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Assessing Needs of Care in European Nations

# DEMOGRAPHIC EPIDEMIOLOGIC PROJECTIONS OF LONG-TERM CARE NEEDS IN SELECTED EUROPEAN COUNTRIES: GERMANY, SPAIN, THE NETHERLANDS AND POLAND

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**Abstract**

Work Package 2 of the ANCIEN project assesses the future numbers of care-dependent elderly in four selected countries: Spain, Poland, Germany and the Netherlands. The estimates are consistent with the available disability data and the mortality forecasts of the EUROPOP 2008 scenarios. The results show the effects of assumptions about how old age disability and mortality are related, and assess the effects of smoking and BMI.

The main determinant of future numbers of disabled elderly turns out to be the demographic ageing of the large baby boom cohorts. The impact of life extension depends on the correlation of old age disability and mortality, and is moderate under reasonable assumptions. Obesity and (quitting) smoking have very little effect.

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# Demographic Epidemiologic Projections of Long-Term Care Needs in Selected European Countries: Germany, Spain, the Netherlands and Poland

## ENEPRI Research Report No. 112/March 2012

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## Summary

Work Package 2 of the ANCIEN project assessed the actual and future numbers of elderly care-dependent people in four selected countries: Spain, Poland, Germany and the Netherlands. Such projections are needed to support provisions for future LTC needs. These countries were representative of European epidemiology and of different systems for the provision of long-term care.

We used the mortality forecasts of the EUROPOP 2008 scenarios as a basis for projections of the number of disabled elderly people, according to several assumptions about how disability and mortality are related. We added scenarios on the effects of smoking and BMI. The data were delivered by Eurostat (forecasts of mortality and populations), the ANCIEN Work Package 1 (elderly people in institutes), SHARE (elderly people living in the community) and the Rotterdam study (prospective study on ageing).

The main determinant of future numbers of disabled elderly people turned out to be the demographic ageing of the large baby boom cohorts. This would cause increases of 44% (Germany), 65% (Spain), 82% (the Netherlands) and 57% (Poland). The impact of life extension depends on the correlation of old age disability and mortality, and is moderate under reasonably conservative assumptions: (+11% for Germany, +7% for Spain, +9% for the Netherlands and +22% for Poland). For Poland, convergence to a German age schedule of disability would limit this increase. Obesity and (quitting) smoking have very little effect.

We conclude that the future numbers of long-term care patients can be robustly predicted and will be mainly determined by demographic ageing.


## Foreword

The report is constructed as a summary of all the findings, with added appendices describing procedures in more detail or giving further explanations. We summarised the results in as few tables and figures as possible. User-friendly spreadsheets –summarising all the output will be made available for the public at the ANCIEN website (http://www.ancien-longtermcare.eu/).

The LIPRO macrosimulation multi-state projection model is already available on the NIDI website (http://www.nidi.knaw.nl/; for a description see http://nidi.nl/Content/NIDI/output/lipro/nidicbgs-publ-23.pdf). The LIPRO model is (relatively) user friendly, and can read input from spreadsheets. All spreadsheet input will be uploaded as a deliverable. They contain the input in (not too difficult) mathematical format. A dedicated manual on how to manipulate the input sheets together with the LIPRO model to generate the output, and how to read the output, will be made available on the ANCIEN website. The method to generate consistent incidence from prevalence is added in an appendix. On the same website, the R syntax will be made available. With the input sheets and some patience, all scenarios using the same principles can be easily run.

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## Introduction

In 2011, the large post-war baby boom that started in 1946 began to reach the retirement age of 65. A 'baby crash' (a sharp decline in fertility) followed the baby boom, and is causing serious imbalances between the baby-boom generations and the small baby-crash generations born after the 1970s.[1] To address policy questions related to the provision of health care services in an ageing population, increasing emphasis has been put on the future development of long-term care need, supply and use, and the functioning of LTC systems. In this paper we use demographic models to project future needs of long-term care in four countries of the EU, Germany (DE), Spain (ES), the Netherlands (NL) and Poland (PL), based on the EUROPOP 2008 mortality forecasts.[2] These four countries have been chosen based on systems analysis of elderly care in the EU (see ANCIEN WP 1). However, the simple generic methods are applicable to all countries that can deliver mortality and prevalence data of basic activities of daily living (ADL) and selected risk factors. (For a further exploration of the rationale, see Appendix A1).

We take the mortality predictions of the EUROPOP 2008 forecasts for granted. We explore the prevalence of disability by two simple sets of scenarios. The first set explores the effect of different relationships between the incidence of senescent disability and mortality. The second set explores the effects of risk factors, notably obesity and smoking. We generate population figures of disabled and non-disabled elderly people (65+) till 2060. For reasons of parsimony and relevance, we only present results up to 2040.

## 1. Methods

Long-term care need is operationalised as having "at least one limitation in basic activities of daily living (basic ADL-disability)", based on the Katz ADL disability scale (Katz et al., 1963). Basic ADL-disability is defined as self-reported difficulty with any of the following items: a) bathing, b) dressing, c) eating, d) indoor transferring and e) toileting and continence. As basic ADL items behave in a hierarchical way (disabilities are added by senescence), a mean score on these items is a good indication of severity.

### *Data used*

For a summary of all data and their sources, see Table A1. We describe the population in terms of state (disabled or not) and risk factor status (smoking or not, obese or not). We define country-specific populations by age, sex, state and risk factor status-specific prevalence in 2008, derived sex and state specific basic ADL incidence and risk and state-specific basic ADL mortality.

The main source of country-specific information is SHARE, the Survey of Health, Ageing and Retirement in Europe (http://www.share-project.org/; see Appendix A2 for more information). This large European dataset contains all necessary information on elderly people residing in the community (a specific country set contains relatively low numbers). We extracted the prevalence of basic ADL disability by single year of age. We added the numbers of residents in long-term care facilities, derived from WP1. Risk factors were distributed over the LTC population as in SHARE. In the Netherlands, many elderly people live in institutions, and not all are disabled. We adjusted this by available data on elderly people from the long-term care register. For other countries, we assumed that all elderly people living in residences were disabled. For Poland no LTC data were available (but disability is so high that adding residents would not make a major difference). The results are shown in Table A2. To make projections over changing age distributions, age-specific disability figures need to be smoothed (to avoid accentuation of peaks and falls by extrapolations). We did this by using Gompertz models.

[1] See: http://europa.eu/legislation_summaries/employment_and_social_policy/situation_in_europe/c10160en.htm

[2] See: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-10-001/EN/KS-SF-10-001-EN.PDF

To understand the effects of a dynamic change of stocks (prevalence) in populations, we need to model flows (incidence) (Barendregt, Bonneux and Van der Maas, 1994). We modelled the flow into disability by reconstructing a hypothetical incidence from prevalence and state and risk factor specific mortality (see A3 for details on methods). This flow is irreversible (does not take into account recovery), and it therefore summarises all changes 'in and out' of disability in a single transition of non-disabled to disabled (the net inflow). Senescent disability is a chronically progressive but highly fluctuating process. Persons generally enter the state of irreversible disability after a long period of ups and downs, which would lead to many events of 'incidence' and subsequent 'recovery'. Identification of incidence and recovery of disability is always tenuous in epidemiologic surveys. The disability process is slow and fluctuating, the beginning is characterised by series of incidence, recovery and misclassification at the margins between disabled and non-disabled people.

State, sex and age-specific mortality is identified by using prospective data from the Rotterdam Study Project (see Appendix A1 for data on methods and results). Proportional hazard ratios were estimated for mortality risk ratios following disability and risk (obesity or smoking) using Cox regression. Interaction with age was statistically not significant and ignored. Population mortality, state prevalence and risk ratios identified sex, state and age specific mortality.

### *Making forecasts*

At this stage, we have a population incidence of disability by risk factor status and mortality by disability state and risk factor status that consistently reproduces the observed population prevalence and mortality for 2008. These can be applied to projections of populations, flowing in at age 55, and to projections of mortality as made by the EUROPOP mortality forecasts. For background information on the EUROPOP scenario and the macrosimulation model used, see Appendix A4.

It is important to note that mortality forecasts such as those of Eurostat, using simple mathematical models, contain sheer endless numbers of implicit 'business as usual' assumptions. The ANCIEN forecast model makes a few of these assumptions explicit. We take from the mortality forecasts the relative mortality declines and keep these consistent over state and risk factor status, but full consistency is not desirable, as mortality may be an important outcome of scenario forecasts. In smoking, consistency would be impossible, as the EUROPOP 2008 scenario does not take into account the different stages of the smoking epidemic that women and men are in. In the male baby boom cohorts, the smoking epidemic is receding, while in the female baby boom cohorts smoking hits it peak. Future life expectancy of women compared to men as forecast by EUROPOP 2008 is therefore necessarily overestimated, based on explicit knowledge of the smoking epidemic.

The demographic simulation model focuses on ages 65 and older, but starts at age 55 as 'run in' population. We identified the numbers that reach their 55th birthday in each calendar year by using the EUROPOP Population forecasts (see A4 for more information on the main assumptions governing the EUROPOP 2008 forecasts). We implicitly introduce the mortality and migration assumptions at ages younger than 55 of the EUROPOP 2008 scenarios. As our scenarios cover the period 2008-2060, our projections are based on the population already living. The model does not therefore need to include fertility. Moreover, since both immigration and emigration rates tend to be low for elderly people, migration is excluded from the model as well. The EUROPOP 2008 scenarios do not make explicit assumptions on the future determinants of the mortality decline. WP2 of ANCIEN does, by dividing the population into able and disabled and considering the effects of obesity and smoking as risk factors. As a consequence, the results of our projections of the population aged 65+ could be slightly different from the EUROPOP 2008 results.

Many mortality forecasts are possible. In the past, simple linear mathematical models projecting age-specific mortality outperformed more complex methodologies. For consistency and comparability, we use the EUROPOP 2008 mortality forecasts, built on such similar linear methods. These project an optimistic future of mortality decrease, based on the unprecedented mortality decrease in the elderly (65+) after the Second World War. All scenarios therefore modify assumptions about the relation between disability incidence and mortality.

## 2. Scenario assumptions

### *Scenarios without risk factors*

#### *Constant incidence and mortality scenario*

To be able to assess the potential of demographic change, independent from changes in mortality, we postulated a (pessimistic) scenario with no mortality change: CONST, from constant mortality (see Table A1 for a short summary of all scenarios). Change in both incidence and mortality is 0%. CONST therefore reflects the demographic change introduced by the cohorts that entered at age 55, and reached 65 in the years 2008-2060 (or more or less the birth cohorts 1943-1995). These predominantly reflect the ageing of the baby boom cohorts, for simplicity (size and duration of the baby boom varied considerably, even in the countries considered) defined as born between 1946 and 1965. In the model, they will die between 2046 and 2065 (beyond the time horizon of 2060). In this report, we only present the results up to 2040; most relevant for policy-making. In the spreadsheets downloadable from the ANCIEN website, results run until 2060. All subsequent scenarios add decreasing mortality to this scenario.

#### *Constant prevalence scenario*

The prevalence scenario (PREV) applies constant age-specific prevalence ratios of disability to the changing populations. This is a much used and simple technique to assess future care needs. The technique makes implicit assumptions that are made explicit by multi-state simulation.

#### *Chronological ageing scenario*

The chronology scenario (CHRON) assumes that age-specific incidence rates are dependent on age, which is the period since birth. Incidence is kept constant. The difference with the PREV scenario is caused by explicit assumptions about survival in disabled or non-disabled states. Indeed, in the prevailing scenario of decreasing mortality, prevalence will increase as decreasing mortality among the disabled extends their survival.

#### *Biological ageing scenario*

The biological scenario (BIOL) assumes that age-related disability is determined by biological (or prospective) age: the remaining years of life before death. This assumes a biologically plausible similar decline of disability incidence to that of mortality. The EUROP 2008 mortality forecasts assume a close interaction of the mortality decrease with age: mortality declines sharply at younger ages, but less at older age and close to nothing in the oldest ages. This is reflected in the biological forecasts. In general, biological scenarios predict the expansion of healthy life, but no expansion of disabled life. Up to now, this is most consistent with observations of severe disability in the available literature.

#### *Delayed ageing scenario*

The delayed ageing scenario is a conservatively modified ageing scenario. DELAY assumes that the disability is delayed in the life course to older ages, similar to mortality. While the biological scenario assumes close interaction of mortality decrease with age, the delay scenario postpones disability, similar to mortality, avoiding this interaction. Incidence is then declining less at younger ages (avoiding the very large disability declines of the multiplicative biological scenario), but declines more at older ages (more consistent with a hypothesis of postponed disability). As incidence decline at younger ages prevents more disability at older ages, the DELAY scenario is a biological scenario, but which is more conservative than the biological scenario BIOL.

## *Scenarios with risk factors: obesity*

### *The BMI scenario*

The background mortality and disability forecast is the EUROPOP 2008 mortality scenario with the DELAY disability scenario.

The mortality of obese people does not differ much from the non-obese, but the prevalence of disability is (a lot) higher. Obesity increases the load on the weight-bearing joints of knees, hips and back, which causes changes in posture and accelerated wear and tear in the fragile joints of the human. This leads to loss of mobility, which with changes in cognition and balance is a major cause of disability. The BMI scenario projects the (increased) prevalence of obesity of inflowing future cohorts to the future but keeps these prevalences constant.

### *The 'back to leaner populations' scenario*

This back-to-leaner populations (LEAN) is an optimistic scenario. It halves the prevalence of obesity in all inflowing 55 year old in the future. This part of the assumption is not so extreme: the prevalence of obesity doubled more or less since the 1960s, so this scenario assumes a return to the prevalence of obesity of the 1960s. The extreme part is that this halving of obesity prevalence happened immediately in 2008... We adopted extreme scenarios, as risk factors had surprisingly little effect on numbers of disabled persons.

### *FAT*

FAT is another extreme scenario, but pessimistic. It assumes that the prevalence of obesity is doubling. Again, this part of the assumption is not extreme: prevalence of obesity in the US is more or less double that of the modelled European countries. What is extreme is the suddenness of that increase.

## *Scenarios with risk factors: smoking*

The background mortality and disability forecast is the EUROPOP 2008 mortality scenario with the DELAY disability scenario. However, as smoking is such a significant cause of death, the EUROPOP scenario makes strong implicit assumptions on smoking scenarios. As these are implicit and not necessarily consistent (trends are very different in women and men), we did not try to model them explicitly. Explicit assumptions on smoking will cause unavoidable changes in the mortality forecasts.

Disability incidence of smokers is close to the incidence of non-smokers. Basic ADL disability in smokers is mainly caused by chronic obstructive pulmonary disease, but this occurs only in a fraction of smokers, and only with severe disease. This causes the typical health paradox of smoking. High mortality inhibits life extension and compresses age-related disability.

### *The smoking scenario*

The smoking scenario (SMOK) projects the (still high) prevalence of smoking (SMOK) of younger cohorts to the future, and assumes they will go on smoking. That is a 'worst case' pessimistic assumption. It is not very realistic, as disabled smokers will often quit smoking as a consequence of the disease that disabled them.

### *The trend scenario*

The trend scenario (TREND) is a realistic future scenario. It adds the assumption that future cohorts and smokers will successfully quit at a rate of 2% per year (which is close to recent observations).

### *The no smoking scenario*

The no-smoking scenario (NoSMOK) modifies the SMOK scenario, by assuming that in the future no 55 year old will be smoking anymore, but that the remaining smokers will go on smoking. These large smoking cohorts will then only be extinct, as it were, by around 2055. This shows the inertia of demographic change: people start smoking as a teenager, but will die of smoking on average fifty years later. In 2040, many smokers will still survive at the age of highest disability, which can cause paradoxical results.

### *The no-smoking and accelerated quitting scenario*

This scenario (NoSQuit) adds high quit rates to the stop-smoking (NoSMOK) scenario. This is an extreme 'no smoking' scenario, as smokers both die or quit and are not replaced by new cohorts of smokers. It also shows the potential of increasing disability, but also decreasing smoking related mortality, compared to the trend scenario.

## 3. Results

### *Life expectancy results*

The life tables show healthy life expectancies, which combine prevalence and mortality in a life table. Multi-state life tables modelling incidences and mortality are mathematically more consistent, but they are not easy to understand (they define synthetic cohorts) and are less applicable to population figures. Healthy life tables are mathematically not consistent (they combine stocks, a result from historical flows, with actual flows: mortality), but they are easy to make and to understand. They split up the remaining life expectancy at age 65, calculated by applying mortality rates to a synthetic cohort, in a fraction with or without disability based on age specific prevalences. Table 1 shows that the ANCIEN method of parsing mortality over disability state and risk factor status succeeds well in reproducing the EUROPOP life expectancies, while adding information on the duration of disability in the synthetic cohort.

The tables can be read as follows: for Germany, life expectancy is at age 65 20.1 years for women and 16.8 years for men. Of these, German men would live 3.3 years with basic ADL disability and German women 4.8 years (reflecting the higher disability prevalence among women). German smokers live on average 3.8 years less (note that this difference is modelled by using Dutch relative mortality risks) – 2.4 'good' years free of basic ADL disability and 1.4 'bad' year. Obese persons live 0.4 years less (which would only be statistically significant in very large studies), but they lose 1.5 years free of basic ADL disability, with a remarkable and often noted difference between women and men. Women pay the price of a long life, less muscle mass (to cater for larger fat reserves, to be used during pregnancy and breast feeding) and skeletal remodelling caused by the conflicting demands of a bipedal life and child birth.

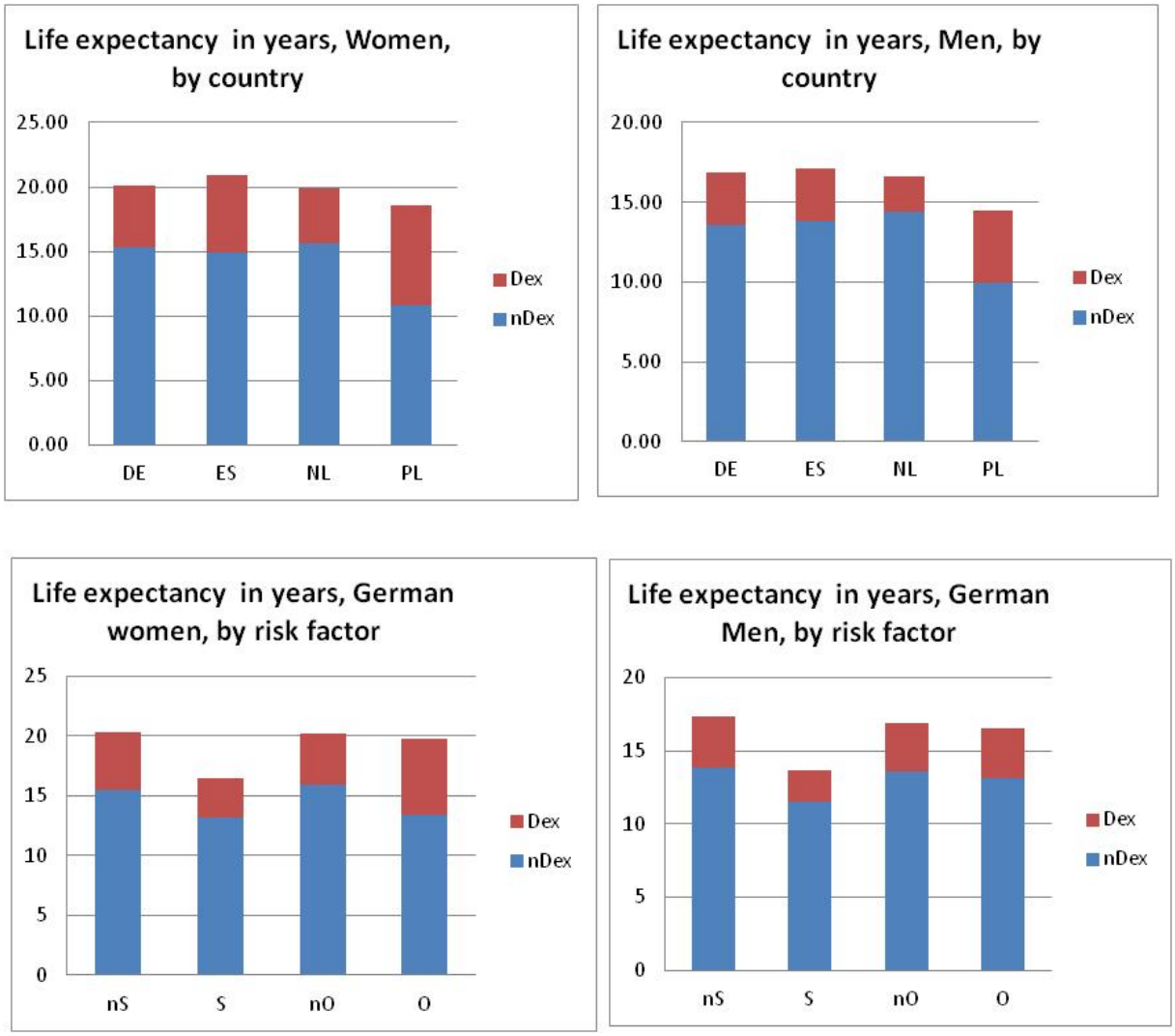
While the Dutch have a lower life expectancy than the Germans and the Spaniards, they have a higher disability-free life expectancy. The Polish population shares the fate of all former EU socialist regimes/political systems: high mortality, particularly among men, combined with high disability. Smoking, alcohol and poor diets are to be blamed. The good news for the Polish population is that they belong to the forerunners, and that we may sincerely hope that our disability forecasts still reflect a bleaker past and are therefore too pessimistic. However, if demography teaches us one thing, it is that history will never be ignored: it takes many decades to leave the past behind.

*Table 1. Non-disabled life expectancies at age 65 by risk factor status in 2008*

| 2008 | Women | | | Men | | |
|---|---|---|---|---|---|---|
| | Ex | nDex | Dex | Ex | nDex | Dex |
| DE | | | | | | |
| Europop | 20.07 | | | 16.82 | | |
| ANCIEN | 20.10 | 15.35 | 4.75 | 16.87 | 13.56 | 3.32 |
| nS | 20.33 | 15.49 | 4.84 | 17.33 | 13.87 | 3.46 |
| S | 16.47 | 13.13 | 3.34 | 13.66 | 11.49 | 2.16 |
| nO | 20.22 | 15.88 | 4.34 | 16.92 | 13.59 | 3.33 |
| O | 19.73 | 13.39 | 6.33 | 16.56 | 13.09 | 3.47 |
| ES | | | | | | |
| Europop | 20.93 | | | 17.09 | | |
| ANCIEN | 20.96 | 14.87 | 6.09 | 17.14 | 13.79 | 3.35 |
| nS | 21.04 | 14.90 | 6.14 | 17.81 | 14.24 | 3.57 |
| S | 17.28 | 12.98 | 4.30 | 14.14 | 11.79 | 2.35 |
| nO | 21.11 | 15.69 | 5.42 | 17.19 | 13.83 | 3.36 |
| O | 20.73 | 13.15 | 7.58 | 16.80 | 13.23 | 3.57 |
| NL | | | | | | |
| Europop | 19.90 | | | 16.55 | | |
| ANCIEN | 19.94 | 15.64 | 4.30 | 16.59 | 14.39 | 2.20 |
| nS | 20.44 | 15.95 | 4.49 | 17.32 | 14.93 | 2.38 |
| S | 16.60 | 13.63 | 2.97 | 13.80 | 12.30 | 1.50 |
| nO | 20.03 | 16.00 | 4.03 | 16.65 | 14.44 | 2.21 |
| O | 19.56 | 13.89 | 5.68 | 16.13 | 13.65 | 2.48 |
| PL | | | | | | |
| Europop | 18.53 | | | 14.45 | | |
| ANCIEN | 18.56 | 10.85 | 7.71 | 14.50 | 9.91 | 4.59 |
| nS | 18.80 | 10.97 | 7.83 | 15.42 | 10.49 | 4.94 |
| S | 14.83 | 9.11 | 5.72 | 11.54 | 8.09 | 3.45 |
| nO | 18.59 | 11.02 | 7.58 | 14.57 | 10.09 | 4.48 |
| O | 18.63 | 10.76 | 7.86 | 14.27 | 9.17 | 5.10 |

(ex, life expectancy nDex life expectancy free of disability, Dex, life expectancy with disability DE (Germany), ES (Spain), NL (Netherlands), PL (Poland); nS (non-Smokers), S (Smokers), nO (not obese, BMI < 30), O (BMI > 30).

*Figure 1. Life expectancy at age 65 by disability status; by country (a and b) and by risk factor status (DE, c and d)*




## 4. Modelled life expectancies in 2040

### *By disability status*

EUROPOP 2008 assumes European convergence: those countries with the lowest life expectancy in 2008 make the largest gains and vice versa. When introducing dynamic states, the forecasted life expectancy will differ from the EUROPOP scenarios. The constant incidence scenario (CHRON) separates mortality into two rates: a mortality rate from the disabled and the non-disabled. This adds the increased life expectancy of disabled people to the prevalence scenario. The Biology scenario adds little disability, compared to 2008, as it is assuming parallel incidence and mortality decline. By parsing mortality in two states, the relative decline of high mortality in the disabled state adds to the forecasted life expectancy. The delay scenario, assuming a linear and more age-independent incidence decline, adds disability by assuming less incidence decline among the younger. The younger disabled will live longer than the older by virtue of being younger. The scenario is therefore more conservative than the biological scenario. Noteworthy is the atypical result of the delay scenario in Poland compared to the three other EU countries: this is caused by high disability among younger persons, less age dependency and therefore less delay effect.

Table 3 and Figure 2 show the consequences of these changes in incidence and mortality, applied to the populations of the four countries studied. Table 3 shows the differences between the main scenarios in terms of numbers and percentages of persons with basic ADL disability as well as annual change in mortality and incidence for the period 2008-2040. Figure 2 shows the change in the number of basic ADL disabled persons in 2040 compared to 2008 distinguished by the different components, as specified by the assumptions. “Demography” shows the consequences of the flowing in of the baby boom cohorts. “Life ext” shows the consequences of life extension, according to the moderate ‘Delay’ scenario. “Chron” shows the consequences of a constant disability incidence (an extreme case).

Germany shows the most moderate changes. This is a consequence of lower birth rates after the second world war. Spain shows a somewhat smaller effect of life extension: a consequence of a lower mortality in 2008 and therefore, in the Europop convergence scenario, somewhat lower life expectancy increase. The Netherlands is demographically the most unstable, with a large baby boom cohort moving in. This is exacerbated by the strong age dependency of the prevalence of basic ADL disability in the Dutch data.

*Table 2. Changes in healthy life expectancies at age 65 in 2040*

| 2040 | F | | | M | | |
|---|---|---|---|---|---|---|
| | Ex | nDex | Dex | ex | nDex | Dex |
| DE | | | | | | |
| Const | 20.10 | 15.35 | 4.75 | 16.87 | 13.56 | 3.32 |
| Europop 2040 | 23.23 | | | 20.13 | | |
| Prev | 23.23 | 17.16 | 6.07 | 20.13 | 15.56 | 4.58 |
| Chron | 23.22 | 16.96 | 6.26 | 20.11 | 15.30 | 4.81 |
| Biol | 23.47 | 18.69 | 4.77 | 20.48 | 16.73 | 3.75 |
| Delay | 23.34 | 17.78 | 5.56 | 20.37 | 16.25 | 4.12 |
| ES | | | | | | |
| Const | 20.96 | 14.87 | 6.09 | 17.14 | 13.79 | 3.35 |
| Europop 2040 | 23.76 | | | 20.29 | | |
| Prev | 23.76 | 16.19 | 7.57 | 20.29 | 15.82 | 4.47 |
| Chron | 23.76 | 16.02 | 7.74 | 20.26 | 15.54 | 4.71 |
| Biol | 24.01 | 17.89 | 6.12 | 20.61 | 16.94 | 3.67 |
| Delay | 23.89 | 17.02 | 6.87 | 20.48 | 16.37 | 4.11 |
| NL | | | | | | |
| Const | 19.94 | 15.64 | 4.30 | 16.59 | 14.39 | 2.20 |
| Europop 2040 | 23.11 | | | 19.80 | | |
| Prev | 23.11 | 17.45 | 5.66 | 19.80 | 16.70 | 3.10 |
| Chron | 23.11 | 17.27 | 5.84 | 19.77 | 16.47 | 3.31 |
| Biol | 23.36 | 18.98 | 4.38 | 20.07 | 17.59 | 2.48 |
| Delay | 23.25 | 18.26 | 4.99 | 19.99 | 17.26 | 2.73 |
| PL | | | | | | |
| Const | 18.56 | 10.85 | 7.71 | 14.50 | 9.91 | 4.59 |
| Europop 2040 | 22.25 | | | 18.58 | | |
| Prev | 22.25 | 12.21 | 10.04 | 18.58 | 11.95 | 6.63 |
| Chron | 22.24 | 11.96 | 10.28 | 18.51 | 11.48 | 7.03 |
| Biol | 22.52 | 13.95 | 8.57 | 18.93 | 13.06 | 5.86 |
| Delay | 22.37 | 12.89 | 9.48 | 18.77 | 12.45 | 6.31 |

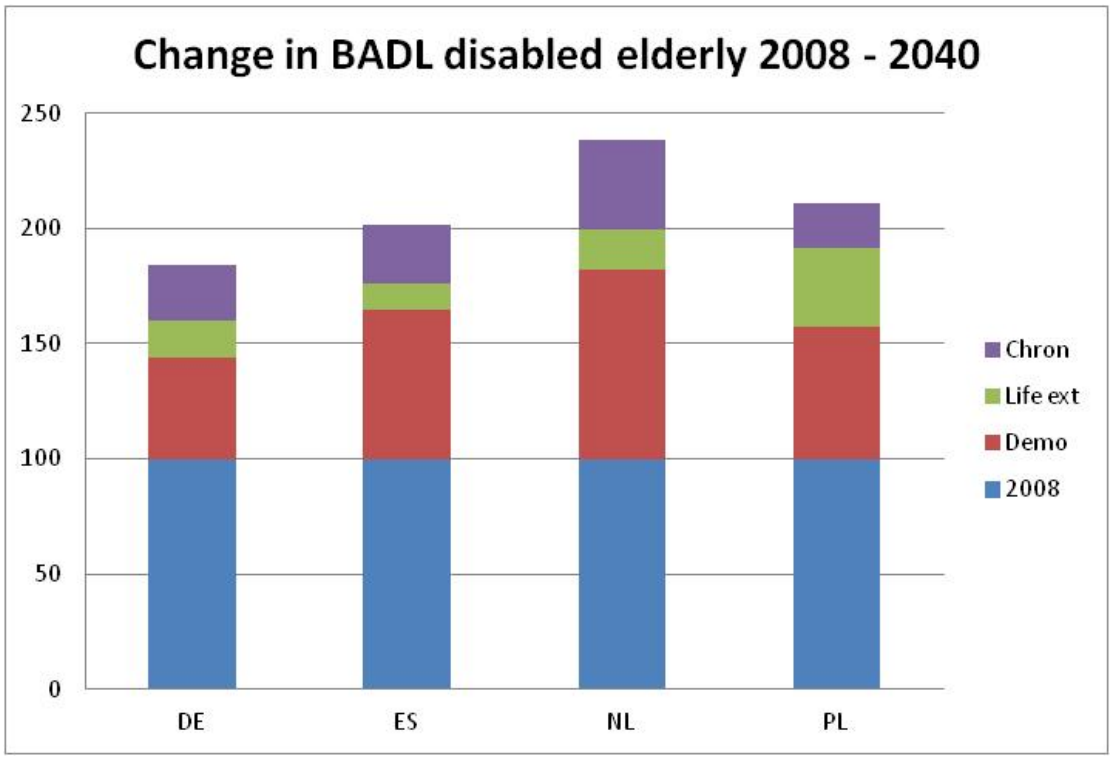
ex, life expectancy nDex life expectancy free of disability, Dex, life expectancy with disability (all expressed in years). See table with data and assumptions for scenarios.

*Table 3. Changes in incidence and mortality (age standardised) and consequences for the populations in 2040*

| | annual change | | 65+ (X 1000) | | | Index | |
|---|---|---|---|---|---|---|---|
| | mortality | incidence | N | n disabl | Prev | 65+ | ADL |
| DE | | | | | | | |
| 2008 | | | 16519 | 3222 | 19.5% | 100 | 100 |
| CONST | 0% | 0% | 21098 | 4636 | 22.0% | 128 | 144 |
| PREV | -1.35% | NA | 24212 | 5724 | 23.6% | 147 | 178 |
| CHRON | -1.35% | 0% | 24163 | 5933 | 24.6% | 146 | 184 |
| BIOL | -1.35% | -1.35% | 24404 | 4475 | 18.3% | 148 | 139 |
| DELAY | -1.35% | -0.91% | 24307 | 5147 | 21.2% | 147 | 160 |
| ES | | | | | | | |
| 2008 | | | 7520 | 1794 | 23.8% | 100 | 100 |
| CONST | 0% | 0% | 12875 | 2952 | 22.9% | 171 | 165 |
| PREV | -1.34% | NA | 14375 | 3509 | 24.4% | 191 | 196 |
| CHRON | -1.34% | 0.00% | 14351 | 3613 | 25.2% | 191 | 201 |
| BIOL | -1.34% | -1.35% | 14469 | 2770 | 19.1% | 192 | 154 |
| DELAY | -1.34% | -0.87% | 14419 | 3161 | 21.9% | 192 | 176 |
| NL | | | | | | | |
| 2008 | | | 2415 | 403 | 16.7% | 100 | 100 |
| CONST | 0% | 0% | 4090 | 734 | 17.9% | 169 | 182 |
| PREV | -1.41% | NA | 4699 | 923 | 19.7% | 195 | 229 |
| CHRON | -1.41% | 0.00% | 4689 | 961 | 20.5% | 194 | 239 |
| BIOL | -1.41% | -1.39% | 4734 | 709 | 15.0% | 196 | 176 |
| DELAY | -1.41% | -0.95% | 4718 | 803 | 17.0% | 195 | 199 |
| PL | | | | | | | |
| 2008 | | | 5131 | 1852 | 36.1% | 100 | 100 |
| CONST | 0% | 0% | 7501 | 2914 | 38.8% | 146 | 157 |
| PREV | -1.53% | NA | 9120 | 3745 | 41.1% | 178 | 202 |
| CHRON | -1.53% | 0.00% | 9155 | 3907 | 42.7% | 178 | 211 |
| BIOL | -1.53% | -1.61% | 9275 | 3218 | 34.7% | 181 | 174 |
| DELAY | -1.53% | -0.91% | 8996 | 3548 | 39.4% | 175 | 192 |

*Note*: N is the population (N), N disabl are the numbers disabled. The index compares the relative change to 2008 (= 100). Prevalence is the period prevalence of basic ADL disabled in the population 65+ in the year 2040. The annual yearly incidence is the average age adjusted change over a year in the period 2008-2040. See table with data and assumptions for scenarios.

*Figure 2. Change in basic ADL disabled elderly in 2040, compared to 2008*

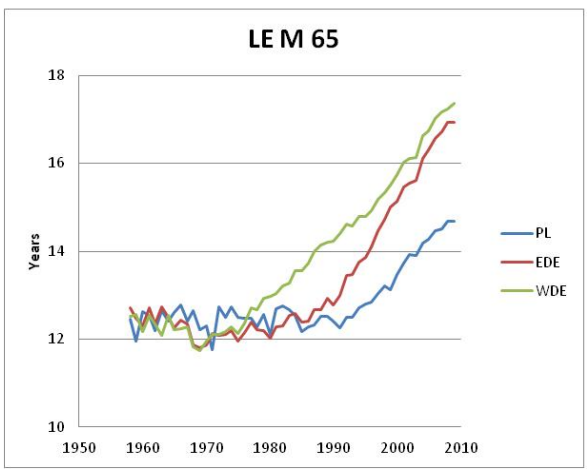


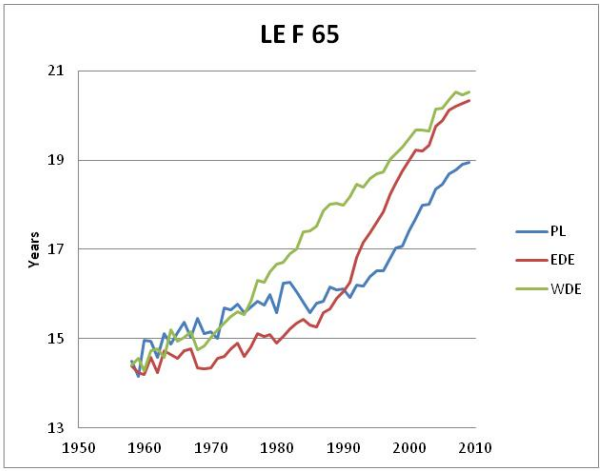

*Note*: "Demo" is the expected change, with constant mortality and incidence. Life extension adds the numbers of the middle 'Delay' scenario. "Chron" adds the numbers if incidence of disability would remain constant.

## *A special case: Poland*

Poland is a former socialist country, whereas Germany was split into two parts: the German Democratic Republic (GDR or East Germany), which became a member of the communist bloc, and the Federal Republic of Germany (FRG or West Germany), which became a free market economy. Figure 3 shows the evolution of life expectancy at age 65 for men and women, Poland and both parts of Germany and the relative mortality differences between the three regions (source: human mortality database, www.mortality.org).

*Figure 3 A and B. Evolution of life expectancy at age 65 from 1958 till 2009, Poland (PL), Eastern Germany (EDE) and Western Germany (WDE)*



Differences between the former socialist regions and western free market economies are predominantly caused by suicide, alcoholism and a longer smoking epidemic (Bonneux, Huisman & de Beer, 2010). While smoking kills, despair, depression and alcoholism are important causes of disability. As the mortality signs of a bleak society are ubiquitous in the former socialist countries of Eastern Europe, they may explain high levels of disability, particularly in those who lived their adult life (15-55) under communist regimes (Bonneux, Huisman & de Beer, 2010). However, the mortality figures also show rapid convergence of life expectancy in Eastern Germany, pulled forward by the unification of Germany. Convergence within Europe may have the same effects.

Therefore, to take into account the different disability history of Poland, we specified an additional 'Convergence' scenario. We compared the German and Polish incidence of disability in both delay scenarios, and then we assumed a gradual linear convergence of disability incidence to the German disability incidence over one generation: under this scenario the Polish would reach the German disability prevalence in 2040. From then onward, the Polish disability incidence follows the German delay scenario. For transparency, we compared the Polish and the German figures only.

*Table 4. Changes in incidence and mortality and consequences for the year 2040*

| | annual change | | 65+ (X 1000) | | | Index | |
|---|---|---|---|---|---|---|---|
| | mortality | incidence | N | n disabl | Prev | 65+ | ADL |
| DE | | | | | | | |
| 2008 | | | 16519 | 3222 | 19.5% | 100 | 100 |
| CONST | 0% | 0% | 21098 | 4636 | 22.0% | 128 | 144 |
| PREV | -1.35% | NA | 24212 | 5724 | 23.6% | 147 | 178 |
| CHRON | -1.35% | 0% | 24163 | 5933 | 24.6% | 146 | 184 |
| BIOL | -1.35% | -1.35% | 24404 | 4475 | 18.3% | 148 | 139 |
| DELAY | -1.35% | -0.91% | 24307 | 5147 | 21.2% | 147 | 160 |
| PL | | | | | | | |
| 2008 | | | 5131 | 1852 | 36.1% | 100 | 100 |
| CONST | 0% | 0% | 7501 | 2914 | 38.8% | 146 | 157 |
| PREV | -1.53% | NA | 9120 | 3745 | 41.1% | 178 | 202 |
| CHRON | -1.53% | 0.00% | 9155 | 3907 | 42.7% | 178 | 211 |
| BIOL | -1.53% | -1.61% | 9275 | 3218 | 34.7% | 181 | 174 |
| DELAY | -1.53% | -0.91% | 8996 | 3548 | 39.4% | 175 | 192 |
| CONVERGENCE | -1.53% | -1.72% | 9306 | 3058 | 32.9% | 181 | 165 |

The EUROPOP 2008 convergence scenario also causes more significant mortality declines in Poland than in Germany (although less than was observed in Eastern Germany: see previous figure). The convergent scenario of disability incidence in Poland would have quite important consequences: it would reduce the numbers of disabled elderly people more than in the biological scenario. However, even then, Poland would still face important increases of disabled elderly; a consequence of demography and demographic inertia. The survivors of the communist era and its legacy of high disability will persist for many years to come.

## 5. Disability changes by risk factor status in 2040

Table 5 shows the consequences of changes in risk factors in 2040 in the life table (delay scenario at baseline). The scenarios are satisfactorily consistent. The sharp mortality decrease, equal between smokers and non-smokers, decreases the life expectancy gap between both, but only slightly.

Differences in life expectancy between the obese and the non-obese are minor, but cause relatively marked changes in life expectancy with disability.

*Table 5. Life expectancy at age 65, by risk factor status in 2040*

| 2040 | F | | | M | | |
|---|---|---|---|---|---|---|
| | Ex | nDex | Dex | ex | nDex | Dex |
| DE | | | | | | |
| 2008 | 20.10 | 15.35 | 4.75 | 16.87 | 13.56 | 3.32 |
| 2040 (delay) | 23.34 | 17.78 | 5.56 | 20.37 | 16.25 | 4.12 |
| nS | 23.58 | 17.91 | 5.67 | 20.75 | 16.54 | 4.21 |
| S | 19.80 | 15.75 | 4.05 | 17.01 | 14.15 | 2.86 |
| nO | 23.52 | 18.43 | 5.10 | 20.54 | 16.74 | 3.81 |
| O | 23.05 | 15.64 | 7.41 | 19.80 | 14.28 | 5.52 |
| ES | | | | | | |
| 2008 | 20.96 | 14.87 | 6.09 | 17.14 | 13.79 | 3.35 |
| 2040 (delay) | 23.89 | 17.02 | 6.87 | 20.48 | 16.37 | 4.11 |
| nS | 24.01 | 17.05 | 6.96 | 21.08 | 16.79 | 4.29 |
| S | 20.32 | 15.26 | 5.06 | 17.38 | 14.34 | 3.04 |
| nO | 24.12 | 18.06 | 6.06 | 20.66 | 16.88 | 3.78 |
| O | 23.74 | 15.25 | 8.49 | 19.93 | 14.44 | 5.49 |
| NL | | | | | | |
| 2008 | 19.94 | 15.64 | 4.30 | 16.59 | 14.39 | 2.20 |
| 2040 (delay) | 23.25 | 18.26 | 4.99 | 19.99 | 17.26 | 2.73 |
| nS | 23.70 | 18.52 | 5.17 | 20.64 | 17.77 | 2.88 |
| S | 19.98 | 16.41 | 3.56 | 17.07 | 15.13 | 1.95 |
| nO | 23.41 | 18.74 | 4.67 | 20.12 | 17.59 | 2.53 |
| O | 22.97 | 16.49 | 6.48 | 19.37 | 15.54 | 3.83 |
| PL | | | | | | |
| 2008 | 18.56 | 10.85 | 7.71 | 14.50 | 9.91 | 4.59 |
| 2040 (delay) | 22.37 | 12.89 | 9.48 | 18.77 | 12.45 | 6.31 |
| nS | 22.59 | 13.01 | 9.59 | 19.58 | 12.93 | 6.65 |
| S | 18.69 | 11.51 | 7.17 | 15.67 | 10.90 | 4.77 |
| nO | 22.57 | 13.87 | 8.70 | 18.94 | 13.05 | 5.89 |
| O | 22.37 | 11.38 | 10.99 | 18.36 | 10.42 | 7.94 |

ex, life expectancy nDex life expectancy free of disability, Dex, life expectancy with disability. NS and NO, non-smokers and non-Obese, S and O smokers and Obese. All in years.

Table 6 and Figure 4 show the effects of quite extreme risk factor scenarios for obesity. The BMI as a usual scenario assumes a constant BMI in the future. The effects are therefore determined by the prevalence of BMI in the younger cohorts that are flowing in. As the reader may notice, the prevalence of an increased BMI (30+) in these cohorts was relatively low in Germany, higher in the Netherlands, high in Spain and very high in Poland. We therefore did not simulate more scenarios, as these four countries show a wide range of responses to an increased BMI.

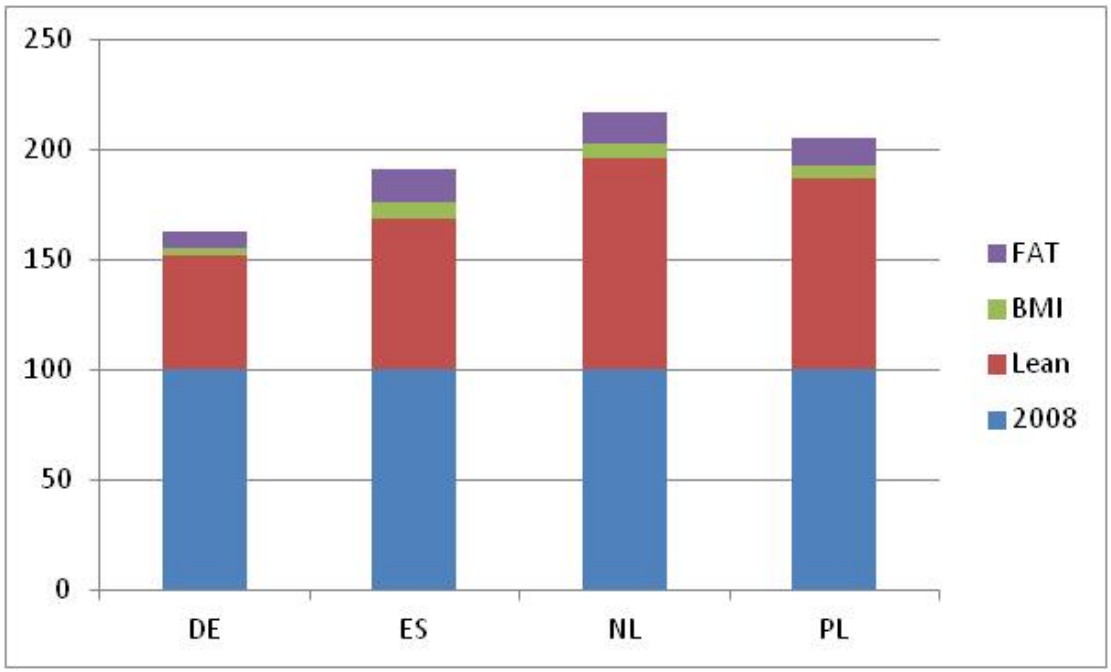
The FAT scenario assumes that all future cohorts have a doubled prevalence of obesity (BMI 30+), which is quite extreme. The LEAN scenario assumes that all future cohorts have a halved prevalence of obesity. If changes were more gradual, effects would be smaller. But even these extreme scenarios, with relatively significant consequences for an individual life course, have a rather limited impact on the prevalence of disability. Every individual born before 1975 will contribute to the prevalence of disability among the 65+ in 2040, while only the obese fraction of that population can contribute to the excess prevalence of disability caused by obesity. The effect on the total population is limited, as expected from the rather limited changes in life expectancy.

The Polish population forecasts are again an outlier, due to the combined effect of both a high prevalence of obesity and disability. The lower mortality among the disabled obese population (called the obesity paradox in epidemiology) can then be significant enough to increase the total population.

*Table 6. The effect of changing BMI on projected ADL disability in 2040*

| | | 65+ (X 1000) | | | Index | |
|---|---|---|---|---|---|---|
| **2040** | **Prevalence of obesity** | N | n disabl | Prev | 65+ | ADL |
| DE | | | | | | |
| DELAY | NA | 24307 | 5147 | 21,2% | 147 | 160 |
| BMI | 12,7% | 24359 | 5017 | 20,6% | 147 | 156 |
| LEAN | 7,2% | 24389 | 4907 | 20,1% | 148 | 152 |
| FAT | 23,7% | 24298 | 5237 | 21,6% | 147 | 163 |
| ES | | | | | | |
| DELAY | NA | 14419 | 3161 | 21,9% | 192 | 176 |
| BMI | 25,3% | 14430 | 3157 | 21,9% | 192 | 176 |
| LEAN | 14,0% | 14457 | 3021 | 20,9% | 192 | 168 |
| FAT | 48,2% | 14376 | 3430 | 23,9% | 191 | 191 |
| NL 2040 | | | | | | |
| DELAY | NA | 4718 | 803 | 17,0% | 195 | 199 |
| BMI | 20,3% | 4713 | 817 | 17,3% | 195 | 203 |
| LEAN | 11,2% | 4723 | 789 | 16,7% | 196 | 196 |
| FAT | 38,5% | 4693 | 873 | 18,6% | 194 | 217 |
| PL 2040 | | | | | | |
| DELAY | NA | 8996 | 3492 | 38,8% | 175 | 189 |
| BMI | 28,7% | 9238 | 3575 | 38,7% | 180 | 193 |
| LEAN | 16,1% | 9257 | 3463 | 37,4% | 180 | 187 |
| FAT | 54,1% | 9199 | 3799 | 41,3% | 179 | 205 |

*Figure 4. Change in basic ADL disabled elderly in 2040, compared to 2008, obesity scenarios*




*Note*: "Lean" shows the consequence when the prevalence of obesity in the future cohorts dramatically halves after 2008, "BMI" adds the numbers of disabled when the prevalence of obesity remains constant at the values of 2008 and "Fat" when the prevalence dramatically doubles. Even extreme scenarios have small effects.

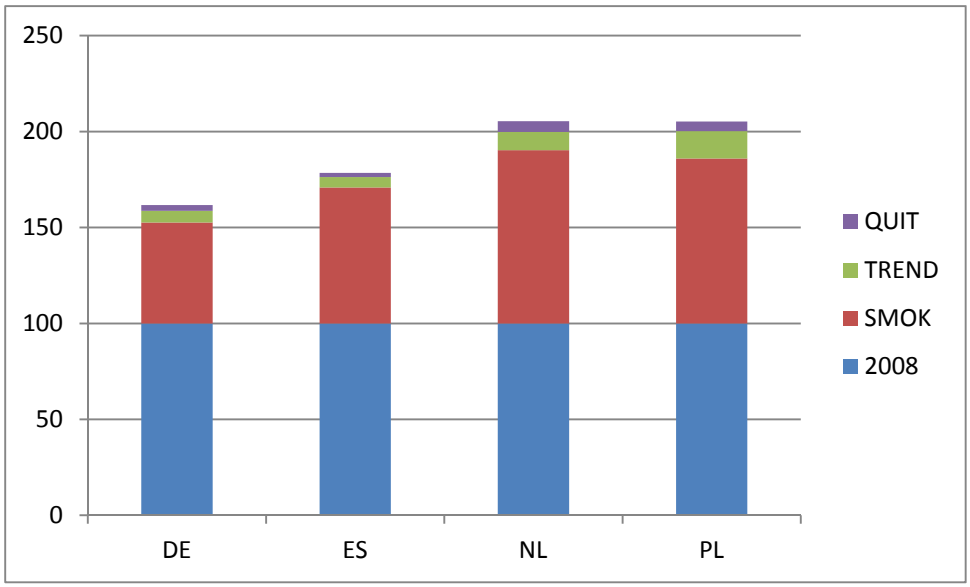
Smoking trends are implicitly taken into account by the Europop 2008 forecast methodology, and in the disability scenarios that do not take into account risk factor status. This methodology does not take heterogeneity into account. However, smoking trends were a major cause of the mortality decline among men in European democracies since the 1970s, but no cause of mortality decline among European women, born before the Second World War. By societal consensus, these female generations were not 'allowed' to smoke. This will change in the future. The female baby boom generation took up smoking in large(r) numbers, and will pay the price with increased mortality. In general, this means that the female future mortality decline has been overestimated in the Europop mortality scenario, while the male future mortality decline has been underestimated.

Table 7 and Figure 5 show the effects of the scenarios, including the risk factor of smoking. In Germany, the largest country, maintaining smoking at the high rates of younger cohorts would decrease the numbers of 65 and older, by the high mortality of smoking, and would decrease the numbers of disabled people disproportionately, as mortality among the disabled is even higher. If both able-bodied and disabled people quit (the NoSquit scenario), more disabled elderly people will survive to an older age. However, this is actually an effect of desirable life extension: quitting smoking is the single most important treatment in cardiovascular and respiratory diseases (among cancer patients, it is probably too late…). The difference between the SMOK and TREND scenario shows that quitting among smokers is the most important reason of disability increase: smokers with disease try to stop. If they do not, the prognosis is poor, mortality is high and disability will be compressed. But this is hardly advisable, common for all treatable diseases and would be a violation of the 'rule of cure'. Indeed, the difference between accelerated quitting scenarios and the trend scenario is very small.

*Table 7. The effect of changing smoking patterns on projected ADL disability in 2040*

| | **Prev smoking** | 65+ (X 1000) | | | Index | |
|---|---|---|---|---|---|---|
| | | N | n disabl | Prev | 65+ | ADL |
| DE | | | | | | |
| 2008 | 8.6 | 16519 | 3222 | 19.5% | 100 | 100 |
| 2040 | | | | | | |
| DELAY | na | 24307 | 5147 | 21.2% | 147 | 160 |
| Trend | 9.2 | 24187 | 5113 | 21.1% | 146 | 159 |
| SMOK | 22.1 | 23653 | 4916 | 20.8% | 143 | 153 |
| noSMOK | 1.2 | 24454 | 5067 | 20.7% | 148 | 157 |
| NoSQuit | 0.2 | 24687 | 5209 | 21.1% | 149 | 162 |
| ES | | | | | | |
| 2008 | 7.7 | 7520 | 1794 | 23.9% | 100 | 100 |
| 2040 | | | | | | |
| DELAY | na | 14419 | 3161 | 21.9% | 192 | 176 |
| Trend | 8.6 | 14404 | 3161 | 21.9% | 192 | 176 |
| SMOK | 21.5 | 14139 | 3065 | 21.7% | 188 | 171 |
| noSMOK | 0.9 | 14534 | 3137 | 21.6% | 193 | 175 |
| noSquit | 0.2 | 14638 | 3200 | 21.9% | 195 | 178 |
| NL | | | | | | |
| 2008 | 15.2 | 2415 | 403 | 16.7% | 100 | 100 |
| 2040 | | | | | | |
| DELAY | na | 4718 | 803 | 17.0% | 195 | 199 |
| Trend | 11.5 | 4729 | 805 | 17.0% | 196 | 200 |
| SMOK | 25.9 | 4617 | 766 | 16.6% | 191 | 190 |
| noSMOK | 1.7 | 4778 | 792 | 16.6% | 198 | 197 |
| noSquit | 0.3 | 4840 | 827 | 17.1% | 200 | 205 |
| PL | | | | | | |
| 2008 | 11.1 | 5131 | 1852 | 36.1% | 100 | 100 |
| 2040 | | | | | | |
| DELAY | na | 8996 | 3548 | 39.4% | 120 | 198 |
| TREND | 10.6 | 9239 | 3591 | 38.9% | 123 | 200 |
| SMOK | 30.2 | 8830 | 3335 | 37.8% | 117 | 186 |
| noSMOK | 1.6 | 9374 | 3562 | 38.0% | 125 | 199 |
| noSquit | 0.2 | 9523 | 3681 | 38.7% | 127 | 205 |

*Figure 5. Change in basic ADL disabled elderly in 2040, compared to 2008, smoking scenarios*




*Note*: SMOK adds the numbers of disabled people when the prevalence of smoking remains constant at the values of the young cohorts in 2008. "Trend" is a realistic scenario assuming slowly declining prevalences (2% per year), and adds successful quitting at a rate of 2% per year. "Quit" is an accelerated quitting scenario, where no new inflowing cohorts are smoking and smokers quit at accelerated rates.

## 6. Strengths and weaknesses of the chosen approach

The main strengths are the reliable population forecasts (regardless of unforeseen catastrophes), and the use of incidence rates to forecast the future prevalence of disability. We recalculated incidence from prevalence and mortality. However, this is not necessarily a weakness, as the transition from non-disabled to disabled occurs in a volatile and fluctuating chronic process. Indeed, incidence of chronic disease is often inconsistent with prevalence, as at the margins of that process, incidence and recovery occur frequently as a consequence of random fluctuations. In prospective studies, this allows for massive misclassification between disabled and non-disabled people, causing the inconsistency between incidence and prevalence.

However, the data used are weak. Prevalence of basic ADL disability is highest among the oldest old population, but data on the prevalence of basic ADL disability in these populations are rare or absent. We are far more confident of the reliability of modelled trends than in the point estimates of basic ADL disability for 2008. Only very different age distributions make trends less certain. This might be a problem for Poland, but not for the other EU member states modelled.

State and risk-factor-dependent mortality was taken from the Rotterdam study, starting in 1990, and applied to all populations (Hofman et al., 2006). Interactions with age were not significant and were ignored, but this might be caused by insufficient power to demonstrate interactions.

We assumed equal mortality trends for disabled and non-disabled persons, or for persons with or without different risk status. This might not be true. Indeed, for dementia (a most important cause of disability), we can observe lower mortality at early stages but increased mortality at later clinical stages in more highly educated people, a consequence of more successful adaptation to cognitive decline by highly educated persons (Reuser, Willekens & Bonneux) They can stave off clinical dementia, until they reach advanced stages of severe disease and poor prognosis.

## 7. Priorities for further research

National estimates of ADL disability by age, gender and other characteristics, particularly at older ages are lacking. Within 20 years, the large birth cohorts of 1946 will celebrate their 85th birthday in greater numbers than ever before. More than half of the men and two thirds of the women of the baby boom generation will survive their 85th birthday according to prospective life tables (life tables that project the survival of cohorts), but we know very little about what is happening among the oldest old population; an age characterised by large variability in life histories. As there was a baby boom, we need a boom of research into the health of elderly people, particularly those of more advanced ages.

Country-specific estimates of state and risk-factor-specific mortality will make country-specific forecasts more specific and reliable. SHARE can deliver this information in the future. However, the quality of mortality follow-up will have to be guaranteed.

We assumed time trends in disability, based on existing data of time series of cross-sectional prevalences as mentioned in the international literature. With longer follow up, SHARE can inform us of trends in prevalence, and maybe even incidence. However, the same condition holds: the quality of follow-up will be of utmost importance.

## Conclusions

The scenarios show the overriding influence of demographic change on future disability, with progressively smaller baby boom birth cohorts from the Netherlands, Spain, Poland, and Germany respectively. These forecasts are very robust: in the life table, 95% survive to age 55, when cohorts enter the model.

Life extension is the second most important factor in the increase of disability. The simple linear forecasts of the EUROPOP scenarios project the period of unprecedented mortality decline among the 55+ after the second world war to the future. The predicted life expectancy among women aged 65 in 2040 is less than 24 years, which is still lower than the actual Japanese female life expectancy at age 65 was in 2009 (24.0 years).

Assuming that a constant disability incidence with sharply decreasing mortality would be a rather pessimistic (the chronology) scenario, the sharply decreasing disability, with little progress in cognitive causes of disability is rather optimistic (the biology scenario). However, the number of life years lived with a disability remained surprisingly constant in the Netherlands. The intermediary ‘Delay’ scenario is therefore a somewhat conservative estimate.

The effects of changing risk factors on disability prevalence are surprisingly small. First, there is demographic inertia: it takes many years to replace populations. Second, every person born between 1943 and 1975 (or 1995) will add to the population of the elderly at risk of disability between 2008 and 2040 (or 2060), but only a fraction of that population is at increased risk. A numerical example shows this. If one-sixth is disabled when not obese but one-third if obese, and 20 out of 100 persons are obese, then among these 100 persons, 20 persons will be disabled. The attributable risk then is one-fifth minus one-sixth = 0.33, or in other words 3.3 added persons are disabled because of obesity. If the prevalence of obesity doubles, from 20% to 40%, the attributable risk doubles and the prevalence of disability increases from 20% to 23%. As in the Netherlands, if the population aged 65+ doubles from 100 to 200, there will be 46 disabled: 20 are added because of the doubling of the population, 6 are added because of obesity. These are six too many, but still much more limited than the total demographic increase.

The effects of quitting smoking are those of life extension. Smoking shortens life and shortens life with added disability. Indeed, many smokers improve the prognosis of their disease considerably by quitting. Extended survival by lifestyle modification can hardly be called a disadvantage. Even extreme scenarios would not add many disabled elderly people. Moreover, for every ‘bad’ year, two to three ‘good’ years are added, increasing the stock of competent elderly people, able to care for their other elderly citizens.

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## Appendices

### *A1 Rationale*

In 2011, the large post-war baby boom, starting in 1946, reached the retirement age of 65. A 'baby crash' (a sharp decline in fertility) followed the baby boom, and is causing serious imbalances between the large baby boom generations and the small baby crash generations born after the 1970s.[3] Extended life expectancy at old age is increasing the number of the oldest old (Oeppen & Vaupel, 2002). Improving health care technology may extend life in disability; a striking example is the sharp decline in acute coronary heart disease mortality, creating large numbers of survivors with heart failure (Bonneux et al., 1994; Peeters et al., 2003).

These developments are likely to cause imbalances between need and supply of long-term care (LTC), straining the financial sustainability of LTC systems. Since health and long-term care consumption by the elderly, especially by the very old and frail, is well above average, health care expenditures are likely to increase significantly (Meerding et al., 1998a; Meerding et al., 1998b). To address policy questions related to the provision of health care services in an ageing population, increasing emphasis has been put on the future development of long-term care need, supply and use, and the functioning of LTC systems. In this paper we use demographic models to project future needs of long-term care in the Netherlands, based on the EUROPOP 2008 mortality forecasts.[4]

Long-term care need is operationalised as having "at least one limitation in activities of daily living" (ADL-disability), based on the Katz ADL disability scale (Katz et al., 1963). ADL-disability is defined as self-reported difficulty with any of the following items: (a) bathing, (b) dressing, (c) eating, (d) indoor transferring and (e) toileting and continence. As generally the ADL items are rather hierarchical, a mean score on these items is a good indication of severity.

Demand for care depends, among other things, on incidence, duration and severity of care dependence. A long-standing debate on compression or expansion of morbidity was started with the seminal paper of James Fries on compression of morbidity (Fries, 1980). Recent analyses confirm an extended life free of care and in good health (Manton, Gu & Lowrimore, 2008), but one which goes together with increased care-dependent life, as the incidence of care is strongly age-dependent (Olshansky, 1991). Fries posited morbidity as being independent of mortality: morbidity could be postponed, mortality was fixed by biology. At the other extremes, predictions of morbidity and health care costs that are age-dependent, posit the same independence, but now it is not mortality, but morbidity which is fixed (Bonneux et al. ,1998). Both disability and mortality at old age are strongly related processes, determined by increasing frailty, a consequence of ageing (Mitnitski et al., 2002). In recent periods, life expectancy is increasing by decreasing mortality of the elderly, being proportional in all age groups (Christensen et al., 2009; Vaupel, 2010). Changes in disability confirm a longer life in good health of the elderly (Cai & Lubitz, 2007; Manton, Gu & Lowrimore, 2008; Reuser, Bonneux & Willekens, 2010). Wear and tear is a chronological process, depending on the duration of exposure, and hence a chronological process, but repair and other plastic responses to damage by wear and tear are biological processes, which may be supported by healthy lifestyles and medical technology (Christensen et al., 2009).

To assess dynamic changes in populations, we need information on dynamic change: transition rates (in demographic terminology) or incidences (in epidemiologic terminology). Through transitions, people move from the one state to the other or to death; the end state.

In a cohort model, numbers of people start in a certain state, and move through states until death. In multi-state life tables, this translates as time spent in a certain state, adding up to a life expectancy at a certain age in certain states. In a simple three-state model (alive without disease, alive with disease,

[3] See http://europa.eu/legislation_summaries/employment_and_social_policy/situation_in_europe/c10160en.htm,

[4] See http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-10-001/EN/KS-SF-10-001-EN.PDF,

death), a cohort model shows life expectancy with or without disease. In a population model, people enter the model during a certain period at a certain age, and move through age and time until they die. In each age/time unit, they can transit to disability or to death. In each period, numbers of survivors in each state at each age are determined by current and past transition rates. If we describe life tables, we describe the period life table: the life table resulting from the age-specific transition rates in a specified (smaller) period. Of course, once the future transition rates are defined, cohort life tables can be described. This would be the life history of individual people entering the model at a certain age, followed up through future time till death. A period life table in 2060 of, say, people aged 65, is defined by the transition rates in the population of 65 and older in 2060, and 2060 only. A cohort life table would be people entering at age 65 in a certain year, say 2010, and then followed up till 2045 (when the life tables are closed at age 100). This cohort life table would summarise the experience of a cohort of 65 year-olds over an extended period of 35 years. In a simple three-state model, we need to identify four incidence flows at every age: incidence (from healthy to disabled (or infirmity, to avoid the D from death, H2I), recovery (from infirmity to health, I2D), death in the state healthy (H2D) or in the state infirmity (I2D). The limitation in the number of states is less inspired by the technological possibilities than by the possibilities of estimation.

If we add risk factors, we can make these transitions risk-factor-dependent. Obesity increases the risk of disability, often just by putting more weight on joints. Smoking is a dangerous fatal habit that increases the risk of dying: all things being equal, smoking therefore tends to decrease disability and associated care needs in a population. In the simplest setting possible, we define two risk states in two risk factors (obese or not, or smoking or not). Obese is defined as having a BMI of 30 and more.

*Table A.1 Summarising source of data and assumptions*

All data are specified by country, sex and single year of age, unless stated otherwise. Projections are made between the years 2008 and 2060. Results are presented as for 2040 (when the large baby boom birth cohorts of 1945-1965 are 75-95 year old, and the peak of ageing is reached).

A Assessment in start year 2008.

A1 Population of 2008 (Eurostat)

A2 Mortality in 2008 (Eurostat)

A3 Prevalence of risk factors, basic ADL disability and risk factor specific disability. Source: EUROSTAT (population), SHARE (European survey, community dwelling elderly), ANCIEN (basic ADL disabled elderly in institutions).

A4 Risk and disability specific mortality ratios (Rotterdam Study, prospective study).

B Forecasts of population and mortality

B1 Entry at age 55 between 2009 and 2060 as projected by EUROPOP 2008

B2 Mortality between 2009 and 2060 as projected by EUROPOP 2008

C Scenarios of disability without risk factors

C1 In the CONST scenario, mortality between 2008 and 2060 is kept constant.

C2 PREV: constant age-specific prevalence of disability

C3 CHRON: constant age-specific incidence of disability

C4 BIOL: relative disability incidence decline similar to mortality. Yields high incidence declines at young age, but lower at older ages.

C5 DELAY: disability incidence delayed with the same time, similar to mortality. Yields higher disability incidence at older ages, but smaller incidence at younger age.

D and E Scenarios of risk factors

D1 BMI: Delay scenario with future inflow of obese people at age 55 at current prevalence.

D2 FAT: Delay scenario with future inflow obese people at age 55 at double the prevalence of 2008 in 2060.

D3 LEAN: Delay scenario with future inflow of obese persons at age 55 at half the prevalence of 2008 in 2060.

E1 SMOK. The (high) smoking prevalence at younger ages are kept constant and propagated in the future. Smokers die at an increased rate, decrementing smoking prevalence.

E2 TREND. The (high) smoking prevalence at younger ages are propagated in the future, but smokers quit successfully at a rate of 2% per year.

E3 NOSMOK. All people quit before age 55. 100% no smokers flow in at age 55 – but it will take 45 years for the remaining smokers to die.

E4 NoSquit. All people quit before age 55, but the remaining smokers quit at an increased rate of 4% per year.

*Table A.2 Prevalence of disability by country and five year groups (source: SHARE 2004-2006 and LTC data 2008)*

| | | Population | In community | In LTC | % disab commun | % in LTC | As observed | As modelled | % as obs | % as exp |
|---|---|---|---|---|---|---|---|---|---|---|
| DE | | | | | | | | | | |
| M | 65-69 | 2,552,272 | 2,533,932 | 18,340 | 7.0% | 1 | 195,847.6 | 172,625 | 7.7% | 6.8% |
| | 70-74 | 1,933,383 | 1,910,831 | 22,552 | 9.1% | 1 | 197,764.8 | 227,356 | 10.2% | 11.8% |
| | 75-79 | 1,281,058 | 1,253,983 | 27,075 | 17.0% | 1 | 245,127.4 | 254,020 | 19.1% | 19.8% |
| | 80-84 | 730,162 | 700,376 | 29,786 | 28.7% | 1 | 239,513.4 | 221,513 | 32.8% | 30.3% |
| | 85+ | 448,078 | 403,075 | 45,003 | 48.0% | 1 | 260,080.4 | 234,570 | 58.0% | 52.4% |
| F | 65-69 | 2,771,752 | 2,755,023 | 16,729 | 8.5% | 1 | 2,512,610.9 | 270,669 | 9.1% | 9.8% |
| | 70-74 | 2,285,279 | 2,255,554 | 29,725 | 13.7% | 1 | 342,369 | 349,782 | 15.0% | 15.3% |
| | 75-79 | 1,767,864 | 1,710,120 | 57,744 | 16.9% | 1 | 357,258.1 | 408,866 | 20.2% | 23.1% |
| | 80-84 | 1,461,945 | 1,343,766 | 118,179 | 26.1% | 1 | 499,556 | 471,528 | 34.2% | 32.3% |
| | 85+ | 1,286,950 | 992,318 | 294,632 | 54.9% | 1 | 1,000,885 | 611,171 | 77.8% | 47.5% |
| All | | 16,518,743 | 15,858,978 | 659,765 | 2,684,031 | 659,765 | 3,589,664 | 3,222,100 | 21.7% | 19.5% |
| Fraction Institutionalised (75+) | | | | 9.5% | | | | | | |
| Fraction disabled in institute (75+) | | | | 18.4% | | | | | | |
| ES | | | | | | | | | | |
| M | 65-69 | 894,485 | | | 69,755 | | 69,755 | 75,074 | | 8.4% |
| | 70-74 | 847,599 | | | 91,337 | | 91,337 | 111,875 | | 13.2% |
| | 75-79 | 706,811 | | 26,541 | 113,017 | 1 | 139,558 | 139,018 | | 19.7% |
| | 80-84 | 450,739 | | 38,144 | 113,795 | 1 | 132,867 | 128,805 | | 28.6% |
| | 85+ | 290,548 | | | 133,705 | | 152,777 | 131,288 | | 45.2% |
| F | 65-69 | 1,003,665 | | | 112,145 | | 112,145 | 109,375 | | 10.9% |
| | 70-74 | 1,030,886 | | | 157,029 | | 157,029 | 188,820 | | 18.3% |
| | 75-79 | 954,907 | | 32,987 | 211,187 | 1 | 244,174 | 264,552 | | 27.7% |
| | 80-84 | 714,212 | | 124,849 | 239,528 | 1 | 289,478 | 280,309 | | 39.2% |
| | 85+ | 626,456 | | | 359,162 | | 434,060 | 364,476 | | 58.2% |
| All | | 7,520,308 | | 222,521 | 1,553,297 | | 1,775,818 | 1,553,297 | 23.6% | 20.7% |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fraction Institutionalised (75+) | | | | 5.9% | 0.206547 | | | | | |
| Disabled in institute (75+) | | | | 12.5% | | | | | | |
| NL | | | | | | | | | | |
| M | 65-69 | 356,076 | 353,008 | 3,068 | 4.9% | 65.8% | 19,333 | 14,040 | 5.4% | 3.9% |
| | 70-74 | 274,516 | 269,011 | 5,505 | 5.2% | 58.8% | 17,295 | 21,510 | 6.3% | 7.8% |
| | 75-79 | 206,574 | 196,892 | 9,682 | 8.3% | 64.3% | 22,486 | 28,680 | 10.9% | 13.9% |
| | 80-84 | 125,720 | 112,531 | 13,189 | 14.3% | 70.7% | 25,404 | 28,187 | 20.2% | 22.4% |
| | 85+ | 76,075 | 54,815 | 21,260 | 40.0% | 79.1% | 38,751 | 28,009 | 50.9% | 36.8% |
| F | 65-69 | 369,382 | 365,892 | 3,490 | 5.4% | 62.9% | 21,865 | 21,638 | 5.9% | 5.9% |
| | 70-74 | 314,516 | 306,495 | 8,021 | 8.7% | 64.1% | 31,709 | 36,942 | 10.1% | 11.7% |
| | 75-79 | 278,271 | 259,095 | 19,176 | 14.6% | 73.8% | 52,038 | 56,734 | 18.7% | 20.4% |
| | 80-84 | 216,243 | 181,660 | 34,583 | 23.4% | 85.9% | 72,274 | 68,387 | 33.4% | 31.6% |
| | 85+ | 197,454 | 116,204 | 81,250 | 40.4% | 93.4% | 122,809 | 98,560 | 62.2% | 49.9% |
| All | | 2,414,827 | 2,215,604 | 199,223 | 259,288 | 164,676 | 423,963 | 402,687 | 17.6% | 16.7% |
| Fraction Institutionalised (75+) | | | | 18.1% | 10.7% | | | | | |
| Disabled in institute (75+) | | | | 47.0% | | | | | | |
| PL | | | | | | | | | | |
| M | 65-69 | 623,780 | | | 0.2039474 | | 127,218 | 118,565 | 20.4% | 19.0% |
| | 70-74 | 552,652 | | | 0.1969697 | | 108,856 | 135,283 | 19.7% | 24.5% |
| | 75-79 | 425,276 | | | 0.3883495 | | 165,156 | 142,939 | 38.8% | 33.6% |
| | 80-84 | 224,505 | | | 0.3703704 | | 83,150 | 105,527 | 37.0% | 47.0% |
| | 85+ | 110,084 | | | 0.6153846 | | 67,744 | 74,301 | 61.5% | 67.5% |
| F | 65-69 | 829,973 | | | 0.3 | | 248,992 | 207,732 | 30.0% | 25.0% |
| | 70-74 | 825,005 | | | 0.3142857 | | 259,287 | 265,723 | 31.4% | 32.2% |
| | 75-79 | 734,451 | | | 0.4100719 | | 301,178 | 310,166 | 41.0% | 42.2% |
| | 80-84 | 502,783 | | | 0.5352113 | | 269,095 | 274,753 | 53.5% | 54.6% |
| | 85+ | 302,867 | | | 0.6571429 | | 199,027 | 216,857 | 65.7% | 71.6% |
| All | | 5,131,376 | | | 1,829,703 | | 1,829,703 | 1,851,846 | 35.7% | 36.1% |

## *A2 Short description of the statistical analysis of the SHARE and Rotterdam Study*

We extracted the data for DE, ES, NL and PL from the SHARE database (Waves 1 and 2, except for Poland that only participated in round 2). basic ADL were identified by the KATZ variables identified in module PH049 (version 2004). These include having difficulties expected to last at least three months in 1) Dressing, 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. For comparability with the Katz scale, 2 and 5 are combined into one variable, and considered positive if at least one was positive. The distributions of the five concerned basic ADL were defined per individual record and by country. Response rate was (to be added for each country).

Obesity was identified according to international convention as a BMI (weight over length squared, identified by self-reported answers on questions PH012 and 013) of 30 or more. To avoid confounding by reverse causation and high mortality of diseased persons with severe weight loss, we excluded those persons with a BMI of less than (to be added). Excluded were: (% DE, ES, NL, PL). Smoking was identified as being a current smoker (BR002).

The results are presented in Table A2.

Follow-up data were kindly provided by the Rotterdam Study. The Rotterdam Study is a large prospective study on ageing in a Dutch community. ('Erasmus Rotterdam Gezondheid Onderzoek' ERGO' (Hu et al., 2005). The study started in 1989, the first round of which covered the period 1989-1993. In total, 7,983 persons took part in the survey. The fifth wave is now coming to an end and the results were scheduled to be available by 2011. In the fourth wave of the original group of respondents, 3,550 were left. After the third wave a group of 3,011 new respondents were added to the survey population. After the fourth wave another group of 4,000 young persons was added. Among others, the survey includes questions on mortality (all waves, complete data available) and morbidity (HAQ and IDAL, Lawton; not included in wave 2). The Health Assessment Questionnaire (HAQ) and Instrumental Activities of Daily Living-scale measure disability slightly different from Katz-ADL disability.

The relative mortality risks are calculated using Cox models. We identified proportional hazard ratios of all cause mortality, defined by disability status and risk factor status. Interactions with age were not statistically significant and therefore ignored. These generic PHR were applied to country-specific mortality and prevalence to identify country specific mortality by disability and risk factor status. The central assumption is that the relative risks between risk factors and disability status are comparable in European populations, but not the absolute risks.

To note the high mortality of smokers, and the relative protection of obesity when disabled (known in the medical literature as the "obesity paradox": obesity increases the risks of disease, but decreases the risk of death when diseased).

*Table A.3 Results of analysis*

| Proportional hazard ratios. | M | F |
|---|---|---|
| Non-disabled, non-smoking | 1 (ref) | 1 (ref) |
| disabled, non-smoking | 1,89 | 1,55 |
| Non-disabled, smoking | 1,70 | 1,80 |
| disabled, smoking | 3,21 | 2,79 |
| Non-disabled, non-obese | 1 (ref) | 1 (ref) |
| disabled, non-obese | 1,89 | 1,55 |
| Non-disabled, obese | 1,11 | 1,11 |
| disabled, obese | 1,72 | 1,41 |

Proportional hazard ratios for all causes of death, compared to a reference populations which is not disabled and not exposed.

## *A3 Description of the incidence-prevalence model*

See below, from page 30 onwards.

## *A4 Description of the multistate demographic model and demographic input*

To project the number of care-dependent elderly people we used a general projection framework distinguishing different groups of persons by ADL disability and risk factor(s). As a point of departure we used the set of internationally consistent population scenarios for the countries of the European Union (EU), Norway and Switzerland compiled by Eurostat (EUROPOP 2008).[5] This set of scenarios has been developed in a consistent framework of convergence. It describes the possible future demographic developments assuming that in the long run (2150) fertility and mortality across countries converge to the 'forerunners' or best performers within the EU. Concerning international migration, it is assumed that migration flows will converge eventually to zero net migration. Whenever the projections resulted in a shortage of the working age population, however, migration has been adjusted upwards. To attune our scenarios as much as possible to the EUROPOP 2008 scenarios, we start our projections at age 55 and base the population inflow at age 55 for all years in the projection period on the outcomes of the EUROPOP 2008 scenarios. As a result, migration is largely covered by EUROPOP 2008 and the population at age 55 is exactly the same as the EUROPOP 2008 scenario. From age 55 onwards our projections will start to deviate to a greater or lesser extent from EUROPOP 2008, depending on the assumptions of the scenarios. Migration at ages 55 and over has been ignored.

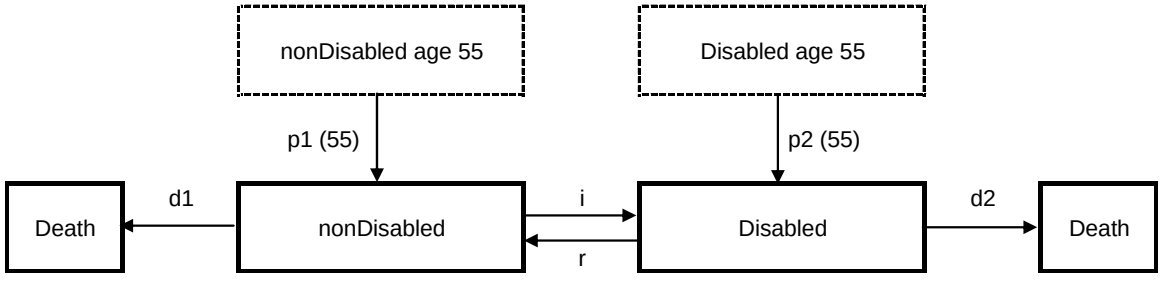
As we lack reliable and comparable data on trends of ADL disability, we based our disability forecasts on the mortality forecasts of the EUROPOP 2008 scenarios. These mortality forecasts co-determine our disability projections, which are therefore entirely consistent with the EUROPOP 2008 scenarios.

In a dynamic multi-state projection life table model, the distribution of people in states is the outcome of transitions people make during their life course. The rates of transition determine cohort and population dynamics. We used the multi-state projection model LIPRO (available at the NIDI website) that generates cohort biographies by conventional macrosimulation. The set of possible states in a projection framework is the state space. For our base projections of ADL disability we used a simplified general state space (the set of possible states in a projection model) of three states:[6]

1. non-Disabled (nD)
2. Disabled (D)
3. the absorbing end state: death

The states determine the possible transitions. Persons can become disabled, can recover from disability or can die. The transitions between the states are represented in Figure A1.

*Figure A.1State space ADL-disability model*




[5] See: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-10-001/EN/KS-SF-10-001-EN.PDF.

[6] At a later stage we will add the risk factors of smoking and body mass index to the model.

The arrow i refers to disability incidence rates and r to recovery from disability rates. Persons, either non-disabled or disabled, can enter the population at age 55 (arrows p1(55) and p2(55)) or can leave the population by dying (arrows d1 and d2).

Due to the lack of reliable data on incidence of disability, we used prevalence data to estimate the incidence rates. Prevalence of disability at a certain age and a given point in time is the outcome of previous developments in incidence of recovery. As a consequence, by using prevalence data to estimate incidence, the resulting incidence into disability refers in fact to a 'net number' of disabled persons. In theory, countless combinations of incidence and recovery can result in the same prevalence figures. For our model, therefore, we set recovery at zero (r=0) as it is already covered by the (net) incidence rates.

Using SHARE survey data[7] we estimate the prevalence in the states nonDisabled and Disabled by age and sex (*p1(x)* and *p2(x)*). Knowing the prevalence of each state at age *x* together with the age-specific incidence rates *i1(x)* and mortality rates for non-disabled and disabled persons (*d1(x)*and *d2(x)*), we can calculate the prevalence in the states nonDisabled and Disabled at age *x+1* (*p1*(*x+1*) and *p2*(*x+1*)). The prevalence of disability at age *x+1* for instance can be calculated as all persons in the state Disabled at age *x+1* divided by all persons survived until age *x+1*. The persons in the state Disabled at age *x+1* are determined as all persons in that state at age *x* that do not leave the state to go to another state or due to death, plus all persons that enter the state. Thus, if we know the incidence rates *i(x)*, the mortality rates *d1(x)* and *d2(x)* and the prevalence at age 55 *p1*(55) and *p2*(55), we can calculate the prevalence of disability for all ages above age 55. However, we do not know the incidence rates, but conversely will estimate them using the prevalence. For this we use the following iterative procedure:

From EUROPOP 2008 we know the mortality rates by age and sex for the total population (*dtot(x)*). As total mortality is the sum of mortality in the two states nonDisabled and Disabled, and mortality rates of disabled persons *d2(x)* can be defined relatively to mortality rates of non disabled persons *d1(x)*, we can calculate *d1(x)* using *dtot(x)* and the relative risk *RR* for the state Disabled (state 2) relative to the state nonDisabled. Assuming a linear model, this comes down to the following:

$$dtot(x) = p1(x)\, d1(x) + p2(x)\, d2(x) \qquad (1)$$

which can be rewritten as

$$dtot(x) = p1(x)\, d1(x) + p2(x)\, RR\, d1(x) \qquad \text{or}$$

$$dtot(x) = (p1(x) + p2(x)\, RR)\, d1(x) \qquad \text{or}$$

$$d1(x) = dtot(x) \,/\, (p1(x) + p2(x)RR) \qquad (2)$$

Once we have calculated *d1(x)* we can easily calculate *d2(x)* by multiplying *d1(x)* with relative risk *RR*.

Next we use the age, sex and disability specific mortality rates together with the estimated prevalence to estimate the age and sex specific incidence rates *i(x)* applying the following two optimization criteria:

1. The total number of deaths as a sum of the number of deaths of non-disabled and disabled persons should be equal to the number of deaths based on EUROPOP 2008, and
2. The squared differences between the estimated prevalence in the states nonDisabled and Disabled (the prevalence input) and the calculated prevalence based on the estimated incidence and mortality rates (the prevalence output) should be minimised.

[7] See: http://www.share-project.org/

As long as the prevalence input differs from the prevalence output, in a next step the prevalence output will be used as input to re-estimate the disability-specific mortality rates and subsequently the incidence rates. This procedure will be repeated until convergence.

The linear estimation procedure provides only reliable estimations of the rates in case the age patterns follow a linear curve. For mortality and incidence rates, however, the exponential function fits the age pattern much better than the linear function, especially at higher ages. Therefore, we used the exponential approach to estimate the incidence and mortality rates. Although the exponential approach is mathematically more complicated than the linear approach, the reasoning behind both approaches is similar. A detailed description of the exponential approach for the estimation of incidence and mortality rates (including risk factors) is given in A3.

In order to give an indication of the severity of disability we calculate the average ADL-score using the age-specific distribution of ADL disability across the different ADL-scores obtained from SHARE (from one to five limitations).

# Estimation of Disability Incidence based on Prevalence

Govert E. Bijwaard

April 20, 2011

## 1 Estimation of Incidence and mortality

We assume that the observed prevalences are the result of a stationary Markov process and that disability is irreversible. In a Markov process a one-to-one relation between the transition rates and the transition probability, the probability to change from one state to another in a given time/age period (usually one year), exits. A Markov model is usually defined in terms of the transition rates between the possible states. The changes in prevalence are directly related to the transition probabilities. The estimation procedure is based on this relation.

### 1.1 Two states model: Illness-death model

For each age $x$ (and gender) we have the following matrix of transition rates (between the two states {nD, D } and the death-state):

$$M(x) = \begin{pmatrix} -\big(\theta(x) + \mu_{nD}(x)\big) & \theta(x) & \mu_{nD}(x) \\ 0 & -\mu_D(x) & \mu_D(x) \\ 0 & 0 & 0 \end{pmatrix}$$

where $\theta(x)$ is the disability incidence rate at age $x$, $(\mu_{nD}(x), \mu_D)(x)$ are the mortality rates at age $x$ for the non-disabled and disabled state. Note that $\theta(x)$ is the "net-incidence". It is not possible to estimate both incidence and recovery when only the prevalences in the two states and the total death rate is available.

Let $Q_D(x)$ be the disability prevalence at age $x$ (by gender) and $Q_{nD}(x)$ be the complement, the prevalence of non-disability at age $x$. Let $P_{ij}(x)$ be the age-specific transition probability from $i = \{nD, D\}$ to $j = \{nD, D, \text{death}\}$ from age $x$ to age $x + 1$ (conditional on survival up to age $x$), that is, the probability

$$Q_D(x+1) = \Big[Q_{nD}(x)P_{nD,D}(x) + Q_D(x)P_{D,D}(x)\Big]/S(x) \quad (1)$$

$$Q_{nD}(x+1) = \Big[Q_{nD}(x)P_{nD,nD}(x) + Q_D(x)P_{D,nD}(x)\Big]/S(x) \quad (2)$$

with $S(x)$ is the survival of all individuals, disabled and non-disabled, from age $x$ to $x+1$, i.e.,

$$S(x) = Q_{nD}(x)\Big[P_{nD,nD} + P_{nD,D}(x)\Big] + Q_D(x)\Big[P_{D,nD}(x) + P_{D,D}\Big] \quad (3)$$

Division by the survival rate is needed because the prevalence at the next age is based on the survivors up to that age.

The transition probability (matrix) follows from the (matrix of) transition rates:

$$P(x, x+1) = \exp(M) = V\Lambda V^{-1} \quad (4)$$

where $V$ is the matrix of eigenvectors of $M$ and $\Lambda$ is the exponentiated matrix of eigenvalues, i.e. if the eigenvalues of $M$ are $\lambda_1, \lambda_2, \lambda_3$ then $\Lambda = \text{diag}\Big(e^{\lambda_1}, e^{\lambda_2}, 1\Big)$ with $\lambda_3 = 0$. In the 2-state illness-death model (without recovery) the transition probability has an analytical solution (see for example Singer and Spilerman (1976))

$$P_{nD,nD}(x) = e^{-\big(\theta(x)+\mu_{nD}(x)\big)} \quad (5)$$

$$P_{nD,D}(x) = \frac{\theta(x)}{\mu_D(x) - \theta(x) - \mu_{nD}(x)}\Big[e^{-\big(\theta(x)+\mu_{nD}(x)\big)} - e^{-\mu_D(x)}\Big] \quad (6)$$

$$P_{D,nD}(x) = 0 \quad (7)$$

$$P_{D,D}(x) = e^{-\mu_D(x)} \quad (8)$$

For known prevalence, total (age-gender specific) mortality, $\mu_{tot}(x)$ and relative mortality risk $\mu_D(x) = r_D \cdot \mu_{nD}(x)$ we can solve for the age-specific incidence and (non-disabled) mortality rate through the following iterative procedure

1. Calculate start value for $\mu_{nD}(x)$ by solving:

$$\exp\big(-\mu_{tot}(x)\big) = Q_{nD}(x)\exp\big(-\mu_{nD}(x)\big) + Q_D(x)\exp\big(-r_D \cdot \mu_{nD}(x)\big)$$

2. Given $\mu_{nD}(x)$ and observed $Q_{nD}(x+1)$ solve equation 2 for $\theta(x)$

$$\arg_\theta\Big[Q^\theta_{nD}(x+1) = Q_{nD}(x+1)\Big]$$

3. Given $\theta(x)$ solve for $\mu_{nD}(x)$ using:

$$\exp\big(-\mu_{tot}(x)\big) = Q_{nD}(x)\Big[1 - P_{nD,nD}(x) - P_{nD,D}(x)\Big] + Q_D(x)\Big[1 - P_{D,D}(x)\Big]$$

4. Repeat step 2 and 3 till convergence

## 1.2 Group specific incidence rate

It is very likely that the disability-incidence depends on observed characteristics, like, e.g., smoking status, obesity or education level. If no transitions between the groups exit, the method in the previous section can easily extended to estimate the incidence rates by using group-specific transition matrices. However, because this resulted in unrealistic results. We therefore take a slightly different route, that uses the results from the illness-death model as input.

Now we assume that the disability incidence and the mortality estimated before is a weighted average of the incidence and mortality by group (smoking- or obesity-status). For example, for smoking we know the age-specific prevalence, $\{Q_{nSnD}(x), Q_{nSD}(x), Q_{SnD}(x), Q_{SD}(x)\}$, the age-specific disability (ADL-only), $\theta(x)$, the age-specific mortality by disability status, $\{\mu_{nD}(x), \mu_D(x)\}$. To estimate the smoking-specific incidence and mortality rates we need the relative mortality risk of smoking, $r_S$ (assumed independent of age) and the relative incidence risk of smoking, $i_S$ (also assumed independent of age), see Table 1.

Then, the mortality of a non-smoking disabled individual at age $x$, $\mu_{nSD}(x)$ solves:

$$e^{-\mu_D(x)} = \frac{Q_{SD}(x)}{Q_{SD}(x) + Q_{nSD}(x)} e^{-r_S \cdot \mu_{nSD}(x)} + \frac{Q_{nSD}(x)}{Q_{SD}(x) + Q_{nSD}(x)} e^{-\mu_{nSD}(x)} \tag{9}$$

and mortality of smoking individual at age $x$ is $r_S \cdot \mu_{nSD}(x)$. The mortality of a non-smoking non-disabled individual at age $x$, $\mu_{nSnD}(x)$ solves

$$e^{-\mu_{nD}(x)} = \frac{Q_{SnD}(x)}{Q_{SnD}(x) + Q_{nSnD}(x)} e^{-r_S \cdot \mu_{nSnD}(x)} + \frac{Q_{nSnD}(x)}{Q_{SnD}(x) + Q_{nSnD}(x)} e^{-\mu_{nSnD}(x)} \tag{10}$$

and mortality of smoking non-disabled individual at age $x$ is $r_S \cdot \mu_{nSnD}(x)$. For incidence by smoking status we have a similar equation to solve. The disability incidence of a non-smoking individual at age $x$, $\theta_{nS}(x)$, solves

$$e^{-\theta(x)} = \big[Q_{SD}(x) + Q_{SnD}(x)\big] e^{-i_S \cdot \theta_{nS}(x)} + \big[Q_{nSD}(x) + Q_{nSnD}(x)\big] e^{-\theta_{nS}(x)} \tag{11}$$

and the disability incidence of a smoking individual at age $x$ is $i_S \cdot \theta_{nS}(x)$.

Of course, the model for obesity is similar, only the prevalences and the relative risks change.

Table 1: Estimated relative risks

| | *Mortality risk disability (only)*[a] | |
|---|---|---|
| | non-disabled | disabled |
| Males | 1 | 1.89 |
| Females | 1 | 1.55 |
| | *Mortality risk smoking*[a]*,* $r_S$ | |
| | non-smoking | smoking |
| Males | 1 | 1.70 |
| Females | 1 | 1.80 |
| | *Disability incidence risk smoking*[b]*,* $i_S$ | |
| Males | 1 | 1.15 |
| Females | 1 | 1.05 |
| | *Mortality risk obesity*[b]*,* $r_O$ | |
| | non-obese | obese[c] |
| Males | 1 | 1.11 |
| Females | 1 | 1.11 |
| | *Disability incidence risk obesity*[b]*,* $i_O$ | |
| Males | 1 | 1.715 |
| Females | 1 | 1.715 |

[a] Source ERGO.

[b] Source Walter et al. (2009).

[c] Obese is defined as BMI $> 30$.

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EUROPEAN COMMISSION
European Research Area

SEVENTH FRAMEWORK PROGRAMME

Funded under Socio-economic Sciences & Humanities

# ANCIEN

**Assessing Needs of Care in European Nations**

***FP7 HEALTH-2007-3.2-2***

Launched in January 2009, ANCIEN is a research project financed under the 7th EU Research Framework Programme. It runs for a 44-month period and involves 20 partners from EU member states. The project principally concerns the future of long-term care (LTC) for the elderly in Europe and addresses two questions in particular:

1) How will need, demand, supply and use of LTC develop?

2) How do different systems of LTC perform?

The project proceeds in consecutive steps of collecting and analysing information and projecting future scenarios on long-term care needs, use, quality assurance and system performance. State-of-the-art demographic, epidemiological and econometric modelling is used to interpret and project needs, supply and use of long-term care over future time periods for different LTC systems.

**Work Packages.** The project started with collecting information and data to portray long-term care in Europe (WP 1). After establishing a framework for individual country reports, including data templates, information was collected and typologies of LTC systems were created. The collected data form the basis of estimates of actual and future long term care needs in selected countries (WP 2). WP 3 builds on the estimates of needs to characterise the response: the provision and determinants of formal and informal care across European long-term care systems. Special emphasis is put on identifying the impact of regulation on the choice of care and the supply of caregivers. WP 6 integrates the results of WPs 1, 2 and 3 using econometric micro and macro-modelling, translating the projected needs derived from WP2 into projected use by using the behavioral models developed in WP3, taking into account the availability and regulation of formal and informal care and the potential use of technological developments.

On the back of projected needs, provisions and use in European LTC systems, WP 4 addresses developing technology as a factor in the process of change occurring in long-term care. This project will work out general principles for coping with the role of evolving technology, considering the cultural, economic, regulatory and organisational conditions. WP 5 addresses quality assurance. Together with WP 1, WP 5 reviews the policies on LTC quality assurance and the quality indicators in the EU member states, and assesses strengths, weaknesses, opportunities and threats of the various quality assurance policies. Finally WP 7 analyses systems performance, identifying best practices and studying trade-offs between quality, accessibility and affordability.

The final result of all work packages is a comprehensive overview of the long term care systems of EU nations, a description and projection of needs, provision and use for selected countries combined with a description of systems, and of quality assurance and an analysis of systems performance.

**Principal and Partner Institutes**

CEPS is responsible for administrative coordination and dissemination of the general results (WP 8 and 9). The Belgian Federal Planning Bureau (FPB) and the Netherlands Bureau for Economic Policy Analysis (CPB) are responsible for scientific coordination. Other partners include: German Institute for Economic Research (DIW); Netherlands Interdisciplinary Demographic Institute (NIDI); Fundación de Estudios de Economía Aplicada (FEDEA); Consiglio Nazionale delle Ricerche (CNR); Universitá Luiss Guido Carli-Luiss Business School (LUISS-LBS); Institute for Advanced Studies (IHS); London School of Economics and Political Science- Personal Social Services Research Unit (PSSRU); Istituto di Studi e Analisi Economica (ISAE); Center for Social and Economic Research (CASE); Institute for Economic Research (IER); Social Research Institute (TARKI); The Research Institute of the Finnish Economy (ETLA); Université de Paris-Dauphine-Laboratoire d`Economie et de Gestion des organisations de Santé (DAUPHINE- LEGOS); University of Stockholm, Department of Economics; Karolinska Institute-Department of Medecine, Clinical Epidemiology Unit ; Institute of Economic Research, Slovak Academy of Sciences (SAS-BIER); Center for Policy studies (PRAXIS). Most of the ANCIEN partners are members of the European Network of Economic Policy Research Institutes (ENEPRI).

***For more information, please visit the ANCIEN website (www.ancien-longtermcare.eu) or the CEPS website (www.ceps.eu).***