating absolute poverty is usually a common ground among political parties.

The prevalence of severe material deprivation is estimated from EU-SILC data, a harmonized sample survey which has been carried out in European countries since 2003 and now covers all EU member states as well as some additional countries like Norway. The survey is output-harmonized, i.e. countries have to deliver to Eurostat micro data on households and persons with harmonized target variables, but the mode of data collection may be country-specific. Minimum effective sample sizes per country guarantee sufficiently precise estimates on poverty and social exclusion indicators.

Figure 1. Country-level correlation between life expectancy and severe material deprivation.



Source: Own figure. Data obtained from Eurostat webpage (accessed on 18 September 2018).
Note: Mediterranean countries are colored differently (orange rather than blue).

[22] For example, the format on the question on the color TV is: "*Does your household have a color TV?*
If you do not have a color TV:
(a) Would you like to have it but cannot afford it, or
(b) Do you not have one for other reasons e.g. you do not want or need it."

In 2016, an estimated 7.5 percent of the EU-28 population was severely materially deprived, with huge country variation from less than 1 percent in Sweden to 30 percent in Bulgaria.[23] On the country level, there is a clear association between SMD and mortality risk, as can be seen in Figure 1, where countries are ranked by ascending SMD rate in 2016 (lowest at the left, highest at the right) and overall life expectancy per country is shown. The country-level correlation between SMD rate and life expectancy is -0.59; countries with high poverty rates usually have lower life expectancies.

In mortality analysis, Mediterranean countries usually stand out, in this case exhibiting rather high SMD rates as well as relatively high life expectancies. Excluding the Mediterranean countries (colored differently in Figure 1 and here including France), the correlation coefficient between SMD rate and life expectancy is -0.81, which means that two thirds of the variation in life expectancy between the remaining EU countries is statistically attributable to variation in SMD rates.

The question is now to which degree such a correlation exists not just on the macro (country) but also on the micro (individual) level where SMD is a binary outcome. We thus investigate the excess mortality of people who are severely materially deprived as opposed to people who are not.

Detailed research questions

The paper aims to assess the normative validity of severe material deprivation by its correlation with mortality risks. Excess mortality, a highly relevant and objective measure, may be seen as the ultimate consequence of deprivation. On the other hand correlation may result from reverse causation due to selection of people in ill health into the deprived population.[24] Regardless of whether poverty follows illness or illness is caused by poverty, morbidity needs to be taken into account when estimating excess mortality. We do this twofold, first by stratifying results by health status and then by including health status as an additional predictor in our model.

A stable finding in demography is that the male population has a lower life expectancy, but in general not a lower healthy life expectancy than the female population (Luy and Gast 2014).[25] Moreover, variation between socio-economic groups is typically found to be larger among men than women. We thus further investigate if the excess mortality of the severely materially deprived, controlling for morbidity, is modified by sex (men vs. women).

[23] Data and detailed methodological information are available from Eurostat: Material deprivation statistics – early results. Statistics Explained, data extracted in June 2018, downloaded on 7 September 2018.
[24] A symposium „Health inequalities – an interdisciplinary discussion of socioeconomic position, health and causality“ took place in Amsterdam on 24 May 2018. The symposium report and an updated discussion paper (reporters: Johan Mackenbach and Jean Philippe de Jong) were published by the FEAM/ALLEA Committee on Health Inequalities in November 2018.
[25] This finding has been summarized by the phrase “Women are sicker, but men die quicker”. See Lahelma et al. (1999).

Finally, we examine if certain disparities of excess mortality can be found between countries. Although the sample is too small for sufficiently precise estimates of excess mortality for single countries, reliable estimates for some groups of countries are possible.

We distinguish between Western and Eastern European countries (meaning the Communist countries before 1989/90), for the latter did not participate in the "cardiovascular revolution" since the 1970's (Zarulli et al. 2012), but faced a long-term stagnation in life expectancy before and some decline after the fall of the Iron Curtain. Since then they have caught up with Western Europe, but accompanied with enormous inequalities between socio-economic groups. For instance, Eurostat estimates the life expectancy gap between the educational levels[26] ISCED 5+ and ISCED 0-2 in 2016 to be around 10 years in Hungary, Poland and Slovakia, whereas the maximum estimate for a Western country is less than 6 years in Finland.[27]

Then, we consider special effects for the severely materially deprived in Mediterranean countries, which stand out in a comparative European perspective because both relatively high deprivation rates and low mortality levels are observed on an aggregate level. Moreover, micro-level studies on mortality by educational level have usually found relatively small gaps in Mediterranean countries. Mentioned possible explanations are a weaker association between educational level and socio-economic position (Mosquera et al. 2018: p. 26), a healthy diet and a delayed smoking epidemic (Mackenbach et al. 2017). It is debatable if France should be counted as a Mediterranean country and since it is a large country, it has a substantial influence on results; we therefore dropped France from this distinction.

Moreover we try to classify countries by their structure of the health care system. As a first—admittedly rough—approach we distinguish between countries in which government schemes and compulsory contributory health insurance schemes and compulsory medical savings accounts cover more or less than 75 percent of total healthcare expenditure in 2015.[28] It may be argued that a lower coverage (and thus greater importance of voluntary health insurance and household out-of-pocket payments) may have adverse effects on the poor. For instance, Ahammer et al. (2017) mention the universal health care system in Austria, in particular accessibility and affordability of medication and surgeries, as a likely reason for the absence of a causal effect of income on mortality. The threshold of 75 percent was chosen by rule of thumb to get two approximately equally large groups of countries. Malta is excluded from this distinction because no data was available.

[26] For details on the educational classification see UNESCO (2012).

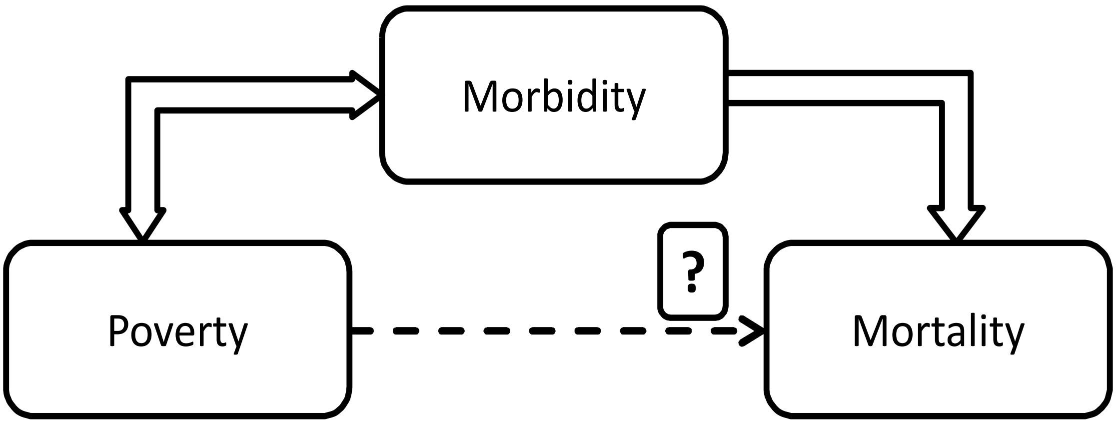
[27] Data obtained from Eurostat website (demo_mlexpecedu) on 26 November 2018. Data are available for 18 countries there.

[28] Data and detailed methodological information are available from Eurostat: Healthcare expenditure statistics. Statistics Explained, data extracted in March 2018, downloaded on 18 September 2018. Most countries range between 70 and 80 percent. Among the countries included in our analysis, the minimum is 43 percent in Cyprus and the maximum is 84 percent in Sweden.

To summarize, we investigate the following three research questions:

1. Is there a substantial and statistically significant association between SMD and mortality risk on an individual level?
2. If so, is this association still substantial and statistically significant when we adjust for different morbidity levels between SMD and non-SMD populations? (Figure 2)
3. If so, is morbidity-adjusted excess mortality of the SMD population different
    a. between men and women?
    b. between groups of countries?
        i. between Western and Eastern Europe?
        ii. between Mediterranean and non-Mediterranean countries?
        iii. between countries in which the share of government schemes and compulsory contributory health care financing schemes in total healthcare expenditure in 2015 was more vs. less than 75 percent?

Figure 2. Schematic representation of the model with morbidity.



Source: Own figure.

Data and methods

Data source

EU-SILC is the official source[29] for comparable poverty data in Europe (such as the at-risk-of-poverty rate or the material deprivation rate). It is an annually harmonized data collection of the European Statistical System defined by EU-regulations (EC 1177/2003). EU-SILC is carried out in all EU member states (plus some additional countries). Most countries started data collection in 2003-2005. The target population is people living in private households.

EU-SILC is output harmonized, which means that it is up to the countries how data required by the regulation is collected. Whereas some countries use traditional face-to-face paper and pencil interviewing, in others most data are queried from registers and the variables which can

[29] For general information on EU-SILC see https://ec.europa.eu/eurostat/web/income-and-living-conditions/overview .

only be measured by survey questions are restricted to a sub-sample of selected respondents (one person per household). The mode of data collection does have some impact on comparability, especially regarding income poverty measures (an experiment where the poverty headcount for the same population was estimated by both survey questions and register queries is given by Angel et al. 2018). On the other hand, the items on which the SMD indicator is based are obtained by survey questions in all countries. Subjective measures of deprivation are however sensitive survey language translation and cultural factors as well as specificities in survey design (Glaser et al. 2015).

EU-SILC has a longitudinal component: in most countries, respondents are to be interviewed in four consecutive calendar years. Vital status information (survived or died) is collected in order to determine the eligibility of respondents for re-interviewing. We use this information for analytical purposes. Although the quality of such vital status information is inferior to data obtained from national mortality registers, differential mortality analyses are usually possible as long as one focuses on relative mortality ratios and controls for country effects. Details on data collection modes and data quality are given by Klotz and Göllner (2017).

We use Eurostat's User Database (UDB) files of EU-SILC, which is a partly anonymized version of the original data transmitted by countries to Eurostat. One longitudinal data release contains data on the current year and the three years prior, e.g. the longitudinal release of 2012 contains information from 2012, 2011, 2010, and 2009. We use the longitudinal releases from 2006 to 2015, so we have information from 2003 to 2015. Since some countries do not transmit vital status information to Eurostat, our analysis only includes 26 countries. For details on the sample see Table 1.

Data preparation

After the original data was extracted from Eurostat's UDB files, we edited data in SAS, Version 9.4, applying the algorithm of Göllner and Klotz (2018). The output of this algorithm is a file in which each line corresponds to a distinct person ever interviewed in EU-SILC, including information on vital status and length of follow-up period (duration between first interview and either death or censoring, based on quarterly information available in UDB data). A few respondents were deleted from our sample because of missing values in key variables such as sex. After that, our sample covers 743,819 individuals aged 35-79 years at baseline, of which 14,066 died in the follow-up period. The total of person-years observed is 1.76 million. Out of the 26 countries, we classify 15 as "Western Europe" and 11 as "Eastern Europe". Excluding France, 8 countries are Mediterranean and 17 are non-Mediterranean. Excluding Malta, the share of government schemes and compulsory contributory health care financing schemes in total healthcare expenditure in 2015 was more than 75 percent in 13 countries and less than 75 percent in 12 countries.

We restrict estimation of mortality rates to respondents aged 35 to 79 years at the time of first interview because in the UDB, respondents aged 80 or older are grouped into an open final age category and the population under 35 years comes with small death counts and irregular age-specific mortality rates. All covariates are measured at the first interview (the baseline of our follow-up). Severe material deprivation is not directly available in the UDB records, so we extracted information on the underlying items and reconstructed the SMD indicator accordingly.

Table 1. Sample characteristics.

Country	EU–SILC Longitudinal Component		Sample totals (people aged 35–79 years at baseline)			Class of country		
	Starting year	Max. years per respondent	Selected respondents	Person-years lived ('000s)	Deaths	West/ East	Mediterranean[1]	Health care spending structure[2]
Austria	2004	4	23,848	55.7	358	West	No	≥75
Belgium	2004	4	23,140	53.2	160	West	No	≥75
Bulgaria	2006	4	20,879	49.5	780	East	No	<75
Cyprus	2005	4	17,873	40.8	224	West	Yes	<75
Czechia	2005	4	28,959	74.8	757	East	No	≥75
Estonia	2004	4	23,705	56.4	701	East	No	≥75
Spain	2004	4	76,142	162.1	972	West	Yes	<75
Finland	2004	4	21,868	43.8	259	West	No	<75
France	2004	9	31,511	119.1	713	West		≥75
Greece	2003	4	31,468	73.1	559	West	Yes	<75
Croatia	2010	4	13,165	22.8	309	East	Yes	≥75
Hungary	2005	4	38,831	92.2	1,080	East	No	<75
Italy	2004	4	89,715	213.9	1,209	West	Yes	<75
Lithuania	2004	4	23,234	54.7	824	East	No	<75
Luxembourg	2003	no limit	14,395	46.9	296	West	No	≥75
Latvia	2005	4	23,324	53.4	838	East	No	<75
Malta	2006	4	9,831	26.6	224	West	Yes	
Netherlands	2005	4	22,522	51.2	144	West	No	≥75
Norway	2003	8	9,681	34.1	32	West	No	≥75
Poland	2005	4	59,539	139.2	1,616	East	No	<75
Portugal	2004	4	31,065	52.6	457	West	Yes	<75
Romania	2007	4	28,433	65.1	446	East	No	≥75
Sweden	2004	4	12,605	30.9	142	West	No	≥75
Slovenia	2005	4	13,017	29.6	309	East	Yes	<75
Slovakia	2005	4	24,652	57.6	435	East	No	≥75
UK	2005	4	30,417	62.0	222	West	No	≥75

Source: Own calculations. EU-SILC data extracted from Eurostat's user database longitudinal component, release version 2016-1.

[1]Excluding France. [2]Percent share of government schemes and compulsory contributory health care financing schemes and compulsory medical savings accounts in total healthcare expenditure in 2015. Data obtained from Eurostat: Healthcare expenditure statistics. Statistics Explained. No data available for Malta.

Although the severe material deprivation indicator refers to all members of a household, for our purposes we can only use the "selected respondents" in the EU–SILC data (for those countries which have implemented such a mode of data collection) because morbidity information is only available for them. Morbidity is operationalized by the Global Activity Limitation Instrument (GALI).[30] The question is
"*For at least the past 6 months, to what extent have you been limited because of a health problem in activities people usually do? Would you say you have been …*
severely limited (1);
limited, but not severely (2); or
not limited at all (3)."

Although the GALI is somewhat limited as it has only three categories to assess morbidity, it has the advantage of being an internationally acknowledged and frequently used instrument.[31] In our model we treat the GALI as a pseudo–metric variate, meaning that the difference between 1 and 2 is assumed as equal to the difference between 2 and 3, so only one parameter is estimated.

Weighting of observations

Although EU–SILC contains several weighting variables, none of them are directly applicable to our analysis. Cross–sectional weights ignore whether a respondent is to be re-interviewed in following years and whether the person can actually be traced. However, those who are not or cannot be re-interviewed are not a random subsample of the entire cross-sectional sample but structurally different. Longitudinal weights, on the other hand, are available only for those who have survived between two survey waves, so they are by themselves not useful for mortality analyses. Moreover, we estimate a multivariate model which already controls for several factors that are typically used in the construction of weights.

What is more important is to account for the substantial variation in sampling fractions in different countries as well as if in a country all respondents or only "selected respondents" are included. We therefore constructed a weight specifically for our purposes, such that the total of (selected) male and female respondents per country matches the population size of that country in the latest 2010/2011 European census round. Within each country and sex, weights are uniform.

Statistical models

An essential feature of our data is that the potential follow-up time varies between respondents, firstly because the longitudinal duration of EU-SILC varies by country, secondly because those respondents only interviewed in recent years have not yet experienced all scheduled re-interviews, and finally because some respondents withdraw early from the survey. A powerful model class which can handle variation in potential follow-up times is

[30] An alternative would be self-assessed health. For an international comparison of self-assessed health by socio-economic status over time see Hu et al. (2016).
[31] For instance, the GALI is frequently used by the REVES international network on health expectancies and the disablement process (https://reves.site.ined.fr/en/).

Proportional Hazards Regression, invented by Cox (1972). In this nonlinear, semiparametric model class the mortality hazard of the *i'th* individual at follow-up time *t* is partitioned into a nonparametric baseline hazard which depends only on *t* and a constant hazard ratio which compares the *i'th* individual with a reference individual as a parametric function of covariates x,

$$h(i,t) = h(t) \times HR(i)$$

$$HR(i) = \exp(x_i^T \beta)$$

Given our research questions, we first estimated a model for the entire sample with SMD as the analytical variable of interest and age, sex, calendar year and country fixed intercepts as covariates. We then included the GALI indicator in our model twofold: First we estimated the model stratified by GALI levels to investigate whether the effect of SMD on relative mortality risk is modified by health status. Then, we estimated the model including the GALI variable as an explanatory variable to average the effect of SMD on mortality, conditional on health. Finally, we estimated the last model stratified by sex and by the three groupings of countries mentioned above. Models were estimated in SAS, version 9.4, applying the PHREG procedure. Relative mortality risk is measured by the mortality hazard ratio. Asymptotic 95 percent confidence intervals are provided to guard against chance variation.

Results

Excess mortality of the severely materially deprived

Estimated mortality hazard ratios of the model without morbidity are given in the left panel of Table 2. Each additional year of age at baseline comes with a 10 percent increase in mortality risk, so when someone is two years older at baseline, his or her mortality risk is increased by 1.21 (= 1.1x1.1), when 3 years older at baseline by 1.33, and so on. Males appear to have a mortality risk almost twice as high as females. The decline in mortality risk over time is visible in a hazard ratio lower than 1 (0.96, which also cumulates multiplicatively) for the calendar year of the baseline interview. The estimated parameters for age, sex and calendar year correspond to what is expected from the demographic literature.

There is also variation in country parameters (not shown in the table), which is caused by both true mortality differences and country-specific data quality.

Controlling for age, sex, period and country, the hazard ratio of the deprived compared to the non-deprived is 1.69. This means that in terms of the mortality risk, the deprived are statistically 5-6 years "older" than the non-deprived or equivalently, that severe material deprivation reduces life expectancy by 5-6 years.[32]

[32] This figure is obtained by taking the logarithm of the SMD hazard ratio with respect to the age hazard ratio as the base: $1.10^5 = 1.61$ and $1.10^6 = 1.77$.

Table 2. Estimated mortality hazard ratios.

Predictor	Model without morbidity		Model with morbidity	
	Estimated hazard ratio	95 percent confidence interval	Estimated hazard ratio	95 percent confidence interval
Age	1.10	(1.10-1.10)	1.08	(1.08-1.09)
Sex=Male	1.90	(1.83-1.97)	1.98	(1.91-2.05)
Calendar year	0.96	(0.96-0.97)	0.96	(0.95-0.97)
Severe material deprivation=Yes	**1.69**	**(1.60-1.78)**	**1.39**	**(1.32-1.47)**
Global activity limitation instrument			0.47	(0.46-0.48)

Source: Own calculations. EU-SILC data extracted from Eurostat's uder database longitudinal component, release version 2016-1. All estimates are controlled for country fixed intercepts.

Effect modification by health status

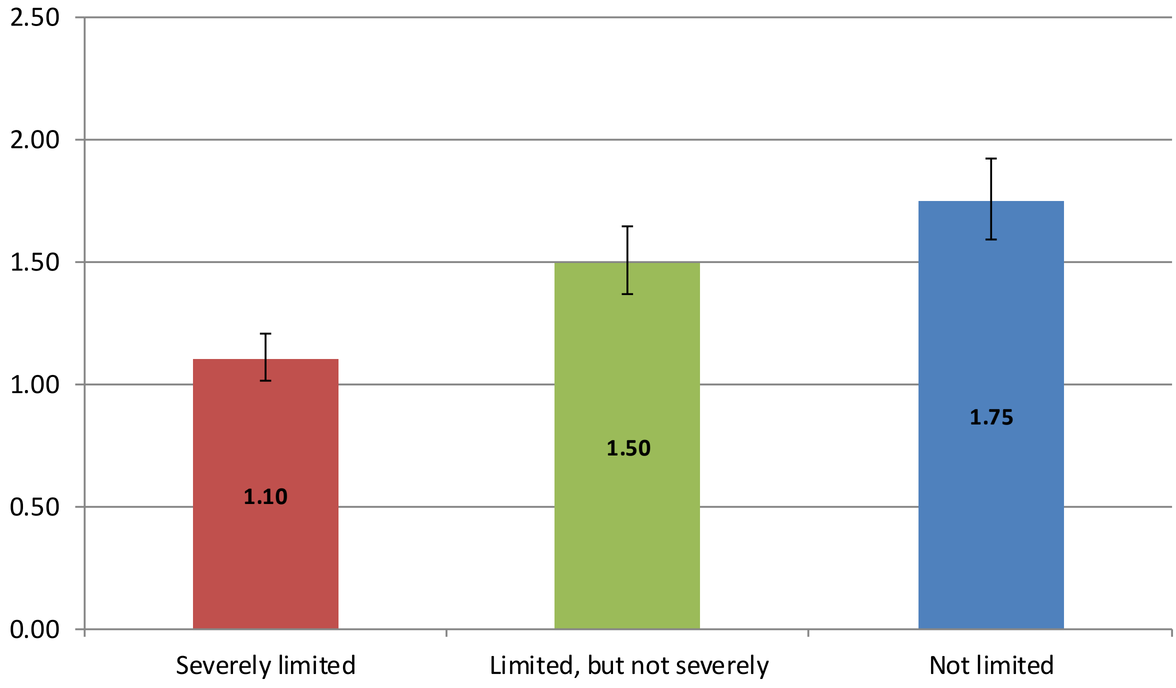
We have seen that SMD comes with a significant disadvantage in life expectancy. The question is now to which degree this is a matter of health disparities between the SMD and the non-SMD population. First we stratify model estimation by GALI (Figure 3). Relative mortality risk in case of SMD is highest when people indicate no health-related limitation in daily activities (1.75), second highest in case of some limitation (1.50) and lowest in case of severe limitation (1.10). All hazard ratios are significantly different from 1 and from each other. The lower relative mortality risk of the deprived in case of severe health limitation somehow resembles the finding of Huisman et al. (2005) that “higher education serves to postpone or avoid disability, but provides less benefit when disability is already present”.

The average excess mortality of the deprived compared to the non-deprived population, controlling for morbidity, is estimated by including the GALI as an explanatory variable in the hazard ratio specification (Table 2, right panel). Then the mortality hazard ratio of the deprived is reduced to 1.39—still a substantial, although a significantly smaller disadvantage than the 1.69 figure in the model without morbidity. In analogy to the approach of Baron and Kenny (1986) of comparing regression parameters across different models, one can conclude that on average, excess morbidity mediates around 40 percent of excess mortality of the deprived.[33] The GALI hazard ratio itself is estimated at 0.47, reflecting the fundamental impact of health status on mortality risk.[34]

[33] The formula of Baron and Kenny (1986) was developed for linear models. In our non-linear model the percentage mediated depends on whether one compares parameters on the linear scale (37 percent, in our case) or on the exponentiated scale (43 percent).

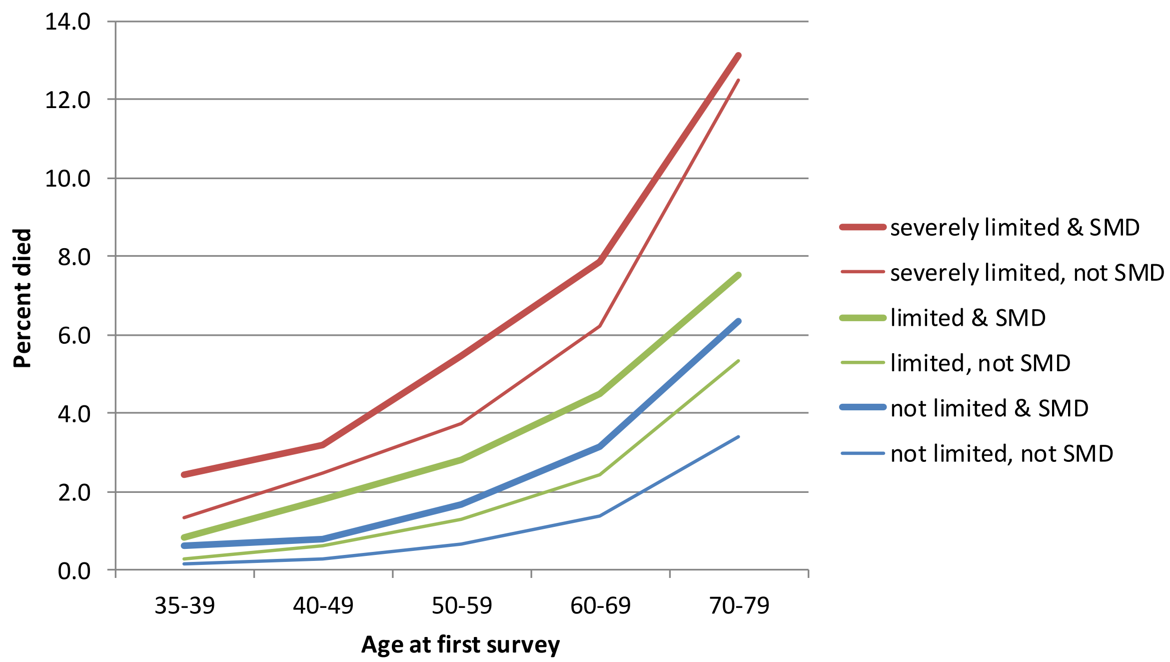
[34] Remember that GALI is coded so that a higher value indicates better health, which is then associated with reduced mortality risk.

Figure 3. Estimated mortality hazard ratio of the severely materially deprived stratified by GALI.



Source: Own figure based on own calculations. EU-SILC data extracted from Eurostat's uder database longitudinal component, release version 2016-1. Models control for age, sex, period and country fixed intercepts. Including 95 percent confidence interval.

Figure 4. Relative frequency of deaths by age, GALI and severe material deprivation (SMD).

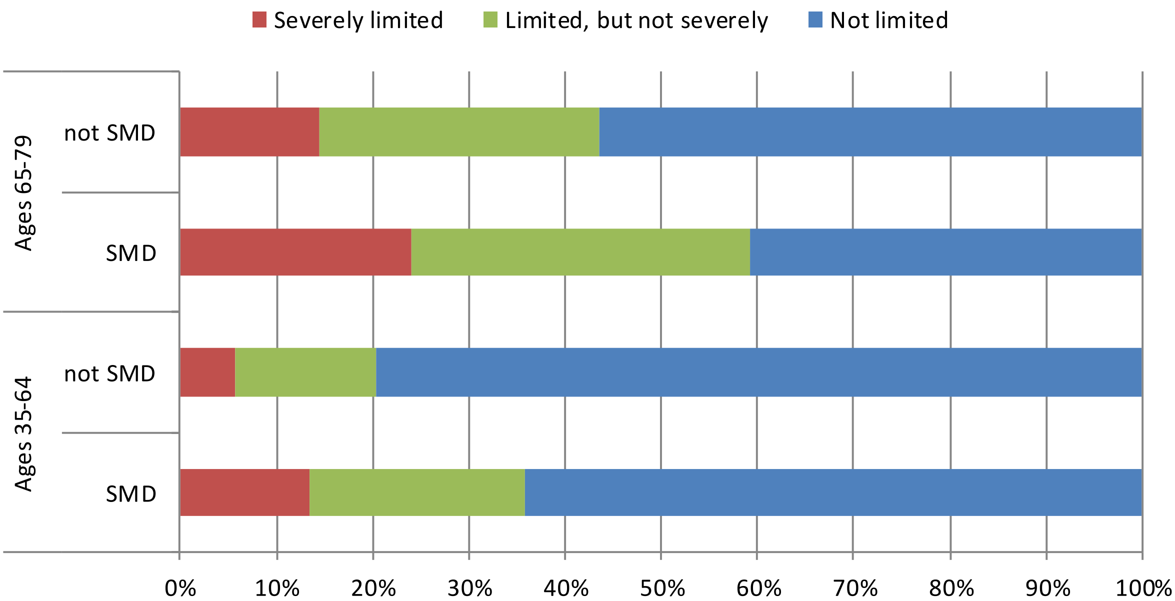


Source: Own figure based on own calculations. EU-SILC data extracted from Eurostat's uder database longitudinal component, release version 2016-1.

The mutual relationships between poverty, morbidity and mortality can also be illustrated by age-specific relative frequencies of deaths (Figure 4). Combining SMD and GALI, our sample is partitioned into six subpopulations. As expected, the percentage of deaths (as opposed to the percentage of censored observations) is highest among the deprived with severe health limitation and lowest among the non-deprived with no health limitation. Severe health limitation in general has a strong impact on mortality. Among the healthier population segments however, the impact of poverty is more important: across all age groups, the deprived with no health limitation face higher mortality risk than the non-deprived with some limitation.

The mortality disadvantage of the deprived has thus two components, a worse distribution of morbidity, and an excess mortality even conditional on morbidity, where the latter is modified by the degree of health limitation. As one can see from Figure 5, both severe health limitation and some health limitation are more prevalent in the deprived than in the non-deprived population, at working as well as retirement ages. As mentioned above, excess mortality of the deprived compared to the non-deprived varies from 10 percent to 75 percent, with an average of 39 percent.

Figure 5. Percent distribution of GALI by age group and severe material deprivation (SMD).

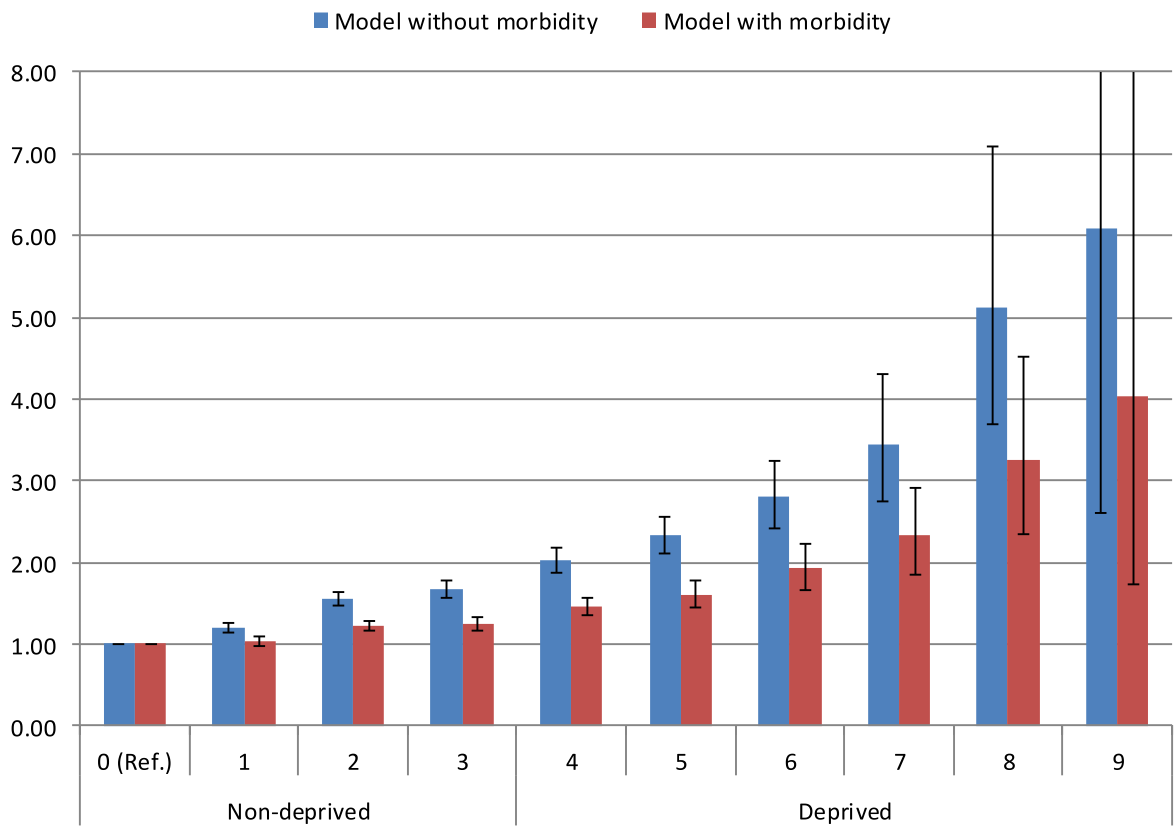


Source: Own figure based on own calculations. EU-SILC data extracted from Eurostat's uder database longitudinal component, release version 2016-1.

Sensitivity analysis: validation of SMD scale cut-off point

The definition of severe material deprivation is based on a cutoff value on a 0-9 scale (0-3 vs. 4 or more). Figure 6 confirms that mortality risks are increasing with increasing levels of deprivation count. The differences between adjacent count values are however not always statistically significant, especially for the model including GALI and for the highest count values, where sample sizes are small. The cut-off point on the deprivation scale which has been chosen by the SPC relates to at least four deprivation items indicating disadvantage. This threshold does seem to indeed reflect a significant increase in mortality risks.

Figure 6. Estimated mortality hazard ratio by material deprivation score (0-9).



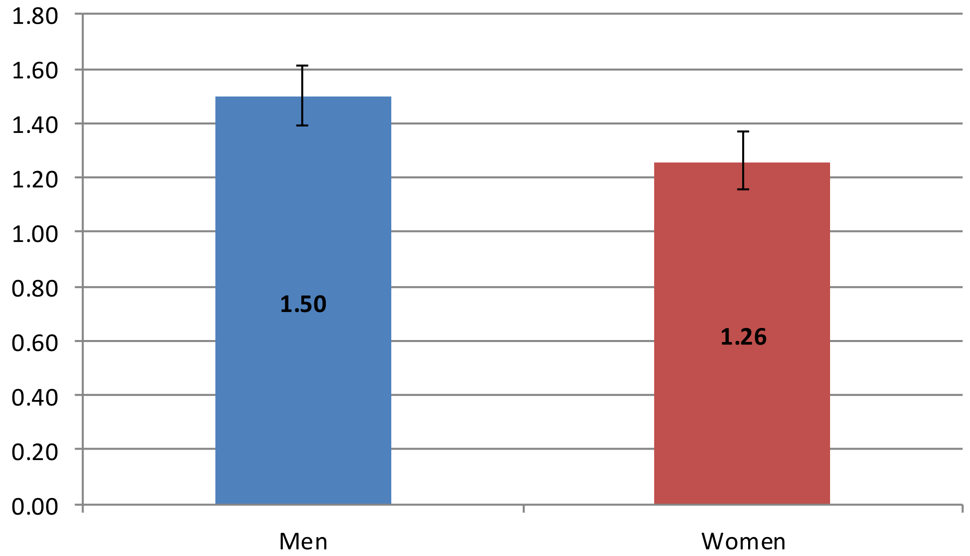
Source: Own figure based on own calculations. EU-SILC data extracted from Eurostat's uder database longitudinal component, release version 2016-1. Models control for age, sex, period and country fixed intercepts. Including 95 percent confidence interval. Vertical axis cut off at 8.

Effect modification by sex and groups of countries

Given that the severely materially deprived face a mortality risk 1.39 times as high as the non-deprived even when accounting for different morbidity levels, it is also of interest to consider whether this excess applies equally to different subpopulations or if there is evidence of effect modification (apart from GALI). For that purpose we estimated the model with morbidity stratified by sex and then by groups of countries.

Comparing men and women (Figure 7), we observe a higher hazard ratio in case of SMD for males than females (1.50 vs. 1.26, $p<0.001$). So the usual finding that variation in mortality risk by socio-economic status is larger among the male population is also visible when socio-economic status is operationalized by SMD. Obviously, the deprived men are a particularly vulnerable group in terms of mortality risk.

Figure 7. Estimated mortality hazard ratio of the severely materially deprived stratified by sex, controlling for GALI.

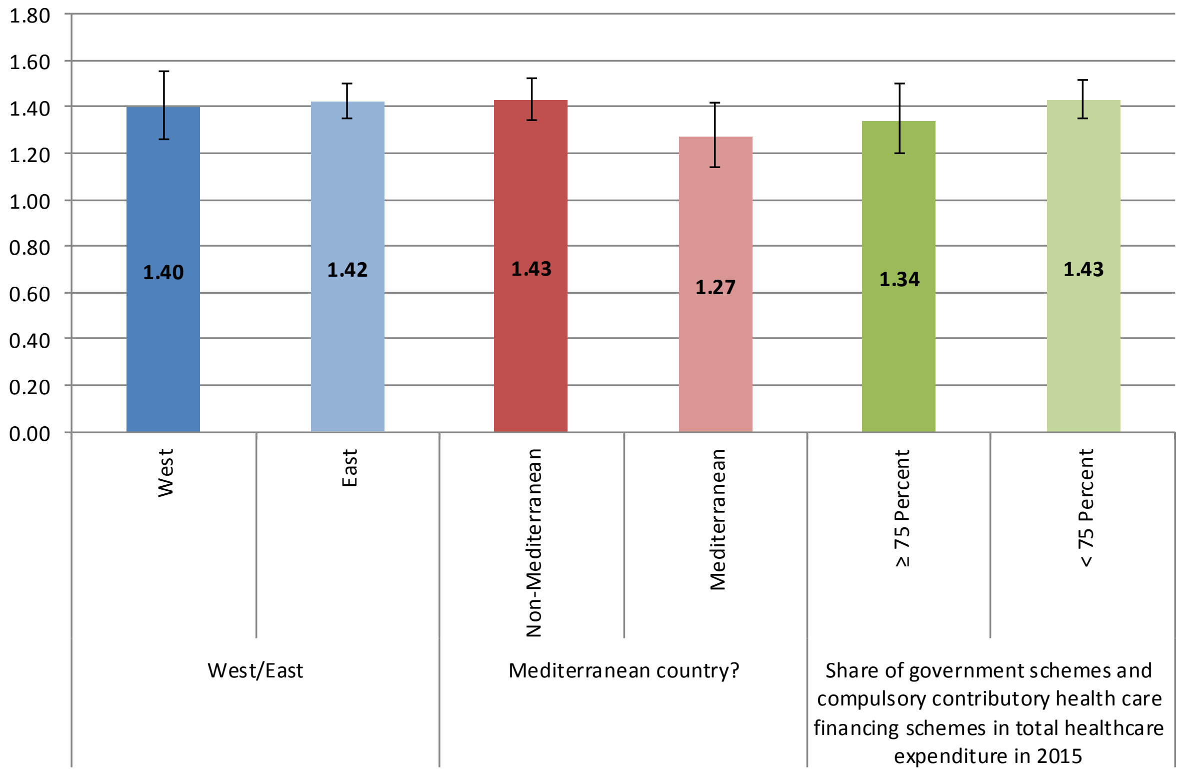


Source: Own figure based on own calculations. EU-SILC data extracted from Eurostat's uder database longitudinal component, release version 2016-1. Models control for morbidity, age, period and country fixed intercepts. Including 95 percent confidence interval.

When comparing groups of countries (Figure 8), it is astonishing that the huge disparity in SMD prevalence between Western and Eastern Europe[35] is not at all reflected in different mortality hazard ratios, which are around 1.4 for both groups of countries. The larger variation in mortality risks that is typically observed in Eastern Europe when measuring socio-economic status by educational level (Corsini 2010) is not visible when we look at absolute poverty. Comparing Mediterranean to non-Mediterranean countries, we indeed estimate a smaller mortality hazard ratio of the deprived in Mediterranean countries (1.27 vs. 1.43, p=0.036). Some difference is also estimated between the hazard ratios of the deprived in countries where government schemes and compulsory contributory health care financing schemes make up more vs. less than 75 percent in total healthcare expenditure (1.34 vs. 1.43), however, this difference is too small to be statistically significant.

[35] In 2016, the estimated prevalence of SMD was 6.7 percent in Western and 13.0 percent in Eastern Europe. Note however that our data covers observations from 2003 to 2015 and in earlier years the gap was even larger.

Figure 8. Estimated mortality hazard ratio of the severely materially deprived stratified by groups of countries, controlling for GALI.



Source: Own figure based on own calculations. EU-SILC data extracted from Eurostat's uder database longitudinal component, release version 2016-1. Models control for morbidity, sex, age, period and country fixed intercepts. Including 95 percent confidence interval.

Discussion and conclusions

We have used the EU-SILC User Database longitudinal sample survey data to estimate excess mortality of Europeans who fall under the official definition of severe material deprivation. To the best of our knowledge, this is the first study investigating the association between this absolute poverty measure and mortality risk. Our findings indicate that the deprived have a substantially higher mortality risk than the non-deprived, and based on a rule of thumb the life expectancy gap is estimated to be 5-6 years. Differential morbidity explains some, but by no means all of excess mortality. Severe material deprivation matters most when health is not severely limited, which is in line with other studies. We also found that the normative cut-off point in the SMD definition (at least 4 out of 9 items) is validated by significantly different mortality risk. Controlling for morbidity, severe material deprivation negatively affects longevity chances especially among men. The deprived are relatively better off, in terms of having a lower relative mortality risk, in Mediterranean than in non-Mediterranean countries.

Although one may of course question the validity of vital status information obtained from a longitudinal sample survey, we believe that our results are robust to this data issue, for two reasons. Firstly, we estimate relative mortality risks, so any bias in mortality rates matters only insofar as the degree of bias is related to SMD status, for which we have not found any evidence (see also Kulhánová et al. 2014). Secondly, all models control for country fixed intercepts, so differences in data quality between countries such as variation in nonresponse rates or vital status accuracy are statistically accounted for (Klotz and Göllner 2017).

A general disadvantage of EU-SILC data is that it covers only the population in private households, but not institutionalized or homeless people. This might be a particular issue in a study of mortality risks, especially when dealing with a small and vulnerable population such as the severely materially deprived. Further research on excess mortality among institutionalized and homeless is therefore needed.

Working with Eurostat's User Database data comes with some limitations. Most notably, the grouping of all respondents aged 80 or over at baseline into the final open age category effectively limits mortality analyses to ages below 80 at baseline. Due to health-related selective survival, it is most likely that relative mortality differences are smaller at the highest ages than in midlife. So for an accurate estimate of the life expectancy loss associated with SMD, some correction should be made for this, for instance by age-specific hazard ratios estimated by an interaction term. Alternatively, may also use other data sources such as national EU-SILC data which do not apply the 80+ age grouping. However, at highest ages survey data are prone to small sample sizes and perhaps also increased measurement error, so it is doubtful if direct estimation of relative mortality risks for highest age groups is meaningful (Cambois et al. 2017).

The major advantage of Eurostat's User Database is that it covers an exceptionally large number of countries (26, in our case). The algorithm which we developed for data preparation (Göllner and Klotz 2018) is generic and may be used for other mortality analyses as well (for instance, relating mortality risk to income poverty levels).

Our model is only a first approach to understanding the association between severe material deprivation and mortality risk, in that it relates deprivation at a baseline point to mortality in a follow-up period. For further research it would be desirable to account for the dynamics of deprivation, for instance, by averaging SMD statuses of the same survey respondents over multiple survey years. EU-SILC with its panel component offers the possibility for such "longitudinal extensions" (see also Guio et al. 2016). In this case, the analytical variable of interest at the micro level would no longer be a binary outcome, but instead the relative frequency of SMD for an individual over time. It is most likely that temporary deprivation affects mortality less than permanent deprivation, so in the latter case the life expectancy gap compared to the non-deprived population might be well above 5-6 years.

One may also investigate the importance of the single items which make up the SMD scale for mortality risk. For the change of SMD rates over time it was found that they were determined mainly by changes in the ability to afford:[36]

- unexpected financial expenses;
- a meal with meat, chicken, fish or vegetarian equivalent every second day; and
- one week's holiday away from home.

[36] Eurostat: Material deprivation statistics – early results. Statistics Explained, data extracted in June 2018, downloaded on 7 September 2018.

In our models we operationalized morbidity by the GALI. Two other health measures are available in EU-SILC's Minimum European Health Module, namely self-rated general health and suffering from any chronic (long-standing) illness or condition. Since the three health measures are highly correlated,[37] one can expect similar model outcomes when operationalizing health differently.

As to the breakdown of countries by the share of government schemes and compulsory contributory health care financing schemes in total healthcare expenditure, one may question the fact that the current distinction is based solely on the 2015 healthcare expenditure statistics, as our data cover a wider time range and structural reforms in healthcare systems may have occurred, for example following the 2008/2009 financial and economic crisis. Then, distinguishing health care systems by a single expenditure statistics is only a rough approach, and more sophisticated welfare state models may be used. As pointed out by Bergqvist et al. (2013), the classical regime models pioneered by Esping-Andersen (1990) are inconsistent in explaining health inequalities, and expenditure models (of which our distinction is a very simple instance) might be a better choice. This argument is further supported by Rydland et al. (2018). One must keep in mind, though, that the sample is limited and that detailed breakdowns compete with the requirement of statistical precision.

Summary

We investigate the association between absolute poverty and relative mortality risk in a contemporary and comparative European perspective. Eurostat's EU-SILC User Database longitudinal data is prepared in such a way that for each survey respondent, one can tell whether this person survived or died while being included in the sample. The relative risk of death is related to age, sex, period, country, morbidity and absolute poverty status at the baseline interview. Morbidity is operationalized by the Global Activity Limitation Instrument and absolute poverty is measured by the severe material deprivation indicator. Cox's proportional hazards regression models are estimated for respondents aged 35-79 years at baseline.

Our findings confirm that the deprived face higher mortality risks than the non-deprived, by an amount equivalent to a loss in life expectancy of 5-6 years. On average, around 40 percent of the excess mortality is statistically mediated by excess morbidity. Being deprived has a particularly adverse effect on mortality risk among men, whereas its effect is mitigated in Mediterranean countries. A possible avenue for future research might be to better understand why these differences exist for Mediterranean countries, and if other countries may be able to learn from that in then implementing measures to reduce mortality risk among the deprived.

[37] To give an example, among the survey respondents who report severe limitations in daily activities, 67 percent rate their general health as bad or very bad; among those reporting no health limitations, 77 percent rate their general health as very good or good (own calculations).

References

Ahammer, A., Horvath, G.T., and Winter-Ebmer, R. (2017): The effect of income on mortality—new evidence for the absence of a causal link. *Journal of the Royal Statistical Society*: Series A (Statistics in Society), 180(3): 793-816.

Angel, S., Heuberger, R., and Lamei, N. (2018): Differences between household income from surveys and registers and how these affect the poverty headcount: evidence from the Austrian SILC. *Social Indicators Research* 138(2): 575-603.

Baron, R.M., and Kenny, D.A. (1986): The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology* 51(6): 1173-1182.

Bergqvist, K., Yngwe, M.Å., and Lundberg, O. (2013): Understanding the role of welfare state characteristics for health and inequalities – an analytical review. *BMC Public Health*, 13: 1234.

Cambois, E., Bricard, D., Camarda, C.G., and Rolland-Guillard, L. (2017): Life expectancy by socioeconomic status: which model fits best? Presentation given at the FACTAGE expert workshop on differential mortality, Statistics Austria, Vienna, 15-17 March 2017.

Carone, G., Eckefeldt, P., Giamboni, L., Laine, V., and Pamies Sumner, S. (2016): Pension reforms in the EU since the early 2000's. Achievements and challenges ahead. Luxembourg: Publications Office of the European Union.

Corsini, V. (2010): Highly educated men and women likely to live longer: Life expectancy by educational attainment. In eurostat: Statistics in focus (24).

Cox, D.R. (1972): Regression Models and Life Tables (with discussion). *Journal of the Royal Statistical Society*. Series B, 34: 187-220.

Esping-Andersen, G. (1990): *The Three Worlds of Welfare Capitalism*. Princeton University Press.

Glaser, T., Kafka, E., Lamei, N., Lyberg, L., and Till, M. (2015): European Comparability and National Best Practices of EU-SILC: A Review of Data Collection and Coherence of the longitudinal component. NetSILC2 Working Paper 5/2015.

Goedemé, T., Zardo Trindade, L., and Vandenbroucke, F. (2017): A pan-European perspective on low-income dynamics in the EU. University of Antwert, Centre for Social Policy, CSB Working Paper 17/03, March 2017.

Göllner, T., and Klotz, J. (2018): Editing EU-SILC UDB Longitudinal Data for Differential Mortality Analyses. SAS code and documentation. FACTAGE project report, May 2018.

Guio, A.C., Marlier, E., Gordon, D., Fahmy, E., Nandy, S., and Pomati, M. (2016): Improving the measurement of material deprivation at the European Union level. *Journal of European Social Policy*, 26(3): 219-333.

Hu, Y., van Lenthe, F.J., Borsboom, G.J., Looman, C.W.N., Bopp, M., Burström, B., Dzúrová, D., Ekholm, O., Klumbiene, J., Lahelma, E., Leinsalu, M., Regidor, E., Santana, P., de Gelder, R., and Mackenbach, J.P. (2016): Trends in socioeconomic inequalities in self-assessed health in 17 European countries between 1990 and 2010. *Journal of Epidemiology and Community Health*, Online First, 19 January 2016.

Huisman, M. (2004): Socioeconomic inequalities in health in Europe. Studies of middle-aged and older populations with a special focus on the role of smoking. Thesis, Erasmus MC Rotterdam.

Huisman, M., Kunst, A., Deeg, D., Grigoletto, F., Nusselder, W., and Mackenbach, J. (2005): Educational inequalities in the prevalence and incidence of disability in Italy and the Netherlands were observed. *Journal of Clinical Epidemiology* 58(10): 1058-1065.

Klotz, J., and Göllner, T. (2017): Estimating Differential Mortality from EU-SILC Longitudinal Data. A Feasibility Study. FACTAGE project report, October 2017.

Kulhánová, I., Hoffmann, R., Eikemo, T.A., Menvielle, G., and Mackenbach, J.P. (2014): Educational inequalities in mortality by cause of death: first national data for the Netherlands. *International Journal of Public Health* 59(5): 687–696.

Kunst, A.E. (1997): Cross-national comparisons of socio-economic differences in mortality. Thesis, Erasmus University Rotterdam.

Lahelma, E., Martinkainen, P., Rahkonen, O., and Silventoinen, K. (1999): Gender differences in illhealth in Finland: patterns, magnitude and change. *Social Science & Medicine* 48(1): 7-19.

Luy, M., and Gast, K. (2014): Do women live longer or do men die earlier? Reflections on the causes of sex differences in life expectancy. *Gerontology* 60(2): 143-153.

Mackenbach, J.P., Kulhánová, I., Artnik, B., Bopp, M., Borrell, C., Clemens, T., Costa, G., Dibben, C., Kalediene, R., Lundberg, O., Martikainen, P., Menvielle, G., Östergren, O., Prochorskas, R., Rodriguez-Sanz, M., Strand, B.H., Looman, C.W.N., and de Gelder, R. (2016): Changes in mortality inequalities over two decades: register based study of European countries. *BMJ* 353: i1732.

Mackenbach, J.P., Bopp, M., Deboosere, P., Kovacs, K., Leinsalu, M., Martikainen, P., Menvielle, G., Regidor, E., de Gelder, R. (2017): Determinants of the magnitude of socioeconomic inequalities in mortality: a study of 17 European countries. *Health & Place* 47: 44-53.

Majer, I.M., Nusselder, W.J., Mackenbach, J.P., and Kunst, A.E. (2011): Socioeconomic inequalities in life and health expectancies around official retirement age in 10 Western-European countries. *Journal of Epidemiology & Community Health* 65(11): 972–979.

Mosquera, I., González-Rábago, Y., Martín, U., and Bacigalupe, A. (2018): Review of socio-economic inequalities in life expectancy and health expectancy in Europe. FACTAGE project report, January 2018.

Nielsen, S.F., Hjorthøj, C.R., Erlangsen, A., and Nordentoft, M. (2011): Psychiatric disorders and mortality among people in homeless shelters in Denmark: a nationwide register-based cohort study. *The Lancet* 377(9784): 2205-2214.

OECD (2017): Health at a Glance 2017: OECD Indicators, OECD Publishing, Paris.

Östergren, O., Lundberg, O., Artnik, B., Bopp. M., Borrell, C., Kalediene, R., Leinsalu, M., Martikainen, P., Regidor, E., Rodríguez-Sanu, M., de Gelder, R., and Mackenbach, J.P. (2017): Educational expansion and inequalities in mortality—A fixed-effects analysis using longitudinal data from 18 European populations. *PloS one* 12(8): e0182526.

Runciman, W.G. (1966): *Relative deprivation and social justice: a study of attitudes to social inequality in twentieth-century England*. Berkeley: University of California Press

Rydland, H.T., Fjær, E.L., Eikemo, T.A., Huits, T., Bambra, C., Wendt, C., Kulhanova, I., Mackenbach, J.P. (2018): Educational inequalities in mortality amenable to healthcare: A comparison of European healthcare systems. In: Wendt, C., Beckfield, J., and Bambra, C. (eds.): The Health of Nations: How Welfare and Healthcare Systems Matter for Health and Health Inequalities. Under review.

Shkolnikov, V.M., Andreev, E.M., Jdanov, D.A., Jasilionis, D., and Valkonen, T. (2009): To what extent do rising mortality inequalities by education and marital status attenuate the general mortality decline? The case of Finland in 1971-2030. Max Planck Institute for Demographic Research Working Paper 2009-018.

Thomas, B. (2012). Homelessness kills. An analysis of the mortality of homeless people in crisis. London: Crisis.

UNESCO (2012): International Standard Classification of Education ISCED 2011. UNESCO Institute for Statistics, Montreal.

Valkonen, T., Martelin, T., Rimpelä, A., Notkola, V., and Savela, S. (1993): Socio-economic mortality differences in Finland 1981-90. Statistics Finland, Väestö 1993:1.

Van Raalte, A.A., Kunst, A.E., Deboosere, P., Leinsalu, M., Lundberg, O., Martikainen, P., Strand, B.H., Artnik, B., Wojtyniak, B., and Mackenbach, J.P. (2011): More variation in lifespan in lower educated groups: evidence from 10 European countries. *International Journal of Epidemiology*, 40(6): 1703-1714.

Zarulli, V., Jasilionis, D., and Jdanov, D.A. (2012): Changes in educational differentials in old-age mortality in Finland and Sweden between 1971-75 and 1996-2000. *Demographic Research*, Volume 26, Article 19, 489-510.