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Foreword by
M. Harvey Brenner

Regional life expectancy in Germany: life table analysis for 1997/1999 to 2004/2006

PART A

METHODS AND SUMMARY OF RESULTS

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Part D. Benchmark plots: life expectancy at age 75

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PART A METHODS AND SUMMRY OF RESULTS

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Foreword by M. Harvey Brenner

During the past several decades, the attempt by scientists to understand differences in the length of life of individual persons has been encompassed in the field of epidemiology. Epidemiology brings together the disciplines of medicine and biostatistics through which risk and benefit factors of individual biology and psychology, the chemical environment, diet, addictive substances, kinetics, working conditions, social relations and many other factors have been shown related to the differentiation of why some individuals have a longer life span than others. The most powerful finding in the field of epidemiology is that socioeconomic status is a primary predictor of length of life.

More recently, it has begun to be understood that national, regional, and specific urban factors – factors that exist above the individual level of analysis – are also highly potent causes and predictors of life expectation. These include not only such factors as national and regional income and wealth (GDP) per capita and unemployment but the complex of industries that distinguish large ecological areas. Obviously, in the light of modern economic restructuring in industrialized countries, globalization of industries, unemployment and the international recession, it has become extremely important to understand differential life expectancy from macroeconomic, industrial and labor market perspectives.

From this point of view Günter Edenharter and his associates recognized the need to construct life tables for regions of Germany. The tables can be used to study geographic units as small as minor urban agglomerations and as large as distinctions of (the former) “West” and “East” Germany. These regional life tables are especially suitable for examination of the impact of the economy, at different levels of life expectation patterns of increasingly smaller units. The construction of such life tables for Germany has demonstrated the feasibility of developing similar demographic descriptors for other European countries in the near future.

The particular motivation of the authors to deal in depth with regional life table analysis for Germany as outlined above arose from the needs of Germany’s largest longitudinal patient registry, QuaSi-Niere. This registry had collected data on patients in renal replacement therapy from the year 1995 to 2006. The registry disseminated the results of their analysis to patients, doctors and health institutions. Their aim was to set up a database that would allow them a better understanding of patients’ regional mortality patterns in the light of the regional life expectancy of the general population. In this way their intention was to illuminate empirically the complex hierarchical pathways in which factors that influence general life expectancy e.g. at the macro level also determine mortality on the micro or patient level. The evidence that could arise from such an analysis can provide important insights for modern health service research.

Life expectancies are in long term use, e.g. by WHO, to describe and analyze health systems at an international level. The further development of these techniques and their application at regional levels seems promising. The publication of this document can be regarded as an important initial step in this direction.

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1 Introduction

Life expectancy at birth or at a higher age, e.g. at age 65, is an important population based health outcome indicator. Based on a standardized life table technique, estimates of life expectancy facilitate regional and temporal comparisons of the fundamental characteristics of health related quality of life.

The authors' interest in regional life table analysis for Germany was mainly stimulated by their common epidemiological work for the German Renal Registry (QuaSi-Niere gGmbH, Berlin). Regional aspects of disease and influencing factors not only at an individual but also at an aggregated level became the focus of their attention. The German Renal Registry was set up in 1994 to monitor quality of health care for patients in renal replacement therapy, i.e. dialysis and renal transplantation. Since 1995 more than 130 000 patients from more than 1 200 reporting dialysis units were registered and have been monitored longitudinally up to the year 2006. Data analysis revealed large regional variations not only with regard to gender, age and the primary diseases which cause renal failure, e.g. diabetes, but also with regard to five year survival rates. Five year survival rates continued to show large regional variations even after adjustment for age, gender and primary disease. A more profound understanding of these results and improvements with regard to epidemiological analysis and reporting of the Renal Registry are expected if the findings from regional life table analysis could be used as background information. This would allow to adjust survival rates for regional background mortality and would also allow to use more advanced modeling techniques, like relative survival models (see e.g. [4]) which are already in use for other severe chronic diseases such as cancer.

The necessity to emphasize regional aspects when analyzing health care in Germany also stems from the expected future demographic developments for Germany (see [8]). The medium-term and long-term regional planning outlook provided by the Federal Office for Building and Regional Planning for the years 2020 and 2050 identifies as the most striking future demographic characteristic the contemporaneous dynamics of shrinking and growing German regions. Looking at population numbers, a large group of shrinking regions will be confronted with a small group of regions that continue growing. Whereas the number of shrinking regions will increase, the number of growing regions will decrease. The population projections of the Federal Office for Building and Regional Planning are confirmed by regional population projections for the year 2025 that were recently published by Bertelsmann Foundation in November 2008 (see this link). Their results also show an enormous future imbalance between the number of shrinking and growing regions. It can be expected that in parallel regional disparities will increase. This will be an enormous challenge not only for regional real estate economics and the providers of public infrastructure but also for the German health care system.

The German paradigm of equivalence of living conditions in all sub-regions, which is explicitly targeted by German regional planning law has become a major point of discussion (see e.g. [7]). Maybe one has to admit already today that equivalence of living conditions is an aim that is too ambitious and can only be achieved at over demanding costs. Extending the point of view from a national to a European Union perspective lets one immediately realize that regional disparities are an even greater matter of concern. The European Commission's economic policy emphasizes the regional dimension of cohesion and evaluates the extent of socioeconomic convergence in the Union of 27 members [6]. Independent of the level of perspective, regional life expectancy will be clearly one of the main indicators for cohesion and the equivalence of living conditions.

Regional life expectancy data for Germany that are currently obtainable from official data sources, e.g. from the German Federal Office for Building and Regional Planning, have restrictions that make them of limited use for our purposes: only life expectancies at birth are provided but neither detailed documentation of the applied life table algorithms nor confidence intervals are available. Taking into account the special needs of the Renal Registry and the fact that more than fifty per cent of the patient population are older than 65 years, the planned life table analysis should provide regional life expectancy at birth, age 65 and age 75 as main indicators for overall regional background mortality. Also, the requirement for a flexible use of customized regional classifications made it unavoidable to set up an own separate database for regional life table analysis. Of course the compiled data and the derived life tables are not only interesting background information for more advanced analysis by the German Renal Registry but, as has been pointed out above, for many other modern epidemiological research activities.

This report is set up for three main purposes.

Firstly, it is intended to serve as a detailed description for the computation of the regional life expectancies based on regional life tables. Thus it can serve as a methodological reference for future research work based on the derived results.

Secondly, it shall provide a comprehensive but purely descriptive presentation of regional life expectancy in Germany as a stimulus for new research questions.

Thirdly, it shall raise discussions about shortcomings and limitations of regional life table analysis and what can be done in future to overcome these issues.

2 Materials and Methods

Data acquisition was done in the years 2006 and 2007 as a joint effort of Günter Edenharter (edenharter research, Berlin) and QuaSi-Niere gGmbH, Berlin. Life table analysis was conducted by Günter Edenharter.

2.1 Regional breakdown

The regional breakdown of Germany is defined by administrative regional units and other non-administrative regional units which are in official use for planning and analysis purposes. The administrative regional units are also covered by the regional system of the European Union which uses sub-national regional units defined by the Nomenclature of Units for Territorial Statistics (NUTS) for levels 1 to 3 and Local Administrative Units (LAU) which are the basic components of NUTS regions and are defined for level 1 (districts) and level 2 (municipalities).

Level	NUTS	German description	English description	Count
R0	Level 0	Staat (Deutschland)	State (Germany)	1
R1	-	West-/Ostdeutschland (mit Berlin)	West/East Germany (with Berlin)	2
R2	Level 1	Bundesländer	Federal States	16
R3	Level 2	Regierungsbezirke	Governorates	41
R4	-	Raumordungsregionen	Regional Planning Units	97
R5	Level 3	Kreise und kreisfreie Städte	Counties and Cities	438
			Total	**595**

Table 1: German regional units

It was decided to use NUTS level 3 ('Counties and Cities') as the smallest regional unit for data acquisition. NUTS level 2 regions ('Governorates') and NUTS level 1 regions ('Federal States') are then set up by aggregating data from NUTS level 3 regions. As population numbers in administrative regional units become very large when moving from NUTS level 3 to NUTS level 2, an additional regional category from the non-administrative regional units is included which covers 97 regions of 'Regional Planning Units'. Table 1 summarizes the German regional units as they were used in the analysis. The most left column (Level) describes our own abbreviation for regional aggregation levels. The English description of German regions is not officially established, other authors may use different terms.

The study period covered the years from 1997 to 2006. Life tables were calculated by aggregating population and death data always for three sequential years, i.e. 1997/1998/1999 to 2004/2005/2006. This results in 8 triple year periods. A triple year period is referred to by quoting the first and the last year separated by a slash, e.g. the notation 1997/1999 is used as an abbreviation for 1997/1998/1999. Population data from 1996 is used to calculate average population numbers for 1997 (see below).

Within the time span covered there had been two major regional revisions at NUTS level 3 and one at NUTS level 2:

Eisenach. In 1998 the city Eisenach (region code 16056) was separated from the county Wartburgkreis (region code 16063) as a new NUTS level 3 unit. For our analysis we decided to continue with the old regional definition of the county Wartburgkreis which includes the city Eisenach, beyond the year 1997. To avoid confusion the new region code 16999 (NUTS code: DEGZZ) was assigned to the combined county Wartburgkreis/ Eisenach.

Hanover. In 2001 the administrative units of city Hanover (region code 03201) and county Hanover (region code 03253) were merged into one new administrative unit at NUTS level 3 (region code 03241). For this reason these two units were also merged backwards for the time span 1996 to 2000.

Brandenburg North-East/South-West. In 2007 the federal state of Brandenburg was split up into two subregions at NUTS level 2, Brandenburg North-East and Brandenburg South-West. To be in accordance with this new regions we carried backward these subdivision for all years.

2.2 Data sources

The computation of standard abridged life tables required population and death data by gender and age groups (<1, 2-5, 5-10, ..., 85-90, 90+) at NUTS level 3. Unfortunately the online data resources of the German Federal Statistical Office do not provide data on population and death numbers that would allow the computation of these standard abridged life tables at NUTS level 3. There are two severe shortcomings related to the online data: The age groups of population and death data do not match in the younger age groups (ages under 10 years) and the oldest age group summarizes population and death numbers for all ages at 75 and older. Life expectancies derived from a life table are sensitive to the width of the last age interval. When the last age interval is too wide, as is the case when e.g. life expectancy for females at birth is 82.42 (see Table 2) and the lower limit of the last age interval already starts at age 75, the calculated life expectancies will be biased [5].

As official online data resources did not meet the needs for regional life table calculations, more elaborate routes had to be followed for the acquisition of population and death data. These routes are described below.

Population data. Population data at NUTS level 3 (yearly 1995-2006, reference date December 31 of each year) were made available from the German Federal Statistical Office upon special requests. Unfortunately population data for Saxony, year 1995, had severe regional incompatibilities with the later years. It was decided that results should be presented in a homogeneous way, for this reason life table analysis starts with 1997/1999.

Death data. For death data two different sources had to be used. With the friendly permission of the Federal Statistics authorities death numbers could be compiled at NUTS level 3 by personal visits to the Berlin research data center. On site it was possible to have access to detailed original data sources. Because of data protection reasons, statistical tables calculated at the research data center can only be transferred for external usage when cell numbers are greater than or equal to 3 (or equal to zero). For this, a decision was made to use only the age groups covering age 75 and older from the Berlin research data center. The age groups younger than age 75 were taken from the online resources of the Federal Statistical Office (GENESIS Online).

2.3 Life table computations

Main reference for the implemented life table calculations is Chiang [2].

Regional life tables were computed as abridged current life tables. An abridged life table is constructed with age intervals that cover more than one year whereas complete life tables use age intervals that cover exactly one year. A current life table is constructed based on a cross-sectional approach that uses population and death data for one year or several years. This is different from a cohort life table where a group of persons is followed up from the birth of the first individual to the death of the last individual. Here we use 20 age groups. The age group intervals are of different length: The first interval covers one year, the second interval covers four years, interval three to nineteen cover five years and the last interval is an open ended interval. The fundamental calculation of an abridged current life table will be explained by the use of one life tables for German females in the year 2006.

An abridged life table can be constructed by setting up 12 columns. The description of each column is as follows:

Column 1.

Age interval $[x_i - x_{i+1})$, $i = 0, \ldots, \omega = 19$.

Column 2.

Average population P_i in interval $[x_i - x_{i+1})$. The average population for a *year*$_j$ is approximated by calculating the mean population of the populations that were reported for the reference dates for December 31 of the *year*$_{j-1}$ before and for December 31 of *year*$_j$.

Column 3.

Number of deaths D_i in interval $[x_i - x_{i+1})$

Column 4.

Length of the age interval $[x_i - x_{i+1})$: $n_i = x_{i+1} - x_i$.

Column 5.

Fraction of last age interval of life: a_i. These numbers were derived from complete life tables for total Germany. A more detailed description will be given below.

Column 6.

Age specific death rate: M_i. It is calculated as:

$$M_i = \frac{D_i}{P_i} \quad .$$

Column 7.

The probability of dying in interval $[x_i - x_{i+1})$: q_i. It is calculated as:

$$q_i = \frac{n_i M_i}{1+(1-a_i)\, n_i M_i}, \quad i=0, \dots, \omega -1.$$

q_ω, the probability of dying in the last age interval is set to 1.0.

Column 8 and 9.

Number living at age x_i: l_i and number dying in interval $[x_i - x_{i+1})$: d_i.

l_0 is called the radix of the life table and is set to 100 000.

Given l_0, d_i and l_i are calculated as:

$$d_i = l_i\, q_i, \quad i=0, \dots, \omega$$

and

$$l_{i+1} = l_i - d_i, \quad i=0, \dots, \omega -1.$$

Column 10.

Number of years lived in the interval $[x_i - x_{i+1})$ by the survivors l_i: L_i.

It is calculated by:

$$L_i = n_i(l_i - d_i) + a_i n_i d_i, \quad i=0, \dots, \omega -1$$

and

$$L_\omega = \frac{l_\omega}{M_\omega} \quad .$$

Column 11.

Total number of years to be lived by persons attaining age x_i: T_i. It is given by:

$$T_\omega = L_\omega$$

and

$$T_i = L_i + L_{i+1} + \dots + L_\omega, \quad i=0, \dots, \omega -1 .$$

Column 12.

Expectation of life at age x_i: e_{x_i}. The final column is calculated as:

$$e_{x_i} = \frac{T_i}{l_i}, \quad i=0, \dots, \omega.$$

A full example is given in Table 2.

Fraction of last age interval of life. The numbers a_i for the fraction of last age interval of life had to be derived from complete life tables. For this purpose complete official life tables from the Federal Statistical Office for total Germany were used for the three periods 1996/1998, 2000/2002 and 2004/2006. For each sex the a_i were calculated following Chiang ([2], pp. 142-145). The a_i that were used in our analysis for all regional units were then calculated by computing the mean of the a_i from the three life tables for each age interval. The results are given in Table 3a (Females) and Table 3b (Males). No attempt was made to calculate a_i at regional levels, e.g. NUTS level 2.

The given example used population and death numbers from a single year for the calculation of a life table. To obtain more stable results especially for the regions at NUTS level 3, the population and death numbers for three sequential years were added up.

Confidence intervals for life expectancies. In regional analysis population numbers often are not very large. To communicate the uncertainty associated with the derived life expectancies it is useful to report the life expectancies with confidence intervals. This is especially important when the population size of regions varies as enormously as it does in our case. The sample variance of life expectancies is essentially determined by the sample variance of the involved q_i, i.e. the age-

Abridged current life table

$[x_i - x_{i+1})$	P_i	D_i	n_i	a_i	M_i	q_i	l_i	d_i	L_i	T_i	e_{x_i}
[0-1)	330 756	1 150	1	0.17	0.00348	0.00347	100 000	347	99 713	8 242 356	82.4
[1-5)	1 392 049	226	4	0.40	0.00016	0.00065	99 653	65	398 457	8 142 643	81.7
[5-10)	1 9166 54	138	5	0.47	0.00007	0.00036	99 589	36	497 848	7 744 186	77.8
[10-15]	1 983 763	190	5	0.54	0.00010	0.00048	99 553	48	497 655	7 246 338	72.8
[15-20)	2 338 246	454	5	0.56	0.00019	0.00097	99 505	97	497 313	6 748 684	67.8
[20-25)	2 389 595	542	5	0.49	0.00023	0.00113	99 409	113	496 755	6 251 371	62.9
[25-30)	2 411 105	593	5	0.52	0.00025	0.00123	99 296	122	496 187	5 754 615	58.0
[30-35]	2 408 389	844	5	0.53	0.00035	0.00175	99 174	174	495 465	5 258 428	53.0
[35-40)	3 193 689	1 837	5	0.54	0.00058	0.00287	99 000	284	494 345	4 762 963	48.1
[40-45)	3 509 089	3 531	5	0.54	0.00101	0.00502	98 716	496	492 449	4 268 618	43.2
[45-50]	3 166 498	5 695	5	0.54	0.00180	0.00896	98 220	880	489 063	3 776 169	38.4
[50-55)	2 827 148	7 947	5	0.53	0.00281	0.01396	97 341	1 359	483 508	3 287 106	33.8
[55-60)	2 501 632	10 480	5	0.53	0.00419	0.02074	95 982	1 991	475 217	2 803 598	29.2
[60-65)	2 282 088	14 302	5	0.53	0.00627	0.03088	93 991	2 903	463 143	2 328 381	24.8
[65-70]	2 826 103	25 675	5	0.54	0.00908	0.04449	91 088	4 053	446 078	1 865 238	20.5
[70-75)	2 106 271	34 215	5	0.54	0.01624	0.07829	87 036	6 814	419 466	1 419 160	16.3
[75-80)	1 804 383	55 616	5	0.53	0.03082	0.14379	80 222	11 535	374 232	999 694	12.5
[80-85)	1 484 923	89 564	5	0.52	0.06032	0.26366	68 687	18 110	300 254	625 462	9.1
[85-90)	733 651	80 274	5	0.50	0.10942	0.42922	50 577	21 709	198 402	325 208	6.4
[90-∞)	449 860		1		0.22766	1.00000	28 868	28 868	126 806	126 806	4.4

Table 2: Construction of an abridged current life table: Females 2006 (Germany)

	(a) Females				(b) Males			
	1996/1998	2000/2002	2004/2006	Mean	1996/1998	2000/2002	2004/2006	Mean
$[x_i - x_{i+1})$	a_i	a_i	a_i	a_i	a_i	a_i	a_i	a_i
[0-1)	0.180	0.179	0.159	0.17	0.177	0.125	0.156	0.15
[1-5)	0.400	0.394	0.395	0.40	0.396	0.390	0.401	0.40
[5-10)	0.475	0.468	0.459	0.47	0.479	0.485	0.484	0.48
[10-15)	0.541	0.547	0.538	0.54	0.560	0.547	0.561	0.56
[15-20)	0.559	0.567	0.553	0.56	0.621	0.620	0.609	0.62
[20-25)	0.484	0.487	0.499	0.49	0.487	0.486	0.498	0.49
[25-30)	0.524	0.520	0.517	0.52	0.511	0.506	0.499	0.51
[30-35)	0.537	0.539	0.527	0.53	0.526	0.523	0.526	0.52
[35-40)	0.538	0.540	0.539	0.54	0.535	0.540	0.540	0.54
[40-45)	0.540	0.545	0.546	0.54	0.537	0.541	0.547	0.54
[45-50)	0.534	0.535	0.540	0.54	0.529	0.534	0.541	0.53
[50-55)	0.529	0.531	0.530	0.53	0.534	0.532	0.534	0.53
[55-60)	0.531	0.525	0.531	0.53	0.534	0.531	0.529	0.53
[60-65)	0.537	0.533	0.522	0.53	0.533	0.529	0.527	0.53
[65-70)	0.536	0.538	0.540	0.54	0.525	0.530	0.529	0.53
[70-75)	0.538	0.537	0.541	0.54	0.521	0.518	0.528	0.52
[75-80)	0.527	0.536	0.538	0.53	0.505	0.518	0.515	0.51
[80-85)	0.520	0.518	0.532	0.52	0.496	0.496	0.512	0.50
[85-90)	0.494	0.498	0.503	0.50	0.466	0.472	0.480	0.47
[90-∞)	-	-	-	-	-	-	-	-

Table 3: Fraction of last age interval of life

specific probabilities of dying. We do not go into any detail here but refer to Chiang ([2], pp. 161) who uses a first order Taylor approximation to derive a formula for the sample variance of life expectancies from abridged current life tables.

Let $se_{e_{x_i}}$ be the standard error of a life expectancy at age x_i. An approximative 95% confidence interval for the life expectancy at age x_i is then given by:

$$(e_{x_i} - 1.96\ se_{e_{x_i}}, e_{x_i} + 1.96\ se_{e_{x_i}}).$$

The detailed computation of $se_{e_{x_i}}$ involves a division by D_i, the number of deaths. In our case, for regional life tables, the number of death was equal to zero in some cases. To overcome this problem, in these cases the D_i were set to one. The effect of this substitution on the calculated life expectancies was negligible.

Technical implementation. Data management was done with SPSS™ Version 15 and 16.

Life table calculations were implemented using the statistical programming language R™ [17]. The algorithm was set up in such a way that a theoretically unlimited number of life tables could be calculated in one single run. 595 regional life tables were computed for females and males and for eight life table periods from 1997/1999 to 2004/2006, which resulted in a total of 9 520 life tables. The mean computation time for a single life table was ca. 0.11 seconds. Adding the calculations for confidence intervals doubled approximately the computation time for each table.

Maps were generated with Adobe Illustrator™. The map geometries were provided by Digital Vector Maps™, San Diego, USA.

		(a) Life expectancy at birth			**(b) Life expectancy at age 65**			**(c) Life expectancy at age 75**		
		Method			Method			Method		
Period	Gender	Chiang	FSO	Difference	Chiang	FSO	Difference	Chiang	FSO	Difference
1996/1998	Female	80.3	80.3	0.060	18.9	18.8	0.053	11.4	11.4	-0.036
1997/1999	Female	80.6	80.6	0.025	19.1	19.1	0.020	11.5	11.5	0.031
1998/2000	Female	80.9	80.8	0.043	19.3	19.2	0.039	11.7	11.6	0.046
1999/2001	Female	81.1	81.1	0.079	19.5	19.4	0.079	11.8	11.8	0.084
2000/2002	Female	81.3	81.2	0.126	19.7	19.5	0.127	11.9	11.8	0.134
2001/2003	Female	81.4	81.3	0.096	19.7	19.6	0.101	11.9	11.8	0.106
2002/2004	Female	81.6	81.5	0.075	19.8	19.8	0.080	12.0	11.9	0.085
2003/2005	Female	81.9	81.8	0.083	20.0	19.9	0.087	12.1	12.0	0.090
2004/2006	Female	82.2	82.1	0.117	20.3	20.2	0.123	12.3	12.2	0.123
1996/1998	Male	74.1	74.0	0.046	15.2	15.1	0.035	9.1	9.2	-0.081
1997/1999	Male	74.5	74.4	0.021	15.4	15.4	0.014	9.3	9.3	-0.003
1998/2000	Male	74.8	74.8	0.040	15.6	15.6	0.037	9.4	9.4	0.020
1999/2001	Male	75.2	75.1	0.079	15.9	15.8	0.086	9.7	9.6	0.077
2000/2002	Male	75.5	75.4	0.129	16.1	15.9	0.171	9.8	9.6	0.190
2001/2003	Male	75.7	75.6	0.135	16.2	16.1	0.164	9.9	9.7	0.192
2002/2004	Male	76.0	75.9	0.131	16.4	16.3	0.160	10.0	9.8	0.197
2003/2005	Male	76.4	76.2	0.146	16.7	16.5	0.176	10.2	10.0	0.214
2004/2006	Male	76.8	76.6	0.184	17.0	16.8	0.221	10.4	10.1	0.257

Table 4: Comparison of method Chiang vs. method Federal Statistical Office (FSO)

2.4 Validation

To validate our methodological approach a comparison of our life table results was made with results from life tables from the Federal Statistical Office (FSO) of Germany. The comparison was made for life expectancy at birth, age 65 and age 75 looking at total Germany. The official life table data published by the FSO of Germany [9] are based on complete life tables with one year age intervals for the same three year life table periods that we use. The results are presented in Table 4a to Table 4c. Method Chiang refers to our approach of calculating abridged life tables and method FSO refers to the official life expectations. The absolute differences in the most right column of each sub-table are presented with three decimal places. Overall, these differences are very small. With few exceptions the life expectancies calculated according to the Chiang method are greater than the life expectancies computed by the FSO method. The maximum difference is found in the life table 2004/2006 for males with life expectation at age 75 and this maximum difference comprises about one quarter of the year.

It can be seen that deviations for males are greater than for females and that these deviations are greater for the more actual life tables. Taking into account that the life expectancies were computed with different life table methodologies (abridged vs. complete) and further different methodological approaches in detail, the close matching of the results is very good.

2.5 Limitations

2.5.1 Validity of population and death data

Data from official data sources are not necessarily correct but may contain some errors. The most important problem to mention here is that population numbers are not based on census data. The population data that we used in the calculations came from an official data source, i.e. the Federal Statistical Office of Germany. However one has to be aware that these data are based on forward projections from population data that were determined by more precise census methods only for special single years in the past. These forward projections are based on birth, death and migration data. The last census years are long-term backward: 1987. The last census was conducted in West Germany and 1981 in East Germany. The next census will be in the year 2011. It is known that updates of population data after census years may raise discontinuities in population number series (see e.g. [11]). Forward projections and true population numbers may diverge over time. In July 2008 an official press release from the Federal Statistical Office of Germany [10] confirmed that official population numbers may overestimate the true German population by 1.3 million. This discrepancy was calculated based on tests for new census methods that will be used in the next census in 2011. These tests were conducted in the years 2001 to 2003.

A comparison between data from the German Pension Fund and population data from the Federal Statistical Office raised the problem that the common population data may overestimate the number of the very elderly [22].

Unfortunately, it cannot be assumed that errors in population numbers act uniformly at regional levels. Some bias may e.g. be associated to the proportion of immigrants (see e.g. [21]) that live in a region. The population numbers of immigrants may be overestimated because these parts of the population show high mobility rates that are not covered in full by official citizen registries. Death numbers may be underestimated because death occurs when they have left Germany without any official notification. Both reporting issues work in the same direction and would lead to an overestimation of life expectancy.

2.5.2 Comparability problems of administrative regional units

Cross-sectional problems. Administrative regional units as provided by NUTS levels are far away from being optimal for regional epidemiological analysis. Population size may vary enormously between units at the same NUTS level. Large regional units which in themselves can be very heterogeneous have to be compared with small very homogeneous units. To overcome this problem larger cities would have to be split up into city districts. Data sets that combine data from NUTS level 3 regions with city district data for larger cities do not exist from a single official source. The set-up of such a database would require considerable human resources.

Longitudinal problems. The classification of administrative regional units is also more or less subject to continuous redefinitions. The smaller a regional unit the higher is the probability that its administrative belonging will change over time. This can make it difficult to compile longitudinally comparable data for the regional units. An example are the administrative changes of regions in Saxony that made 1995 data incomparable with data for the following years. Especially shrinking regions in East Germany may raise the need to reorganize into larger administrative units. This could make it difficult to monitor regional developments consistently over time.

2.5.3 Life expectancy and health

As described above, life expectancy is an important population based health outcome indicator and life expectancy in industrialized nations continued to increase substantially following a centennial upward trend. However increased life expectancy does not in itself mean that the additional years of life are spend in good health. Obviously, information about quality of life that would make it possible to distinguish between additional years of life spent in good or ill-health would provide a much more precise description of population health. Health aspects of quality of life may involve a complex number of dimensions. Different concepts of health combined with life expectancy may lead to different health expectancy indicators that may deliver inconsistent conclusions. Complexity increases even more when indicators allow for international comparisons.

Despite the problems involved, methods have been developed that allow extension of life table techniques to compute disability-free life expectancies. When standardized data are available, these data will allow international comparisons (see e.g. [12]). These methods require data of the gender and age-specific prevalence of the population in healthy and unhealthy states, which are derived e.g. from cross-sectional surveys. What data sources would allow an extension of these approaches to regional level analysis so small as NUTS levels 3 is an unsolved problem.

3 Summary of results

3.1 Regional variation

The most actual life table period 2004/2006 is used to describe the regional variation of life expectancy within Germany for life expectancy at birth, at age 65 and age 75 separated by gender. Figure 1 to Figure 3 show, how the variation of life expectancy increases when the population size of the covered regional unit decreases. Life expectancies for total Germany (aggregation level R0) and East and West Germany (aggregation level R1) are provided as reference points in the left of each graph. For aggregation levels R2 (federal states) to R5 (counties and cities) the results are summarized by boxplots which show the maximum value, the 75th percentile, the median (50th percentile), 25th percentile and the minimum. These data are also provided numerically in Table 5a (Females) and Table 5b (Males). Figure 1 to Figure 3 indicate the overall higher level of life expectancies for females. In general, the variation in life expectancy is higher in males than in females. At aggregation level R5, the range of life expectancies at birth is 7.3 years for males and 4.4 years for females. The difference in the gender associated variation of life expectancies at age 65 is much less pronounced (R5, range females: 3.2 years, range males 4.2 years) and no longer visible for life expectancies at age 75 (R5, range females and males: 2.8 years).

Table 5a and Table 5b also provide a presentation of relative life expectancy. This was defined for each level of regional aggregation as percentage points in relation to the region with maximum live expectancy. The region with maximum live expectancy was set to 100%. As expected, for females and males, the range of this relative life expectancy increases with decreasing population size of the covered regions. Worth mentioning is that the range of relative life expectancy increases significantly when the remaining life time for the life expectancies shortens from at birth to age 65 and furthermore to age 75. The same pattern shows up for females and males. At aggregation level R5, the relative life expectancy at birth for females in the region with minimum life expectancy is 94.8% compared to the region with maximum life expectancy, for males the relative life expectancy is 90.9% . For age 75 these relative life expectancies are with 79.6% for females and 76.2% for males strikingly lower. Figure 4 to Figure 6 present at aggregation level R5 maps for regional life expectancy at birth, age 65 and age 75. Separate maps for females and males are shown side by side. The most striking feature of these maps is the strong gradient of decreasing life expectancy that runs from south-west to north-east.

The interpretation and explanation of these results in an epidemiological analysis which will try to use the regional socioeconomic context to enlighten these demographic findings is a challenging and interesting task which has to be accomplished in the future.

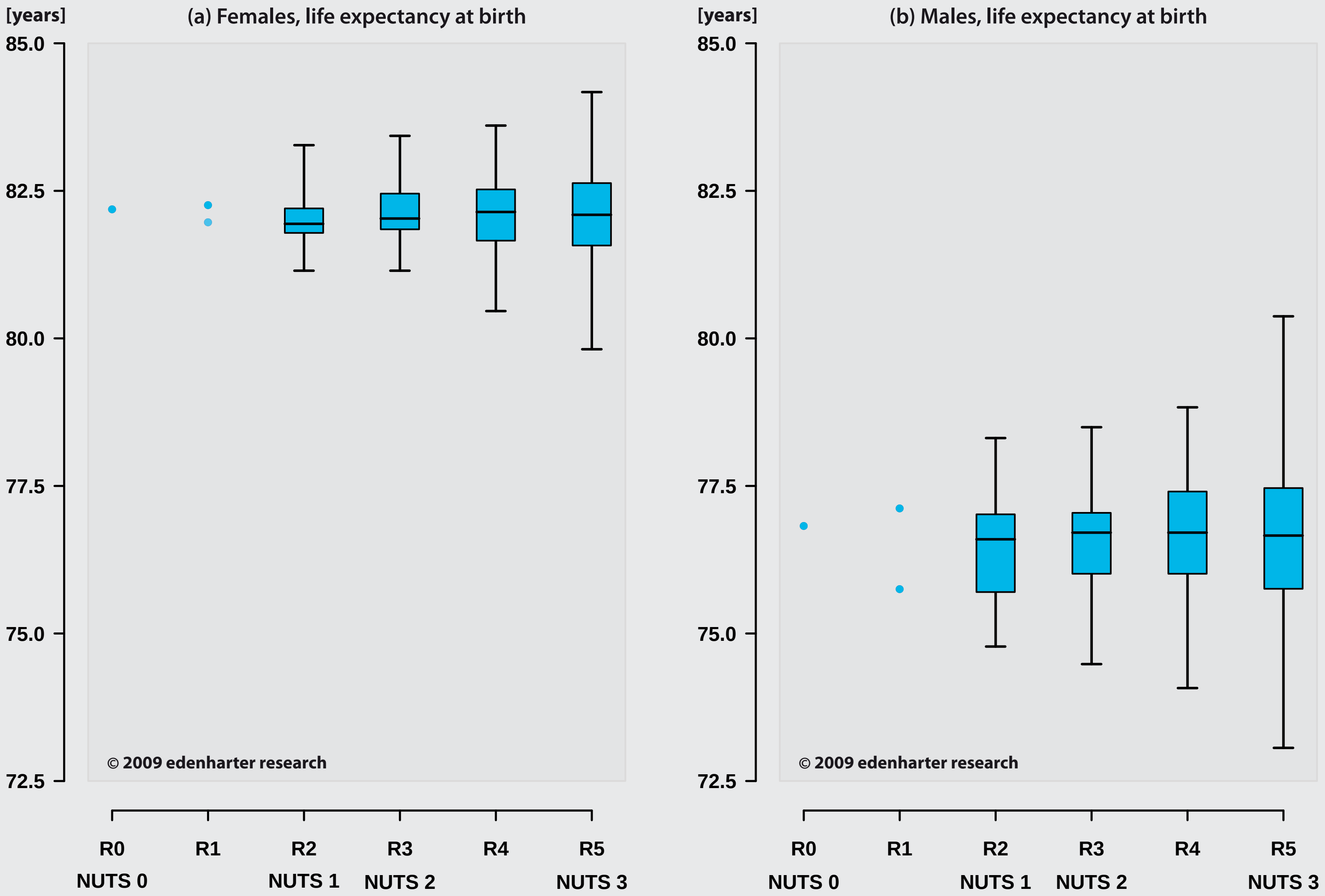


Figure 1: Variation of regional life expectancy at birth, 2004/2006, boxplots

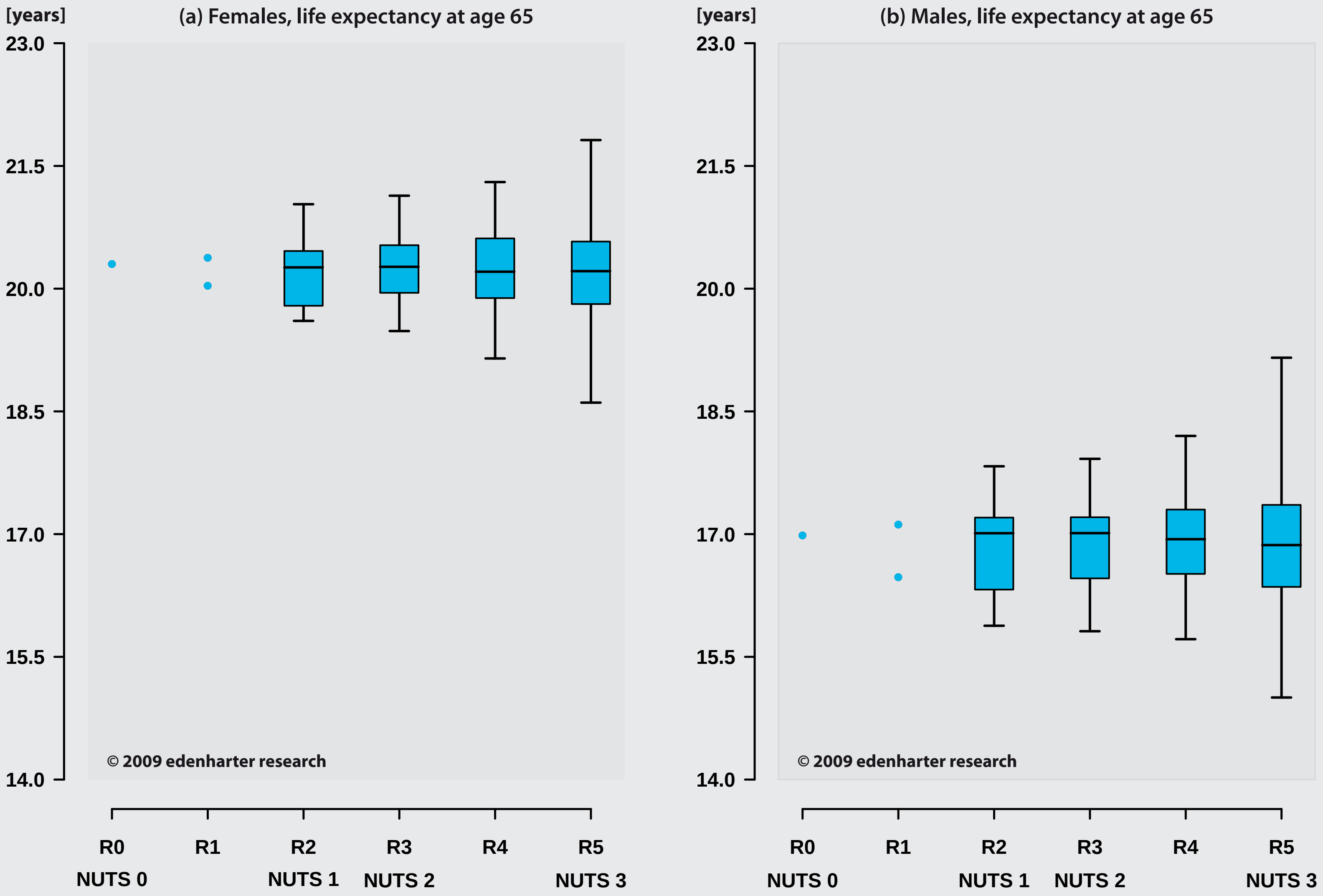


Figure 2: Variation of regional life expectancy at age 65, 2004/2006, boxplots

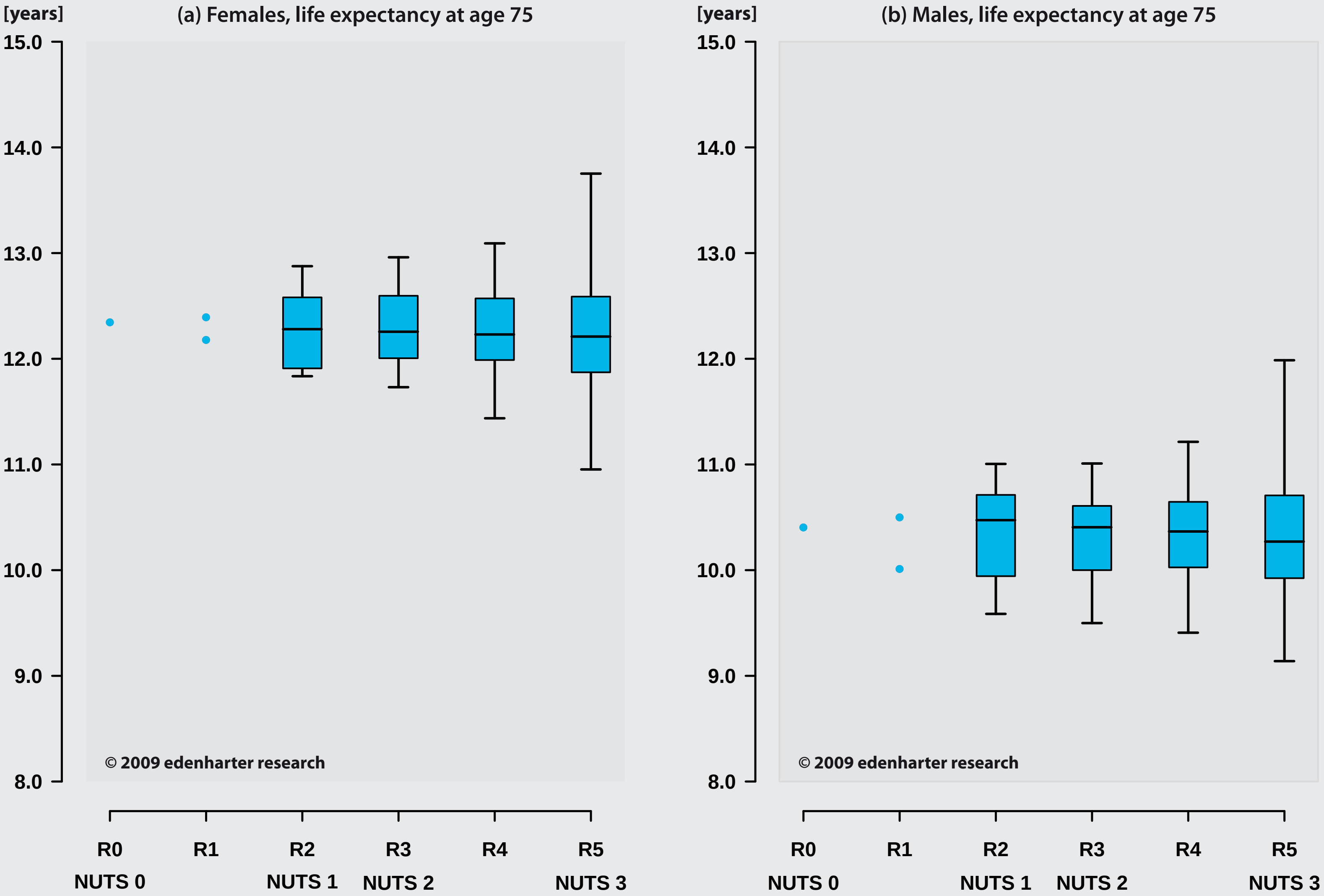


Figure 3: Variation of regional life expectancy at age 75, 2004/2006, boxplots

		(a) Females 2004/2006						(b) Males 2004/2006					
		absolute [years]			relative to maximum (%)			absolute [years]			relative to maximum (%)		
Level		at birth	at age 65	at age 75	at birth	at age 65	at age 75	at birth	at age 65	at age 75	at birth	at age 65	at age 75
R0	Germany	82.2	20.3	12.3				76.8	17.0	10.4			
R1	East	82.0	20.0	12.2	99.7	98.3	98.3	75.7	16.5	10.0	98.2	96.2	95.3
R1	West	82.3	20.4	12.4	100.0	100.0	100.0	77.1	17.1	10.5	100.0	100.0	100.0
	Federal States							Federal States					
R2	Minimum	81.1	19.6	11.8	97.4	93.2	91.9	74.8	15.9	9.6	95.5	89.1	87.1
R2	Q25	81.8	19.8	11.9	98.2	94.1	92.5	75.7	16.3	9.9	96.7	91.5	90.3
R2	Median	81.9	20.3	12.3	98.4	96.3	95.4	76.6	17.0	10.5	97.8	95.4	95.2
R2	Q75	82.2	20.5	12.6	98.7	97.3	97.7	77.0	17.2	10.7	98.3	96.5	97.3
R2	Maximum	83.3	21.0	12.9	100.0	100.0	100.0	78.3	17.8	11.0	100.0	100.0	100.0
	Governorates							Governorates					
R3	Minimum	81.1	19.5	11.7	97.3	92.2	90.5	74.5	15.8	9.5	94.9	88.2	86.3
R3	Q25	81.8	19.9	12.0	98.1	94.4	92.6	76.0	16.5	10.0	96.8	91.8	90.8
R3	Median	82.0	20.3	12.3	98.3	95.9	94.6	76.7	17.0	10.4	97.7	94.9	94.5
R3	Q75	82.5	20.5	12.6	98.8	97.1	97.2	77.0	17.2	10.6	98.2	96.0	96.4
R3	Maximum	83.4	21.1	13.0	100.0	100.0	100.0	78.5	17.9	11.0	100.0	100.0	100.0
	Regional Planning Units							Regional Planning Units					
R4	Minimum	80.5	19.1	11.4	96.2	89.9	87.4	74.1	15.7	9.4	94.0	86.4	83.9
R4	Q25	81.7	19.9	12.0	97.7	93.3	91.6	76.0	16.5	10.0	96.4	90.7	89.4
R4	Median	82.1	20.2	12.2	98.2	94.9	93.4	76.7	16.9	10.4	97.3	93.1	92.4
R4	Q75	82.5	20.6	12.6	98.7	96.8	96.0	77.4	17.3	10.6	98.2	95.1	94.9
R4	Maximum	83.6	21.3	13.1	100.0	100.0	100.0	78.8	18.2	11.2	100.0	100.0	100.0
	Counties and Cities							Counties and Cities					
R5	Minimum	79.8	18.6	11.0	94.8	85.3	79.6	73.1	15.0	9.1	90.9	78.3	76.2
R5	Q25	81.6	19.8	11.9	96.9	90.8	86.3	75.8	16.4	9.9	94.3	85.4	82.8
R5	Median	82.1	20.2	12.2	97.5	92.7	88.8	76.7	16.9	10.3	95.4	88.0	85.7
R5	Q75	82.6	20.6	12.6	98.2	94.3	91.5	77.5	17.4	10.7	96.4	90.6	89.3
R5	Maximum	84.2	21.8	13.8	100.0	100.0	100.0	80.4	19.2	12.0	100.0	100.0	100.0

Table 5: Regional variation of life expectancy, 2004/2006

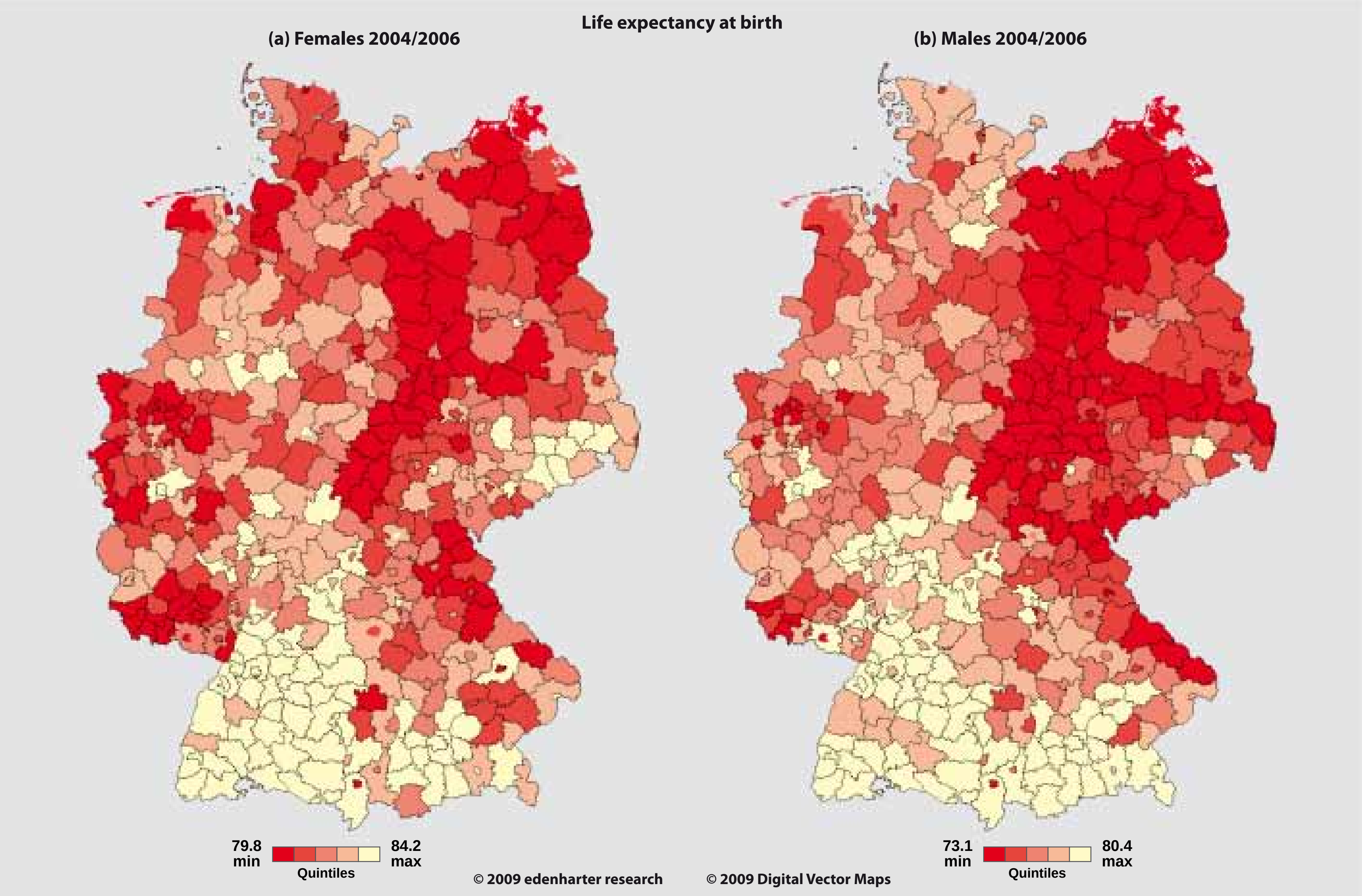


Figure 4: Life expectancy at birth, R5: counties and cities, map

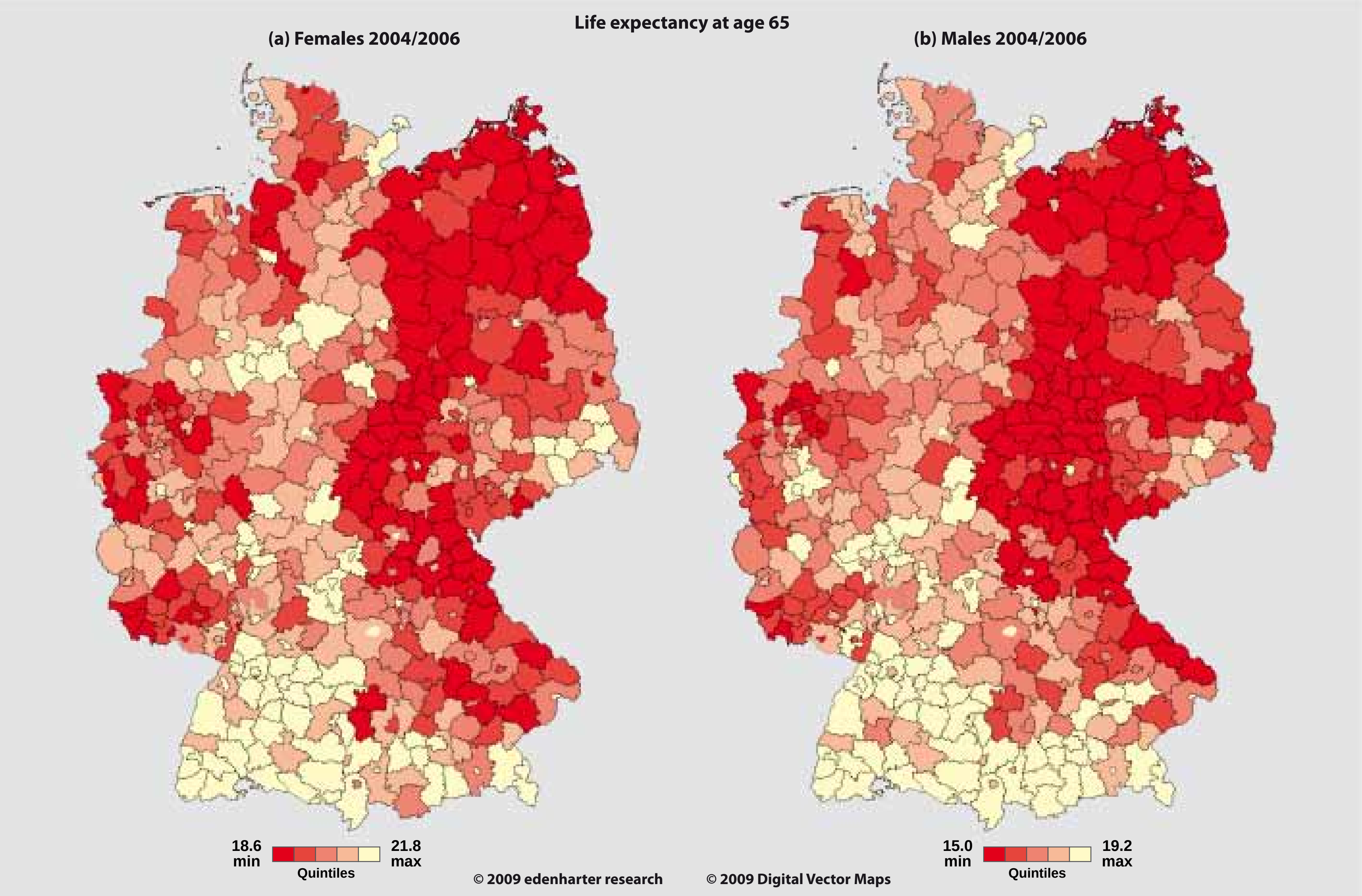


Figure 5: Life expectancy at age 65, R5: counties and cities, map

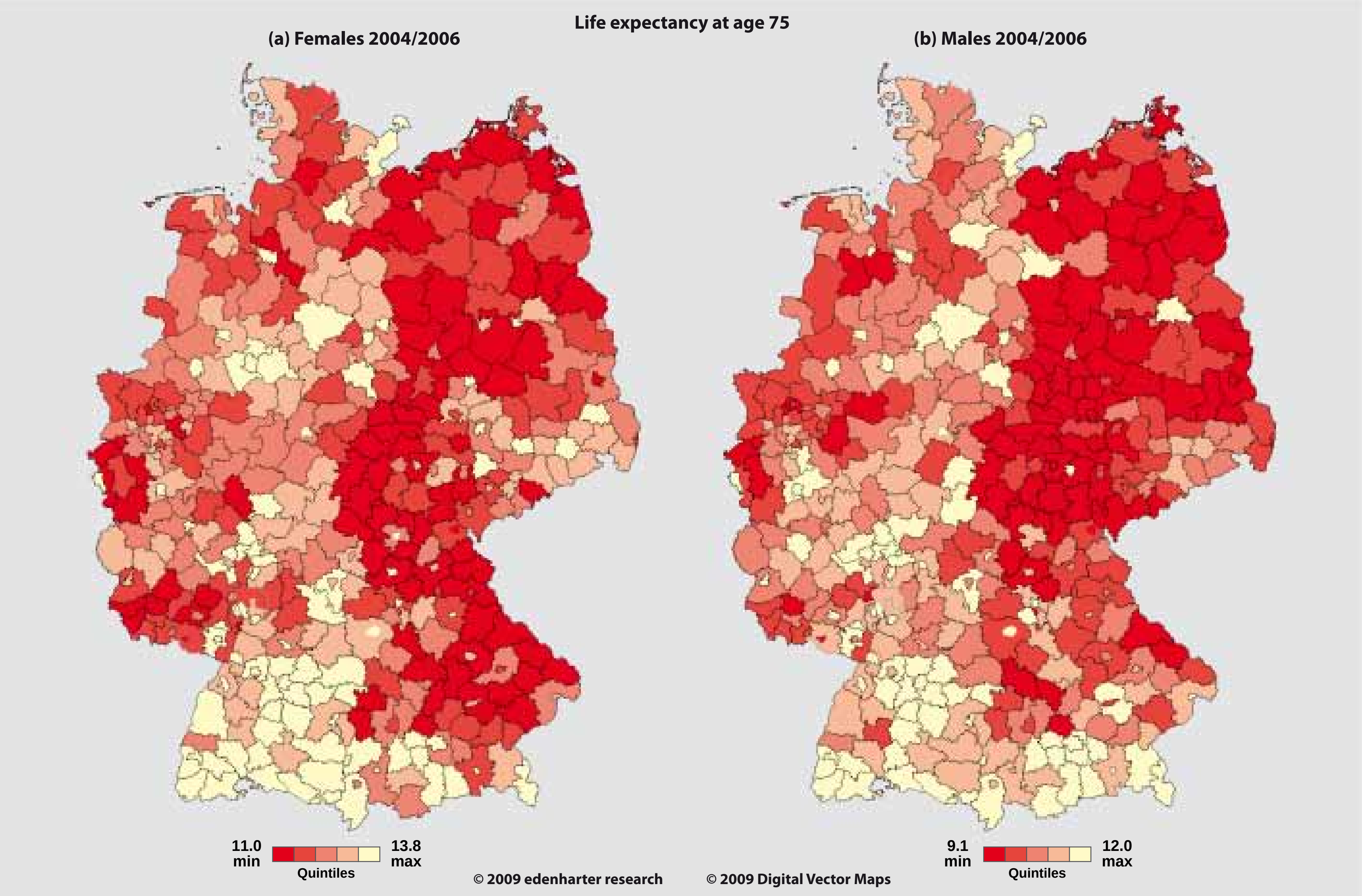


Figure 6: Life expectancy at age 75, R5: counties and cities, map

3.2 Change over time

Change over time is described by a comparison of the life table periods 1997/1999 and 2004/2006. Table 6a and Table 6b present data for the absolute and relative differences between life expectancy at birth, age 65 and age 75 between these periods. Absolute differences were computed for each region by subtracting from the life expectancies in the period 2004/2006 the life expectancies for the period 1997/1999. Relative differences were measured for each region by the percentage growth in life expectancy from 1997/1999 to 2004/2006.

Changes in life expectancy for total Germany (aggregation level R0) and East and West Germany (aggregation level R1) are reported at the top of each table. The relative differences indicate a stronger increase in life expectancy for the elderly population. The growth of life expectancy was higher in West Germany than in East Germany, for males as well as for females. For the elderly population, age 65 and age 75, the growth of life expectancies were much larger than for the total population at birth.

For the aggregation levels R2 (federal states) to R5 (counties and cities) the results are reported by providing in Table 6a and Table 6b for absolute and relative differences of life expectancy the five number summary which would also allow the drawing of boxplots: the maximum value, the 75th percentile, the median (50th percentile), 25th percentile and the minimum. The variation of absolute and relative differences increases with decreasing population size. At aggregation level R5 the negative minimum values indicate that not all regions experienced a positive development. At all age levels males show a negative sign of life expectancy change at the minimum value. For females only change of life expectancy at birth and at age 75 have a negative sign at the minimum value.

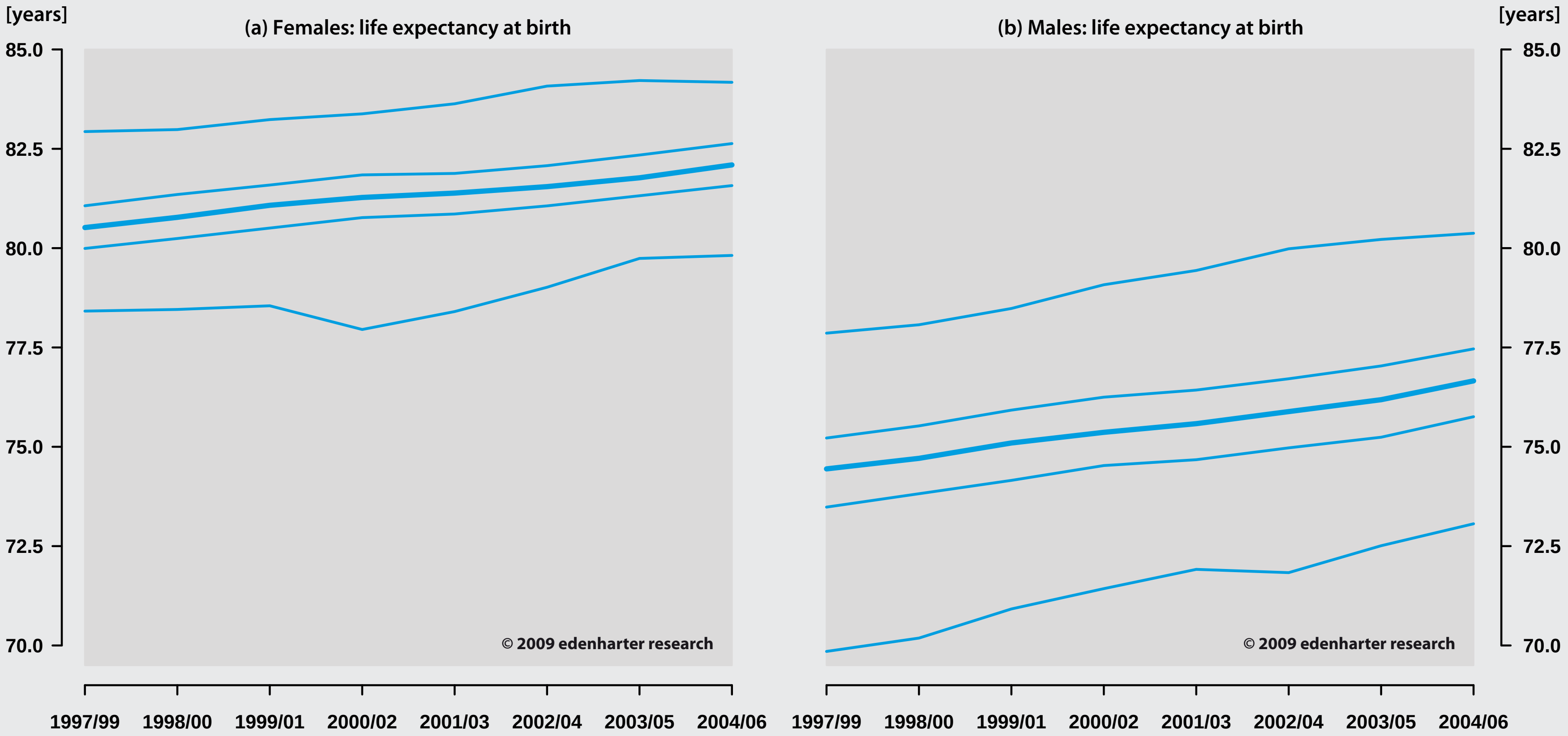
For regional aggregation level R5 a more detailed description of the development of life expectancy for the periods from 1997/1999 to 2004/2006 is given in Figure 7 to Figure 9. These figures provide a combined presentation of line boxplots with numerical presentation of the data in tables below the plots. The tables also inform about the range (maximum - minimum) and the interquartil range (Q75 - Q25) for each life table period. Range and interquartil range describe variation among the regions and can be used as measures of convergence over time. Again, information for females and males is presented in parallel.

In general, life expectation at all ages and for females and males show an upward trend where females move at higher levels with lower variation than males.

To analyze potential convergence of life expectancies among regions over time the interquartile range and the range can be inspected. The interquartile range is nearly constant over time within all subgroups and thus does not provide evidence for convergence. The range does not show smooth uniform movements. For this reason a separate table is set up that shows the development of the relative range over time with the range of the period 1997/1999 set to 100%. No single pattern can be identified for all subgroups. Only life expectancy at age 75 years of females shows a nearly steady decline of the range over time. Two subgroups, life expectancy at birth of females and life expectancy at age 75 of males show peak levels of the range over time that are more than 20% above the range of the base period 1997/1999. As the range measures the distance between the extremes it can be assumed that single regions, probably with small population numbers experienced very special conditions, but this has to be analyzed in more detail in the future: these regions can be identified from the data and it can be assumed that a more detailed analysis of these regions that also looks at cause-specific death would provide interesting insight into the underlying causes.

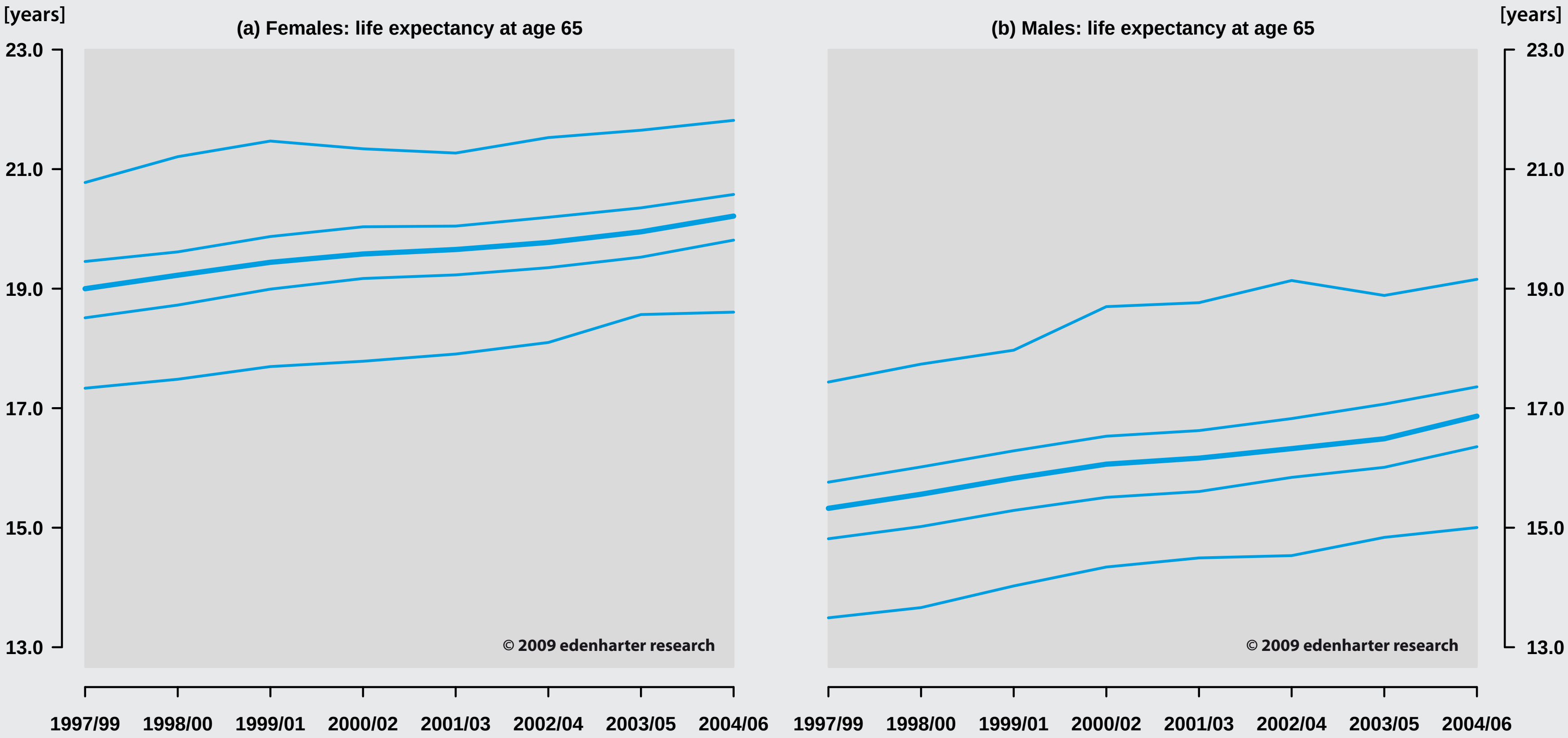
		(a) Females						(b) Males					
		absolute [years]			relative [%]			absolute [years]			relative [%]		
Level		at birth	at age 65	at age 75	at birth	at age 65	at age 75	at birth	at age 65	at age 75	at birth	at age 65	at age 75
R0	Germany	1.6	1.2	0.8	2.0	6.4	7.3	2.4	1.6	1.1	3.2	10.5	12.2
R1	East	1.5	1.1	0.8	1.8	5.9	6.8	2.3	1.6	1.1	3.0	10.3	12.1
R1	West	2.0	1.5	1.0	2.5	8.1	9.3	2.6	1.7	1.1	3.6	11.3	13.0
	Federal States												
R2	Minimum	1.1	0.9	0.6	1.3	4.7	4.6	2.1	1.3	0.8	2.8	8.1	8.1
R2	Q25	1.4	1.1	0.7	1.7	5.6	6.5	2.2	1.5	1.1	3.0	10.1	11.7
R2	Median	1.6	1.2	0.8	1.9	6.4	7.4	2.3	1.6	1.1	3.2	10.9	12.6
R2	Q75	2.0	1.5	1.0	2.5	7.9	8.9	2.6	1.7	1.3	3.5	11.5	13.4
R2	Maximum	2.2	1.6	1.1	2.7	8.8	10.2	3.2	1.9	1.5	4.5	12.6	16.0
	Governorates												
R3	Minimum	1.1	0.9	0.5	1.3	4.6	4.6	1.9	1.2	0.8	2.5	7.9	8.1
R3	Q25	1.4	1.1	0.7	1.7	5.5	6.2	2.1	1.5	1.0	2.9	9.6	11.4
R3	Median	1.6	1.2	0.8	1.9	6.2	7.2	2.3	1.6	1.1	3.1	10.4	12.5
R3	Q75	1.9	1.4	1.0	2.4	7.5	8.9	2.6	1.7	1.2	3.4	11.1	13.3
R3	Maximum	2.3	1.8	1.2	2.9	9.4	10.4	3.2	2.0	1.5	4.5	12.9	16.0
	Regional Planning Units												
R4	Minimum	0.8	0.5	0.3	1.0	2.8	2.7	1.6	1.0	0.7	2.2	6.8	7.9
R4	Q25	1.3	1.0	0.7	1.6	5.4	6.1	2.1	1.5	1.0	2.8	9.6	10.8
R4	Median	1.5	1.2	0.8	1.9	6.2	7.1	2.3	1.6	1.1	3.0	10.3	12.4
R4	Q75	1.9	1.4	1.0	2.4	7.6	8.8	2.6	1.7	1.2	3.5	11.4	13.6
R4	Maximum	2.6	1.9	1.6	3.2	10.2	14.0	3.5	2.3	1.8	5.0	15.9	20.9
	Counties and Cities												
R5	Minimum	-0.2	0.1	-0.1	-0.3	0.5	-1.2	-0.6	-0.3	-0.2	-0.8	-2.0	-1.5
R5	Q25	1.2	1.0	0.7	1.5	5.1	5.8	2.0	1.4	0.9	2.6	8.8	10.0
R5	Median	1.6	1.2	0.9	2.0	6.4	7.5	2.3	1.6	1.1	3.1	10.4	12.3
R5	Q75	2.0	1.5	1.1	2.5	8.0	9.6	2.7	1.8	1.3	3.6	12.0	14.6
R5	Maximum	3.2	2.3	1.8	4.0	12.7	17.6	4.1	2.6	2.2	5.7	17.5	25.9

Table 6: Change in life expectancy 1997/1999 to 2004/2006



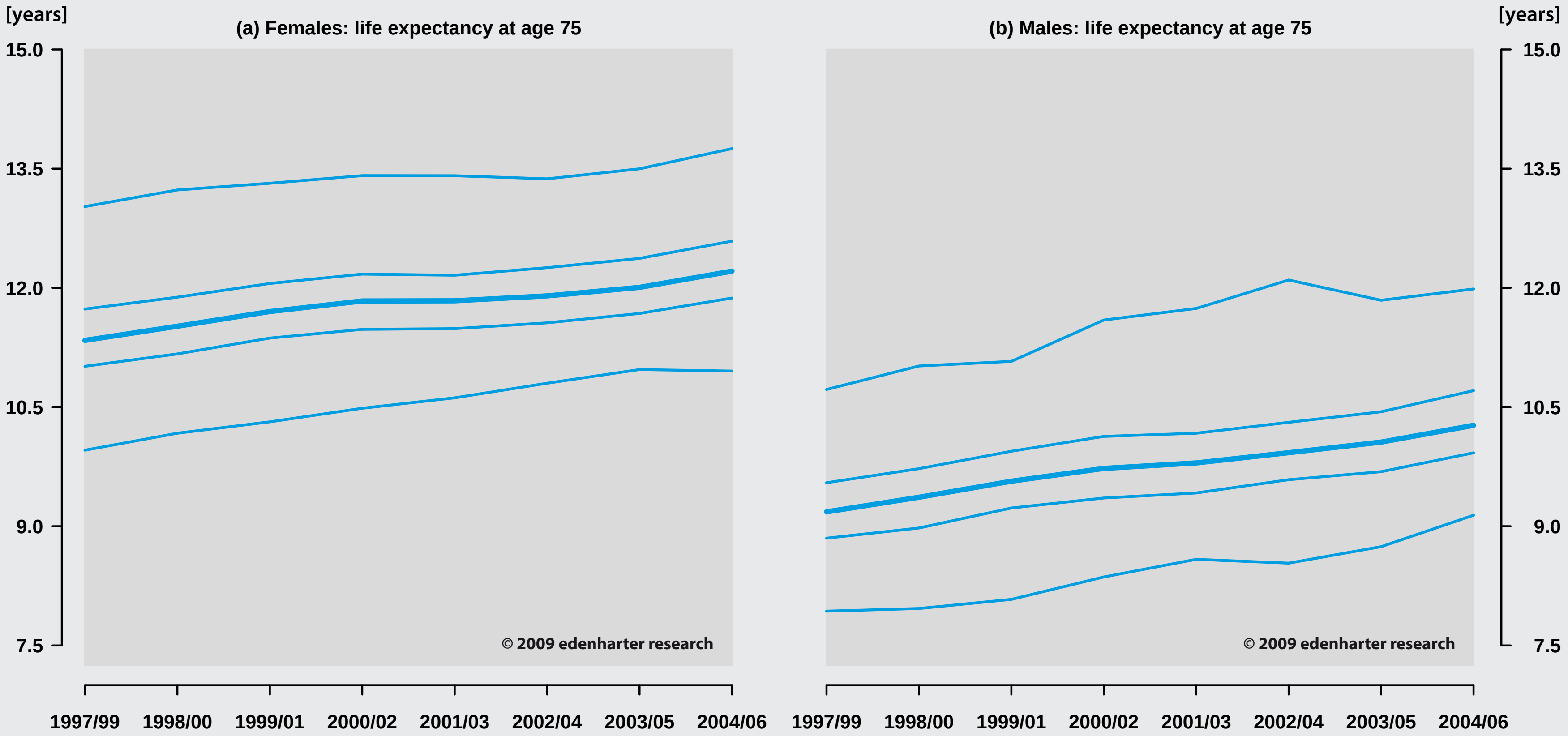
Maximum	82.9	83.0	83.2	83.4	83.6	84.1	84.2	84.2	77.9	78.1	78.5	79.1	79.4	80.0	80.2	80.4	Maximum
Q75	81.1	81.3	81.6	81.8	81.9	82.1	82.3	82.6	75.2	75.5	75.9	76.2	76.4	76.7	77.0	77.5	Q75
Median	80.5	80.8	81.1	81.3	81.4	81.5	81.8	82.1	74.4	74.7	75.1	75.4	75.6	75.9	76.2	76.7	Median
Q25	80.0	80.2	80.5	80.8	80.9	81.1	81.3	81.6	73.5	73.8	74.2	74.5	74.7	75.0	75.2	75.8	Q25
Minimum	78.4	78.5	78.5	78.0	78.4	79.0	79.7	79.8	69.9	70.2	70.9	71.4	71.9	71.8	72.5	73.1	Minimum
Range	4.5	4.5	4.7	5.4	5.2	5.1	4.5	4.4	8.0	7.9	7.6	7.6	7.5	8.2	7.7	7.3	Range
Q75-Q25	1.1	1.1	1.1	1.1	1.0	1.0	1.0	1.1	1.7	1.7	1.8	1.7	1.8	1.7	1.8	1.7	Q75-Q25

Figure 7: Time trends of life expectancy at birth, R5: counties and cities, line boxplots and tables



Maximum	20.8	21.2	21.5	21.3	21.3	21.5	21.7	21.8	17.4	17.7	18.0	18.7	18.8	19.1	18.9	19.2	Maximum
Q75	19.5	19.6	19.9	20.0	20.0	20.2	20.4	20.6	15.8	16.0	16.3	16.5	16.6	16.8	17.1	17.4	Q75
Median	19.0	19.2	19.4	19.6	19.7	19.8	20.0	20.2	15.3	15.6	15.8	16.1	16.2	16.3	16.5	16.9	Median
Q25	18.5	18.7	19.0	19.2	19.2	19.4	19.5	19.8	14.8	15.0	15.3	15.5	15.6	15.8	16.0	16.4	Q25
Minimum	17.3	17.5	17.7	17.8	17.9	18.1	18.6	18.6	13.5	13.7	14.0	14.3	14.5	14.5	14.8	15.0	Minimum
Range	3.4	3.7	3.8	3.6	3.4	3.4	3.1	3.2	3.9	4.1	3.9	4.4	4.3	4.6	4.0	4.2	Range
Q75-Q25	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.1	1.0	Q75-Q25

Figure 8: Time trends of life expectancy at age 65, R5: counties and cities, line boxplots and tables



Maximum	13.0	13.2	13.3	13.4	13.4	13.4	13.5	13.8	10.7	11.0	11.1	11.6	11.7	12.1	11.8	12.0	Maximum
Q75	11.7	11.9	12.1	12.2	12.2	12.3	12.4	12.6	9.5	9.7	9.9	10.1	10.2	10.3	10.4	10.7	Q75
Median	11.3	11.5	11.7	11.8	11.8	11.9	12.0	12.2	9.2	9.4	9.6	9.7	9.8	9.9	10.1	10.3	Median
Q25	11.0	11.2	11.4	11.5	11.5	11.6	11.7	11.9	8.8	9.0	9.2	9.4	9.4	9.6	9.7	9.9	Q25
Minimum	10.0	10.2	10.3	10.5	10.6	10.8	11.0	11.0	7.9	8.0	8.1	8.4	8.6	8.5	8.7	9.1	Minimum
Range	3.1	3.1	3.0	2.9	2.8	2.6	2.5	2.8	2.8	3.1	3.0	3.2	3.2	3.6	3.1	2.8	Range
Q75-Q25	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.7	0.8	0.8	Q75-Q25

Figure 9: Time trends of life expectancy at age 75, R5: counties and cities, line boxplots and tables

Relative range of life expectancy over time, period 1997/1999 equal to 100%								
(a) Life expectancy at birth			(b) Life expectancy at age 65			(c) Life expectancy at age 75		
Period	**Females**	**Males**	**Period**	**Females**	**Males**	**Period**	**Females**	**Males**
1997/1999	100.0	100.0	1997/1999	100.0	100.0	1997/1999	100.0	100.0
1998/2000	100.2	98.4	1998/2000	108.2	103.3	1998/2000	99.8	109.4
1999/2001	103.7	94.4	1999/2001	109.6	100.0	1999/2001	97.9	107.4
2000/2002	120.1	95.5	2000/2002	103.3	110.5	2000/2002	95.5	115.9
2001/2003	115.7	93.9	2001/2003	97.7	108.3	2001/2003	91.2	113.2
2002/2004	112.1	101.8	2002/2004	99.6	116.7	2002/2004	83.9	127.7
2003/2005	99.1	96.2	2003/2005	89.6	102.6	2003/2005	82.4	111.2
2004/2006	96.4	91.3	2004/2006	93.2	105.3	2004/2006	91.3	102.0

Table 7: Relative range of life expectancy over time, period 1997/1999 equal to 100%

3.3 Gender differences

It has to be accepted that, in modern affluent societies, being male is the most relevant demographic risk factor for early mortality ([13], [20]). Male excess mortality may be attributed to biological and behavioral causes and potential interaction between these two sources.

In Figure 10 male excess mortality is shown as male to female mortality ratio. This is derived from the probabilities of dying which were calculated by the Federal Statistical Office of Germany using a complete life table with single age years for the period 2004/2006 (data source: [9]). Male excess mortality which is weak within the first years of life begins to increases steeply with age 16 and peaks at age 21 with a value slightly above 3.0. After age 21 it decreases irregularly to a value of 2.0 at age 30. From age 31 to age 65 excess mortality remains close to a value of 2.0. After age 65 male excess mortality begins to decrease slowly and smoothly and finally reaches a value very close to 1.0 at age 100. During all their working life, age-specific mortality is considerably higher for males than for females.

The reasons for gender associated mortality differences are complex. Different patho-physiological mechanisms may act in females and males. For example., cardiovascular diseases are one of the most important causes of death for females as well as for males with males more strongly affected than females. Gender associated effects are well established for cardiovascular diseases ([19], [18]) and continuing in-depth efforts are made to highlight the underlying biological pathways and gender specific therapeutic options. In comparison to females, a much earlier onset of cardiovascular disease is observed in males. Thus lower male life expectancy can be attributed by a considerable amount to gender differences related to cardiovascular death. The temporal link between menopause and the subsequent rise in vascular events suggests as an immediate hypothesis that lower cardiovascular risk in females is associated with the protective effects of ovarian hormones, but this is discussed controversially [14].

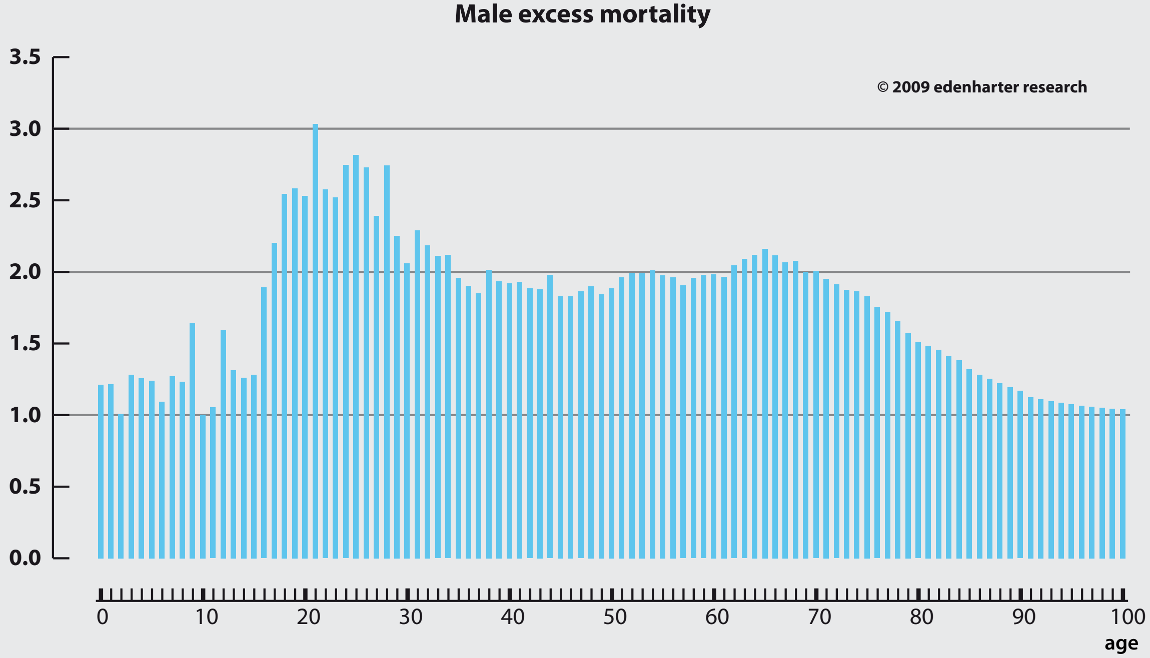


Figure 10: Age-specific male:female mortality ratio, Germany 2004/2006, bar chart

Behavioral gender specific causes are also widely accepted. Differences in risk-taking behavior may explain that death rates related to accidents or drug misuse are much higher for young male adults than for young female adults.

An interesting contribution to gender specific death highlighting biological and behavioral causes was accomplished by Luy [15]. He undertook an analysis of a cloistered population in comparison to the general population and concluded that under the special environmental conditions of nuns and monks, biological factors appear to confer a maximum survival advantage for women of no more than one year in remaining life expectancy at young adult ages.

Table 8 describes higher female life expectancy by providing absolute and relative differences between females and males. Absolute differences are calculated by subtracting male life expectancy from female life expectancy for each region. Relative differences are derived by expressing this difference as percentage points of male life expectancy for each region. Female enhanced life expectancy is slightly more pronounced in West Germany than in East Germany.

The variation of absolute and relative differences increases with decreasing population size of the regions. At all levels of regional aggregation it is found that relative higher female life expectancy is more elevated for the elderly population, age 65 and age 75, than for the total population at birth.

Figure 11 to Figure 13 present at regional aggregation level R5 (counties and cities) maps for higher female life expectancy at birth, age 65 and age 75, respectively. The geographical pattern found for higher female life expectancy at birth seems to be very similar to the pattern that we found for life expectancy at birth (see Figure 4). The interpretation of the patterns found for higher female life expectancy at age 65 and age 75 seems to be much more difficult.

		Higher female life expectancy 2004/2006					
		absolute [years]			relative [%]		
Level		at birth	at age 65	at age 75	at birth	at age 65	at age 75
R0	Germany	5.4	3.3	1.9	7.0	19.5	18.7
R1	East	5.1	3.3	1.9	6.7	19.0	18.0
R1	West	6.2	3.6	2.2	8.2	21.6	21.7
	Federal States						
R2	Minimum	4.8	3.1	1.7	6.2	17.8	16.3
R2	Q25	5.1	3.2	1.8	6.6	18.3	16.8
R2	Median	5.3	3.3	1.9	7.0	19.5	18.3
R2	Q75	6.2	3.5	2.1	8.2	21.4	21.0
R2	Maximum	6.8	3.8	2.3	9.1	23.7	24.0
	Governorates						
R3	Minimum	4.5	2.9	1.5	5.8	16.5	15.0
R3	Q25	5.0	3.1	1.8	6.6	18.2	16.8
R3	Median	5.4	3.3	1.9	7.1	19.5	18.7
R3	Q75	5.8	3.6	2.1	7.7	21.5	20.9
R3	Maximum	7.0	3.9	2.5	9.4	24.7	26.1
	Regional Planning Units						
R4	Minimum	4.2	2.7	1.4	5.5	15.0	12.9
R4	Q25	5.0	3.1	1.8	6.4	18.0	16.7
R4	Median	5.4	3.3	1.9	7.1	19.7	18.5
R4	Q75	5.8	3.5	2.1	7.7	21.1	20.8
R4	Maximum	7.2	3.9	2.5	9.6	24.7	26.1
	Counties and Cities						
R5	Minimum	3.0	1.6	0.6	3.7	8.8	5.5
R5	Q25	4.9	3.1	1.7	6.3	17.7	16.1
R5	Median	5.5	3.3	2.0	7.1	19.9	18.8
R5	Q75	6.1	3.6	2.2	8.0	22.0	22.1
R5	Maximum	8.3	4.8	3.4	11.2	30.0	35.7

Table 8: Higher female life expectancy 2004/2006

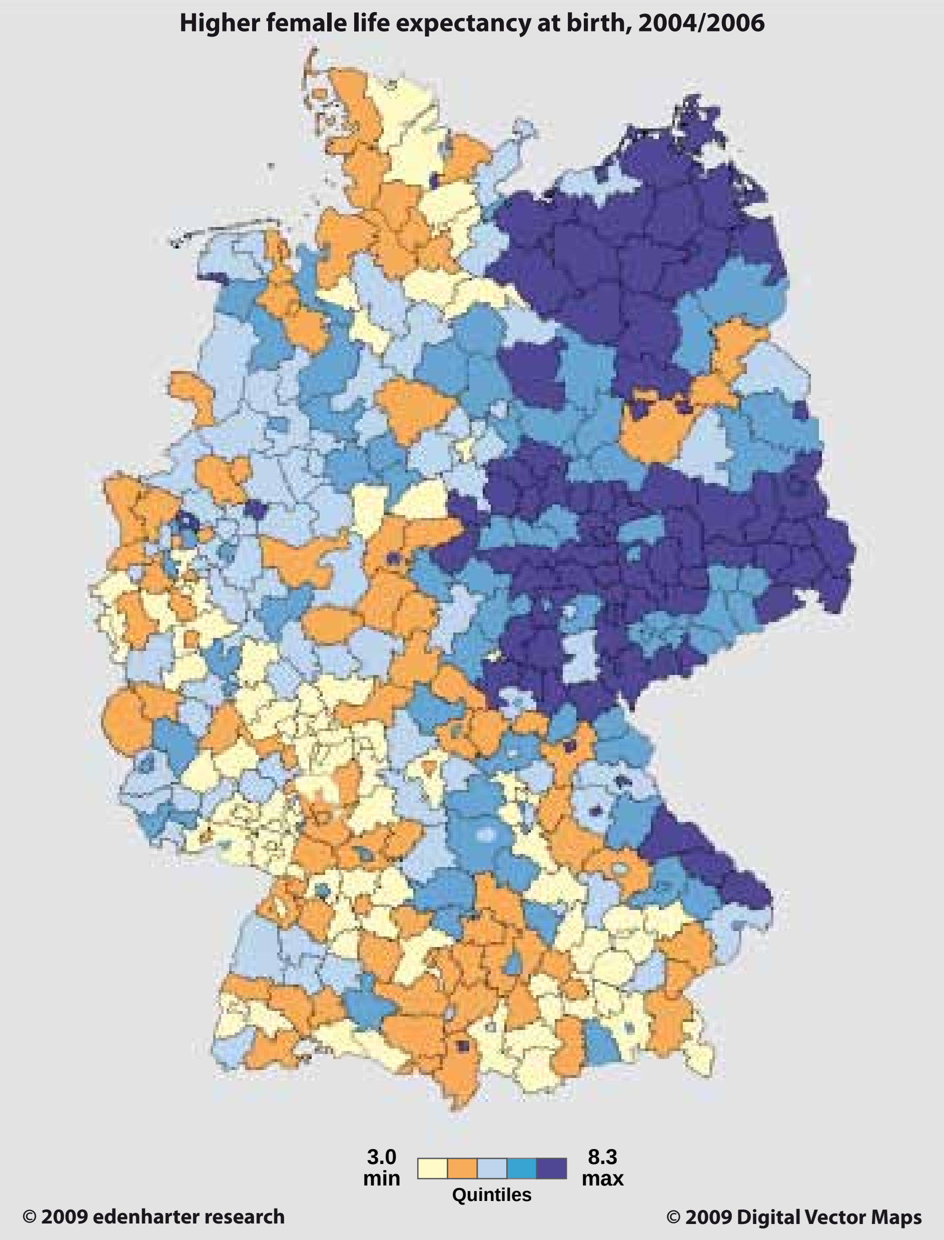

Higher female life expectancy at birth, 2004/2006

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Figure 11: Higher female life expectancy at birth, R5: counties and cities, 2004/2006, map

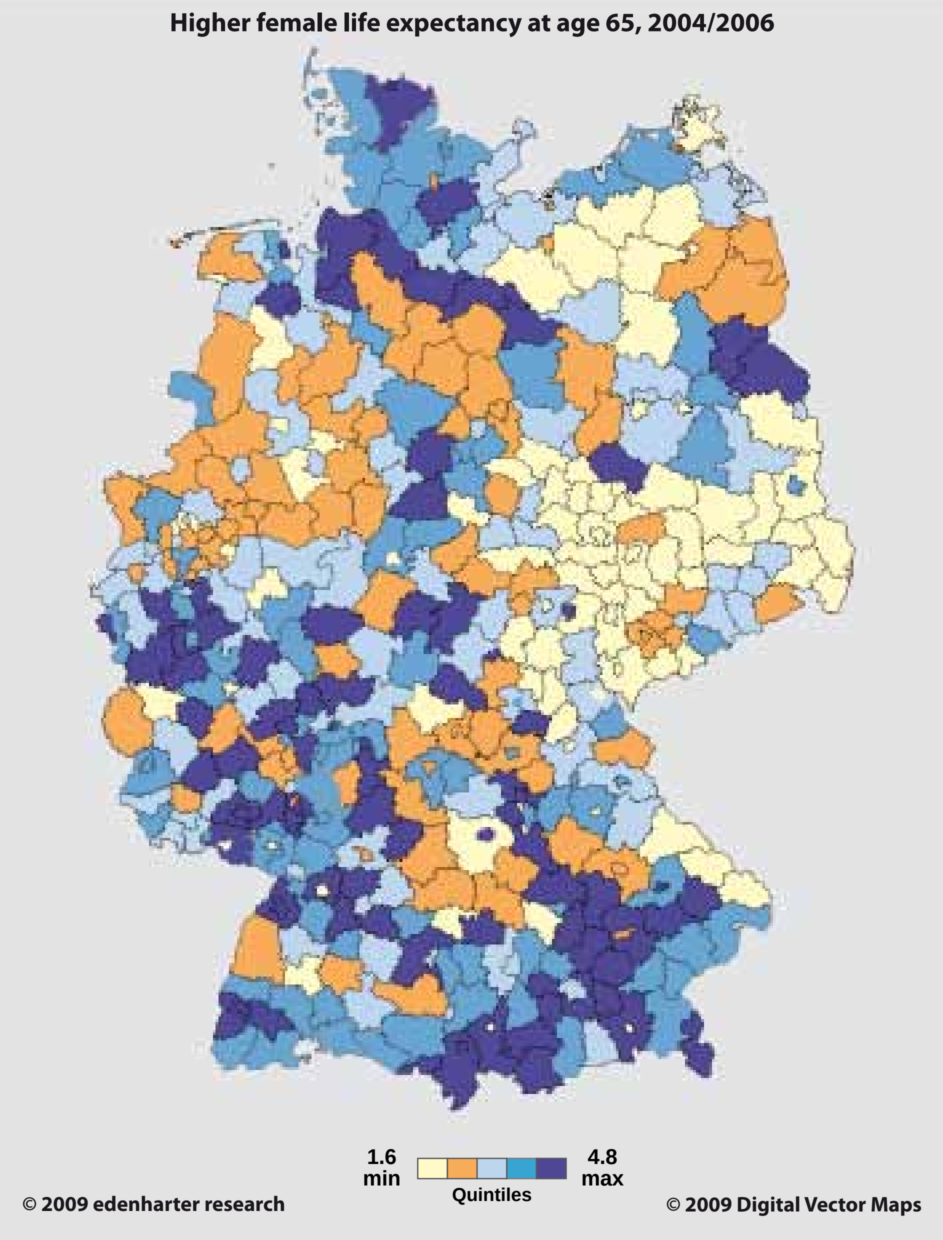
Higher female life expectancy at age 65, 2004/2006

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Figure 12: Higher female life expectancy at age 65, R5: counties and cities, 2004/2006, map

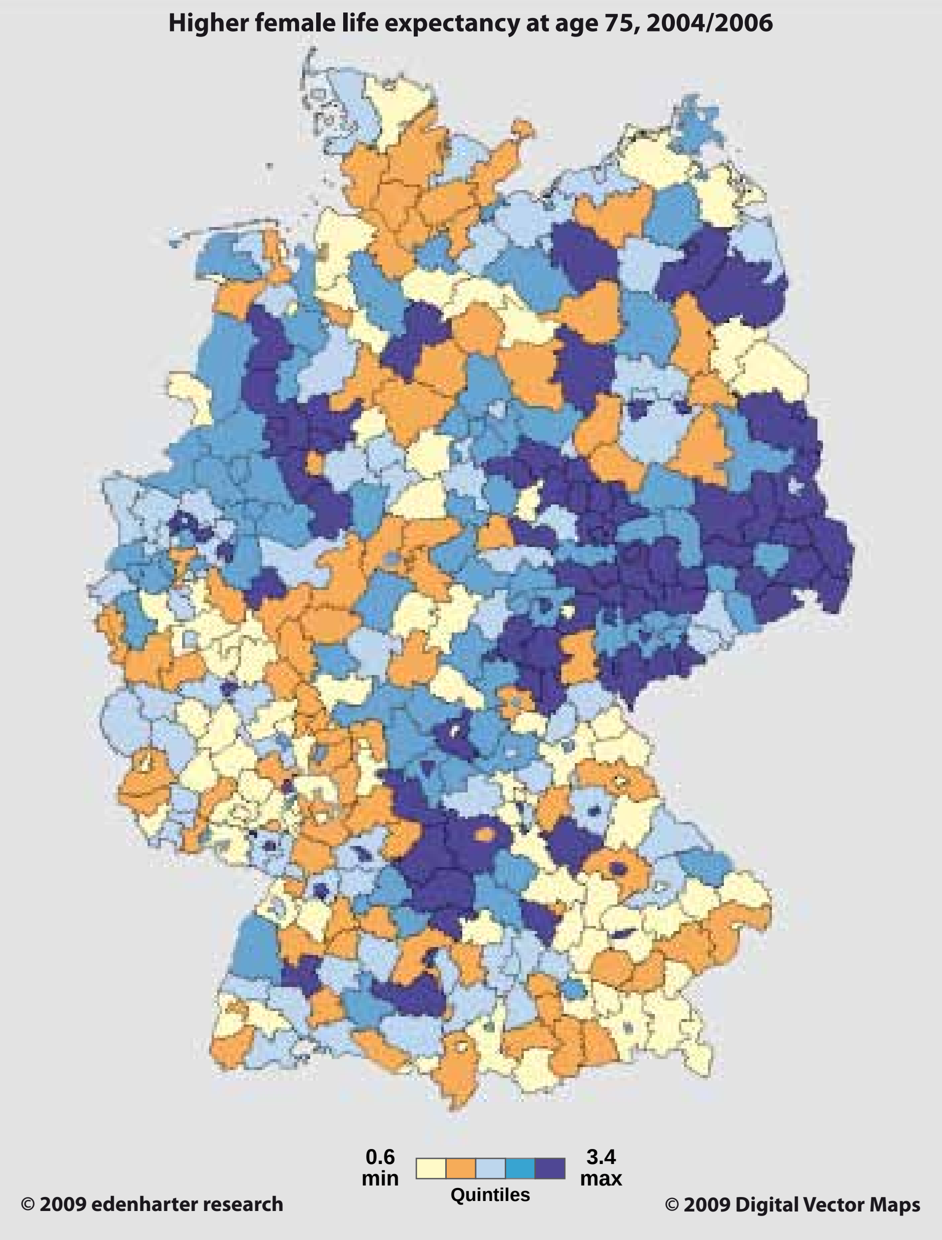

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Figure 13: Higher female life expectancy at age 75, R5: counties and cities, 2004/2006, map

3.4 International comparison

In this section we compare the German regional data (level R5, counties and cities) with the international life expectancy at birth data for 187 countries which is provided by the World Bank [23]. Figure 14 provides boxplots which are defined as described above for the 438 German counties and cities (life table period 2004/2006) and 187 countries (year 2005) for which data were available from the World Bank. Again analysis is separated by gender. Even when our life table computations will be different from the World Bank's approach, this will allow a crude comparison where German regions can be ranked with regard to life expectancy at an international level. Of course, it would be of greater interest to compare regional variations within different countries and not regional variations within Germany with international countries at national levels but such comparisons have to be postponed until future research work is carried out.

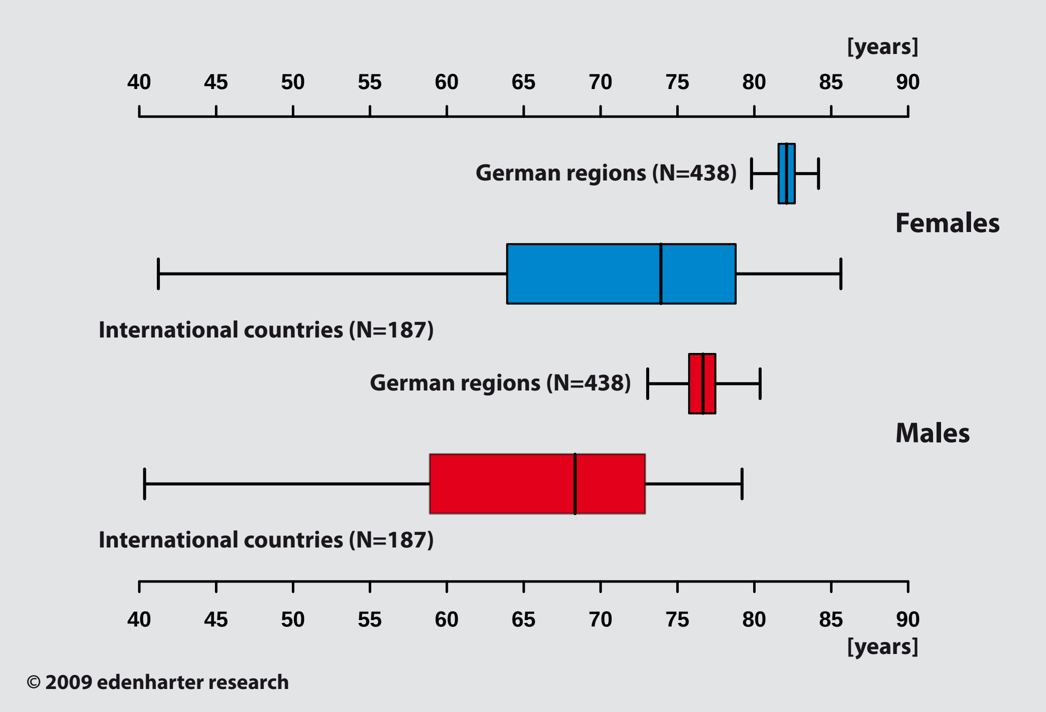

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Figure 14: Life expectancy at birth, comparison of German counties and cities with international countries, boxplots

Figure 14 shows that life expectancy at birth in German regions is located in the upper quartile of the international countries' life expectancies. With regard to female German regional life expectancy, it can been seen that some countries perform better than the German region with maximum female life expectancy at birth. Details are provided in Figure 15. Interestingly, with regard to German regional male life expectancy, some German regions outperform the country with maximum international male life expectancy. To make the comparison more detailed, only a selection of international countries is considered in a second step. For females and males only, those countries were included in the comparison which had higher or equal life expectancy than the German region with minimum life expectancy in each group. This approach allowed the set up of Figure 15. In this figure German counties and cities are represented again by boxplots as described above, separately for females and males. The positions of the selected international countries are marked by vertical lines below (barcode plot) and the names of the countries with life expectancies in parentheses are tabulated thereunder. For females life expectancy at national level in Hong-Kong and Japan even outperforms the best performing German region. For males additional data analysis showed that indeed 8 German regions had a life expectancy which was above the level of the internationally best performing country, i.e. Iceland.

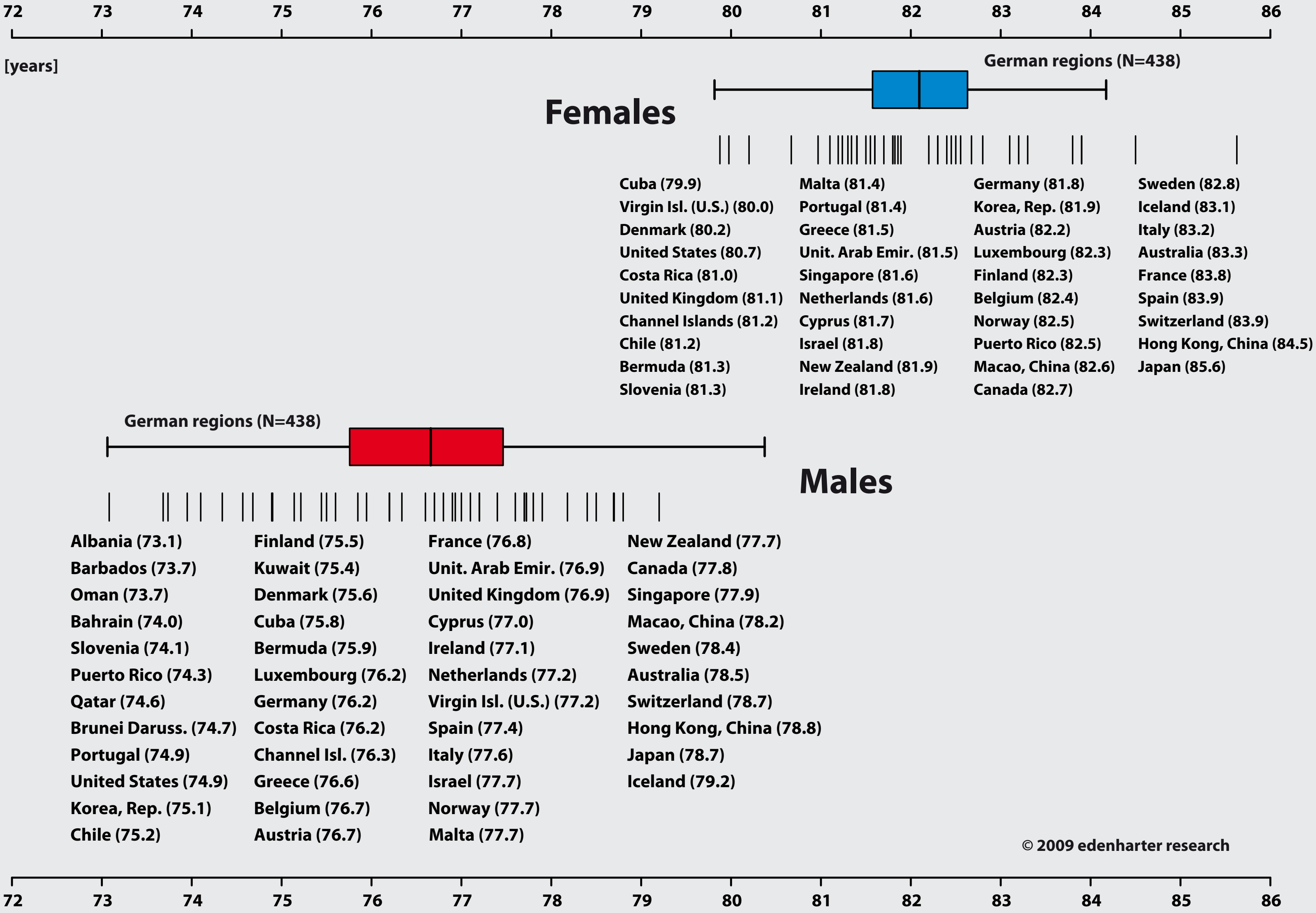

Figure 15: Life expectancy at birth, comparison of German counties and cities with selected international countries, boxplots and barcode plots

4 Conclusions and outlook

This report has provided a detailed description for the computation of regional life expectancies. A presentation of the first results for Germany highlighted different aspects of regional life expectancy: regional variation of life expectancy, change over time, gender differences and international comparisons. The findings raised many interesting questions that have to be answered by future research work.

From the experience that we gained by conducting this kind of analysis, it became evident that regional life table analysis is useful and feasible even with regions as small as NUTS level 3 units. No relevant technical difficulties are expected doing it at a much larger scale, e.g. at the level of the European Union. The number of all EU-27 NUTS level 0 to NUTS level 3 units is about 1 700. This is less than three times the number of units that we had used in our analysis where the number of regional units was equal to 595. A larger concern will be the limitations that were already outlined above and which will be of higher relevance if a group of more heterogeneous countries is involved: validity of population and death data and comparability problems of administrative regional units. At least in the longer run and with continuing success of EU wide harmonization it can be expected that none of these problems will be a fundamental issue. Of course, also non-EU countries should be considered. Further candidate countries for doing regional life table analysis are Russia and the United States. For Russia, regional mortality analysis has already been done and corresponding databases are available [1]. Based on harmonized methods, these data can be used for an analog approach such as ours.

Overall, regional life table analysis is a promising area for future epidemiological research that can provide valuable insights which can be used to improve the living conditions of populations worldwide. In the following we provide a short overview of what has already been done with life expectancy data from this project and what is planned for the future.

The life expectancy data has already been used to adjust survival rates of German dialysis patients for regional background mortality. Such an approach takes into account that dialysis units across the country are operating within regional populations of different health. Data from the German Renal Registry have also been used to calculate relative survival models. For this purpose the abridged life tables were extrapolated to complete life tables as described in [5].

Further research work will cover the epidemiological modeling of regional German life expectancy. Work on this has already started. Regional disparities within Germany had originally motivated this kind of research. The actual economic development which can be described as the largest global recession since the Great Depression of 1929 and after will deepen regional disparities even more. Life expectancy data are appropriate to describe the regional health outcomes of substantial economic change. Global recession will result in higher unemployment and lower income. Regions will be affected differently according to their dependence on their industrial structure. First preliminary results describing the effects of unemployment on regional life expectancy in Germany were presented in March 2009 at an international seminar in Berlin on “Health Issues during International Recession, Globalisation and Economic Restructuring”. Attendees of this seminar were representatives of the EU Commission, WHO, ILO, OECD and international academic researchers. Material from this project will also be used in the final report of the EU project “Development of Macro Indicators of Restructuring and Workers’ Health” (principal investigator: Prof. Dr. M. H. Brenner). It is planned to present more comprehensive epidemiological models at the 5th International Vilnius Conference “Knowledge-Based Technologies and OR methodologies for Strategic Decisions of Sustainable Development” (KORSD-2009), September 30 - October 3, 2009, Vilnius, Lithuania. A separate sub-project will focus on the modeling of gender differences of regional life expectancy. Publications are expected to be finalized at the end of the year 2009.

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Dr Lutz Xander from Technische Universität Berlin, Department of Public Health, used the epigraph “MORS CERTA, HORA INCERTA” when he introduced his online “Mortality Studio” in the year 2000.

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