European Commission

Health-related constraints to raising Retirement Ages in the EU: A probabilistic Markov-Model of age-related disability rates for selected disease causes and related impacts on public payer cash benefit expenditure

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Health and Consumers

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Summary

This project investigates the impact of preventing chronic diseases on disability, unemployment and death. In doing so, a simulation model that describes the path running from chronic diseases (mental diseases, musculoskeletal diseases, cardiovascular diseases and cancer) to disability, employment and death for several European Union (EU) countries (Austria, Belgium, Denmark, Germany, France, the Netherlands, Spain, Italy, and Sweden) was developed. Such a model enables performing various scenario analyses from both a public payer perspective (i.e. changes in the official retirement age) or/and from an epidemiological perspective (i.e. changes in disease or disability incidence). To estimate parameters for the simulation model we used data on health and (un) employment from the Survey of Health, Aging and Retirement in Europe (SHARE) in combination with data from the Human Mortality Database and summary statistics from the 2015 Ageing Report. An extensive literature review and two expert consultation rounds were conducted in order to inform and validate our approach. Results from the simulation model show that, in epidemiological scenarios, for all countries and both genders, decreasing disease and disability incidence results in increases in the total number of years lived as well as in the total number of years lived free of disabilities and active in labour force and decreases in the public payer expenditures. Furthermore, in public policy scenarios, our analyses showed the limitations of public policies aimed at increasing the pension age for all investigated countries (in terms of benefits for public expenditure), while indicating that for some EU countries, such policies may make more sense than for others. In general, we found that such policies result in better outcomes for the public payer if implemented in countries in which the official retirement age is below age 65. For women as, compared to men, they would benefit more of potential reductions in disability incidences and as they also have earlier retirement ages in some of the investigated EU countries. Hence, these analyses showed that different public policies and/or epidemiological scenarios may affect various population groups differently within the EU.

Introduction

The aim of this project is to develop a simulation model for assessing the impact of disabilities induced by various chronic disease categories as well as the potential impact of successful disease prevention programmes on health and thereafter on labour force participation. In doing so, we developed a Markov model that describes the path running from chronic diseases (mental diseases, musculoskeletal diseases, cardiovascular diseases and cancer) to disability, employment and death for several European Union (EU) countries. We developed one model structure that was estimated for each disease category separately. This means that the transition probabilities employed in the Markov model are conditional on one of the four disease categories. These analyses were performed for nine EU countries (Austria, Belgium, Denmark, Germany, France, the Netherlands, Spain, Italy, and Sweden).

Background and context

The empirical literature suggests that poor health reduces the capability to work, which in turn decreases labour force participation (1). Popular measures of health status used in studies linking health to labour market participation include self-rated health and various definitions of disability (2,3). Most studies focused on the elderly, and results suggest that health is the most important determinant of labour supply for older workers (4,5). However, to what extent increased health improves employment prospects is more difficult to answer given the many possible pathways running from health to labour market status and vice versa. For example, poor health may restrict workers in performing their job, but also current health status may be the result of current and past work choices. Although many studies found a negative effect of reverse changes in health on labour outcomes, there is lack of consensus on the strength of the effect (3). Estimates of the causal effect of health on labour market participation are sensitive to both the choice of health measure and to identification assumptions regarding the effect of health on labour market status (3).

Furthermore, the size of the causal effect depends on the institutional context, such as disability insurance schemes or early retirement policies (6). Preventing disability is key to preventing labour market exits at an early age. This can be achieved by preventing chronic diseases that have been linked to disability. Several studies have shown that mental diseases, musculoskeletal diseases, cardiovascular diseases and cancer are strongly linked to disability (7). A recent study looked at characteristics of persons who extended their employment beyond official retirement age (8). In line with other research, they found that on average these people were healthier and chronic diseases were less prevalent in this group. While mental and musculoskeletal diseases do not have a strong impact on mortality, cancer and cardiovascular diseases strongly influence life expectancy. Thus, prevention of these diseases is likely to have differential effects on the supply of labour as well as pension entitlements.
Even though the strength of the estimated impact of health on labour market status varies between studies, all evidence suggests that productivity and labour participation can be extended by preventing the incidence of chronic diseases. Up to date, we do not know what the potential impact of preventing those diseases would be in terms of increasing labour supply at various ages. This is the aim of the project. This is crucial if we want to assess the impact of raising the official retirement age. However, as mentioned above, preventing chronic diseases might also further increase pension entitlements if it increases life expectancy. Simulation modelling can be a powerful tool to quantify the strengths of different policy options and to better highlight the trade-offs involved.

This report will be structured as follows. Section 2 presents the methods used in developing the simulation model. This includes: systematic literature reviews, development of the Markov model structure as well as details regarding the estimation of the Markov model transition rate matrix (and thereafter transition probability matrix). Section 3 highlights the most important results obtained by running the Markov simulation model. Section 4 presents the main conclusions of these analyses.

Methodology

The methodology included in this report will be classified in two parts. The first part presents the methodology for the systematic scientific literature review as well as the grey literature review. We have performed these literature reviews in order to identify whether similar simulation models have been developed in the literature as well as potential data sources necessary to populate such a model. In this part we also included the results of the literature searches as these have an influence on the proposed methodology for the second part. The second part presents various aspects of the Markov model development such as: Markov model structure, estimation of model parameters and details about model implementation.

Note that we consulted internationally renowned experts twice in this project. First, for complementing the literature review as well as for obtaining recommendations/suggestions regarding the proposed Markov model. Second, after developing and running the model, we approached the experts in a second round to ask about their opinion on the model and the obtained results. Appendix A1 includes a list of approached experts as well as a list of those experts that provided feedback at each consultation round. It is worth mentioning that, although useful, conducting these expert consultation rounds during the project, proved difficult as in most cases the experts either do not respond or respond with delay. Suggestions and comments given by the reviewers have been incorporated in the construction of the model as well as in the report. Appendices A2 and A3 provide detailed information on experts' response at the first and second consultation round, respectively. Supplementary files were attached to this report illustrating the two reports sent to the experts at the two consultation rounds.

Part I: Literature review

Scientific literature review for model structure

a) Databases, key search terms and eligibility criteria

In order to investigate whether there are similar Markov models developed in the scientific literature, we have performed a search on the following databases: PubMed, Google Scholar, Embase and Econlit. For performing the scientific literature review we included the following search terms: Retirement, Retirement age, Chronic disease, Markov model and the MeSH terms: Return to work, Markov chains, Insurance, disability, and Chronic disease. We have limited our search to publications that included the following combinations of the above terms:
(Return to work [MESH] OR Retirement OR "Retirement age") AND (Markov model OR Markov chains [MESH] OR "simulation model")

- (Return to work [MESH] OR Retirement OR "Retirement age") AND (Markov model OR Markov chains [MESH] OR "simulation model") AND (Chronic disease [MESH])
- (Return to work [MESH] OR Retirement OR "Retirement age") AND (Markov model OR Markov chains [MESH] OR "simulation model") AND (Insurance, Disability [MESH])
- (Return to work [MESH] OR Retirement OR "Retirement age") AND (Markov model OR Markov chains [MESH] OR "simulation model") AND (Chronic disease [MESH]) AND (Insurance, Disability [MESH])
- ("simulation model" OR "Markov model") AND retirement AND "disability insurance"

Eligibility criteria has been assessed in two steps. In the first step, we used a general criteria on all searches, hence we selected:

- Publications from 2000 onwards
- Only peer-reviewed publications, articles in English, French, German, Italian, Spanish, Romanian and Dutch
- Availability of full-text articles

In the second step, the titles and abstracts were screened. We exclude publications based on the following eligibility criteria:

- Publication is not related with labour force
- Publication does not use a simulation model
- The simulation model does not include the state disability
- The model does not link chronic diseases with disability and employment

b) Results

Figure 1 provides an overview of the different phases of the literature review. Searching with the above key words resulted in an initial number of 243 duplicates. Removing duplicates resulted in 156 publications. Of these 156 publications, after screening for titles and abstracts 107 publications were discarded, since these publications clearly did not meet the eligibility criteria. The main reason of exclusion at this step involved an analysis that did not apply a simulation model. Of these, 47 publications were discarded because they did not meet the eligibility criteria, particularly the simulation models presented did not include a state for disability or chronic diseases. Hence these studies did not link in any way unemployment, retirement and disability. For example, some studies developed a Markov model including states such as: employment, unemployment and retirement (9,10) while others looked at states such as full-time work, part-time work and retirement (11).
One publication[1] that partially met the eligibility criteria has been identified and was included it in the literature review (12). This publication was found in Google Scholar and has been published in the ASTIN bulletin-The journal of the International Actuarial

[1] Ventura-Marco, Manuel and Vidal-Meliá, Carlos, 2013, "An Actuarial Balance Sheet Model for Defined Benefit Pay-As-You-Go Pension Systems with Disability and Retirement Contingencies", *ASTIN Bulletin -The Journal of the IAA*, , pp. Available at SSRN: http://ssrn.com/abstract=2064502 or http://dx.doi.org/10.2139/ssrn.2064502.

Association (IAA). This study presents a theoretical 'balance sheet model' that is in fact a first order Markov model for connecting a type of pension scheme ('defined benefit pay-as-you-go (DB PAYG)') with retirement and disability benefits. This theoretical model was developed for informing with respect to the difference between incomes from contributions and spending with pensions and disability insurance under the DB PAYG pension scheme. The authors proposed an age-specific first Markov model as shown in figure 2 for modelling the transitions between generations of contributors, generations of retired pensioners and generations of disability pensioners. However, the authors do not model transitions from the states disabled to retired and from disabled to contributors, respectively. Note that, although the Markov model developed in this publication did not link chronic diseases with disability and employment status, it did model the transitions from active (or being a contributor) to disabled, to retired and to death, therefore we have considered presenting this study as it is the most similar one with the one we aim at developing.

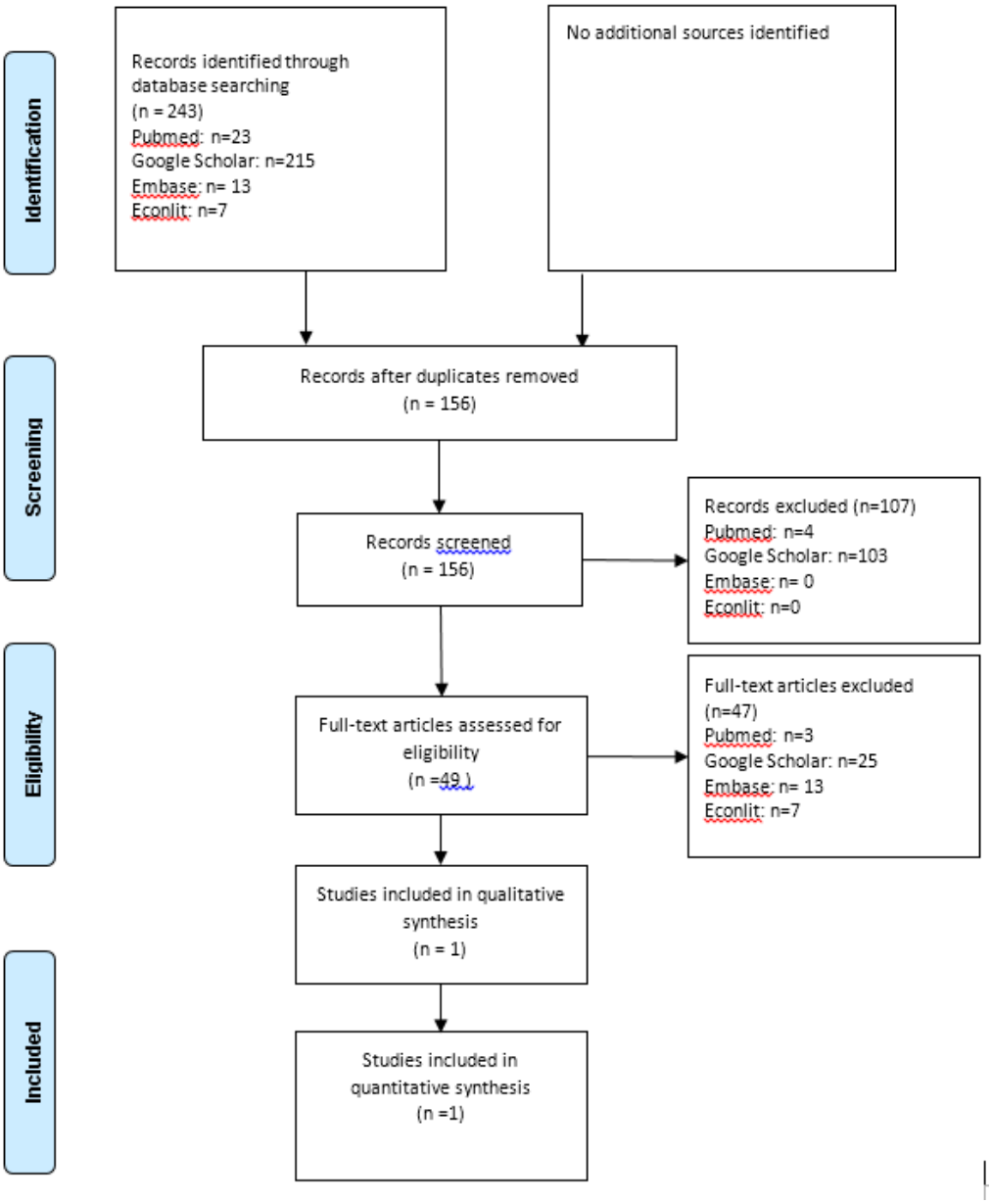

Figure 1: Search flow chart (source PRISMA)

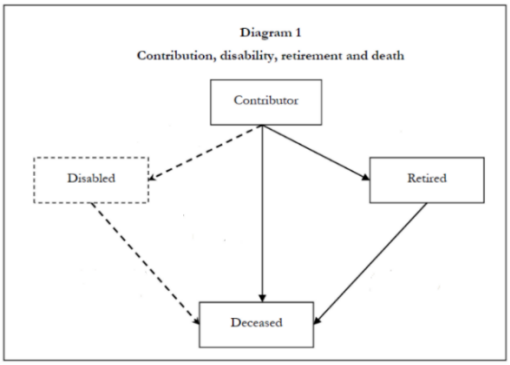

Figure 2: The model used in (12)

In the scientific literature, no study that models the path running from chronic disease to disability, employment and death using a simulation Markov model has been published. The next section presents a grey literature review for model search.

Grey literature review for model structure

a) Data bases, key search terms and eligibility criteria

The scientific literature review was complemented by a grey literature search for investigating whether a model with similar aims has been developed within the health and social sector by consultancies and/or researchers employed at different (health care) organizations. We also performed a search on national compiled data-sources. We performed the search on the following data sources:

- A review of ministerial websites – both health ministries and social affairs ministries of all EU countries
- Health portals (such as http://ec.europa.eu/health/index_en.htm)
- Projects by The Economic Policy Committee's Working Group on Ageing Populations and Sustainability
- The Commission's Directorate General for Employment and the European Foundation for the Improvement of Living and Working Conditions
- The European Commission's Directorate General for Health and Consumer Affairs on Health status, and Framework Programmes
- Websites of WHO and OECD and key policy documents of DG SANCO
- Work carried out under the European Innovation Partnership on Active and Healthy Ageing.

The search was performed in all 24 EU languages. We use the same search terms for the grey literature as for the scientific literature. In order to ensure the requested language coverage we have tested the functionality of those terms on Google and Google Scholar and, when necessary, we have refined them. For example, the key word *"simulation model" and retirement and "disability, insurance"* were translated in Dutch as *"Simulatiemodel" en pensioen en "handicap, verzekering",* in German as "*Simulationsmodell*" *und Ruhestand und "Behinderung, Versicherung"* and in Romanian as *"Model de simulare", și de pensionare și "handicap, asigurare"*. For the grey search we have used the same eligibility criteria as in the systematic literature, i.e. we excluded documents if:

- Document is not related to labour force
- Document does not use a simulation model
- The simulation model does not include the state disability

- The model does not link chronic diseases with disability and employment

b) Results

Table 1 presents a synthesis of the results found with the grey literature review. The first search resulted in 6,409 hits. Although, the majority of hits resulted through general searching engines such as Google, we have obtained some hits through the European Union sites and health and social affairs ministries. In the WHO database, we have obtained 1 hit whereas in the OECD database we have initially obtained 17 hits. However, after applying the eligibility criteria we were unable to identify any projects that had a similar goal as ours. For example, we have found an occasional paper available on EU sites commissioned by the Economic Policy Committee and Directorate-General for Economic and Financial affairs,[2] which aims at comparing the differing pension schemes within EU and to improve accuracy of pensions' projections over time. Country-specific semi-aggregated models were applied for each EU country (except for Sweden that applies a dynamic microsimulation model) for simulating the functioning of pension systems, i.e. the accrual of pension rights and changes in the level of pensions given certain demographics, labor force and macroeconomic developments. The developed models included states such as employed, unemployed, pensioner and dead and they simulated transitions from one state to another. Although there are some similarities between the applied models for various EU countries, these models were developed for country-specific purposes. However, to our knowledge, none of the applied country-specific models actually links information on employment with chronic diseases incidence. Therefore, we were not able to identify any document with similar purposes as ours.

Table 1: Results of grey search/national databases search

Data base	Number of hits n=6,409	Number of documents that met the eligibility criteria (n=0)
Google	6,326	0
Health ministries	16	0
Social affairs ministries	13	0
DG SANCO	5	0
Projects by The Economic Policy Committee's Working Group on Ageing Populations and Sustainability	5	0
The Commission's Directorate General for Employment and the European Foundation for the Improvement of Living and Working Conditions	5	0
The European Commission's Directorate General for Health and Consumer Affairs on Health status, and Framework Programmes	16	0
WHO	1	0
OECD	17	0
The European Innovation Partnership on Active and Healthy Ageing	5	0

[2] Pension Schemes and Projection Models in EU-25 Member States, November 2007

Concluding, in both the scientific and the grey literature, no study that models the path running from chronic disease to disability, employment and death using a simulation Markov model has been published. Although studies that model the path running from employment to retirement were found, the vast majority did not include disability as a model state whereas no study has been identified to include disability, chronic diseases and employment status together in the analysis. In Section 3, we will propose a Markov model structure for describing the path running from chronic diseases to disability, employment and death.

Literature search for transition data

a) Databases, key words and eligibility criteria

For modelling the path running from chronic diseases to disability, employment and death, longitudinal datasets are needed that include information on: employment status, disability indicators, such as activities of daily living (ADL), and at least the four chronic disease categories indicated (mental disorders, diseases of the musculoskeletal system and connective tissue, diseases of the circulatory system, and cancer). A longitudinal dataset containing multiple measurements allows to estimate incidence rates (going from non-diseased to diseased) and the average age of disease onset.
Furthermore, in order to obtain transitions to death, such data needs to include information on mortality. For allowing a cross-country comparison the data needs to be collected for various EU countries. In order to identify such a dataset, we have performed an extensive search for longitudinal surveys on aging and living conditions for as many European countries as possible. We used the databases of: Google, Google Scholar, PubMed and Eurostat. For our search we have used general terms such as: longitudinal survey, longitudinal database, European Union survey, aging; and also more specific terms such as: labour force, employment, chronic disease, disability. The combination of general and more specific terms resulted in the following key words combinations used:

- (“Longitudinal survey” OR “longitudinal database”) AND "Aging" AND ("Labour force" OR “Employment”) " AND "Europe"
- “European Union Survey” AND "Aging" AND ("Labour force" OR “Employment”)
- (“Longitudinal survey” OR “longitudinal database”) AND "Aging" AND ("Labour force" OR “Employment”) AND "Europe" AND ("Chronic disease") AND (Disability)
- “European Union Survey” AND "Aging" AND "Labour force" AND ("Chronic disease") AND (Disability)

We have applied two selection criteria for selecting relevant longitudinal surveys. First, we excluded surveys if:

- Dataset is not freely available (at least for research purpose)
- Dataset does not allow cross-country comparison by including information for various EU countries

On identified databases using the first selection criteria, we have further excluded datasets if:

- Dataset is not longitudinal
- Dataset does not include information on labor force, disability and the chronic diseases: cancer, cardiovascular diseases, mental diseases and musculoskeletal diseases.

b) Results

After performing the first hits and applying the first selection criteria we have identified six surveys that are freely available and that include information about various European countries, hence allowing cross-country comparisons:

- The European Union Labor Force Survey (LFS)
- The European Union Community Household Panel (ECHP)
- The European Statistics on Income and Living conditions (EU-SILC)
- The European Social Survey (ESS)
- The Survey of Health, Aging and Retirement in Europe (SHARE)
- European Health Interview Survey (EHIS)

Table 2 illustrates the characteristics of these six surveys according to the second selection criteria. Of the remaining surveys, two have been excluded because they are not longitudinal (ESS and EHIS) and three have been excluded because they did not include information on the chronic diseases of interest to us (EU LFS, ECHP, EU-SILC).

Finally, the only freely available survey that allows cross-country comparisons between EU member states and that includes information on employment status, health (disability) and chronic diseases is SHARE. Furthermore, compared to other surveys such as ECHP or EU-SILC, SHARE includes more detailed measurements of disabilities. Disability is measured in SHARE using questions regarding activities of daily living (ADL). For example, individuals are asked whether they experience difficulties in performing daily activities such as: walking across a room, dressing, bathing, making phone calls, taking medications, etc. Given the above, we used the SHARE survey for estimating the transition probabilities as well as the average ages of disease onset in our Markov model. The two questions used for measuring disability with SHARE data are included in appendix A4:

SHARE includes about 85,000 individuals (approximately 150,000 interviews) aged over 50, started in 2004 and is still running. Five waves have been collected so far. In wave 1, which was performed in 2004, ten EU countries were included: Austria, Belgium, Germany, Denmark, Spain, France, Greece, Italy, the Netherlands and Sweden. In the subsequent waves of SHARE, generally some EU countries were added but also other were dismissed, e.g. Greece was discarded in wave 4. Therefore, for nine EU countries five rounds of measurements are available in SHARE. However, wave 3 has a different design compared to the other waves in SHARE, i.e. is intended at learning more about people's life history including children, partner, accommodation, health status starting childhood, etc. Therefore, the focus is on past rather than on present; questions have different forms than those in the other waves. For example, disability is monitored differently in this wave, i.e. disability questions regarding activities of daily living (ADL) as in the other waves are not included but some questions about past life periods with disability or illness are included. Because of its focus on past rather than present and because of a completely different formulation of questions compared to other waves, we excluded wave 3 from our analyses. Therefore we used waves 1,2,4 and 5 for the nine EU countries.

Note that we are aware of other available datasets such as the Global Burden of Disease (GBD) database. However, our choice of using SHARE is based on the fact that this allowed to estimate a relation with disability and mortality using a consistent set of definitions. If, for example, we had been interested in assessing only the relationship between disease incidence and mortality, a database such as GBD would have been a better choice.

Table 2: Characteristics of the selected surveys after first eligibility criteria

Survey	*Survey is longitudinal*	*Survey includes information on employment*	*Survey includes information on chronic disease*[3]	*Survey includes information on disability*	*Number of European Union countries included*	*Survey start year*	*Survey end year*	*Waves frequency*
EU LFS[4]	Yes	Yes	-	-	*All EU member states included*	*1983*	*onwards*	*Yearly*
ECHP	Yes	Yes	-	Yes	*All EU member states as in 1994, Austria and Finland.*	*1994*	*2001*	*Yearly*
EU-SILC	Yes	Yes	-	Yes[5]	• *2004: EU15* except Germany, the Netherlands and the UK • *2007: EU27*	*2003*	*onwards*	*Yearly*
ESS	-	-	Yes	Yes	*All EU28 except Malta*	*2002*	*onwards*	*Every two years*
SHARE	*Yes*	Yes	Yes	Yes	• 2004: 10 EU countries • 2013: 19 EU countries	2004	onwards	*Every two years*
EHIS	*Yes*[6]	*Yes*	*Yes*	*Yes*	• 2006: Austria and Estonia • 2007: Slovenia • 2008: Belgium, Bulgaria, Czech Republic, Cyprus, France, Latvia, Malta and Romania • 2009: Greece, Spain, Hungary, Poland and Slovak Republic	*First round:2006-2009*	*Second round scheduled for 2014*	*Every 5 years*

[3] We are assessing the inclusion of the chronic disease categories: cancer, mental disorders, cardiovascular diseases and musculoskeletal disorders.
[4] Characteristics of the freely available EU LFS data (not all EU LFS data is freely available)
[5] EU-SILC includes only one question with the global disability instrument (GALI)
[6] Only one round has been performed, second round scheduled for 2014

Part II: Markov model development

Markov model structure

Figure 3 displays the causal structure of the developed model. In the model it is assumed that having a chronic disease increases the risk of becoming disabled and that being disabled increases the risk of unemployment. Therefore, having a chronic disease increases mortality risk both directly and indirectly through its effect on disability, which increases mortality risk independently (Majer et al. 2011a). Note that we considered independent effects of chronic disease on employment. However, the sample size did not allow us to reliably estimate this relation.

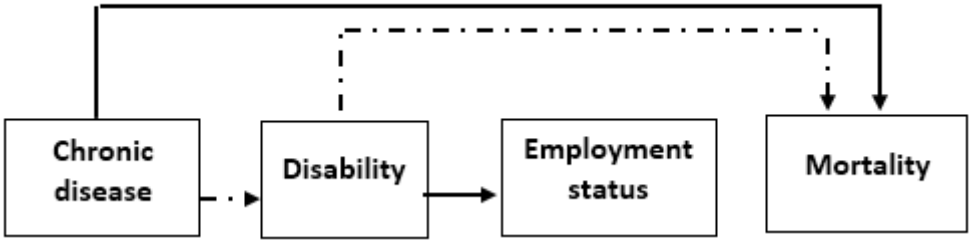

Figure 3: *Causal chain running from chronic disease to employment and death underlying the model*

For developing the Markov model, we subdivided the population of the model into different groups (called states). We modeled changes over time in the size of these groups by allowing transitions between them. Therefore, the structure of a Markov model is fully specified by states and transitions between these states. States in the model depend on age and gender and were defined based on disease status (diseased or non-diseased), disability status (disabled or not disabled) and employment status (employed or not employed). Thus, for each age and gender there are 8 different possible states (not diseased and not disabled and employed, diseased and not disabled and employed, etc.). Death is also a state of the model. Note that such a model will be developed for each disease category and for each country separately.
For defining the structure of the Markov model proposed here, let us denote by S the number of sick or diseased people, $\overline{S}$ the number of non-sick (non-diseased) individuals, D the number of disabled, $\overline{D}$ the number of non-disabled, E the number of those working (employed), $\overline{E}$ the number of those not-working (depending on age, these are either unemployed or retired). Note that, the not-sick indicates without the disease modelled (e.g. cancer) but other diseases are possible. Therefore, eight model states can be defined: $\overline{S}\,\overline{D}$E, $\overline{S}\,\overline{D}\,\overline{E}$, S$\overline{D}E , S\overline{D}\,\overline{E}$, $\overline{S}$DE, $\overline{S}$D$\overline{E}$, SDE, SD$\overline{E}$ and *Death*, which is an absorbing state. When defining transitions between states it is important to make a distinction between rates and probabilities.

Rates are instantaneous measures that range from zero to infinity and describe the instantaneous rate of an event (e.g. disease), i.e. the rate at which new cases are occurring at any particular moment. Therefore, incidence rate measures the rate at which new cases of an event occur per unit of time, and time is an integral part of the calculation of incidence rate. In contrast, probabilities (also known as cumulative incidences) assess the probability of an event occurring during a stated period of observation and they are defined between zero and one. The main difference between

rates and probabilities relates to time: incidences can be assessed at any time while probabilities can be assessed only after the entire period of time has elapsed. Despite their distinction, rates can be converted to probabilities and vice versa.

Estimating our Markov model involves, first, estimating the one year incidence rate matrix and, second, transforming the rate matrix into a probability matrix (13). Since, SHARE is a longitudinal database, transitions can be observed by changes in, for example, disease status, from one measurement round to the other. Table 3 presents the transition rate matrix underlying our Markov model indicating the transitions between the different states. Note that in the transition matrix, only one change per infinitely small unit of time is indicated, e.g. from not sick to sick or from not employed to employed. However, if we convert this transition rate matrix to a probability matrix, multiple changes can occur (e.g. it is possible to become sick and disabled within a year). Due to data limitations, we have estimated only incidence transitions from: not sick to sick, from not-disabled to disabled and from employed to unemployed and not the reverse situation assuming for example that once unemployed one stays unemployed (in Table 3 this can be seen by all the zeros below the diagonal).

The Markov model will have a half-year cycle. Note that, compared to probabilities, rates have many convenient properties, e.g. can be added, subtracted, multiplied or divided. Hence, we can easily obtain the half year incidence matrix (by diving by two the one year incidence rate matrix) and consequently obtain the half-year probability matrix. Given that the Markov model will be age, gender, disease and country specific, such a matrix would need to be computed for each age, gender, disease and country separately.
Table 3 indicates the transition rate matrix that needs to be estimated for fully calculating the Markov model according to the causal chain presented in Figure 3. When estimating such a matrix, there are two possibilities. The first possibility is to estimate all transitions in this matrix simultaneously by using a multi-state Markov model (MSM) approach and therefore allow correlations between states. Such a model can be fitted with the software R with a variety of available packages, e.g. msm (14), HiddenMarkov (15) and mhsmm (16). However, due to sample size limitations it was impossible to estimate this model by age, gender, country and disease in such a way. The second possibility for estimating the incidence matrix is to use traditional regression analyses for estimating transitions separately. Therefore, we used Poisson regression for estimating separately: disease incidence rates, disability incidence rates, unemployment incidence rates and mortality rates. Separate models will be developed for estimating each of these transition rates. Details regarding the estimation of each of these elements follow in the next section.

Table 3: The transition rate matrix underlying our Markov model

	$\overline{S}\ \overline{D}$ E	$\overline{S}\ \overline{D}\ \overline{E}$	S $\overline{D}$ E	S $\overline{D}\ \overline{E}$	$\overline{S}$ DE	$\overline{S}$ D $\overline{E}$	SDE	SD $\overline{E}$	Death
$\overline{S}\ \overline{D}$ E	-sum row	✓	✓	0	✓	0	0	0	✓
$\overline{S}\ \overline{D}\ \overline{E}$	0	-sum row	0	✓	0	✓	0	0	✓
S $\overline{D}$ E	0	0	-sum row	✓	0	0	✓	0	✓
S $\overline{D}\ \overline{E}$	0	0	0	-sum row	0	0	0	✓	✓
$\overline{S}$ DE	0	0	0	0	-sum row	✓	✓	0	✓
$\overline{S}$ D $\overline{E}$	0	0	0	0	0	-sum row	0	✓	✓
SDE	0	0	0	0	0	0	-sum row	✓	✓
SD $\overline{E}$	0	0	0	0	0	0	0	-sum row	✓
Death	0	0	0	0	0	0	0	0	0

Markov model estimation

Poisson regression is often used to model count data and it is also a common method used in epidemiology to estimate disease incidence or rates.
A random variable Y has a Poisson distribution with parameter μ if it takes integer values y=0,1,2,…with probability:

$$P(Y=y)=\frac{e^{-\mu}\mu^{y}}{y!},\ \mu>0 \qquad (1)$$

This distribution is described only by one parameter μ, which plays the role of both mean and variance; hence for a Poisson variable, the mean equals the variance.
Let us assume we have a sample of observations $y_1, y_2, ...y_n$ which can be treated as realizations of independent Poisson random variables. In Poisson regression, the aim is to model μ_i as a function of explanatory variables. Give the constraint of $\mu_i > 0$, Poisson regression can be estimated within a generalized linear model framework (glm) by using a log link function:

$$\log(\mu_i)=X_i^{'}\beta, \qquad (2)$$

where X denotes a matrix of explanatory variables and β is a vector of estimated coefficients.
For estimating a Poisson regression model we used aggregate level data, i.e. data grouped by all the variables included in the model. For example, if the outcome variable depends on age and gender, then expected number of events will be grouped by age and gender. The rate is a count of events occurring to a particular unit of observation divided by some measure of that unit's *exposure*. With Poisson regression this is handled as an offset, where the exposure variable enters on the right-hand side of the equation, but with a parameter estimate (for log(exposure)) constrained to 1.

In this way, we obtain incidence per one unit, in this case one person. Therefore, equation (2) becomes:

$$\log(\mu_i) = X_i^{'}\beta + \log(\text{exposure}), \quad (3)$$

Separate Poisson models will be developed for estimating the following transitions:

Model (a): Disease incidence was estimated as a function of *age, gender and country*. SHARE includes questions about the presence of each of the chronic diseases analyzed. We defined cancer incidence if someone answered with 'Yes' at a question about cancer or malignant tumour, including leukaemia or lymphoma. We defined cardiovascular disease incidence if individuals answered positive at a question about heart attack including myocardial infarction or coronary, stroke or cerebral vascular disease. Musculoskeletal diseases incidences were defined if someone answered positive to being diagnosed with arthritis, including osteoarthritis, or rheumatism and osteoporosis. Furthermore, SHARE includes an entire module with about 20 questions referring to mental health, e.g. questions about depression, irritability, happiness, appetite, fatigue and similar behaviour factors that may indicate mental instability are included in the mental health module. Mental disorders incidence was defined if someone answered positively to the question about having depression.

Model (b): Disability incidence was estimated as a function of *age, gender, country and chronic disease*. Questions about ADL are included in SHARE. A positive answer indicating difficulties in performing any of the ADL (e.g. walking across a room, dressing, bathing, preparing food) was classified as disability. Appendix A4 illustrates the two questions used for measuring disability.

Model (c): Unemployment incidence was estimated as a function of *age, gender, country and disability* level. In SHARE a direct question about employment status (i.e. if an individual is employed, unemployed, receiving old-age pension or disability benefit) is available. We collapsed responses in employed and unemployed (this group includes also those receiving old age and disability pensions).

Model (d): Mortality rates was estimated by *age, gender, chronic disease and disability level*. We used the end of life module in SHARE. At each new wave in SHARE, if an individual has deceased, a questionnaire is sent to a close relative/family to obtain information about that person's death (date, age, cause of death etc.).

For estimating the above transitions 17 separate models were fitted: four models for estimating disease incidence for each disease separately (model type a), four models for estimating disability incidence estimated separately for each disease (model type b), one model for estimating unemployment rate (model c), four models for estimating mortality rate (model type d), four models used to calibrate the estimated mortality rates (details about these models will follow). These models allowed to complete the transition rate matrix presented in table 3 with the following transitions estimated:

1. From not-sick to sick using model (a)
2. From not-disabled and not-sick to disabled and not-sick using model (b)
3. From not-disabled and sick to disabled and sick using model (b)
4. From employed and not-disabled to unemployed and not-disabled using model (c)
5. From employed and disabled to unemployed and disabled using model (c)
6. From not-sick and not-disabled to death using model (d)
7. From not-sick and disabled to death using model (d)

8. From sick and not-disabled to death using model (d)
9. From sick and disabled to death using model (d)

Table 4 presents the transition rate matrix indicating each of the nine described transitions. Summary output results of the 17 models developed for estimating these transitions can be found in Appendix A5. Models' fit was evaluated by plotting the observed versus estimated transition per person-year at each age. Details regarding estimation of each of these models follow below.

Table 4: The transition rate matrix

	$\overline{S}\ \overline{D}$E	$\overline{S}\ \overline{D}\ \overline{E}$	S$\overline{D}$E	S$\overline{D}\ \overline{E}$	$\overline{S}$DE	$\overline{S}$D$\overline{E}$	SDE	SD$\overline{E}$	Death
$\overline{S}\ \overline{D}$E	-sum row	**4**	**1**	0	**2**	0	0	0	**6**
$\overline{S}\ \overline{D}\ \overline{E}$	0	-sum row	0	**1**	0	**2**	0	0	**6**
S$\overline{D}$E	0	0	-sum row	**4**	0	0	**3**	0	**7**
S$\overline{D}\ \overline{E}$	0	0	0	-sum Row	0	0	0	**3**	**7**
$\overline{S}$DE	0	0	0	0	-sum row	**5**	**1**	0	**8**
$\overline{S}$D$\overline{E}$	0	0	0	0	0	-sum row	0	**1**	**8**
SDE	0	0	0	0	0	0	-sum row	**5**	**9**
SD$\overline{E}$	0	0	0	0	0	0	0	-sum row	**9**
Death	0	0	0	0	0	0	0	0	0

a) Disease incidence

By following the causal chain illustrated in figure 3, we first estimated disease incidence as a function of age, gender and country. Let $Y_{disease_i}$ denote disease incidence outcome for individual i, if $Y_{disease_i} \sim Poisson(\mu_i)$, then:

$$\log\left(E\left[Y_{disease_i}\right]\right) = \beta_0 + \beta_1 a_i + \beta_2 a^2 + \beta_3 g + \beta_4 a * g + \beta_5 c + \log(\text{exposure}), \quad (4)$$

where $E\left[Y_{disease_i}\right]$ denotes the expected value of disease incidence for observation *i*, *a* denotes age, *g* denotes gender and *c* denotes country. Such a model has been estimated for each chronic disease: cancer, cardiovascular diseases, musculoskeletal disease and mental disorders; therefore in order to estimate disease incidence we fitted four different models. Summary results of each of these model are included in Appendix A5 (models 1-4).
The model denoted by equation (4) estimates the transitions from the state not-sick to the state sick with other combinations of disability and employment status which due to sample sizes restrictions were not included in equation 4, i.e. this is transition 1 as denoted in table 4.

Figure 3 shows results of the estimated disease incidence (continuous lines) per person-year against observed data for cancer, cardiovascular disease, musculoskeletal diseases and mental disorders for various countries in EU. Note that, in this estimation we used aggregate level data; therefore, we do not observe here the sample size limitations at the individual level. Figure 3 indicates that the lowest incidence was for cancer while the highest incidence appears to be for mental health disorders. Furthermore, women have higher disease incidences especially for mental and musculoskeletal disorders. Moreover, there seem to be differences by countries: e.g. incidences appear higher in Germany than in Italy for these four diseases.

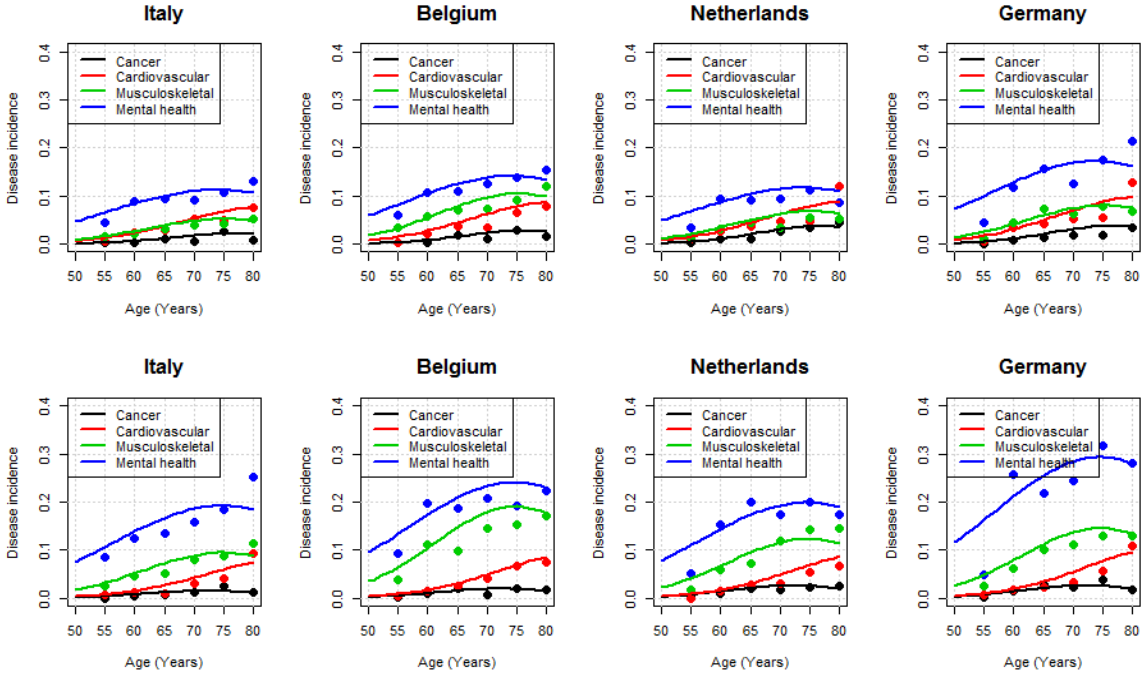

Figure 3: Chronic diseases incidence per person-year at each age for some countries for men (top) and women (bottom)

b) Disability incidence

Let $Y_{disability_i}$ denote disability incidence outcome for individual *i*, if $Y_{disability_i} \sim Poisson(\mu_i)$ then:

$$\log\left(E\left[Y_{disability_i}\right]\right) = \beta_0 + \beta_1 a_i + \beta_2 a^2 + \beta_3 g + \beta_4 a * g + \beta_5 c + \beta_6 dis + \beta_7 dis * a + \log(\text{exposure}) \quad (5)$$

where *dis* denotes one of the four chronic diseases. This model has been estimated separately for each disease in part; therefore, for estimating disability incidence we fitted four Poisson regression models. Appendix A5 shows the summary results of these models (models 5-8).

Since disability is modelled as a function of disease status, model 5 estimates two transitions: from state not-disabled and sick to disabled and sick, from not-disabled and not-sick to disabled and not-sick regardless of the employment status which was not included here due to sample size restrictions. These are transitions number 2 and 3 as indicated in table 4.

Figure 4 indicates the disability incidence per person-year for each age and gender for various EU countries and for each disease separately. We observe that disability

incidence is higher for women than for men. Furthermore, compared to cancer, other diseased appear to induce higher disability incidences.

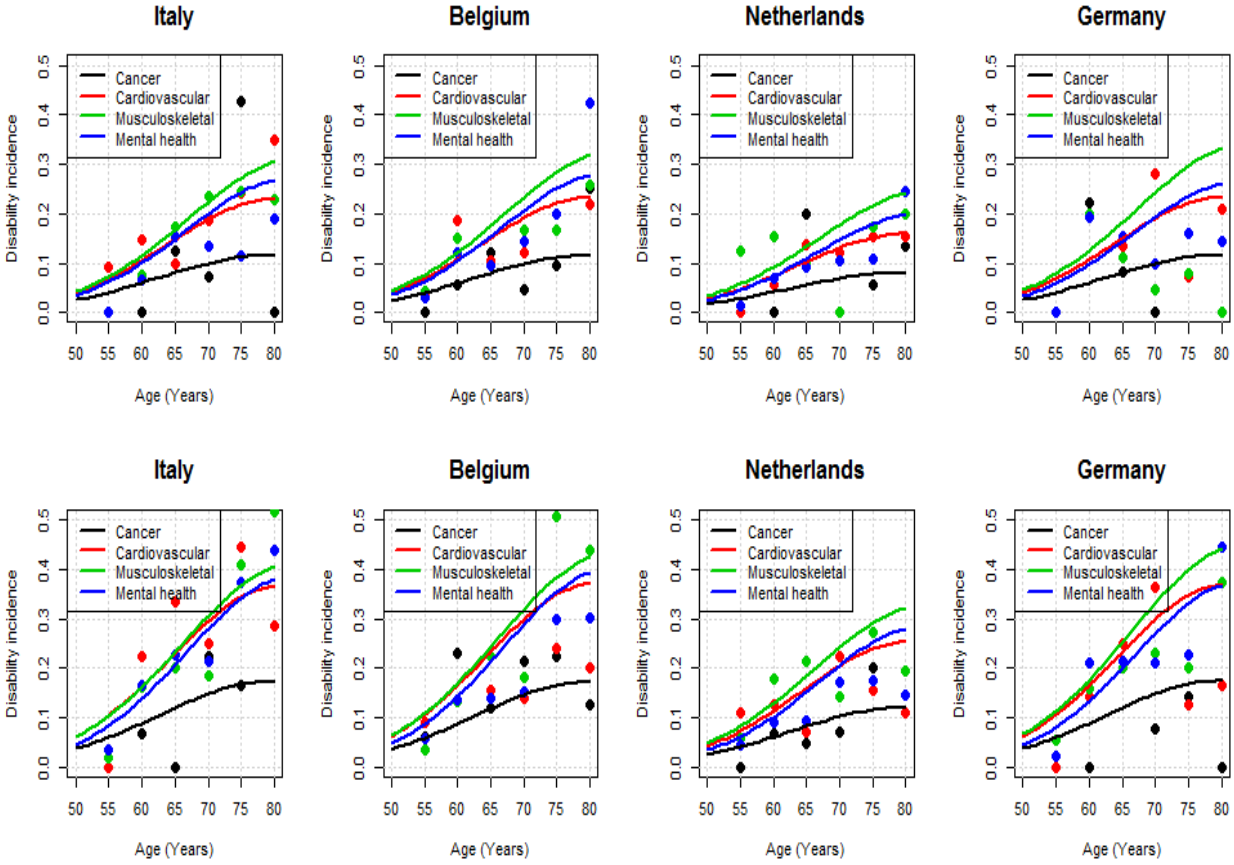

Figure 4: Disability incidence (conditional on having the disease) per person-year at each age due to chronic diseases for men (top) and women (bottom)

c) Unemployment incidence

Unemployment incidence has been modelled as a function of age, gender, country and disability. Let Y_{unemp_i} denote unemployment incidence outcome for individual *i*, if $Y_{unemp_i} \sim Poisson(\mu_i)$ then:

$$\log\left(E\left[Y_{unemp_i}\right]\right) = \beta_0 + \beta_1 a_i + \beta_2 a^2 + \beta_3 g + \beta_4 a * g + \beta_5 c + \beta_6 disab + \beta_7 disab * age + \log(\text{exposure}) \quad (6)$$

where *disab* denotes disability level (disabled or not-disabled).
Since unemployment incidence is modelled as a function of disability status, model 6 estimates two transitions: from state employed and not-disabled to the state unemployed and not-disabled, form the state employed and disabled to the state unemployed and disabled for all diseases combined. Due to sample size limitations, it was not possible to estimate such a model for each disease separately. Summary results of fitting this model with the programme R are included in Appendix A5 (model 9). These transitions are denoted by transition number 4 and 5 as indicated in table 4.
In our dataset, the vast majority of individuals aged above 60 were already unemployed, therefore we estimated this model by including only individuals aged 50-60 and we predicted from this model until the official retirement age is reached.

Figure 5 shows the estimated unemployment incidences against the observed aggregate values for men and women, for various countries. Figure 5 indicates that unemployment incidence was higher for those disabled compared to those not disabled and that the difference in incidence between the two groups increase with advancing age. Unemployment incidence appears similar for men and women but there are significant country differences, e.g. unemployment incidence in Italy is larger than that in Germany or the Netherlands.

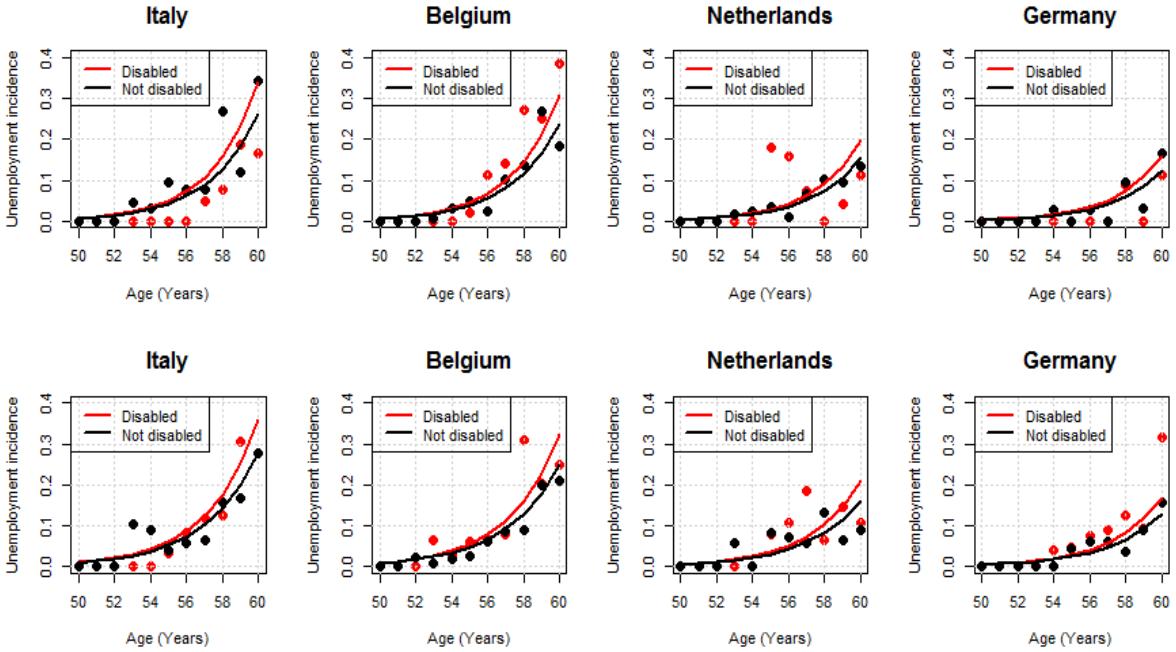

Figure 5: Unemployment incidence per person-year at each age for men (top) and women (bottom) for some selected countries

d) Mortality rates estimation

We estimated mortality rates as a function of age, gender, disease and disability. Because of sample size limitations we first estimated mortality rates by pooling the data for all countries together. Subsequently, we calibrated these results using total mortality rates for each country as obtained mortality data publicly available in the Human Mortality Database (http://www.mortality.org/). Similar to previous transition estimates, we used a Poisson regression model to estimate total mortality as a function of age, gender, disease and disability:

$$\log\left(E\left[m_s(a,g)\right]\right) = \beta_0 + \beta_1 a_i + \beta_2 a^2 + \beta_3 g + \beta_4 a * g + \beta_5 disab + \beta_6 dis + \beta_7 dis * a + \log(\text{exposure}) \quad (7)$$

where $m_s(a,g)$ denotes mortality rate for age *a*, gender *g* and state *s.* Because mortality is estimated as a function of disease and disability then in fact transitions from combinations of these variables (i.e. not sick and not disabled, sick and not disabled, not sick and disabled; and sick and disabled) to death are estimated. Hence, *s* denote these states $s = \left(\overline{S}\overline{D}, S\overline{D}, \overline{S}D, SD\right)$. Therefore, because employment status is not included in the model, we have four different transitions (instead of eight) to death. In theory, employment can be included in equation 7; however, the sample size of our dataset is not allowing it in this case. These transitions are denoted by transition numbers 6, 7, 8 and 9 as indicated in table 4. Here we excluded other

interactions for example, between age and disability or between disease and disability as these did not show sufficient power. Model 7 was estimated for each disease separately; therefore, for estimating mortality rates we fitted four models; summary results of these models are showed in Appendix A5 (models 10-13).
Figures 6 and 7 illustrates mortality rates estimates from the model against observed mortality in the SHARE data for each state. These figures show that for all states, men have higher mortality than women. Furthermore, for both men and women, those in a health state sick (with one of the four chronic disease) have substantially higher mortality than those not sick with the highest mortality being for those diagnosed with cancer. As expected, the highest mortality is observed for those who are in the state sick and disabled and the smallest for those healthy (i.e. in the state not sick and not disabled). Note that here healthy (not-sick) indicates without one of the four diseases (e.g. cancer) but does not excludes the possibility of other diseases.

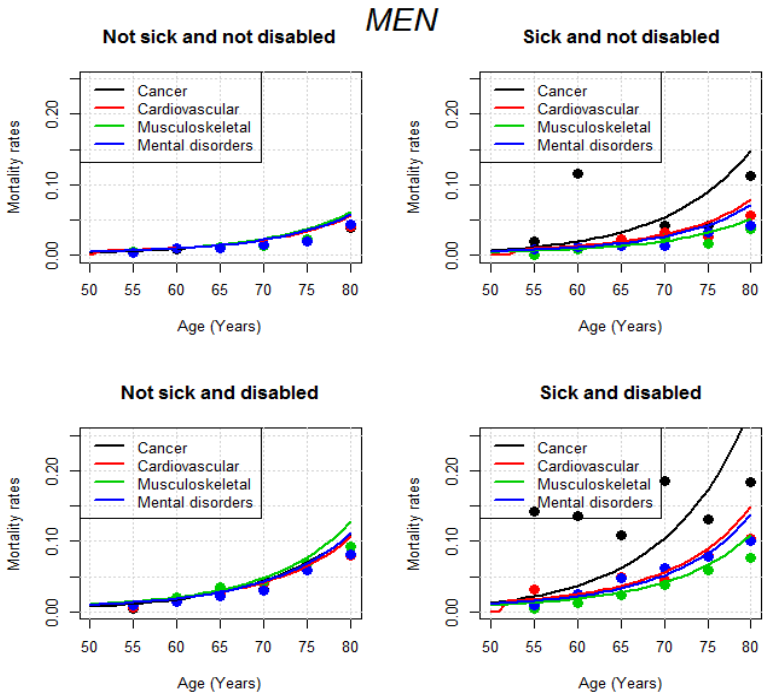

Figure 6: Mortality estimates per person-year at each age, by disease, for each defined health state for men

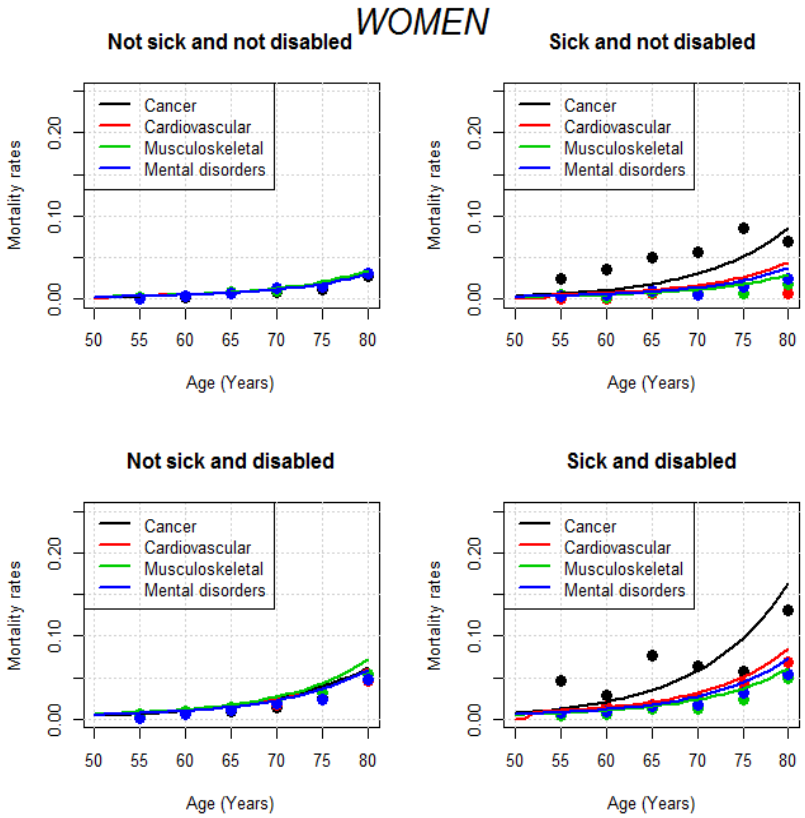

Figure 7: Mortality estimates per person-year at each age, by disease, for each defined health state for women

e) Calibration mortality rates

The mortality rates estimated for each country, for each state $s = \left(\overline{S}\overline{D}, S\overline{D}, \overline{S}D, SD\right)$, i.e. $m_s(a,g,c)$, were calibrated against total mortality rates as provided by Human Mortality database $m(a,g,c)$. The intuition behind this is that total mortality should equal the sum of mortality for all states *s* weighted with the proportion of individuals (or the probability of) being in each state *s*, $p_s(a,g,c)$:

$$m(a,g,c) = \sum_s m_s(a,g,c) p_s(a,g,c) \tag{8}$$

As shown in the previous section, due to sample size restrictions we estimated mortality rates by pooling the data for all countries together; therefore, assuming that $m_s(a,g,c) = m_s(a,g)$. We estimated the probability of being in state *s* by using multinomial logit regressions in which:

$$p_s(a,g,c) = \frac{\exp\left(\eta_s(a,g,c)\right)}{\sum_{s=1}^{4} \exp\left(\eta_s(a,g,c)\right)}, \qquad \text{where} \tag{9}$$

$$\eta_s(a,g,c) = \beta_0 + \beta_1 a_i + \beta_2 a^2 + \beta_3 g + \beta_4 a * g + \beta_5 c \quad (10)$$

Note that, model (9) was fitted for each disease separately (summary results of these models are showed in Appendix A5, models 14-17). For expressing ratios of mortality rates at different states we used relative risks, $RR_s(a,g,s)$ for each state *s* at age *a* and gender *g;* these were calculated as the mortality rate for a particular state *s*, divided by the mortality rate of the reference level state which here was chosen as the state described by those that are not sick and not disabled, i.e. s= $\overline{S}\overline{D}$ (or transition number 6 as showed in table 4).

$$RR_s(a,g,c) = \frac{m_s(a,g,c)}{m_{s_{refference}}(a,g,c)} \quad (11)$$

Then, the calibrated mortality rates for country *c* and the reference state s= $\overline{S}\overline{D}$ is:

$$m_{s_{refference}}(a,g,c) = \frac{m(a,g,c)}{\sum_s RR_s(a,g,c) \times p_s(a,g,c)} \quad (12)$$

And the calibrated mortality rates for country *c* and the states $s = (S\overline{D}, \overline{S}D, SD)$ are:

$$m_s(a,g,c) = RR_s(a,g,c) m_{s_{refference}}(a,g,c) \quad (13)$$

Figure 8 presents mortality rates estimates calibrated for some countries for men and women.

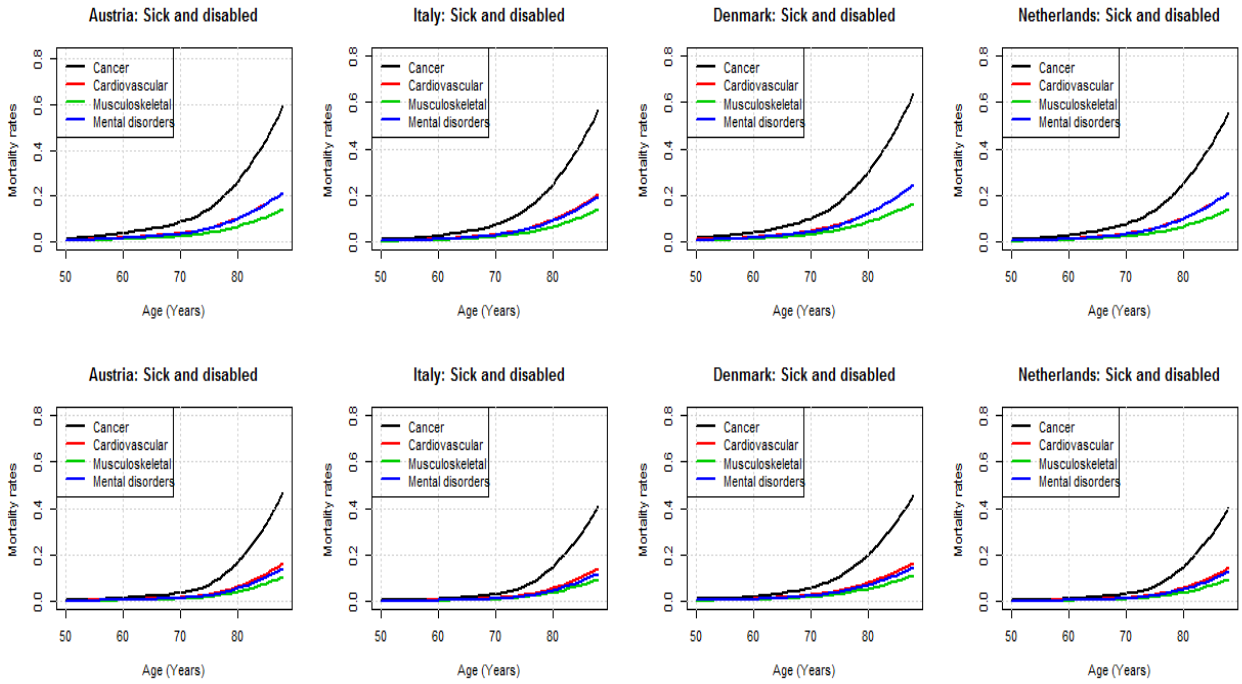

Figure 8: mortality rates calibrated by country for men (top) and women (bottom)

Markov model inputs

All of the above models were used to estimate the transition rate matrix (and consequently the transition probability matrix) of the Markov model. This is an important input for building the Markov model. Note that, as mentioned, a separate Markov model was built for each disease and country with transitions being also age and gender specific. The Markov model will have a cycle length of half a year. Furthermore, the initial cohort will consist of people healthy (not sick and not disabled) and active in the workforce (employed). It is worth mentioning that since a separate model is built for each disease, the state healthy (without one specific disease e.g. either cancer or cardiovascular diseases) indicates a different cohort for the four analysed diseases. The simulation model will be run starting with age 50 until the cohort reaches age 100, when the remaining survivors die, after being retired once they reached the official retirement age.

Markov model outputs

The simulation model produced the following outcomes:

- *Life expectancy (LE)* : the total number of years expected to be lived at a certain age
- *Disability-free life expectancy (DFLE)*: expected number of years to be lived free of disabilities at a certain age
- *Working life expectancy (WLE)*: the expected number of years in employment at a certain age
- *Rcp*: the ratio of the number of years paying contributions to those receiving a pension
- *The public payer cash benefit expenditures (PPCBE):* calculated by subtracting in each year the sum of entitlements (e.g. old-age pensions, disability pensions) from that of contributions. This outcome is estimated by attaching a monetary value of either contributions or entitlements to each state defined in a model: employed individuals are paying contributions, individuals with disability are receiving a disability insurance (DI) pension and those retired (after official retirement age) are receiving an old age pension. Table 5 shows the type of monetary value attached to each model state. In our analyses we have considered only pension contributions and we ignored, for example, contributions for unemployment (in this case, the underlying assumption is that contributions for unemployment equal to unemployment benefits). Monetary values for average pension contributions and average old-age pensions were derived from the 2015 Aging Report (17) and from Eurostat. The number of disability pensioners for each analysed country was not available in the above data sources, therefore, for estimating average disability pension for each analysed country, we assumed that the number of those receiving disability pensions equals the average reported for the EU-28, i.e. about 10% of the total number of pensioners. In the second consultation round, experts found this as a reasonable assumption. Details regarding monetary values calculation are included in Appendix A6. PPCBE will be calculated by subtracting, in each year, the sum of disability and old-age entitlements from the sum of pension contributions paid by those working. This outcome will be obtained in various scenarios as detailed in what follows.
- *Rcp€*: the ratio of total paid contributions to total pension benefits received at an individual level.[7]

[7] Note that estimating the ratio of total paid contributions to total pension benefits at a system level would require a large number of complex calculations for each country separately in order to approximate the number of individuals in each state (e.g. taking into account the populations

Table 5: Monetary values assigned to each model state

Model state	Before official retirement age	After official retirement age
$\bar{S}\bar{D}E$	Pension contributions	Pension contributions
$\bar{S}\bar{D}\bar{E}$	-	Old-age pension
$S\bar{D}E$	Pension contributions	Pension contributions
$S\bar{D}\bar{E}$	-	Old-age pension
$\bar{S}DE$	Pension contributions	Pension contributions
$\bar{S}D\bar{E}$	Disability insurance	Old-age pension
SDE	Pension contributions	Pension contributions
$SD\bar{E}$	Disability insurance	Old-age pension
Death	0	0

Markov model uncertainty: probability sensitivity analysis (PSA)

In order to assess the uncertainty resulting from epidemiologic input data (i.e. estimated incidences) we performed a probability sensitivity analysis (PSA) by simulating the Markov model for a large number of times, e.g. 1000 times. PSA can be performed in various ways: the straightforward approach in this case would be to bootstrap either the regression coefficients or residuals of the estimated models. However, bootstrapping 17 models simultaneously would result in large computer burden. An alternative solution would be to assume a distribution for the transition probabilities instead of bootstrapping the incidences. Therefore, we assumed the transition probabilities follow a Dirichlet distribution which is a multivariate generalization of the beta distribution (i.e. when more than two transitions are possible from one state):

$$P_i \sim Dirichlet(n_i P_i), \quad (14)$$

where n_i denotes the expected number of events used in Poisson regressions (for each age, gender, disease and country) and P_i is a vector of transition probabilities from state *i* to other states. Note that, the smaller the sample size used (n_i), the higher the uncertainty produced will be.

Implementation

The statistical analyses (i.e. estimation of transition incidences and Markov model simulations) as well as the PSA were programmed in the open source software R which can be run on all software platforms (Windows, Apple, Linux). Given the large number of models that needed to be fitted to estimate the incidence matrix as well as the fact that this transition was age, gender, country and disease specific, programming such a model in Excel (which is not developed for these type of calculations) will quickly become cumbersome. Besides developing a full model in R with the option to conduct PSA developed, a model in Excel in which users can easily carry out scenario analysis as well as run a PSA was developed. Note that, in order to run this model in Excel some simplifications were imposed (e.g. a smaller number of PSA simulations can be

structure, number of those in the state healthy or not-sick and not-disabled and employed for each country). This is beyond the scope of this project and has not been reported here.

run in Excel compared to R). This model is submitted as an attachment to the present document.

Results

Base-case scenario

In the baseline scenario, the model was run with the default transition probabilities estimated using the SHARE data. Furthermore, we assumed everybody was retired after the official retirement age (as reported in (17)) was reached in each of the nine European countries analysed. The starting cohort of the model was that of the disease-free, disability-free and working population at age 50. Note that disease-free indicates without the disease modelled, e.g. for the model with cancer, disease-free indicated without cancer but does not exclude the possibility of other diseases. Therefore, the population cohort is different for the four diseases.

Table 6 presents the outcome results (i.e. LE, DFLE, WLE, PPCBE, Rcp, Rcp€) for each of the nine EU countries by disease and gender. Results indicate that there are some differences between LE as reported in the Human Morality Database for year 2009 and those obtained with our model for the four diseases. One reason for this is that different mortality rates are experienced by each disease. We observed that, for musculoskeletal and mental health problems mortality estimates from calibration tend to be similar to those of the general population. However, for more fatal diseases such as cancer, calibrated mortality values are higher than those of the general population. Table 6 shows that, for the analysed countries, compared to men, women live longer lives, but spend less years free of disabilities and less years in employment. Note that PPCBE as calculated here is negative because we accounted only for contributions of those aged above 50 and disregarded the contributions of the younger working population. Note that, for the remaining of this report, PPCBE should be viewed as a cost rather than a benefit.

Table 6: Outcome results baseline scenario

Country	Disease	Gender	LE	DFLE	WLE	PPCBE	Rcp	RcpE
Austria	muscu	men	28.74	11.89	9.19	-302530.19	0.47	0.14
Austria	muscu	women	33.37	9.8	8.93	-417600.88	0.37	0.1
Austria	cancer	men	26.56	11.19	9.14	-266542.71	0.52	0.15
Austria	cancer	women	31.47	9,00	8.89	-383461.61	0.39	0.11
Austria	cardio	men	27.71	11.55	9.16	-285693.65	0.49	0.14
Austria	cardio	women	32.67	8.92	8.89	-406873.88	0.37	0.1
Austria	mh	men	27.73	12.94	9.2	-275324.07	0.5	0.15
Austria	mh	women	33,00	11.05	8.96	-407117.65	0.37	0.1
Belgium	muscu	men	28.11	10.21	9.03	-280952.2	0.47	0.16
Belgium	muscu	women	32.8	8.23	8.75	-389925.84	0.36	0.12
Belgium	cancer	men	26.26	9.53	8.99	-256244.55	0.52	0.17
Belgium	cancer	women	31.04	7.47	8.71	-368176.83	0.39	0.12
Belgium	cardio	men	27.38	9.69	9,00	-273476.52	0.49	0.16
Belgium	cardio	women	32.29	7.25	8.7	-391742.47	0.37	0.12
Belgium	mh	men	27.48	10.65	9.04	-265286.44	0.49	0.17
Belgium	mh	women	32.73	8.82	8.76	-382093.97	0.37	0.12

Denmark	muscu	men	26.99	12.51	10.96	-351847.79	0.68	0.16
Denmark	muscu	women	30.58	10.39	10.86	-469600.85	0.55	0.12
Denmark	cancer	men	25.28	11.86	10.9	-314556.47	0.76	0.18
Denmark	cancer	women	28.86	9.62	10.82	-433972.26	0.6	0.13
Denmark	cardio	men	26.36	12.14	10.92	-339705.63	0.71	0.17
Denmark	cardio	women	30.16	9.46	10.81	-469239.5	0.56	0.12
Denmark	mh	men	26.34	12.95	10.96	-330267.12	0.71	0.17
Denmark	mh	women	30.4	11.05	10.88	-457803.82	0.56	0.13
France	muscu	men	28.77	11.48	9.38	-222769.36	0.48	0.23
France	muscu	women	34.56	9.45	9.18	-334118.31	0.36	0.16
France	cancer	men	26.9	10.49	9.32	-201769.6	0.53	0.24
France	cancer	women	32.73	8.38	9.13	-314936.37	0.39	0.17
France	cardio	men	28.22	10.84	9.34	-219360.85	0.49	0.23
France	cardio	women	34.17	8.3	9.13	-337806.33	0.36	0.16
France	mh	men	28.35	11.87	9.38	-212968.74	0.49	0.24
France	mh	women	34.69	10.04	9.2	-331115.39	0.36	0.16
Germany	muscu	men	28.16	9.98	10.6	-179475.61	0.6	0.27
Germany	muscu	women	32.84	8.03	10.49	-259206.56	0.47	0.2
Germany	cancer	men	26.01	9.42	10.54	-156261.21	0.68	0.29
Germany	cancer	women	30.85	7.38	10.45	-238431.54	0.51	0.21
Germany	cardio	men	27.25	9.63	10.55	-170306.5	0.63	0.28
Germany	cardio	women	32.2	7.22	10.44	-257029.39	0.48	0.2
Germany	mh	men	27.4	10.86	10.61	-163284.66	0.63	0.29
Germany	mh	women	32.7	9.04	10.52	-249622.4	0.47	0.21
Italy	muscu	men	29.33	10.4	8.89	-202583.68	0.43	0.21
Italy	muscu	women	34.05	8.33	8.54	-292510.61	0.33	0.15
Italy	cancer	men	27.55	9.38	8.84	-184227.57	0.47	0.23
Italy	cancer	women	32.34	7.27	8.5	-272456.33	0.36	0.16
Italy	cardio	men	28.74	9.75	8.86	-198418.52	0.45	0.22
Italy	cardio	women	33.59	7.24	8.5	-290026.75	0.34	0.15
Italy	mh	men	28.83	10.88	8.9	-192782.32	0.45	0.22
Italy	mh	women	34.11	8.96	8.56	-291129.24	0.34	0.15
Netherlands	muscu	men	29.45	12.11	10.21	-320281.37	0.53	0.13
Netherlands	muscu	women	34.04	9.91	9.98	-433506.21	0.41	0.1
Netherlands	cancer	men	27.18	12.02	10.17	-281521.51	0.6	0.14
Netherlands	cancer	women	31.81	9.66	9.95	-397040.45	0.46	0.1
Netherlands	cardio	men	28.55	12.17	10.19	-304075.97	0.55	0.13
Netherlands	cardio	women	33.38	9.37	9.95	-427643.96	0.42	0.1
Netherlands	mh	men	28.58	12.92	10.22	-296187.49	0.56	0.14
Netherlands	mh	women	33.72	10.9	10.01	-416630.87	0.42	0.1
Spain	muscu	men	28.77	10.8	9.59	-195431.37	0.5	0.22
Spain	muscu	women	34.57	8.78	9.37	-289912.39	0.37	0.16
Spain	cancer	men	26.85	9.6	9.53	-176959.3	0.55	0.24
Spain	cancer	women	32.76	7.55	9.32	-273961.68	0.4	0.17

Spain	cardio	men	28.1	9.98	9.54	-191444.05	0.51	0.23
Spain	cardio	women	34.11	7.51	9.32	-292310.1	0.38	0.16
Spain	mh	men	28.15	11.38	9.6	-183644.16	0.52	0.23
Spain	mh	women	34.57	9.53	9.4	-284929.89	0.37	0.16
Sweden	muscu	men	28.91	11.18	12.99	-253775.89	0.82	0.23
Sweden	muscu	women	34.62	9.14	13.21	-378044.13	0.62	0.17
Sweden	cancer	men	26.48	11.03	12.92	-209648.84	0.95	0.27
Sweden	cancer	women	32.27	8.86	13.18	-335217.54	0.69	0.19
Sweden	cardio	men	27.94	11.34	12.95	-234760.94	0.86	0.25
Sweden	cardio	women	33.92	8.72	13.17	-367966.56	0.63	0.18
Sweden	mh	men	27.96	12.04	12.99	-228993.5	0.87	0.25
Sweden	mh	women	34.25	10.18	13.25	-362614.59	0.63	0.18

* muscu indicates musculoskeletal disease, mh indicates mental disorders, cardio indicates cardiovascular disease

Alternative scenarios

Further we will illustrate various alternative scenarios compared to the baseline scenario. We performed alternative scenarios from both an epidemiological point of view (e.g. decreasing disease incidences) as well as from a public policy perspective (e.g. increasing the official retirement age). In addition, combination scenarios were also performed (e.g. changes in disease incidence together with changes in official regiment age). All the hypothetical scenarios presented in this report used value changes (e.g. percentage of disease incidence) that were chosen arbitrarily.

Epidemiological scenarios

Epidemiological scenarios were performed by decreasing disease incidence as well as disability incidence.

a) Decreasing disease incidence

Table 7 shows relative changes (percentage changes compared to the base-case scenario) when assuming that disease incidence would decrease by 30%. We observed the following:

- LE increases for all diseases and countries
- For all diseases and countries, years spend free of disability and not sick (DFLE1) increase whereas years spent free of disability and sick (DFLE2) decrease. By adding the two states we calculated the total years spent free of disability (DFLE): we observed that for some diseases the DFLE decreases (mental disorders as well as musculoskeletal diseases) whereas for others DFLE increases (cancer and cardiovascular diseases).
- Changes in WLE are small but for some diseases, especially those with higher prevalence (e.g. mental and musculoskeletal disease) slight increases are observed.
- PPCBE increases. This is to be expected given that people leave longer but they do not work longer as indicated by WLE.
- Changes in Rcp and Rcp€ are negative (decreases) which is to be expected since PPCBE increases.

Table 7: Relative changes (%) in outcomes when disease incidence decreases by 30%

Country	Disease	Gender	LE	DFLE	DFLE1	DFLE2	WLE	PPCBE	Rcp	Rcp€
Austria	muscu	men	0.52	0.25	4.95	-25.84	0	0.87	0	0
Austria	muscu	women	0.36	0.31	7.15	-24.64	0	0.54	-2.7	0
Austria	cancer	men	0.79	-0.63	1.14	-29.41	0	1.62	0	0
Austria	cancer	women	0.73	-0.78	1.07	-29.09	0	1.21	0	0
Austria	cardio	men	0.83	-0.17	4.15	-25.9	0	1.64	0	0
Austria	cardio	women	0.73	-0.11	2.05	-26.98	0	1.13	0	0
Austria	mh	men	0.47	0.39	14.96	-20.53	0	0.79	-2	0
Austria	mh	women	0.18	0.36	19.16	-17.81	0	0.25	0	0
Belgium	muscu	men	0.46	0.39	7.44	-24.23	0	0.73	0	0
Belgium	muscu	women	0.21	0.36	10.53	-22.22	0	0.21	0	0
Belgium	cancer	men	0.99	-0.73	1.12	-29.51	0	1.92	-1.92	0
Belgium	cancer	women	0.93	-0.94	1	-29.79	0	1.53	0	0
Belgium	cardio	men	0.84	-0.21	3.8	-26.77	0	1.57	-2.04	0
Belgium	cardio	women	0.71	-0.14	1.62	-27.27	0	1.08	0	0
Belgium	mh	men	0.4	0.38	14.99	-20.37	0	0.6	0	0
Belgium	mh	women	0.12	0.45	18.96	-18.22	0.11	0.1	0	0
Denmark	muscu	men	0.52	0.48	8.1	-23.67	0.09	0.98	0	0
Denmark	muscu	women	0.33	0.48	11.37	-21.51	0.09	0.46	0	0
Denmark	cancer	men	0.95	-0.84	1.75	-28.28	0	2.14	-1.32	-5.56
Denmark	cancer	women	1	-1.04	1.59	-28.4	0	1.94	-1.67	0
Denmark	cardio	men	0.83	-0.16	4.6	-25.39	0	1.83	-1.41	-5.88
Denmark	cardio	women	0.8	-0.11	2.3	-28.57	0	1.39	-1.79	0
Denmark	mh	men	0.46	0.39	15.31	-20.22	0	0.9	0	0
Denmark	mh	women	0.23	0.45	19.33	-17.64	0.09	0.3	0	0
France	muscu	men	0.42	0.44	9.86	-22.26	0	0.75	0	0
France	muscu	women	0.14	0.53	13.61	-19.89	0	0.11	0	0
France	cancer	men	1.04	-0.86	1.34	-29.49	0	2.36	-1.89	0
France	cancer	women	0.98	-0.95	1.29	-29.03	0	1.73	-2.56	0
France	cardio	men	0.85	-0.18	4.08	-26.14	0	1.82	0	0
France	cardio	women	0.7	-0.12	1.81	-28.07	0	1.15	0	0
France	mh	men	0.35	0.42	17.46	-18.85	0.11	0.59	0	0
France	mh	women	0.09	0.4	21.54	-16.34	0	0.04	0	0
Germany	muscu	men	0.5	0.3	5.86	-25.14	0	0.92	0	0
Germany	muscu	women	0.27	0.37	8.49	-23.65	0	0.33	0	0
Germany	cancer	men	1.27	-1.06	1.51	-27.85	0	3	-1.47	0
Germany	cancer	women	1.17	-1.22	1.48	-29.03	0	2.19	-1.96	0
Germany	cardio	men	0.88	-0.21	4.1	-26.32	0	1.92	-1.59	-3.57
Germany	cardio	women	0.71	-0.14	1.78	-28.26	0	1.22	-2.08	0
Germany	mh	men	0.33	0.46	17.66	-18.87	0.09	0.55	0	0
Germany	mh	women	0.09	0.44	21.72	-16.14	0.1	0.03	0	0
Italy	muscu	men	0.38	0.38	9.32	-22.84	0	0.67	0	0
Italy	muscu	women	0.12	0.48	12.79	-20.39	0	0.16	0	0
Italy	cancer	men	0.87	-0.64	1.01	-30.61	0	1.9	0	0

Italy	cancer	women	0.8	-0.69	0.87	-27.78	0	1.36	-2.78	0
Italy	cardio	men	0.84	-0.21	3.78	-26.56	0	1.78	-2.22	-4.55
Italy	cardio	women	0.68	-0.14	1.76	-29.55	0	1.17	0	0
Italy	mh	men	0.31	0.46	16.95	-19.28	0	0.52	-2.22	0
Italy	mh	women	0.09	0.45	21.08	-16.8	0	0.1	-2.94	0
Netherlands	muscu	men	0.48	0.33	6.08	-25	0	0.78	0	0
Netherlands	muscu	women	0.29	0.4	8.73	-23.64	0	0.35	0	0
Netherlands	cancer	men	1.1	-1.08	1.94	-27.87	0	2.13	-1.67	0
Netherlands	cancer	women	1.07	-1.35	1.73	-28.57	0	1.76	-2.17	0
Netherlands	cardio	men	0.84	-0.16	4.83	-25.62	0	1.51	0	0
Netherlands	cardio	women	0.72	-0.21	2.33	-26.92	0	1.06	0	0
Netherlands	mh	men	0.42	0.39	15.04	-20.41	0	0.66	-1.79	0
Netherlands	mh	women	0.18	0.37	19.04	-17.85	0	0.13	0	0
Spain	muscu	men	0.45	0.46	8.22	-23.68	0	0.82	0	0
Spain	muscu	women	0.14	0.57	11.49	-21.36	0	0.15	0	0
Spain	cancer	men	0.82	-0.63	0.88	-30	0	1.83	-1.82	0
Spain	cancer	women	0.76	-0.79	0.7	-28.21	0	1.33	-2.5	-5.88
Spain	cardio	men	0.85	-0.2	3.54	-26.45	0	1.8	0	-4.35
Spain	cardio	women	0.7	-0.13	1.55	-30.23	0	1.14	-2.63	0
Spain	mh	men	0.39	0.44	15.69	-19.88	0	0.69	-1.92	0
Spain	mh	women	0.12	0.42	19.87	-17.58	0	0.07	0	0
Sweden	muscu	men	0.48	0.36	5.58	-25.81	0	1.04	-1.22	0
Sweden	muscu	women	0.29	0.44	8.02	-24.07	0	0.42	-1.61	0
Sweden	cancer	men	1.25	-1.18	2.03	-28.45	0	3.36	-2.11	-3.7
Sweden	cancer	women	1.15	-1.47	1.77	-28.72	0	2.39	-1.45	0
Sweden	cardio	men	0.86	-0.18	4.87	-25.26	0	2.06	-1.16	-4
Sweden	cardio	women	0.68	-0.11	2.38	-27.4	0	1.26	0	-5.56
Sweden	mh	men	0.46	0.42	14.58	-20.82	0.08	0.91	-1.15	0
Sweden	mh	women	0.15	0.39	18.6	-18.33	0	0.14	0	0

* muscu indicates musculoskeletal disease, mh indicates mental disorders, cardio indicates cardiovascular disease

b) Decreasing disability incidence

Table 8 illustrates relative changes (compared to the base-case scenario) of the considered outcomes when disability incidences is assumed to decrease by 30%. We observed that, compared to changes in disease incidences, changes in disability incidence have a stronger impact on all outcomes. In general, for all countries and diseases, LE, DFLE, WLE increase whereas the cost indicated by PPCBE and Rcp decreases. Rcp€ tends to either remain unchanged or increase but there are large differences by countries, gender and diseases.

Table 8: Relative changes (%) in outcomes when disability incidence decreases by 30%

Country	Disease	Gender	LE	DFLE	WLE	PPCBE	Rcp	Rcp€
Austria	muscu	men	1.4	21	0.5	-2.3	-2.1	0
Austria	muscu	women	0.5	24.6	0.6	-0.5	0	0
Austria	cancer	men	1.6	22.3	0.7	-2.7	0	6.7

Austria	cancer	women	0.5	26.4	0.7	-0.6	0	0
Austria	cardio	men	1.4	21.6	0.5	-2.7	0	7.1
Austria	cardio	women	0.5	26.2	0.7	-0.7	0	0
Austria	mh	men	1.5	18.9	0.4	-2	-2	0
Austria	mh	women	0.6	22.4	0.6	-0.2	0	0
Belgium	muscu	men	1.2	22.6	0.7	-4.5	0	6.3
Belgium	muscu	women	0.4	25.9	0.7	-4.9	0	0
Belgium	cancer	men	1.4	24.3	0.7	-5	0	5.9
Belgium	cancer	women	0.5	28.4	0.8	-5	0	8.3
Belgium	cardio	men	1.1	23.7	0.7	-5	0	6.3
Belgium	cardio	women	0.4	28.1	0.8	-4.8	0	0
Belgium	mh	men	1.2	21.3	0.6	-4.6	0	5.9
Belgium	mh	women	0.5	24.6	0.7	-4.8	0	8.3
Denmark	muscu	men	1.7	19.7	0.7	-1.6	-1.5	0
Denmark	muscu	women	0.9	23.3	0.8	-3.1	0	8.3
Denmark	cancer	men	1.9	20.9	0.7	-1.8	-2.6	0
Denmark	cancer	women	1.1	25.5	0.7	-3.4	0	7.7
Denmark	cardio	men	1.6	20.4	0.6	-2.1	-1.4	0
Denmark	cardio	women	0.9	25.2	0.8	-3.5	0	8.3
Denmark	mh	men	1.6	18.3	0.6	-1.7	-1.4	0
Denmark	mh	women	1	21.8	0.7	-3	0	0
France	muscu	men	1.4	21.2	0.6	-3.9	0	4.3
France	muscu	women	0.5	24.8	0.7	-4.6	0	6.3
France	cancer	men	1.6	23.4	0.8	-4.5	-1.9	4.2
France	cancer	women	0.5	27.6	0.8	-4.8	0	5.9
France	cardio	men	1.3	22.6	0.6	-4.4	0	4.3
France	cardio	women	0.4	27.1	0.8	-4.6	2.8	6.3
France	mh	men	1.3	20.1	0.6	-4	0	0
France	mh	women	0.5	23.5	0.7	-4.5	0	6.3
Germany	muscu	men	1.2	22.9	0.8	-5.6	0	3.7
Germany	muscu	women	0.4	26.4	0.8	-5.4	0	5
Germany	cancer	men	1.5	24.7	0.8	-6.1	-1.5	6.9
Germany	cancer	women	0.5	28.9	0.8	-5.6	0	4.8
Germany	cardio	men	1.2	23.9	0.9	-6	0	3.6
Germany	cardio	women	0.3	28.1	0.8	-5.3	0	5
Germany	mh	men	1.2	21	0.8	-5.7	0	3.4
Germany	mh	women	0.4	24.3	0.8	-5.6	2.1	4.8
Italy	muscu	men	1	22.7	0.6	-3.8	0	4.8
Italy	muscu	women	0.3	26.1	0.7	-1.7	3	6.7
Italy	cancer	men	1.1	24.9	0.7	-4.3	0	4.3
Italy	cancer	women	0.3	28.6	0.7	-1.9	0	6.3
Italy	cardio	men	0.9	24.2	0.6	-4.2	-2.2	4.5
Italy	cardio	women	0.3	28.3	0.7	-1.8	0	6.7
Italy	mh	men	1	21.5	0.6	-3.8	-2.2	4.5
Italy	mh	women	0.4	24.7	0.7	-1.5	0	6.7
Netherlands	muscu	men	1.3	21.1	0.6	-3.8	0	0

Netherlands	muscu	women	0.5	24.4	0.7	-4.7	2.4	0
Netherlands	cancer	men	1.7	21.9	0.7	-3.9	-1.7	7.1
Netherlands	cancer	women	0.7	26.4	0.8	-4.9	0	10
Netherlands	cardio	men	1.3	21.4	0.6	-4	0	7.7
Netherlands	cardio	women	0.5	25.9	0.7	-4.8	2.4	0
Netherlands	mh	men	1.3	19.3	0.5	-3.6	-1.8	0
Netherlands	mh	women	0.5	22.7	0.6	-4.5	0	0
Spain	muscu	men	1.3	22.1	0.6	-3.4	0	4.5
Spain	muscu	women	0.3	25.7	0.7	-4.2	0	6.3
Spain	cancer	men	1.3	24.4	0.6	-4.2	-1.8	4.2
Spain	cancer	women	0.3	28.3	0.8	-4.4	0	0
Spain	cardio	men	1.1	23.6	0.7	-4	0	0
Spain	cardio	women	0.3	28.1	0.8	-4.2	0	0
Spain	mh	men	1.2	20.7	0.5	-3.4	-1.9	4.3
Spain	mh	women	0.3	24.1	0.6	-4.1	2.7	6.3
Sweden	muscu	men	1.3	21.8	0.8	-3.8	-1.2	4.3
Sweden	muscu	women	0.3	25.4	0.8	-4.2	0	5.9
Sweden	cancer	men	1.7	22.9	0.9	-3.9	-1.1	3.7
Sweden	cancer	women	0.5	27.5	0.8	-4.4	0	5.3
Sweden	cardio	men	1.4	22	0.8	-4	-1.2	4
Sweden	cardio	women	0.4	26.8	0.8	-4.3	1.6	0
Sweden	mh	men	1.4	19.9	0.8	-3.9	-1.1	4
Sweden	mh	women	0.4	23.5	0.8	-4.3	0	5.6

* muscu indicates musculoskeletal disease, mh indicates mental disorders, cardio indicates cardiovascular disease

Public policy scenarios

In public policy scenarios we performed analyses assuming that the official retirement age increases with a number of years and that disability insurance pensions decreases with a certain percentage.

a) Increasing official retirement age

By increasing official retirement age, two effects should be noticed:

- A substitution effect: those disabled will substitute from the old-age pensions to disability pensions
- A contribution effect: those healthy (free of disease) would work longer therefore contributing to the public system for longer.

Table 9 presents relative changes in PPCBE (%) when official retirement age is increased from one to 10 years. We noticed that, depending on country, gender, disease, the number of years that the official retirement age is increased with, PPCBE cost can either increase or decrease but mostly would increase. This is because the substitution effect is much stronger than the contribution effect. We observe that the results depend also on what the official retirement age was in a particular country. For example, in Austria for women official retirement age is 60 years; in this case increasing official retirement age would result in decreasing costs for the public payer.

On the other hand, in Sweden, the official retirement age is 67 for both men and women and further increases in the official retirement age are likely to result in more costs for the public payer. Relative changes in Rcp, Rcp€ as well as WLE are presented in Appendix A7 (table (i), table (ii) and table (iii), respectively.

Table 9: Relative changes in PPCBE (%) when official retirement age is increased

Country	Disease	Gender	Increasing official retirement age (number of years)									
			1	2	3	4	5	6	7	8	9	10
Austria	muscu	men	-0.8	-1.3	-1.6	-1.5	-1.3	-0.8	-0.2	0.6	1.5	2.5
Austria	muscu	women	-0.9	-2.2	-3.9	-5.8	-7.9	-9.8	-11.6	-13.1	-14.6	-15.8
Austria	cancer	men	-0.5	-0.8	-0.8	-0.5	0	0.6	1.4	2.3	3.3	4.3
Austria	cancer	women	-0.8	-2	-3.7	-5.7	-7.8	-9.8	-11.7	-13.4	-14.9	-16.4
Austria	cardio	men	-0.7	-1.1	-1.3	-1.2	-0.8	-0.3	0.4	1.2	2.1	3.1
Austria	cardio	women	-0.7	-1.9	-3.5	-5.4	-7.3	-9.2	-10.9	-12.5	-13.9	-15.3
Austria	mh	men	-1.4	-2.5	-3.3	-3.7	-3.9	-3.8	-3.4	-2.9	-2.3	-1.5
Austria	mh	women	-1.1	-2.7	-4.6	-6.8	-9.1	-11.3	-13.2	-15	-16.5	-17.9
Belgium	muscu	men	1.4	3	5	7.1	9.5	12	14.6	17.3	20	22.7
Belgium	muscu	women	2	4.1	6.4	8.8	11.3	13.8	16.4	19.1	21.7	24.3
Belgium	cancer	men	1.9	4	6.4	8.9	11.6	14.4	17.2	20	22.7	25.4
Belgium	cancer	women	2.3	4.8	7.3	10	12.7	15.4	18.1	20.9	23.6	26.3
Belgium	cardio	men	1.7	3.6	5.7	8.1	10.6	13.2	15.9	18.6	21.4	24.1
Belgium	cardio	women	2.2	4.6	7.1	9.7	12.3	14.9	17.6	20.2	22.9	25.5
Belgium	mh	men	1.2	2.7	4.5	6.6	8.9	11.4	14.1	16.7	19.5	22.2
Belgium	mh	women	1.8	3.8	6	8.3	10.7	13.3	15.8	18.5	21.1	23.7
Denmark	muscu	men	0.1	0.2	0.4	0.9	1.7	2.8	4.1	5.6	7.2	8.8
Denmark	muscu	women	1.2	2.4	3.6	5.1	6.7	8.5	10.4	12.4	14.4	16.4
Denmark	cancer	men	0.6	1	1.6	2.4	3.5	4.8	6.2	7.7	9.3	10.7
Denmark	cancer	women	1.7	3.3	4.9	6.6	8.5	10.5	12.5	14.6	16.6	18.6
Denmark	cardio	men	0.3	0.5	0.9	1.5	2.5	3.6	5	6.5	8	9.6
Denmark	cardio	women	1.6	3.1	4.7	6.4	8.2	10.2	12.2	14.3	16.3	18.4
Denmark	mh	men	-0.2	-0.4	-0.5	-0.2	0.4	1.3	2.5	3.9	5.4	7
Denmark	mh	women	1	1.9	2.9	4.2	5.7	7.3	9.1	11.1	13	15.1
France	muscu	men	-0.2	0	0.4	1.1	2	3.1	4.4	5.8	7.2	8.7
France	muscu	women	0.7	1.6	2.7	3.9	5.2	6.6	8.1	9.6	11.2	12.8
France	cancer	men	0.4	1	1.9	2.9	4.2	5.5	7	8.5	10.1	11.6
France	cancer	women	1.1	2.3	3.7	5.1	6.6	8.2	9.8	11.4	13.1	14.7
France	cardio	men	0.1	0.5	1.2	2.1	3.2	4.4	5.8	7.2	8.7	10.2
France	cardio	women	1	2.2	3.5	4.9	6.4	7.9	9.4	11	12.6	14.2
France	mh	men	-0.4	-0.4	-0.1	0.5	1.3	2.3	3.5	4.9	6.3	7.8
France	mh	women	0.6	1.3	2.3	3.4	4.6	6	7.4	8.9	10.4	12
Germany	muscu	men	0	5.2	5.2	11.3	11.3	18	18	24.9	24.9	31.6
Germany	muscu	women	0	5.7	5.7	11.9	11.9	18.3	18.3	24.7	24.7	31
Germany	cancer	men	0	6.4	6.4	13.4	13.4	20.7	20.7	27.8	27.8	34.3
Germany	cancer	women	0	6.5	6.5	13.2	13.2	20.1	20.1	26.8	26.8	33.2
Germany	cardio	men	0	5.7	5.7	12.1	12.1	19	19	26	26	32.6
Germany	cardio	women	0	6.2	6.2	12.7	12.7	19.2	19.2	25.7	25.7	32
Germany	mh	men	0	4.5	4.5	10.1	10.1	16.6	16.6	23.5	23.5	30.2

Germany	mh	women	0	5.2	5.2	11.1	11.1	17.4	17.4	23.8	23.8	30.2
Italy	muscu	men	-2	-2	-3.2	-3.2	-3.7	-3.7	-3.7	-3.7	-3.4	-3.4
Italy	muscu	women	-2.1	-2.1	-4.6	-4.6	-6.7	-6.7	-8.4	-8.4	-9.8	-9.8
Italy	cancer	men	-1.5	-1.5	-2.3	-2.3	-2.5	-2.5	-2.3	-2.3	-2	-2
Italy	cancer	women	-1.7	-1.7	-3.9	-3.9	-5.9	-5.9	-7.5	-7.5	-9	-9
Italy	cardio	men	-1.7	-1.7	-2.5	-2.5	-2.9	-2.9	-2.8	-2.8	-2.5	-2.5
Italy	cardio	women	-1.6	-1.6	-3.7	-3.7	-5.5	-5.5	-7	-7	-8.3	-8.3
Italy	mh	men	-2.5	-2.5	-3.9	-3.9	-4.6	-4.6	-4.8	-4.8	-4.6	-4.6
Italy	mh	women	-2.4	-2.4	-5.2	-5.2	-7.5	-7.5	-9.3	-9.3	-10.8	-10.8
Netherlands	muscu	men	1.8	3.7	6	8.7	11.6	14.8	18.2	21.7	25.3	28.9
Netherlands	muscu	women	2.5	5.2	8.1	11.2	14.5	17.9	21.5	25.1	28.8	32.5
Netherlands	cancer	men	2.1	4.4	7.1	10	13.1	16.5	19.9	23.5	27	30.5
Netherlands	cancer	women	2.9	5.9	9.1	12.5	16	19.7	23.4	27.2	31	34.8
Netherlands	cardio	men	1.8	3.8	6.1	8.7	11.6	14.8	18.1	21.5	25	28.6
Netherlands	cardio	women	2.8	5.7	8.7	12	15.5	19	22.7	26.4	30.1	33.8
Netherlands	mh	men	1.3	2.9	4.9	7.2	9.9	12.9	16.1	19.5	23	26.6
Netherlands	mh	women	2.2	4.5	7.1	10	13.1	16.4	19.9	23.5	27.2	30.9
Spain	muscu	men	0.1	0.5	1.2	2.1	3.3	4.6	6.1	7.7	9.4	11.1
Spain	muscu	women	1	2.1	3.3	4.8	6.3	7.9	9.6	11.4	13.1	14.9
Spain	cancer	men	0.8	1.9	3.1	4.6	6.3	8	9.9	11.8	13.7	15.5
Spain	cancer	women	1.4	3	4.6	6.3	8.1	10	11.8	13.7	15.6	17.5
Spain	cardio	men	0.6	1.3	2.3	3.6	5	6.5	8.2	10	11.7	13.5
Spain	cardio	women	1.4	2.8	4.3	6	7.7	9.4	11.2	13.1	14.9	16.7
Spain	mh	men	-0.2	-0.1	0.3	1	2	3.3	4.7	6.2	7.8	9.5
Spain	mh	women	0.8	1.7	2.8	4	5.4	7	8.6	10.3	12	13.8
Sweden	muscu	men	2.5	4.8	7.1	9.5	12.2	15	17.8	20.6	23.4	26.1
Sweden	muscu	women	2.8	5.3	7.7	10.2	12.8	15.5	18.2	20.9	23.6	26.2
Sweden	cancer	men	3	5.6	8.2	10.8	13.5	16.3	19	21.6	24.1	26.3
Sweden	cancer	women	3.2	6	8.7	11.4	14.1	16.9	19.7	22.5	25.2	27.8
Sweden	cardio	men	2.5	4.7	6.9	9.3	11.9	14.5	17.2	20	22.6	25.1
Sweden	cardio	women	2.9	5.6	8.2	10.8	13.4	16.1	18.9	21.6	24.2	26.9
Sweden	mh	men	2.2	4.1	6.1	8.4	10.9	13.5	16.3	19	21.8	24.5
Sweden	mh	women	2.5	4.8	7.1	9.5	12	14.6	17.3	20	22.8	25.4

* muscu indicates musculoskeletal disease, mh indicates mental disorders, cardio indicates cardiovascular disease

b) Decreasing disability pensions

Table 10 presents relative changes (%) to the base-case scenario when disability pensions are assumed to decrease by 20%. We observe that for all countries and diseases, PPCBE decreases between 1% and 8% whereas Rcp€ increases up to about 7% for some countries.

Table 10: Relative changes (%) in PPCBE, Rcp, Rcp€ when disability pensions are decreased by 20%

Country	Disease	Gender	PPCBE	Rcp€
Austria	muscu	men	-4.1	0
Austria	muscu	women	-0.8	0

Austria	cancer	men	-5	6.7
Austria	cancer	women	-1	0
Austria	cardio	men	-4.4	7.1
Austria	cardio	women	-0.9	0
Austria	mh	men	-3.9	0
Austria	mh	women	-0.7	0
Belgium	muscu	men	-6	6.3
Belgium	muscu	women	-5.8	0
Belgium	cancer	men	-7.1	5.9
Belgium	cancer	women	-6.7	8.3
Belgium	cardio	men	-6.5	6.3
Belgium	cardio	women	-6.3	0
Belgium	mh	men	-6	5.9
Belgium	mh	women	-5.6	8.3
Denmark	muscu	men	-4	6.3
Denmark	muscu	women	-4.2	8.3
Denmark	cancer	men	-4.9	0
Denmark	cancer	women	-5	7.7
Denmark	cardio	men	-4.3	0
Denmark	cardio	women	-4.6	8.3
Denmark	mh	men	-4	5.9
Denmark	mh	women	-4	0
France	muscu	men	-5.7	4.3
France	muscu	women	-5.3	6.3
France	cancer	men	-7	8.3
France	cancer	women	-6.2	5.9
France	cardio	men	-6.2	4.3
France	cardio	women	-5.8	6.3
France	mh	men	-5.7	4.2
France	mh	women	-5	6.3
Germany	muscu	men	-7.6	3.7
Germany	muscu	women	-7	5
Germany	cancer	men	-9.2	6.9
Germany	cancer	women	-8	9.5
Germany	cardio	men	-8.2	3.6
Germany	cardio	women	-7.4	5
Germany	mh	men	-7.5	3.4
Germany	mh	women	-6.6	4.8
Italy	muscu	men	-5.4	4.8
Italy	muscu	women	-1.8	6.7
Italy	cancer	men	-6.5	4.3
Italy	cancer	women	-2.2	6.3
Italy	cardio	men	-5.8	4.5
Italy	cardio	women	-2.1	6.7
Italy	mh	men	-5.3	4.5
Italy	mh	women	-1.7	6.7

Netherlands	muscu	men	-5	0
Netherlands	muscu	women	-5.1	0
Netherlands	cancer	men	-5.9	7.1
Netherlands	cancer	women	-5.8	10
Netherlands	cardio	men	-5.2	7.7
Netherlands	cardio	women	-5.4	0
Netherlands	mh	men	-4.8	0
Netherlands	mh	women	-4.8	0
Spain	muscu	men	-5	4.5
Spain	muscu	women	-4.7	6.3
Spain	cancer	men	-6.3	4.2
Spain	cancer	women	-5.6	0
Spain	cardio	men	-5.6	4.3
Spain	cardio	women	-5.2	0
Spain	mh	men	-5	4.3
Spain	mh	women	-4.4	6.3
Sweden	muscu	men	-5.9	4.3
Sweden	muscu	women	-5.2	5.9
Sweden	cancer	men	-7.3	3.7
Sweden	cancer	women	-6.1	5.3
Sweden	cardio	men	-6.2	4
Sweden	cardio	women	-5.5	0
Sweden	mh	men	-5.9	4
Sweden	mh	women	-5	5.6

* muscu indicates musculoskeletal disease, mh indicates mental disorders, cardio indicates cardiovascular diseases

Combination scenarios

Table 11 shows results of scenario analyses when the official retirement age was assumed to increase by 5 years and disability incidence was assumed to decrease by 30% for all countries. In this case, to some extent, the substitution effect is alleviated by the contribution effect. However, this depends both on country and disease. While the PPCBE cost decreases for some countries, it increases for others. Generally, Rcp and Rcp€ increase. The highest impact is observed for women (as they experience in general more disabilities and have earlier retirement age than men) and for Austria because official retirement age for women in Austria is 60 years, which is the earliest from all investigated countries.

Table 11: Relative changes (%) in when official retirement age is increased by 5 years and disability incidence is decreased by 30%

Country	Disease	Gender	LE	DFLE	WLE	PPCBE	Rcp	Rcp€
Austria	muscu	men	1.4	21	2	-8.7	0	7.1
Austria	muscu	women	0.5	24.6	18.1	-10.3	24.3	30
Austria	cancer	men	1.6	22.3	2	-8.2	1.9	13.3
Austria	cancer	women	0.5	26.4	18.3	-10.4	28.2	27.3
Austria	cardio	men	1.4	21.6	2	-8.8	2	14.3

Austria	cardio	women	0.5	26.2	18.3	-10	27	30
Austria	mh	men	1.5	18.9	2	-11.3	0	13.3
Austria	mh	women	0.6	22.4	18	-11.4	27	30
Belgium	muscu	men	1.2	22.6	1.9	-0.8	2.1	0
Belgium	muscu	women	0.4	25.9	1.8	2.9	2.8	0
Belgium	cancer	men	1.4	24.3	1.8	0.7	0	0
Belgium	cancer	women	0.5	28.4	1.8	4.4	2.6	0
Belgium	cardio	men	1.1	23.7	1.8	0	0	6.3
Belgium	cardio	women	0.4	28.1	1.8	4.5	2.7	-8.3
Belgium	mh	men	1.2	21.3	1.8	-1.8	0	0
Belgium	mh	women	0.5	24.6	1.9	2	0	0
Denmark	muscu	men	1.7	19.7	7.3	-6.6	10.3	12.5
Denmark	muscu	women	0.9	23.3	7.5	-1.3	10.9	8.3
Denmark	cancer	men	1.9	20.9	7.2	-5.5	9.2	5.6
Denmark	cancer	women	1.1	25.5	7.2	0.2	10	7.7
Denmark	cardio	men	1.6	20.4	7.1	-6.4	9.9	5.9
Denmark	cardio	women	0.9	25.2	7.2	0.2	10.7	8.3
Denmark	mh	men	1.6	18.3	7.2	-8.3	9.9	11.8
Denmark	mh	women	1	21.8	7.4	-2.4	8.9	7.7
France	muscu	men	1.4	21.2	1.1	-7.4	0	4.3
France	muscu	women	0.5	24.8	1.2	-2.7	2.8	6.3
France	cancer	men	1.6	23.4	1.2	-6	0	8.3
France	cancer	women	0.5	27.6	1.2	-1.3	0	0
France	cardio	men	1.3	22.6	1.1	-6.7	0	4.3
France	cardio	women	0.4	27.1	1.2	-1.2	2.8	0
France	mh	men	1.3	20.1	1.1	-8.5	0	4.2
France	mh	women	0.5	23.5	1.2	-3.5	0	6.3
Germany	muscu	men	1.2	22.9	3.6	0.2	5	0
Germany	muscu	women	0.4	26.4	3.7	3.4	4.3	0
Germany	cancer	men	1.5	24.7	3.5	1.5	2.9	3.4
Germany	cancer	women	0.5	28.9	3.6	4.7	5.9	0
Germany	cardio	men	1.2	23.9	3.6	0.5	4.8	0
Germany	cardio	women	0.3	28.1	3.6	4.7	4.2	0
Germany	mh	men	1.2	21	3.7	-1.8	4.8	3.4
Germany	mh	women	0.4	24.3	3.9	1.8	6.4	0
Italy	muscu	men	1	22.7	0.6	-12.2	0	14.3
Italy	muscu	women	0.3	26.1	9.5	-11.4	15.2	20
Italy	cancer	men	1.1	24.9	0.7	-11.4	0	8.7
Italy	cancer	women	0.3	28.6	9.3	-10.6	11.1	18.8
Italy	cardio	men	0.9	24.2	0.7	-11.5	-2.2	9.1
Italy	cardio	women	0.3	28.3	9.3	-10	11.8	20
Italy	mh	men	1	21.5	0.6	-13.5	-2.2	13.6
Italy	mh	women	0.4	24.7	9.6	-12.2	11.8	26.7
Netherlands	muscu	men	1.3	21.1	4.4	0.9	5.7	0
Netherlands	muscu	women	0.5	24.4	4.4	4.8	7.3	0
Netherlands	cancer	men	1.7	21.9	4.3	1.5	3.3	7.1

Netherlands	cancer	women	0.7	26.4	4.4	5.9	4.3	0
Netherlands	cardio	men	1.3	21.4	4.3	0.4	5.5	7.7
Netherlands	cardio	women	0.5	25.9	4.4	5.8	7.1	0
Netherlands	mh	men	1.3	19.3	4.4	-1.2	3.6	0
Netherlands	mh	women	0.5	22.7	4.5	3.2	7.1	0
Spain	muscu	men	1.3	22.1	2.8	-5.9	2	9.1
Spain	muscu	women	0.3	25.7	2.9	-1.4	5.4	6.3
Spain	cancer	men	1.3	24.4	2.7	-3.7	1.8	4.2
Spain	cancer	women	0.3	28.3	2.8	0.7	2.5	0
Spain	cardio	men	1.1	23.6	2.8	-4.6	3.9	4.3
Spain	cardio	women	0.3	28.1	2.8	0.6	2.6	0
Spain	mh	men	1.2	20.7	2.8	-7.5	1.9	8.7
Spain	mh	women	0.3	24.1	3	-2.5	5.4	6.3
Sweden	muscu	men	1.3	21.8	6.9	1.8	9.8	4.3
Sweden	muscu	women	0.3	25.4	7.3	5	11.3	5.9
Sweden	cancer	men	1.7	22.9	6.7	2.1	10.5	3.7
Sweden	cancer	women	0.5	27.5	7.3	5.8	11.6	0
Sweden	cardio	men	1.4	22	6.8	0.7	10.5	4
Sweden	cardio	women	0.4	26.8	7.3	5.6	12.7	0
Sweden	mh	men	1.4	19.9	6.9	-0.6	10.3	8
Sweden	mh	women	0.4	23.5	7.5	3.4	12.7	0

* muscu indicates musculoskeletal disease, mh indicates mental disorders, cardio indicates cardiovascular diseases

Table 12 shows results of scenario analyses in which we assumed the official retirement age increases by 5 years and that the disability pensions are reduced by 20%. We observe that in this case, for all countries, all diseases, both genders, and the public payer PPCBE cost decreases (between 1% and 17%) while both Rcp and Rcp€ increase.

Table 12: Relative changes (%) in when official retirement age is increased by 5 years and disability pensions are decreased by 20%

Country	Disease	Gender	WLE	PPCBE	Rcp	Rcp€
Austria	muscu	men	1.3	-10.7	2.1	7.1
Austria	muscu	women	17.6	-11.1	24.3	30
Austria	cancer	men	1.2	-11.2	1.9	13.3
Austria	cancer	women	17.7	-11.5	28.2	27.3
Austria	cardio	men	1.2	-10.9	2	14.3
Austria	cardio	women	17.7	-10.9	27	30
Austria	mh	men	1.3	-13.1	2	13.3
Austria	mh	women	17.5	-12	27	30
Belgium	muscu	men	1	-3.8	2.1	6.3
Belgium	muscu	women	0.9	-1.1	2.8	0
Belgium	cancer	men	0.9	-3.6	1.9	5.9
Belgium	cancer	women	0.9	-1	2.6	8.3
Belgium	cardio	men	0.9	-3.5	2	6.3
Belgium	cardio	women	0.9	-0.7	0	0

Belgium	mh	men	1	-4.5	2	5.9
Belgium	mh	women	1	-1.3	0	0
Denmark	muscu	men	6.3	-9.1	11.8	12.5
Denmark	muscu	women	6.3	-4	10.9	16.7
Denmark	cancer	men	6.1	-9.2	10.5	11.1
Denmark	cancer	women	6.1	-3.7	10	7.7
Denmark	cardio	men	6.1	-8.9	9.9	11.8
Denmark	cardio	women	6.1	-3.1	8.9	8.3
Denmark	mh	men	6.3	-10.5	11.3	17.6
Denmark	mh	women	6.3	-4.7	8.9	7.7
France	muscu	men	0.4	-10.2	2.1	8.7
France	muscu	women	0.4	-5.6	0	6.3
France	cancer	men	0.4	-10.2	0	12.5
France	cancer	women	0.4	-5.7	0	5.9
France	cardio	men	0.4	-9.7	2	8.7
France	cardio	women	0.4	-5.1	2.8	6.3
France	mh	men	0.4	-10.9	2	8.3
France	mh	women	0.4	-5.9	0	6.3
Germany	muscu	men	2.5	-3.7	5	3.7
Germany	muscu	women	2.7	-1.4	4.3	5
Germany	cancer	men	2.5	-4.2	4.4	6.9
Germany	cancer	women	2.6	-1.7	3.9	4.8
Germany	cardio	men	2.6	-3.8	4.8	3.6
Germany	cardio	women	2.6	-1.3	4.2	5
Germany	mh	men	2.7	-5.1	4.8	3.4
Germany	mh	women	2.9	-1.8	4.3	0
Italy	muscu	men	0	-15.6	0	14.3
Italy	muscu	women	8.4	-12.9	12.1	20
Italy	cancer	men	0.1	-16.4	0	13
Italy	cancer	women	8.1	-13.1	11.1	18.8
Italy	cardio	men	0	-15.4	0	13.6
Italy	cardio	women	8.1	-12.2	11.8	20
Italy	mh	men	0	-16.6	0	18.2
Italy	mh	women	8.5	-13.4	8.8	26.7
Netherlands	muscu	men	3.4	-1	5.7	0
Netherlands	muscu	women	3.4	2.4	7.3	0
Netherlands	cancer	men	3.4	-1.3	5	7.1
Netherlands	cancer	women	3.4	2.5	4.3	0
Netherlands	cardio	men	3.4	-1.4	7.3	7.7
Netherlands	cardio	women	3.3	2.8	7.1	0
Netherlands	mh	men	3.5	-2.6	5.4	7.1
Netherlands	mh	women	3.6	1.4	4.8	0
Spain	muscu	men	2	-8.6	4	9.1
Spain	muscu	women	2	-4.3	2.7	6.3
Spain	cancer	men	1.8	-8	3.6	8.3
Spain	cancer	women	1.8	-3.9	2.5	0

Spain	cardio	men	1.9	-7.8	3.9	4.3
Spain	cardio	women	1.8	-3.6	2.6	6.3
Spain	mh	men	2	-9.9	1.9	13
Spain	mh	women	2	-4.8	2.7	6.3
Sweden	muscu	men	5.7	-2.7	9.8	8.7
Sweden	muscu	women	6.2	0.1	9.7	5.9
Sweden	cancer	men	5.5	-4.1	11.6	7.4
Sweden	cancer	women	6.1	-0.3	11.6	5.3
Sweden	cardio	men	5.6	-3.7	11.6	4
Sweden	cardio	women	6.2	0.1	11.1	0
Sweden	mh	men	5.8	-4.4	11.5	8
Sweden	mh	women	6.3	-0.6	11.1	5.6

* muscu indicates musculoskeletal disease, mh indicates mental disorders, cardio indicates cardiovascular diseases

Probability sensitivity analysis (PSA)

Table 13 shows results of the probability sensitivity analysis (i.e. uncertainty estimates around each reported outcome) with the Markov model being run 100 times for one country only (i.e. Austria), for all diseases and both genders for the base-case scenario. We observe that, as expected, diseases reported to have lower incidences (e.g. cancer and cardiovascular diseases) in SHARE result in outcome results with higher uncertainty than diseases such as musculoskeletal diseases and mental health disorders that are more prevalent.

Table 13: Confidence Intervals (CI) estimates for base-case scenario model for Austria, 100 simulations

CI	Disease	Gender	LE	DFLE	WLE	PPCBE	Rcp	Rcp€
Lower	mh	men	25.31	9.04	7.59	-314808	0.41	0.07
Mean	mh	men	**27.70**	**12.90**	**9.00**	**-276252**	**0.50**	**0.10**
Upper	mh	men	30.09	16.76	10.41	-237696	0.59	0.13
Lower	muscu	men	24.52	6.77	7.41	-354371	0.40	0.07
Mean	muscu	men	**28.50**	**11.70**	**9.00**	**-301775**	**0.50**	**0.10**
Upper	muscu	men	32.48	16.63	10.59	-249178	0.60	0.13
Lower	cardio	men	19.53	6.62	6.46	-363784	0.30	0.04
Mean	cardio	men	**27.10**	**11.40**	**9.00**	**-279074**	**0.50**	**0.10**
Upper	cardio	men	34.67	16.18	11.54	-194365	0.70	0.16
Lower	cancer	men	23.76	5.62	7.16	-320974	0.36	0.06
Mean	cancer	men	**26.40**	**11.00**	**8.90**	**-269915**	**0.50**	**0.10**
Upper	cancer	men	29.04	16.38	10.64	-218855	0.64	0.14
Lower	mh	women	30.11	7.70	6.80	-456147	0.22	0.08
Mean	mh	women	**32.10**	**10.50**	**7.80**	**-413418**	**0.30**	**0.10**
Upper	mh	women	34.09	13.30	8.80	-370688	0.38	0.12
Lower	muscu	women	27.35	5.17	5.62	-488547	0.20	0.08
Mean	muscu	women	**32.00**	**9.10**	**7.70**	**-418303**	**0.30**	**0.10**
Upper	muscu	women	36.65	13.03	9.78	-348059	0.40	0.12
Lower	cardio	women	29.14	4.83	6.26	-455092	0.21	0.08

Mean	cardio	women	**31.50**	**8.20**	**7.70**	**-411898**	**0.30**	**0.10**
Upper	cardio	women	33.86	11.57	9.14	-368704	0.39	0.12
Lower	cancer	women	28.31	4.98	6.52	-428020	0.29	0.08
Mean	cancer	women	**30.30**	**8.40**	**7.80**	**-386714**	**0.40**	**0.10**
Upper	cancer	women	32.29	11.82	9.08	-345409	0.51	0.12

* muscu indicates musculoskeletal disease, mh indicates mental disorders, cardio indicates cardiovascular diseases

Conclusions

The aim of these analyses was to investigate the impact of four chronic diseases on health and thereby on employment and retirement for nine European countries by considering the chain running from chronic disease to disability and unemployment. We hypothesized that preventing important chronic diseases may have an impact on disability occurrence, which in turn may influence labour force participation. Modelling such a chain of events is complex but can be achieved by making use of simulations. The analyses were performed for nine European countries (Austria, Belgium, Demark, France, Germany, the Netherlands, Italy, Spain, and Sweden) and for four chronic diseases (cancer, cardiovascular diseases, mental diseases and musculoskeletal disorders). To our knowledge, this is the first time such a model is developed for addressing this purpose. The following outputs were reported: life expectancy (LE), disability-free life expectancy (DFLE), working life expectancy (WLE), the public payer cost benefit expenditure (PPCBE), the ratio of the number of years paying contributions (i.e. working) to those receiving benefits from of public pensions (Rcp), the ratio of total paid contributions to total received benefits at an individual level (Rcp€).

Our results show that, generally, for all countries and both genders, decreasing disease and disability incidence results in increases in LE, DFLE, WLE and decreases the public payer expenditure budget. In general, changes in disease incidence and disability incidence results in similar outputs changes for all countries and similar patterns by gender: compared to women, men have higher increases in LE, smaller increases in DFLE, smaller public payer costs. Furthermore, we found that the impact of changing the retirement age may be different depending on country, gender and the chronic disease with which it has been linked. Policies aimed at increasing the official retirement age seem to have a stronger impact for countries in which the official retirement age is below the age of 65, for example for countries such as Austria. It has less of an impact for countries in which the official retirement age is above the age 65, such as Sweden. In addition, such policies seem to be more relevant for women than for men since in many of the investigated EU countries there are different retirement ages between the two genders. All in all, we found that different public policies and/or epidemiological scenarios may affect various population groups differently in the EU.

These analyses are complementary to the on-going European found study about *'Extending working lives through flexible retirement schemes' (forthcoming in 2016 building on earlier reports such as 'Work preferences after 50' and 'Income from work after retirement')*. Our analyses clearly show the limitations of public policies aimed at increasing the pension age for all investigated countries (in terms of benefits for public expenditure), while indicating that for some EU countries, such policies may make more sense than for others.

There are some limitations and assumptions that were used to perform these analyses. Perhaps the most important limitation is with respect to the sample size available in SHARE. After conducting a systematic literature review, SHARE has been identified as the most suitable dataset for our purposes since it includes a clear set of definitions for disability and it allows linking chronic diseases to disability, unemployment and death. We are aware of other datasets with larger sample sizes that also include information on disease incidence, such as the Global Burden of disease database; however, these did not include a consistent set of definitions for

disability. Nevertheless, the true incidence of some diseases such as musculoskeletal diseases and mental disorders is rather difficult to assess.

In order to develop the complex simulation model using the SHARE data, some assumptions were necessary. First, for unemployment, voluntary routes are lumped together with the involuntary routes in the sense that pensioners are lumped together with those unemployed, which results in high non-employment rates. Second, we have modelled the impact of chronic diseases on disability, and labour force. However, the effect can also be reverse for example from employment to disability. In a situation where someone is partially disabled there may be positive health effects if this person is still working part-time. Hence, whether or not someone works while having a disability may actually influence whether (i) someone returns back to work fulltime and whether (ii) one dies. Third, we haven't consider spillover effects. It could well be the case that if one is affected by a change in the retirement age, then the caregiver also adjusts his/her labour market status and this would be especially important if their partner is disabled. Fourth, we did not account for those partially disabled as no such information is available in SHARE. Fifth, we estimated model parameters using Poisson regression and considering states independently; a semi-Markov model would have been more appropriate as it would have accounted for all dependencies between states. However, that was not possible with SHARE. Last, for the group disease mental disorders we have used the question about depression; experts draw attentions that monitoring mental disorders using survey data may be challenging. All of the above merit further investigation.

These analyses have some noteworthy strengths. The developed simulation model has the advantage that it allows performing various scenarios incorporating simultaneous changes from both a public payer perspective (i.e. changes in the official retirement age) as well as from an epidemiological perspective (i.e. changes in disease or disability incidence). Furthermore, complementary to the model developed in R, an Excel model has been developed that enables users to perform various scenarios for different population groups, while also changing other model inputs such as various monetary values.

Supplementary files

The following supplementary files will be attached to this document:

- An Excel model that can be used to perform Markov model calculations and various scenario analyses selected by the user. This model will load a dataset file with transition parameter as obtained from software R. Separate files will be attached for each country, disease and gender.
- Datasets files for each country, gender and disease as indicated above.
- Documents sent to the experts in the two consultation rounds.

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Appendix

A1: List of experts

We have approached a selected number of experts in the fields of: epidemiology, public health, labour force, econometrics, Markov modelling. We have conducted two rounds of experts' consultation. For the first round, initially, we contacted 17 experts. Of these, 10 indicated that they would like to participate in this study. Finally, for the first round we received eight responses from experts. In the second round, we contacted 10 experts of which nine provided feedback. For each round, documents including our findings and questions regarding our study design were sent to the experts. Table A1.1 provides a list with the names and expertize of the approached experts and of those that replied in the first and second round. Details regarding each round of experts' consultation follow in sections A2 and A3, respectively.

Table A1.1 The list with the approached experts

	Name	Affiliation	Expertise	e-mail	Received comments first round	Received comments second round
1	Dr. Pilar Garcia-Gomez	Erasmus School of Economics	Health and labour economics	garciagomez@ese.eur.nl	-[8]	+[9]
2	Prof. Dr. Lex Burdorf	Erasmus Medical Centre	Epidemiology of work and health	a.burdorf@erasmusmc.nl	+	+
3	Dr. Tim Marsh	Heart Institute	Modeling		-	-
4	Prof. Dr. Herman van Oyen	Wetenschappelijk Instituut Volksgezondheid	Disabilitiy and life expectancy	Herman.VanOyen@wiv-isp.be	+	+
5	Dr. Franco Sassi	OECD	Health Economics	franco.sassi@oecd.org	-	-
6	Prof. Dr. Ties boersma	WHO	Health Statistics and Information systems	boermat@who.int	-	-
7	Prof. Dr. Jean Marie Robine	INSERM	Disabilitiy and life expectancy	jean-marie.robine@INSERM.FR	-	-
8	Dr. Istvan Majer	Pharmerit	modelling disability	imajer@pharmerit.com	+	+
9	Prof. Dr. Maarten Lindeboom	Vrije Universiteit Amsterdam	Health and labour economics		-	-
10	Prof. Dr. Tony Blakely	University of Otago	Epidemiology & modelling	tony.blakely@otago.ac.nz	+	+

[8] '-' indicates that the expert did not respond
[9] '+' indicates that the expert responded

	Name	Affiliation	Expertise	e-mail	Received comments first round	Received comments second round
11	Fritz von NORDHEIM	DG SANCO	Pension systems	**Fritz.Von-nordheim**@cec.eu.int	-	-
12	Anne d'addio	OECD	Pension systems + labour economics	anna.daddio@oecd.org	+	+
13	Prof. Dr. Marianna Virtanen	Finnish Institute of Occopational Health	Epidemiology & disability	marianna.virtanen@ttl.fi	-	-
14	Robert Anderson	HoU, Eurofound, Dublin	Occupational health, EU pension systems	Robert.Anderson@eurofound.europa.eu	+	+
15	Professor Danny Pieters	KU Leuven	Arbeidsjurist, pension systems	danny.pieters@kuleuven.be	-	-
16	Dr. Nancy Hoeymans	RIVM	Disability & epidemiology	Nancy.hoeymans@rivm.nl	+	+
17	Anne Gielen	Erasmus University	Labour economics	gielen@ese.eur.nl	+	+

A2: Expert consultation: round 1

In the first expert consultation round we have developed a document including results of our literature review and a proposed model design for our study (please see the supplementary file named: Expert consultation_round 1). Below, we include the questions asked to experts as well as a summary response provided by experts for each question.

Question 1: Are you aware of any relevant studies using a similar modelling approach that has not been mentioned in this report? If not, are there studies with a different approach that might be interesting for us to have a look at?

The majority of experts are not aware of any similar study. This is in accordance with our findings from the extensive literature search. Although, some experts indicated that the literature on this topic is abundant, all experts agree that there are no studies that investigate the impact of various chronic diseases on health and thereby on employment and retirement.

Question 2: Do you agree with the data sources proposed? Do you think that important data sources were not taken into consideration?

All expert agree that SHARE is the best data for the purposes of this project. We will develop regarding on definitions of retirement and disability below. Some experts indicated EU-SILC may be also used complementary to SHARE as it includes more EU countries; however, compared to SHARE, EU-SILC includes only one question regarding global disability instrument (GALI). Therefore, due its broader health measures, SHARE is the preferred database.

Question 3: Do you agree with the proposed model structure? Can it be improved given the data-sources we propose to use?

Regarding the Markov model structure proposed there were some confusions raised by experts. These were mainly due to a confusion between the underlying causal chain of a Markov model and the actual Markov model structure and states. We hope the following points will clarify the issues raised by the experts:
In this project the concept of disability has two meanings: an epidemiological meaning and an economic meaning. In the epidemiological sense, by disability is implied the functional limitations in mobility, e.g. as indicated by questions on daily leaving (ADL). In the economic sense, being in a state of disability implies receiving a disability insurance. Therefore, for calculating the public payer cash benefit expenditures both of these meanings are necessary as we need to multiply the percentages in different states with the contributions (in the working states) or entitlements (in the not working states)
Given the confusion around the definition of disability, we have included in Appendix A4, the two questions activities of daily living (ADL) disabilities as available from SHARE. Furthermore, several experts raised the issue of using various severity levels for disability. Indeed, various levels of disability may be considered here; however, as mentioned, extending the number of model states imposes additional data constraints. In other words, the larger the number of states included in the model, the smaller the sample used for estimating transition probabilities between these states which may result in inaccurate input parameters.

In this analyses we did not differentiate between old-age retirement and early retirement; we will only look at people that are working or employed and those that are not-working or unemployed, regardless of their type of retirement they have.
We will not include homemakers in the model. Note that we are looking at average population number per states with the population distribution including many categories among which homemakers; therefore, homemakers are indirectly included in these averages. Paying particular focus to this population group is beyond the goal of this project.
Note that, the model does not account that people can combine old age pensions or disability pension with work. In the proposed model here, we assume individuals are either employed or unemployed.

Question 4: What do you consider to be important limitations of our proposed approach?

Besides the points raised at question 3, some experts suggested including social class in the model as both labour force participation and disability should be strongly influenced by social class. However, this would require considerably more effort and is beyond the aim of the current EU tender call.

A3: Expert consultation: round 2

For the second round of expert consultation we sent a report including results of the developed models and of various scenario analyses (please see the supplementary file named: Expert consultation_round 2). The addressed questions with summary responses are included in this round of expert consultation are presented below.

Question 1: What do you think of the choices we have made with respect to the regressions used for estimating model' parameters? Do you have any suggestions with respect to the estimation of the model parameters?
The majority of experts found that the model specifications used to estimate transition probabilities for populating the Markov model make sense. However, some experts argue that ideally, more confounders (e.g. education, occupation) should be included for establishing a stronger causal chain. Nevertheless, experts also acknowledge that given the sample size available in SHARE database, this would be too much to ask.
Some experts asked for more details regarding the model estimation (e.g. model equations, model output). The current report includes more details regarding the model estimation; e.g. output results of all fitted models were incorporated in Appendix A5.

Question 2: In your opinion, how credible are our estimates of the transition probabilities? How would you propose comparing these with other studies?
Experts find our results to be in line with results generally presented in the literature: increasing disease risk with increasing age, higher risk of disability for women, higher mortality risk for men. Furthermore, some experts indicate that estimates of disability and employment rates may be sensitive to cut-off points chosen and classification.

Question 3: What do you think of the data sources (i.e. 2015 Aging report, Eurostat site and Pension Adequacy report) used to estimate average monetary values? We were unable to identify the number of disability pensioners for each EU country included in the analysis. Do you have any suggestion with respect to other potentially data sources that can be used for this purpose?
Most experts think getting such datasets can be tricky and the majority do not have any suggestions on this. One expert indicated that 'Pensions at a Glance and taxing

Wages (OECD publications)' may be useful for deriving old-age pensions and data on social protection statistics for all EU countries up to 2012 may be useful for deriving disability insurance benefits. We have checked both of these data sources but we were not able to identify the number of those disabled. Note that the information on total spending on disability insurance for each investigated country was found but we needed the number of those disabled to obtained average disability insurance pensions for each country and this information was not identified.

Question 4: How do you think that results of the scenario analyses should be presented in order to be most useful for policy?
The experts think that the model implemented results in interesting results which may be useful for policy purposes. However, it is crucial for policy makers to understand the strengths/limitations of the model in order to properly assess the relevance of the model predictions. It should be made clear that in practice the impact of policies aimed at improving health will depend on many other factors that are not included in the model. Some experts would prefer the results to be displayed in graphs rather than tables; however, given the large number of countries and the four disease areas displaying results in graphs would quickly become cumbersome.
Some experts also indicate concerns regarding uncertainty around the provided estimates. For addressing this issue, in this report, results of a probability sensitivity analysis (PSA) are included. Furthermore, a PSA has also been implemented in the attached Excel model.

Question 5: What do you think is the policy relevance of the results of the scenario analyses?
Generally, experts find that these results are relevant for policy purposes. Again, here it is crucial to be clear about what can and what cannot be concluded from the scenario analyses. The general experts' impression about these analyses was rather positive.

Other comments

- In general, experts indicated that more details about the model estimation and more output results should be included in the report. This advice has been considered when developing this current (final) report.
- We have modelled the impact of chronic diseases on disability and labour force. However, the effect can also be reverse, for example, from employment to disability. In a situation where someone is partially disabled there may be positive health effects if this person is still working part-time (because it gives structure, a network, keep you active). So whether or not someone works while having a disability may actually influence whether (i) someone returns back to work fulltime and whether (ii) one dies. We do agree that reverse causality may be important, but given the data constraints, this could not be achieved in this study. Nevertheless, this is an important adjustment that is worth considering for future analyses (especially if new datasets become available).
- Spillover effects were not considered either. It could well be the case that if one is affected by a change in the retirement age, then the spouse also adjusts his/her labour market status and this would be especially important if the partner is disabled. Such developments may be considered in future analyses.
- Experts acknowledge that a semi-Markov model would have been more appropriate as it would have taken into account all dependencies. That was also our first option but due to sample size limitations we could not estimate all transitions simultaneously.
- For the group disease mental disorders we have used the question about depression. Experts mention that monitoring mental disorders using survey

data may be challenging and this should be reported as another limitation of our analyses.

- Experts also draw attention on the fact that the number of persons answering the question on cancer may be low in some countries, which may lead to an underestimation of the incidence of this disease in projection exercises. Note that, compared to the other three diseases investigated, cancer is the least prevalent one.

A4: Disability questions in SHARE

We used the following disability questions: activities of daily leaving (ADL) questions as indicated in SHARE

HEALTH AND ACTIVITIES
Please look at card 9.We need to understand difficulties people may have with various activities because of a health or physical problem. Please tell me whether you have any difficulty doing each of the everyday activities on card 9. Exclude any difficulties that you expect to last less than three months.(Because of a health problem, do you have difficulty doing any of the activities on this card?)
1. Walking 100 metres
2. Sitting for about two hours
3. Getting up from a chair after sitting for long periods
4. Climbing several flights of stairs without resting
5. Climbing one flight of stairs without resting
6. Stooping, kneeling, or crouching
7. Reaching or extending your arms above shoulder level
8. Pulling or pushing large objects like a living room chair. Lifting or carrying weights over 10 pounds/5 kilos, like a heavy bag of groceries
10. Picking up a small coin from a table
96. None of these

MORE HEALTH AND ACTIVITIES
Please look at card 10.Here are a few more everyday activities. Please tell me if you have any difficulty with these because of a physical, mental, emotional or memory problem. Again exclude any difficulties you expect to last less than three months.(Because of a
health or memory problem, do you have difficulty doing any of the activities on card 10?)
1. Dressing, including putting on shoes and socks
2. Walking across a room
3. Bathing or showering
4. Eating, such as cutting up your food
5. Getting in or out of bed
6. Using the toilet, including getting up or down
7. Using a map to figure out how to get around in a strange place
8. Preparing a hot meal
9. Shopping for groceries
10. Making telephone calls
11. Taking medications
12. Doing work around the house or garden
13. Managing money, such as paying bills and keeping track of expenses
96. None of these

A5: Markov model estimation: models' outputs

This section presents summary results of the models fitted for estimating the incidence transition matrix used for the Markov model simulation. A total of 17 models were fitted for estimating: disease incidence, disability incidence, unemployment incidence, mortality rates and mortality rates calibration. These models were fitted using R.

a) Models fitted for estimating disease incidence

Model (1) Cardiovascular diseases

```
Call:
glm(formula = inc ~ age + I(age^2) + gender + age:gender + country +
    offset(log(exposed)), family = poisson(link = log), data = d1_first[d1_first$disease ==
    "cardio", ])

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-3.2890  -0.9229  -0.1412   0.6677   2.9985

Coefficients:
                     Estimate Std. Error z value Pr(>|z|)
(Intercept)        -1.526e+01  9.381e-01 -16.263  < 2e-16 ***
age                 2.873e-01  2.621e-02  10.963  < 2e-16 ***
I(age^2)           -1.580e-03  1.828e-04  -8.643  < 2e-16 ***
genderwomen        -1.536e+00  2.805e-01  -5.477 4.32e-08 ***
countryBelgium      1.243e-01  7.061e-02   1.760  0.07846 .
countryDenmark      6.661e-02  8.207e-02   0.812  0.41702
countryFrance       5.620e-02  7.209e-02   0.780  0.43562
countryGermany      1.965e-01  8.307e-02   2.365  0.01804 *
countryItaly        1.174e-01  7.418e-02   1.583  0.11353
countryNetherlands  1.144e-01  7.795e-02   1.467  0.14237
countrySpain       -3.562e-03  7.632e-02  -0.047  0.96277
countrySweden       2.165e-01  7.554e-02   2.866  0.00415 **
age:genderwomen     1.799e-02  3.841e-03   4.685 2.80e-06 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 2662.84  on 737  degrees of freedom
Residual deviance:  910.72  on 725  degrees of freedom
AIC: 3091.3

Number of Fisher Scoring iterations: 5
```

Model (2) Cancer

```
Call:
glm(formula = inc ~ age + I(age^2) + gender + age:gender + country +
    offset(log(exposed)), family = poisson(link = log), data = d1_first[d1_first$disease ==
    "cancer", ])

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.9666  -0.9599  -0.2685   0.6036   3.3855

Coefficients:
                     Estimate Std. Error z value Pr(>|z|)
(Intercept)        -22.360297   1.609522 -13.893  < 2e-16 ***
age                  0.458807   0.044820  10.237  < 2e-16 ***
I(age^2)            -0.002822   0.000312  -9.046  < 2e-16 ***
genderwomen          1.824669   0.459428   3.972 7.14e-05 ***
countryBelgium       0.249222   0.120363   2.071   0.0384 *
countryDenmark       0.334079   0.135270   2.470   0.0135 *
countryFrance        0.284529   0.120503   2.361   0.0182 *
countryGermany       0.574700   0.131074   4.385 1.16e-05 ***
countryItaly         0.019848   0.131800   0.151   0.8803
countryNetherlands   0.502563   0.124243   4.045 5.23e-05 ***
countrySpain         0.004985   0.134387   0.037   0.9704
countrySweden        0.646439   0.119788   5.397 6.79e-08 ***
age:genderwomen     -0.028232   0.006432  -4.389 1.14e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 1297.79  on 737  degrees of freedom
Residual deviance:  851.16  on 725  degrees of freedom
AIC: 2264.2

Number of Fisher Scoring iterations: 5
```

Model (3) Mental diseases

```
Call:
glm(formula = inc ~ age + I(age^2) + gender + age:gender + country +
    offset(log(exposed)), family = poisson(link = log), data = d1_first[d1_first$disease ==
    "mh", ])

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-4.6506  -0.9654  -0.1047   0.7365   4.3257

Coefficients:
                     Estimate Std. Error z value Pr(>|z|)
(Intercept)        -7.0318249  0.5306637 -13.251  < 2e-16 ***
age                 0.1146355  0.0151632   7.560 4.03e-14 ***
I(age^2)           -0.0006495  0.0001084  -5.993 2.06e-09 ***
genderwomen         0.5897938  0.1630230   3.618 0.000297 ***
countryBelgium      0.1949336  0.0439613   4.434 9.24e-06 ***
countryDenmark      0.0370757  0.0510390   0.726 0.467582
countryFrance       0.3092043  0.0447545   6.909 4.88e-12 ***
countryGermany      0.4154805  0.0508916   8.164 3.24e-16 ***
countryItaly        0.3580071  0.0458397   7.810 5.72e-15 ***
countryNetherlands  0.0142707  0.0491469   0.290 0.771534
countrySpain        0.2012740  0.0481586   4.179 2.92e-05 ***
countrySweden       0.0401035  0.0490155   0.818 0.413255
age:genderwomen    -0.0014205  0.0023539  -0.603 0.546195
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 2510.9  on 737  degrees of freedom
Residual deviance: 1399.3  on 725  degrees of freedom
AIC: 4272.8

Number of Fisher Scoring iterations: 5
```

Model (4) Musculoskeletal diseases

```
Call:
glm(formula = inc ~ age + I(age^2) + gender + age:gender + country +
    offset(log(exposed)), family = poisson(link = log), data = d1_first[d1_first$disease ==
    "bone", ])

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-4.0519  -0.8998  -0.1200   0.6788   4.6671

Coefficients:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)       -13.505790   0.654201 -20.645  < 2e-16 ***
age                 0.254154   0.018408  13.807  < 2e-16 ***
I(age^2)           -0.001489   0.000130 -11.458  < 2e-16 ***
genderwomen         1.086359   0.200882   5.408 6.38e-08 ***
countryBelgium      0.675551   0.056689  11.917  < 2e-16 ***
countryDenmark      0.525417   0.065487   8.023 1.03e-15 ***
countryFrance       0.905258   0.055537  16.300  < 2e-16 ***
countryGermany      0.431940   0.067392   6.409 1.46e-10 ***
countryItaly        0.953277   0.057655  16.534  < 2e-16 ***
countryNetherlands  0.234797   0.064895   3.618 0.000297 ***
countrySpain        0.738821   0.059868  12.341  < 2e-16 ***
countrySweden       0.199116   0.064226   3.100 0.001934 **
age:genderwomen    -0.007330   0.002853  -2.569 0.010192 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 3183.9  on 737  degrees of freedom
Residual deviance: 1106.7  on 725  degrees of freedom
AIC: 3704.5

Number of Fisher Scoring iterations: 5
```

b) Estimating disability incidence

Model (5) Cardiovascular diseases

```
Call:
glm(formula = inc ~ age + I(age^2) + gender + age:gender + country +
    as.factor(lev_disease):age + offset(log(exposed)), family = poisson(lin = log),
    data = d2[d2$disease == "cardio", ])

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-4.5241  -0.9500  -0.3186   0.6414   3.6803

Coefficients:
                                Estimate Std. Error z value Pr(>|z|)
(Intercept)                   -1.413e+01  9.608e-01 -14.707  < 2e-16 ***
age                            3.096e-01  2.894e-02  10.698  < 2e-16 ***
I(age^2)                      -1.923e-03  2.176e-04  -8.837  < 2e-16 ***
genderwomen                    3.320e-01  2.323e-01   1.429   0.1530
countryBelgium                 3.308e-01  5.045e-02   6.556 5.51e-11 ***
countryDenmark                -9.110e-02  5.966e-02  -1.527   0.1268
countryFrance                  1.021e-01  5.226e-02   1.954   0.0507 .
countryGermany                 3.293e-01  5.892e-02   5.588 2.30e-08 ***
countryItaly                   3.165e-01  5.337e-02   5.930 3.02e-09 ***
countryNetherlands            -4.606e-02  5.611e-02  -0.821   0.4117
countrySpain                   2.667e-01  5.533e-02   4.819 1.44e-06 ***
countrySweden                  6.090e-02  5.595e-02   1.088   0.2764
age:genderwomen                1.646e-03  3.484e-03   0.472   0.6366
age:as.factor(lev_disease)1 -1.529e-03  7.204e-04  -2.122   0.0338 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 3286.5  on 1115  degrees of freedom
Residual deviance: 1621.2  on 1102  degrees of freedom
AIC: 4381.7

Number of Fisher Scoring iterations: 5
```

Model (6) Cancer diseases

```
Call:
glm(formula = inc ~ age + I(age^2) + gender + age:gender + country +
    as.factor(lev_disease) + offset(log(exposed)), family = poisson(lin = log),
    data = d2[d2$disease == "cancer", ])

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-4.1603  -0.7366  -0.4168   0.4181   3.8669

Coefficients:
                            Estimate Std. Error z value Pr(>|z|)
(Intercept)               -1.373e+01  9.342e-01 -14.692  < 2e-16 ***
age                        2.966e-01  2.811e-02  10.553  < 2e-16 ***
I(age^2)                  -1.801e-03  2.110e-04  -8.537  < 2e-16 ***
genderwomen                3.258e-01  2.250e-01   1.448   0.1477
countryBelgium             3.145e-01  4.946e-02   6.359 2.03e-10 ***
countryDenmark            -6.135e-02  5.796e-02  -1.059   0.2898
countryFrance              1.270e-01  5.087e-02   2.496   0.0126 *
countryGermany             3.274e-01  5.765e-02   5.679 1.35e-08 ***
countryItaly               3.252e-01  5.198e-02   6.256 3.95e-10 ***
countryNetherlands        -4.459e-02  5.483e-02  -0.813   0.4161
countrySpain               2.753e-01  5.388e-02   5.110 3.22e-07 ***
countrySweden              7.671e-02  5.449e-02   1.408   0.1592
as.factor(lev_disease)1 -8.224e-01  9.497e-02  -8.659  < 2e-16 ***
age:genderwomen            9.774e-04  3.367e-03   0.290   0.7716
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 3251.1  on 1115  degrees of freedom
Residual deviance: 1381.5  on 1102  degrees of freedom
AIC: 3802.5

Number of Fisher Scoring iterations: 6
```

Model (7) Mental diseases

```
Call:
glm(formula = inc ~ age + I(age^2) + gender + age:gender + country +
    as.factor(lev_disease):age + offset(log(exposed)), family = poisson(lin = log),
    data = d2[d2$disease == "mh", ])

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-3.6845  -1.0466  -0.2223   0.6435   3.6386

Coefficients:
                              Estimate Std. Error z value Pr(>|z|)
(Intercept)                 -1.517e+01  1.071e+00 -14.168  < 2e-16 ***
age                          3.262e-01  3.212e-02  10.154  < 2e-16 ***
I(age^2)                    -1.987e-03  2.405e-04  -8.263  < 2e-16 ***
genderwomen                  2.277e-01  2.563e-01   0.889  0.37426
countryBelgium               4.090e-01  5.658e-02   7.229 4.88e-13 ***
countryDenmark               1.897e-02  6.596e-02   0.288  0.77370
countryFrance                1.684e-01  5.871e-02   2.868  0.00413 **
countryGermany               3.424e-01  6.670e-02   5.134 2.84e-07 ***
countryItaly                 3.735e-01  5.993e-02   6.232 4.61e-10 ***
countryNetherlands           6.889e-02  6.206e-02   1.110  0.26701
countrySpain                 2.934e-01  6.246e-02   4.697 2.64e-06 ***
countrySweden                1.770e-01  6.170e-02   2.868  0.00413 **
age:genderwomen              1.516e-03  3.819e-03   0.397  0.69146
age:as.factor(lev_disease)1  1.256e-03  4.584e-04   2.739  0.00616 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 3180.2  on 1115  degrees of freedom
Residual deviance: 1609.7  on 1102  degrees of freedom
AIC: 4800.4

Number of Fisher Scoring iterations: 5
```

Model (8) Musculoskeletal diseases

```
Call:
glm(formula = inc ~ age + I(age^2) + gender + age:gender + country +
    as.factor(lev_disease):age + offset(log(exposed)), family = poisson(lin = log),
    data = d2[d2$disease == "bone", ])

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-3.4129  -0.9410  -0.2736   0.6468   3.6734

Coefficients:
                              Estimate Std. Error z value Pr(>|z|)
(Intercept)                 -1.367e+01  1.018e+00 -13.426  < 2e-16 ***
age                          2.893e-01  3.060e-02   9.452  < 2e-16 ***
I(age^2)                    -1.738e-03  2.295e-04  -7.575 3.61e-14 ***
genderwomen                  5.012e-01  2.446e-01   2.049  0.04048 *
countryBelgium               2.895e-01  5.363e-02   5.398 6.75e-08 ***
countryDenmark              -1.076e-01  6.311e-02  -1.705  0.08816 .
countryFrance                5.359e-02  5.572e-02   0.962  0.33614
countryGermany               3.296e-01  6.214e-02   5.304 1.13e-07 ***
countryItaly                 2.458e-01  5.716e-02   4.300 1.71e-05 ***
countryNetherlands           1.555e-02  5.833e-02   0.267  0.78977
countrySpain                 1.718e-01  5.959e-02   2.882  0.00395 **
countrySweden                1.242e-01  5.807e-02   2.139  0.03241 *
age:genderwomen             -2.714e-03  3.659e-03  -0.742  0.45831
age:as.factor(lev_disease)1  2.765e-03  5.390e-04   5.129 2.91e-07 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 3113.6  on 1115  degrees of freedom
Residual deviance: 1628.8  on 1102  degrees of freedom
AIC: 4618.6

Number of Fisher Scoring iterations: 5
```

c) Estimating unemployment incidence

Model (9)

```
Call:
glm(formula = inc ~ age + gender + age:gender + country + disability +
    disability:age + offset(log(exposed)), family = poisson(link = log),
    data = d3)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.9955  -0.9265  -0.3724   0.5184   3.2537

Coefficients:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)     -23.19959    1.29702 -17.887  < 2e-16 ***
age               0.36206    0.02242  16.149  < 2e-16 ***
genderwomen       1.91981    1.64396   1.168 0.242889
countryBelgium    0.04225    0.11840   0.357 0.721239
countryDenmark   -0.76167    0.14477  -5.261 1.43e-07 ***
countryFrance    -0.10513    0.11992  -0.877 0.380661
countryGermany   -0.61876    0.16231  -3.812 0.000138 ***
countryItaly      0.13919    0.13351   1.043 0.297179
countryNetherlands -0.39517  0.13512  -2.925 0.003450 **
countrySpain     -0.17552    0.14424  -1.217 0.223647
countrySweden    -1.61160    0.19119  -8.430  < 2e-16 ***
disability1      -1.10499    1.75429  -0.630 0.528774
age:genderwomen  -0.03115    0.02850  -1.093 0.274382
age:disability1   0.02275    0.03039   0.749 0.454030
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 1407.19  on 394  degrees of freedom
Residual deviance:  501.31  on 381  degrees of freedom
AIC: 1248.9

Number of Fisher Scoring iterations: 5
```

IV) Estimating mortality rates

Model 10) Cardiovascular diseases

```
Call:
glm(formula = inc ~ age + I(age^2) + gender + age:gender + disability +
    offset(log(exposed)) + lev_disease:age, family = poisson(link = log),
    data = mor[mor$disease == "cardio", ], maxit = 45)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.6814  -0.8856  -0.2742   0.7270   2.6247

Coefficients:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)     -6.1246532  1.1413019  -5.366 8.03e-08 ***
age             -0.0150804  0.0317540  -0.475  0.63485
I(age^2)         0.0006917  0.0002193   3.154  0.00161 **
genderwomen     -1.3214859  0.3305647  -3.998 6.40e-05 ***
disability       0.6515734  0.0478176  13.626  < 2e-16 ***
age:genderwomen  0.0099776  0.0043501   2.294  0.02181 *
age:lev_disease  0.0042173  0.0005692   7.410 1.26e-13 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 3263.59  on 311  degrees of freedom
Residual deviance:  385.26  on 305  degrees of freedom
AIC: 1359.3

Number of Fisher Scoring iterations: 5
```

Model (11) Cancer diseases

```
Call:
glm(formula = inc ~ age + I(age^2) + gender + age:gender + disability +
    offset(log(exposed)) + lev_disease:age, family = poisson(link = log),
    data = mor[mor$disease == "cancer", ], maxit = 45)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.8313  -0.9191  -0.1178   0.9251   3.5505

Coefficients:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)     -5.8945850  1.1401966  -5.170 2.34e-07 ***
age             -0.0215260  0.0317227  -0.679 0.497412
I(age^2)         0.0007347  0.0002190   3.355 0.000794 ***
genderwomen     -1.4900141  0.3312328  -4.498 6.85e-06 ***
disability       0.6604008  0.0474241  13.925  < 2e-16 ***
age:genderwomen  0.0121254  0.0043595   2.781 0.005413 **
age:lev_disease  0.0118847  0.0007208  16.488  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 3551.72  on 311  degrees of freedom
Residual deviance:  506.57  on 305  degrees of freedom
AIC: 1477.2

Number of Fisher Scoring iterations: 5
```

Model (12) Mental diseases

```
Call:
glm(formula = inc ~ age + I(age^2) + gender + age:gender + disability +
    offset(log(exposed)) + lev_disease:age, family = poisson(link = log),
    data = mor[mor$disease == "mh", ], maxit = 45)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-3.0725  -0.8899  -0.1098   0.7360   3.5943

Coefficients:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)     -6.2289222  1.1418705  -5.455 4.90e-08 ***
age             -0.0142890  0.0317726  -0.450  0.65291
I(age^2)         0.0007035  0.0002194   3.206  0.00134 **
genderwomen     -1.3242098  0.3308006  -4.003 6.25e-05 ***
disability       0.6643072  0.0478911  13.871  < 2e-16 ***
age:genderwomen  0.0091752  0.0043536   2.108  0.03507 *
age:lev_disease  0.0025670  0.0005322   4.823 1.41e-06 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 3244.48  on 311  degrees of freedom
Residual deviance:  395.97  on 305  degrees of freedom
AIC: 1444.8

Number of Fisher Scoring iterations: 5
```

Model (13) Musculoskeletal diseases

```
Call:
glm(formula = inc ~ age + I(age^2) + gender + age:gender + disability +
    offset(log(exposed)) + lev_disease:age, family = poisson(link = log),
    data = mor[mor$disease == "bone", ], maxit = 45)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-3.4535  -0.9551  -0.1710   0.6985   2.4468

Coefficients:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)     -6.1668861  1.1417899  -5.401 6.62e-08 ***
age             -0.0162286  0.0317655  -0.511 0.609430
I(age^2)         0.0007282  0.0002193   3.320 0.000899 ***
genderwomen     -1.3449814  0.3306685  -4.067 4.75e-05 ***
disability       0.7328194  0.0480176  15.261  < 2e-16 ***
age:genderwomen  0.0102048  0.0043536   2.344 0.019079 *
age:lev_disease -0.0021199  0.0005776  -3.670 0.000242 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 3227.67  on 311  degrees of freedom
Residual deviance:  388.61  on 305  degrees of freedom
AIC: 1372.1

Number of Fisher Scoring iterations: 5
```

d) Estimating prevalence for each state s

Model (14) Cardiovascular diseases

```
Call:
multinom(formula = state_cardio ~ age + I(age^2) + gender + age:gender +
    country, data = dat)

Coefficients:
  (Intercept)        age     I(age^2) genderwomen countryBelgium countryDenmark countryFrance countryGermany countryItaly countryNetherlands countrySpain countrySweden age:genderwomen
1  -7.9630341 0.10998923 -0.0003536184  -1.7082429     0.14606814     0.01943653    0.17597569    0.007025952  -0.38135829         0.2108536  -0.33834068     0.3863292      0.01301042
2   0.5624017 -0.08360199  0.0009884700  -0.1661033     0.21830090    -0.45315749   -0.04552991    0.166067095   0.19340092        -0.2814219   0.05952665    -0.2470887      0.01388306
3  -4.3239612 -0.01836854  0.0008775298  -0.7554934     0.08352165    -0.44588716   -0.04564091    0.050806242   0.02308103        -0.4351299  -0.08507522    -0.1421888      0.01267910

Std. Errors:
  (Intercept)        age     I(age^2)  genderwomen countryBelgium countryDenmark countryFrance countryGermany countryItaly countryNetherlands countrySpain countrySweden age:genderwomen
1 8.219152e-05 0.002701801 3.928009e-05 1.488842e-05   1.822987e-05   1.154621e-05  1.526635e-05   4.820529e-06 3.453765e-06      1.281061e-05 1.990050e-06  5.927091e-06    0.0006424909
2 3.379506e-05 0.001072002 1.582025e-05 1.108157e-05   9.252674e-06   3.879502e-06  6.186628e-06   2.371332e-06 2.930486e-06      3.687132e-06 2.477710e-06  1.248021e-06    0.0002500447
3 5.730989e-05 0.001904749 2.706487e-05 1.526429e-05   1.287563e-05   5.281209e-06  9.090838e-06   5.172817e-06 5.842601e-06      5.909344e-06 2.175045e-06  3.854087e-06    0.0003939100

Residual Deviance: 156222
AIC: 156300
```

Model (15) Cancer diseases

```
Call:
multinom(formula = state_cancer ~ age + gender + age:gender +
    country, data = dat)

Coefficients:
  (Intercept)        age genderwomen countryBelgium countryDenmark countryFrance countryGermany countryItaly countryNetherlands countrySpain countrySweden age:genderwomen
1   -7.169515 0.05504004  2.50212832     0.2394166     0.3361696     0.2682991     0.3261014   -0.3901782         0.2102704  -0.20712668     0.4723942     -0.03763710
2   -3.804653 0.05110950 -0.03336876     0.1977273    -0.4381136    -0.0542929     0.1396207    0.1905942        -0.3202744   0.08216967    -0.2492394      0.01071511
3   -9.499632 0.09550809  2.60210348     0.2420532    -0.3713845     0.1283638     0.3184259   -0.1020429        -0.2789761  -0.41649218    -0.1529880     -0.02782030

Std. Errors:
  (Intercept)        age genderwomen countryBelgium countryDenmark countryFrance countryGermany countryItaly countryNetherlands countrySpain countrySweden age:genderwomen
1  0.34040006 0.004911423   0.4627593     0.11514327     0.12060577     0.11374952     0.13296895    0.14239222         0.11966453    0.13835877     0.11622709      0.007087023
2  0.09875258 0.001466093   0.1280469     0.02942585     0.03488028     0.03000266     0.03571472    0.03129096         0.03271101    0.03238797     0.03338354      0.001964323
3  0.32708764 0.004647536   0.3938519     0.08052456     0.10113803     0.08107569     0.09342178    0.09096419         0.09353858    0.10100128     0.09214019      0.005765115

Residual Deviance: 131633.1
AIC: 131705.1
```

Model (16) Mental diseases

```
Call:
multinom(formula = state_mh ~ age + I(age^2) + age:gender + gender +
    country, data = dat)

Coefficients:
  (Intercept)        age     I(age^2) genderwomen countryBelgium countryDenmark countryFrance countryGermany countryItaly countryNetherlands countrySpain countrySweden age:genderwomen
1    1.828659 -0.08728573 0.0005354965  0.09965843     0.2057716     0.06736301    0.70821258     0.4239108   0.23842023         0.01301619   0.14628086     0.1233215     0.0096699179
2   -1.180432 -0.03820489 0.0006951998 -0.14467648     0.1938772    -0.36137702   -0.05470361     0.1396393   0.08554705        -0.24098614  -0.07749374    -0.1372762     0.0110586726
3    3.427726 -0.18863924 0.0017511913  0.12535203     0.2960000    -0.54055744    0.40279176     0.4129858   0.43337700        -0.43459778   0.27998718    -0.3551287     0.0170576644

Std. Errors:
  (Intercept)        age     I(age^2)  genderwomen countryBelgium countryDenmark countryFrance countryGermany countryItaly countryNetherlands countrySpain countrySweden age:genderwomen
1 4.620842e-05 0.001463427 2.224097e-05 1.294333e-05   1.022028e-05   7.591323e-06  9.514854e-06   2.463727e-06 2.792583e-06       5.942710e-06 2.870793e-06 1.415628e-06   0.0003496782
2 3.952670e-05 0.001285909 1.879957e-05 9.983907e-06   1.040463e-05   4.550594e-06  5.553477e-06   2.900915e-06 3.429428e-06       4.863870e-06 1.998868e-06 1.618884e-06   0.0002901283
3 4.090998e-05 0.001323846 1.931604e-05 1.289270e-05   1.027141e-05   3.416269e-06  7.681475e-06   3.486197e-06 4.623420e-06       3.747579e-06 2.899281e-06 1.071514e-06   0.0003158418

Residual Deviance: 200852.8
AIC: 200930.8
```

Model (17) Musculoskeletal diseases

```
Call:
multinom(formula = state_bone ~ age + I(age^2) + gender + age:gender +
    country, data = dat)

Coefficients:
  (Intercept)        age     I(age^2) genderwomen countryBelgium countryDenmark countryFrance countryGermany countryItaly countryNetherlands countrySpain countrySweden age:genderwomen
1  -12.478134 0.26416060 -0.0017679406 0.37176491     0.78903726     0.9079909    0.9777972     0.1566808   0.9182313         0.0196465   0.6620898    -0.1579297     0.0056933819
2    1.419588 -0.11150492 0.0012357278 -0.01211312     0.01346557    -0.6540327   -0.2886028     0.1183311  -0.1251791        -0.3934896  -0.2182492    -0.2563524     0.0076174434
3   -6.136570 0.05586726 0.0000778114 0.07593419     0.84059714     0.2924209    0.7533436     0.2628814   1.0632076        -0.1273606   0.8000721    -0.3159599     0.0182565655

Std. Errors:
  (Intercept)        age     I(age^2)  genderwomen countryBelgium countryDenmark countryFrance countryGermany countryItaly countryNetherlands countrySpain countrySweden age:genderwomen
1 6.455733e-05 0.002083478 3.078924e-05 1.984315e-05   1.568035e-05   1.231786e-05  1.497162e-05   2.532102e-06 6.498352e-06       5.114597e-06 3.713509e-06 9.527105e-07   0.0004724375
2 3.610470e-05 0.001160479 1.704361e-05 9.215081e-06   9.361416e-06   3.818991e-06  5.907472e-06   2.909957e-06 2.856436e-06       4.292024e-06 2.374662e-06 1.421738e-06   0.0002691116
3 4.380406e-05 0.001428568 2.059745e-05 1.488894e-05   1.186716e-05   4.813018e-06  8.965847e-06   2.338745e-06 7.134185e-06       3.143853e-06 3.461901e-06 7.951103e-07   0.0003334455

Residual Deviance: 178646.3
AIC: 178724.3
```

A6: Calculation of monetary values

Average public pensions contributions were calculated from the 2015 Aging Report (17) by dividing the total contributions as % of GDP by the total number of those employed (calculated using the employment rate and the total number of working population). Finally these total public pension contributions were adjusted to contributions for old-age and disability pensions by using information on percentage from GDP of each type of pension. For example, for Austria old-age and disability pensions represent 11.6% of GDP while total spending with public pensions represents 13.9% of GDP. In this case contributions for old-age and disability pensions represents about 83% of total contributions for public pensions.

Table A6.1: Average pension contributions (values of year 2013)

Country	GDP*10^6	Population aged 15-64 *10^3	Pension contributions % GDP	Employment rate (%)	Average contributions to public pensions	Average contributions to old-age and disability pensions
Austria	313067	5717	8.3	72.3	6286	5217
Belgium	382692	7316	8	61.8	6771	5968
Denmark	248975	3629	7.4	72.6	6993	6154
France	2059852	41844	10.6	63.9	8166	7015
Germany	2737600	53732	10.5	73.5	7278	6186
Italy	1560024	38993	10.5	55.5	7569	6219
Netherlands	602658	11067	6.5	74.3	4764	4624
Spain	1022988	31165	12.1	54.5	7288	5867
Sweden	420849	4977	6	74.6	6801	5960

*all monetary values are in Euro
** values for Netherlands and Denmark are at 2010 values

Values for ***old-age pensions*** were taken from the Eurostat site by dividing the total value of old-age pensions by the total number of those receiving an old age pension (see table A2.2).
http://ec.europa.eu/eurostat/web/products-datasets/-/spr_exp_pens
http://ec.europa.eu/eurostat/web/products-datasets/-/spr_pns_ben

Table A6.2: Average **old-age** pensions (values of year 2012)

Country	Total old-age pensionsX10^9	Total number of old-age pensioners	Average old-age pension
Austria	32.77933	1681214	19497
Belgium	31.22115	1769768	17641
Denmark	27.3768	1021700	26795
France	249.74095	15617000	15992
Germany	232.03468	17502971	13257
Italy	167.281	11789167	14189
Netherlands	58.814	3136000	18754

Spain	75.73102	5541293	13667
Sweden	37.98693	1930931	19673

*all monetary values are in Euro

Average disability pensions were calculated by dividing total disability expenditures to the number of those receiving disability pension. We assumed that the number of those receiving disability pensions is fixed at the average level for EU28 i.e. about 10% of the total number of pensioners for all countries in our analysis with the exception of Denmark and Sweden which were found to have higher values (i.e. 15% of total number of pensioners) as indicated in the Pension Adequacy report.

Table A6.3: Average **disability** pensions (values of year 2012)

Country	Total disability expenditures X10^6	Total number of pensioners	Average disability pension
Austria	6669.35	2465000	27056
Belgium	8576.22	2800000	30629
Denmark	10002.00	1344000	49613
France	42622.78	18724500	22763
Germany	60066.46	23577000	25477
Italy	26218.00	17157000	15281
Netherlands	13887.00	3360000	41330
Spain	18804.95	9087000	20694
Sweden	15791.98	2592000	40617

*all monetary values are in Euro

A7: Other scenario analyses

Table (i): Relative changes in Rcp (%) when official retirement age is increased

			Increasing official retirement age (number of years)									
Country	**Disease**	**Gender**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Austria	muscu	men	0	0	2.1	2.1	2.1	2.1	2.1	2.1	4.3	4.3
Austria	muscu	women	0	2.7	8.1	16.2	24.3	32.4	43.2	51.4	62.2	73
Austria	cancer	men	1.9	1.9	1.9	1.9	1.9	3.8	3.8	3.8	3.8	5.8
Austria	cancer	women	2.6	5.1	13	17.9	28.2	35.9	46.2	59	69.2	82.1
Austria	cardio	men	0	2	2	2	2	2	4.1	4.1	4.1	4.1
Austria	cardio	women	2.7	5.4	11	18.9	27	35.1	45.9	56.8	67.6	78.4
Austria	mh	men	0	0	0	0	2	2	2	2	4	4
Austria	mh	women	2.7	5.4	11	18.9	27	35.1	45.9	56.8	67.6	78.4
Belgium	muscu	men	0	2.1	2.1	2.1	2.1	2.1	2.1	2.1	4.3	4.3
Belgium	muscu	women	0	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Belgium	cancer	men	0	0	0	1.9	1.9	1.9	1.9	1.9	1.9	3.8
Belgium	cancer	women	0	0	0	0	2.6	2.6	2.6	2.6	2.6	2.6
Belgium	cardio	men	0	0	0	2	2	2	2	2	2	2
Belgium	cardio	women	0	0	0	0	0	0	2.7	2.7	2.7	2.7
Belgium	mh	men	0	0	0	2	2	2	2	2	2	4.1

Belgium	mh	women	0	0	0	0	0	0	0	0	2.7	2.7
Denmark	muscu	men	1.5	4.4	5.9	8.8	11.8	14.7	17.6	20.6	23.5	26.5
Denmark	muscu	women	1.8	3.6	5.5	7.3	10.9	12.7	14.5	18.2	20	23.6
Denmark	cancer	men	1.3	2.6	5.3	7.9	10.5	14.5	17.1	19.7	22.4	26.3
Denmark	cancer	women	1.7	3.3	5	8.3	10	13.3	15	18.3	20	23.3
Denmark	cardio	men	1.4	2.8	5.6	8.5	9.9	12.7	15.5	19.7	22.5	25.4
Denmark	cardio	women	0	1.8	5.4	7.1	8.9	12.5	14.3	17.9	19.6	23.2
Denmark	mh	men	1.4	4.2	5.6	8.5	11.3	14.1	18.3	21.1	23.9	26.8
Denmark	mh	women	0	1.8	5.4	7.1	8.9	12.5	14.3	17.9	19.6	23.2
France	muscu	men	0	0	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
France	muscu	women	0	0	0	0	0	0	0	0	2.8	2.8
France	cancer	men	0	0	0	0	0	0	0	1.9	1.9	1.9
France	cancer	women	0	0	0	0	0	0	0	0	0	0
France	cardio	men	2	2	2	2	2	2	2	2	2	2
France	cardio	women	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
France	mh	men	2	2	2	2	2	2	2	2	2	2
France	mh	women	0	0	0	0	0	0	0	0	0	2.8
Germany	muscu	men	0	3.3	3.3	5	5	6.7	6.7	10	10	11.7
Germany	muscu	women	0	2.1	2.1	4.3	4.3	6.4	6.4	8.5	8.5	10.6
Germany	cancer	men	0	1.5	1.5	4.4	4.4	7.4	7.4	8.8	8.8	11.8
Germany	cancer	women	0	2	2	3.9	3.9	5.9	5.9	7.8	7.8	11.8
Germany	cardio	men	0	1.6	1.6	4.8	4.8	6.3	6.3	9.5	9.5	11.1
Germany	cardio	women	0	2.1	2.1	4.2	4.2	6.3	6.3	8.3	8.3	10.4
Germany	mh	men	0	3.2	3.2	4.8	4.8	7.9	7.9	9.5	9.5	12.7
Germany	mh	women	0	2.1	2.1	4.3	4.3	8.5	8.5	10.6	10.6	12.8
Italy	muscu	men	0	0	0	0	0	0	0	0	0	0
Italy	muscu	women	3	3	9.1	9.1	12.1	12.1	18.2	18.2	24.2	24.2
Italy	cancer	men	0	0	0	0	0	0	0	0	0	0
Italy	cancer	women	0	0	5.6	5.6	11.1	11.1	16.7	16.7	19.4	19.4
Italy	cardio	men	0	0	0	0	0	0	0	0	0	0
Italy	cardio	women	2.9	2.9	5.9	5.9	11.8	11.8	14.7	14.7	20.6	20.6
Italy	mh	men	0	0	0	0	0	0	0	0	0	0
Italy	mh	women	0	0	5.9	5.9	8.8	8.8	14.7	14.7	20.6	20.6
Netherlands	muscu	men	0	1.9	3.8	3.8	5.7	7.5	7.5	9.4	11.3	11.3
Netherlands	muscu	women	2.4	2.4	4.9	4.9	7.3	7.3	7.3	9.8	9.8	12.2
Netherlands	cancer	men	0	1.7	3.3	3.3	5	6.7	8.3	10	10	11.7
Netherlands	cancer	women	0	0	2.2	2.2	4.3	4.3	6.5	6.5	8.7	10.9
Netherlands	cardio	men	1.8	1.8	3.6	5.5	7.3	7.3	9.1	10.9	10.9	12.7
Netherlands	cardio	women	2.4	2.4	4.8	4.8	7.1	7.1	7.1	9.5	9.5	11.9
Netherlands	mh	men	0	1.8	1.8	3.6	5.4	7.1	7.1	8.9	10.7	12.5
Netherlands	mh	women	0	2.4	2.4	4.8	4.8	7.1	7.1	9.5	9.5	11.9
Spain	muscu	men	0	0	2	2	4	4	4	4	6	6
Spain	muscu	women	0	2.7	2.7	2.7	2.7	2.7	5.4	5.4	5.4	5.4
Spain	cancer	men	0	1.8	1.8	1.8	3.6	3.6	3.6	5.5	5.5	5.5
Spain	cancer	women	0	0	0	2.5	2.5	2.5	2.5	2.5	5	5
Spain	cardio	men	2	2	2	3.9	3.9	3.9	5.9	5.9	5.9	7.8

Spain	cardio	women	0	0	0	0	2.6	2.6	2.6	2.6	2.6	5.3
Spain	mh	men	0	0	1.9	1.9	1.9	3.8	3.8	3.8	5.8	5.8
Spain	mh	women	0	2.7	2.7	2.7	2.7	5.4	5.4	5.4	5.4	8.1
Sweden	muscu	men	1.2	2.4	4.9	7.3	9.8	13.4	15.9	18.3	22	24.4
Sweden	muscu	women	0	1.6	4.8	6.5	9.7	12.9	16.1	17.7	21	24.2
Sweden	cancer	men	1.1	3.2	6.3	8.4	11.6	14.7	17.9	21.1	24.2	27.4
Sweden	cancer	women	1.4	2.9	5.8	8.7	11.6	13	15.9	20.3	23.2	26.1
Sweden	cardio	men	1.2	3.5	5.8	8.1	11.6	14	17.4	19.8	23.3	26.7
Sweden	cardio	women	1.6	3.2	6.3	7.9	11.1	14.3	17.5	19	22.2	25.4
Sweden	mh	men	1.1	3.4	5.7	8	11.5	13.8	17.2	19.5	23	26.4
Sweden	mh	women	1.6	3.2	4.8	7.9	11.1	14.3	15.9	19	22.2	25.4

* muscu indicates musculoskeletal disease, mh indicates mental disorders, cardio indicates cardiovascular disease

Table (ii): Relative changes in Rcp€ (%) when official retirement age is increased

			Increasing official retirement age (number of years)									
Country	**Disease**	**Gender**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Austria	muscu	men	0	0	0	0	0	0	0	0	0	0
Austria	muscu	women	0	10	10	20	20	30	40	50	60	60
Austria	cancer	men	0	0	0	0	0	0	0	0	0	0
Austria	cancer	women	0	0	9.1	18.2	18.2	27.3	36.4	45.5	54.5	54.5
Austria	cardio	men	0	7.1	7.1	7.1	7.1	7.1	0	0	0	0
Austria	cardio	women	0	10	10	20	30	30	40	50	60	60
Austria	mh	men	0	0	0	0	6.7	6.7	6.7	6.7	0	0
Austria	mh	women	0	10	10	20	30	40	50	50	60	70
Belgium	muscu	men	0	0	0	-6.3	-6.3	-6.3	-6.3	-12.5	-12.5	-12.5
Belgium	muscu	women	0	-8.3	-8.3	-8.3	-8.3	-8.3	-16.7	-16.7	-16.7	-16.7
Belgium	cancer	men	0	0	0	-5.9	-5.9	-5.9	-11.8	-11.8	-11.8	-11.8
Belgium	cancer	women	0	0	0	-8.3	-8.3	-8.3	-8.3	-8.3	-16.7	-16.7
Belgium	cardio	men	0	0	0	-6.3	-6.3	-6.3	-6.3	-12.5	-12.5	-12.5
Belgium	cardio	women	-8.3	-8.3	-8.3	-8.3	-8.3	-16.7	-16.7	-16.7	-16.7	-16.7
Belgium	mh	men	0	0	-5.9	-5.9	-5.9	-5.9	-11.8	-11.8	-11.8	-11.8
Belgium	mh	women	0	0	-8.3	-8.3	-8.3	-8.3	-8.3	-8.3	-16.7	-16.7
Denmark	muscu	men	0	0	0	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Denmark	muscu	women	0	0	0	0	0	0	0	0	0	0
Denmark	cancer	men	0	0	0	0	0	0	0	0	0	0
Denmark	cancer	women	0	0	0	0	0	0	0	0	0	0
Denmark	cardio	men	0	0	0	0	0	0	0	0	0	0
Denmark	cardio	women	0	0	0	0	0	0	0	0	0	0
Denmark	mh	men	0	0	0	5.9	5.9	5.9	5.9	5.9	5.9	5.9
Denmark	mh	women	0	0	0	0	0	0	0	0	0	0
France	muscu	men	0	0	0	0	0	-4.3	-4.3	-4.3	-4.3	-4.3
France	muscu	women	0	0	0	0	0	-6.3	-6.3	-6.3	-6.3	-6.3
France	cancer	men	0	0	0	0	0	0	-4.2	-4.2	-4.2	-4.2
France	cancer	women	0	0	-5.9	-5.9	-5.9	-5.9	-5.9	-5.9	-11.8	-11.8

France	cardio	men	0	0	0	0	0	-4.3	-4.3	-4.3	-4.3	-8.7
France	cardio	women	0	0	0	-6.3	-6.3	-6.3	-6.3	-6.3	-6.3	-12.5
France	mh	men	0	0	0	0	-4.2	-4.2	-4.2	-4.2	-4.2	-8.3
France	mh	women	0	0	0	0	0	0	-6.3	-6.3	-6.3	-6.3
Germany	muscu	men	0	-3.7	-3.7	-7.4	-7.4	-11.1	-11.1	-11.1	-11.1	-14.8
Germany	muscu	women	0	-5	-5	-5	-5	-10	-10	-15	-15	-15
Germany	cancer	men	0	-3.4	-3.4	-6.9	-6.9	-10.3	-10.3	-10.3	-10.3	-13.8
Germany	cancer	women	0	-4.8	-4.8	-4.8	-4.8	-9.5	-9.5	-14.3	-14.3	-14.3
Germany	cardio	men	0	-3.6	-3.6	-7.1	-7.1	-10.7	-10.7	-14.3	-14.3	-14.3
Germany	cardio	women	0	-5	-5	-5	-5	-10	-10	-15	-15	-15
Germany	mh	men	0	-3.4	-3.4	-6.9	-6.9	-10.3	-10.3	-10.3	-10.3	-13.8
Germany	mh	women	0	-4.8	-4.8	-9.5	-9.5	-9.5	-9.5	-14.3	-14.3	-14.3
Italy	muscu	men	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Italy	muscu	women	6.7	6.7	13.3	13.3	13.3	13.3	20	20	26.7	26.7
Italy	cancer	men	0	0	0	0	0	0	0	0	0	0
Italy	cancer	women	6.3	6.3	6.3	6.3	12.5	12.5	18.8	18.8	25	25
Italy	cardio	men	0	0	0	0	0	0	0	0	0	0
Italy	cardio	women	6.7	6.7	13.3	13.3	13.3	13.3	20	20	26.7	26.7
Italy	mh	men	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Italy	mh	women	6.7	6.7	13.3	13.3	20	20	20	20	26.7	26.7
Netherlands	muscu	men	0	0	-7.7	-7.7	-7.7	-7.7	-7.7	-15.4	-15.4	-15.4
Netherlands	muscu	women	-10	-10	-10	-10	-10	-10	-20	-20	-20	-20
Netherlands	cancer	men	0	0	0	-7.1	-7.1	-7.1	-7.1	-7.1	-14.3	-14.3
Netherlands	cancer	women	0	0	0	0	-10	-10	-10	-10	-10	-20
Netherlands	cardio	men	0	0	0	0	0	-7.7	-7.7	-7.7	-7.7	-15.4
Netherlands	cardio	women	0	-10	-10	-10	-10	-10	-20	-20	-20	-20
Netherlands	mh	men	0	0	-7.1	-7.1	-7.1	-7.1	-7.1	-14.3	-14.3	-14.3
Netherlands	mh	women	0	0	0	-10	-10	-10	-10	-10	-10	-20
Spain	muscu	men	0	0	0	0	0	0	0	0	-4.5	-4.5
Spain	muscu	women	0	0	0	0	-6.3	-6.3	-6.3	-6.3	-6.3	-6.3
Spain	cancer	men	0	0	0	-4.2	-4.2	-4.2	-4.2	-4.2	-8.3	-8.3
Spain	cancer	women	-5.9	-5.9	-5.9	-5.9	-5.9	-5.9	-11.8	-11.8	-11.8	-11.8
Spain	cardio	men	0	0	-4.3	-4.3	-4.3	-4.3	-4.3	-4.3	-8.7	-8.7
Spain	cardio	women	0	-6.3	-6.3	-6.3	-6.3	-6.3	-6.3	-6.3	-12.5	-12.5
Spain	mh	men	4.3	4.3	4.3	4.3	0	0	0	0	0	0
Spain	mh	women	0	0	0	0	0	0	-6.3	-6.3	-6.3	-6.3
Sweden	muscu	men	0	0	0	0	-4.3	-4.3	-4.3	-4.3	-4.3	-8.7
Sweden	muscu	women	0	0	0	0	-5.9	-5.9	-5.9	-5.9	-5.9	-5.9
Sweden	cancer	men	-3.7	-3.7	-3.7	-3.7	-7.4	-7.4	-7.4	-7.4	-7.4	-7.4
Sweden	cancer	women	0	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-10.5	-10.5	-10.5
Sweden	cardio	men	-4	-4	-4	-4	-4	-8	-8	-8	-8	-8
Sweden	cardio	women	-5.6	-5.6	-5.6	-5.6	-5.6	-5.6	-11.1	-11.1	-11.1	-11.1
Sweden	mh	men	0	0	0	0	-4	-4	-4	-4	-4	-8
Sweden	mh	women	0	-5.6	-5.6	-5.6	-5.6	-5.6	-5.6	-5.6	-5.6	-5.6

* muscu indicates musculoskeletal disease, mh indicates mental disorders, cardio indicates cardiovascular diseases

Table (iii): Relative changes inWLE (%) when official retirement age is increased

			Increasing official retirement age (number of years)									
Country	**Disease**	**Gender**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Austria	muscu	men	0.2	0.4	0.8	1	1.3	1.5	1.8	2.1	2.4	2.6
Austria	muscu	women	1	3.5	7.3	12.1	17.6	23.3	29	34.8	40.5	46.4
Austria	cancer	men	0.2	0.4	0.7	1	1.2	1.5	1.8	2	2.3	2.5
Austria	cancer	women	1.1	3.6	7.4	12.3	17.7	23.3	29.1	34.9	40.6	46.3
Austria	cardio	men	0.1	0.4	0.7	0.9	1.2	1.4	1.7	2	2.3	2.5
Austria	cardio	women	1.1	3.6	7.4	12.3	17.7	23.3	29.1	34.9	40.6	46.3
Austria	mh	men	0.2	0.4	0.8	1.1	1.3	1.6	2	2.2	2.5	2.8
Austria	mh	women	1	3.5	7.3	12.1	17.5	23.2	29	34.8	40.6	46.4
Belgium	muscu	men	0.2	0.4	0.6	0.8	1	1.2	1.4	1.7	1.9	2.1
Belgium	muscu	women	0.1	0.3	0.5	0.7	0.9	1.1	1.4	1.5	1.7	1.9
Belgium	cancer	men	0.1	0.3	0.6	0.7	0.9	1.1	1.3	1.6	1.7	1.9
Belgium	cancer	women	0.1	0.3	0.6	0.7	0.9	1.1	1.3	1.5	1.7	1.8
Belgium	cardio	men	0.1	0.3	0.6	0.8	0.9	1.1	1.3	1.6	1.8	2
Belgium	cardio	women	0.2	0.3	0.6	0.7	0.9	1.1	1.3	1.5	1.7	1.8
Belgium	mh	men	0.1	0.3	0.6	0.8	1	1.2	1.4	1.7	1.9	2.1
Belgium	mh	women	0.2	0.5	0.6	0.8	1	1.3	1.5	1.7	1.9	2.2
Denmark	muscu	men	0.6	1.9	3.3	4.8	6.3	7.8	9.3	10.9	12.4	13.9
Denmark	muscu	women	0.6	1.8	3.2	4.8	6.3	7.8	9.3	10.9	12.3	13.9
Denmark	cancer	men	0.6	1.8	3.2	4.7	6.1	7.6	9.1	10.6	12	13.5
Denmark	cancer	women	0.6	1.8	3.1	4.6	6.1	7.6	9.1	10.5	12	13.5
Denmark	cardio	men	0.6	1.7	3.2	4.7	6.1	7.6	9.1	10.6	12.1	13.6
Denmark	cardio	women	0.6	1.8	3.1	4.6	6.1	7.6	9.1	10.5	12	13.5
Denmark	mh	men	0.6	1.8	3.3	4.8	6.3	7.8	9.4	10.9	12.4	14
Denmark	mh	women	0.6	1.8	3.3	4.8	6.3	7.9	9.5	11	12.6	14.1
France	muscu	men	0.1	0.1	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.9
France	muscu	women	0	0.1	0.2	0.3	0.4	0.5	0.5	0.7	0.8	0.9
France	cancer	men	0.1	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.8	0.8
France	cancer	women	0.1	0.2	0.2	0.3	0.4	0.5	0.5	0.7	0.8	0.9
France	cardio	men	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.7
France	cardio	women	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.7	0.8	0.9
France	mh	men	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.9	0.9
France	mh	women	0	0.1	0.2	0.3	0.4	0.5	0.7	0.8	0.8	0.9
Germany	muscu	men	0	1.2	1.2	2.5	2.5	4	4	5.4	5.4	6.8
Germany	muscu	women	0	1.1	1.1	2.7	2.7	4.1	4.1	5.6	5.6	7.1
Germany	cancer	men	0	1.1	1.1	2.5	2.5	3.8	3.8	5.1	5.1	6.5
Germany	cancer	women	0	1.1	1.1	2.6	2.6	4	4	5.4	5.4	6.8
Germany	cardio	men	0	1.2	1.2	2.6	2.6	3.9	3.9	5.3	5.3	6.6
Germany	cardio	women	0	1.1	1.1	2.6	2.6	4	4	5.4	5.4	6.8
Germany	mh	men	0	1.2	1.2	2.7	2.7	4.1	4.1	5.6	5.6	7.1
Germany	mh	women	0	1.3	1.3	2.9	2.9	4.4	4.4	5.9	5.9	7.4
Italy	muscu	men	0	0	0	0	0	0	0	0	0	0
Italy	muscu	women	1.4	1.4	4.8	4.8	8.4	8.4	12.1	12.1	15.6	15.6
Italy	cancer	men	0	0	0	0	0.1	0.1	0.1	0.1	0.1	0.1

Italy	cancer	women	1.4	1.4	4.6	4.6	8.1	8.1	11.6	11.6	15.2	15.2
Italy	cardio	men	0	0	0	0	0	0	0	0	0	0
Italy	cardio	women	1.4	1.4	4.7	4.7	8.1	8.1	11.6	11.6	15.2	15.2
Italy	mh	men	0	0	0	0	0	0	0	0	0	0
Italy	mh	women	1.4	1.4	4.8	4.8	8.5	8.5	12.1	12.1	15.9	15.9
Netherlands	muscu	men	0.4	1.1	1.9	2.6	3.4	4.2	5.1	5.9	6.7	7.4
Netherlands	muscu	women	0.4	1.1	1.9	2.6	3.4	4.2	5	5.8	6.6	7.4
Netherlands	cancer	men	0.5	1.2	1.9	2.7	3.4	4.2	5	5.8	6.6	7.4
Netherlands	cancer	women	0.5	1.1	1.9	2.6	3.4	4.2	5	5.7	6.5	7.3
Netherlands	cardio	men	0.4	1.1	1.9	2.6	3.4	4.2	5	5.8	6.6	7.4
Netherlands	cardio	women	0.4	1.1	1.8	2.6	3.3	4.1	4.9	5.6	6.4	7.2
Netherlands	mh	men	0.4	1.2	2	2.7	3.5	4.4	5.2	6	6.8	7.6
Netherlands	mh	women	0.4	1.1	1.9	2.7	3.6	4.4	5.2	6	6.8	7.7
Spain	muscu	men	0.2	0.6	1	1.6	2	2.4	2.8	3.2	3.6	4.2
Spain	muscu	women	0.3	0.6	1.1	1.6	2	2.5	2.9	3.3	3.7	4.2
Spain	cancer	men	0.2	0.6	1	1.4	1.8	2.2	2.6	3	3.4	3.8
Spain	cancer	women	0.3	0.6	1.1	1.4	1.8	2.3	2.7	3	3.4	3.9
Spain	cardio	men	0.3	0.6	1	1.5	1.9	2.3	2.7	3.1	3.6	4
Spain	cardio	women	0.3	0.6	1.1	1.4	1.8	2.3	2.7	3	3.4	3.9
Spain	mh	men	0.2	0.6	1.1	1.6	2	2.4	2.9	3.3	3.8	4.3
Spain	mh	women	0.2	0.6	1.1	1.6	2	2.4	2.9	3.4	3.8	4.3
Sweden	muscu	men	0.6	1.7	2.9	4.3	5.7	7	8.4	9.8	11.1	12.5
Sweden	muscu	women	0.6	1.7	3.1	4.6	6.2	7.7	9.2	10.8	12.3	13.9
Sweden	cancer	men	0.5	1.6	2.9	4.2	5.5	6.8	8.2	9.5	10.8	12.2
Sweden	cancer	women	0.6	1.7	3.1	4.6	6.1	7.7	9.2	10.7	12.2	13.7
Sweden	cardio	men	0.5	1.6	2.9	4.2	5.6	6.9	8.3	9.7	11	12.4
Sweden	cardio	women	0.6	1.7	3.1	4.6	6.2	7.7	9.2	10.7	12.2	13.7
Sweden	mh	men	0.6	1.7	3	4.4	5.8	7.2	8.5	9.9	11.3	12.7
Sweden	mh	women	0.6	1.7	3.2	4.8	6.3	7.8	9.4	11	12.6	14.2

* muscu indicates musculoskeletal disease, mh indicates mental disorders, cardio indicates cardiovascular diseases