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Sigma and beta convergence in regional mortality: A case study of the Netherlands

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Research Article

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Contents

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Abstract

BACKGROUND
For allocation of health budgets it is important to know whether regional mortality differences tend to decline or to increase. Sigma convergence tests can measure whether the dispersion of the regional distribution of mortality has declined. Beta convergence tests can examine whether regions with a low level of life expectancy have experienced a stronger increase than regions with a high level. In demographic research, however, sigma and beta convergence have not been formally assessed simultaneously.

OBJECTIVE
We demonstrate the application of both sigma and beta convergence tests to the study of trends in regional mortality differences for the Netherlands.

METHODS
Using all-cause mortality and population data for 40 Dutch NUTS-3 regions, by year (1988–2009), age group, and sex, we assess both sigma and beta convergence, and its significance.

RESULTS
Beta convergence proved statistically significant. The regions with the lowest life expectancy in 1988 generally exhibited the highest increase from 1988 to 2009, and vice versa. However, dispersion measures displayed no statistically significant sigma convergence.

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CONCLUSION
Whereas the absence of sigma convergence shows that regional mortality differences have not declined, beta convergence indicates that the disadvantage of regions with low life expectancy is not persistent.

CONTRIBUTION
We demonstrated the added value of simultaneously studying sigma convergence, beta convergence, and trajectories of regions in the tails of the distribution. Where absence of sigma convergence does not imply that disadvantaged regions did not improve, beta convergence does not always indicate complete convergence due to structural differences across regions.

1. Introduction

The debate in mortality research about whether differences in mortality levels at the population level decline (converge) or increase (diverge) focuses on between-country differences (e.g., Meslé and Vallin 2002; Vallin and Meslé 2004; Kunst et al. 2004; Moser, Shkolnikov, and Leon 2005; McMichael et al. 2004; Mustard, Derksen, and Black 1999; Singh 2003; Boyle et al. 2004). It is important to widen the scope of this debate to include regional mortality trends, as Vallin and Meslé (2004) also suggested. To the extent that policymakers aim to reduce inequity across regions, it is important to know whether the mortality experience of regions is becoming more or less equal, as this provides essential information for the allocation of central governmental budgets to the different regions in a country. Valkonen (2001) also stressed the need for systematic studies on the trends in differential mortality, including mortality by region.

Convergence of health due to diminishing returns of increases in health expenditures, improvement of education, and economic development is to be expected (Gächter and Theurl 2011). By contrast, divergence may occur due to the 'Matthew effect': regions with high life expectancy may experience even faster improvements. The Matthew effect may occur due to differences in education, as highly educated people may have better access to health care and may benefit more from medical progress (Ben-Shlomo, White, and Marmot 1996; Morris, Sutton, and Gravelle 2005). Another cause of the Matthew effect may be differences in life styles, as unhealthy life styles may have cumulative effects, both within cohorts across the life course and between cohorts, as children from disadvantaged families may have poor health (Ross and Wu 1996; Rigney 2010). Furthermore, selective migration may contribute to divergence, as healthy people tend to move to regions with favourable living conditions (Bentham 1988; Valkonen 2001).

Recent studies show ambiguous results, even when restricted to overall mortality and to low-mortality countries. Both within the United Kingdom (Boyle, Exeter, and Flowerdew 2004; Leyland 2004; Dorling 1997; Leyland 2004; Shaw et al. 1999; 2004), between provinces in Canada (Mustard, Derksen, and Black 1999; Manuel and Hockin 2000), and for the 2,068 counties in the United States (Ezzati et al. 2008), a tendency from convergence in the past to divergence in the more recent past follows from the various studies; in New Zealand, recent divergence has been observed as well (Pearce and Dorling 2006). On the other hand, Gächter and Theurl (2011) observed continuing convergence in Austria. In addition, Valkonen (2001) observed clear differences between several European countries in the trend in regional differences. Finland, Sweden, France, Italy, Romania, and Russia showed a decline after 1970 in the range and the average deviation of life expectancy levels between regions, whereas Spain, Poland, and females in Austria and Denmark experienced an increase (Valkonen 2001). Montero-Granados, de Dios Jiménez, and Martín (2007) observed different results for different geographical scale levels in Spain.

In the above studies, different approaches, dispersion measures, and outcome measures were used to assess convergence. Earlier demographic and epidemiological studies focussed on studying trends in dispersion measures over time. In a few instances scatterplots with the end values versus the initial values were shown (Vallin and Meslé 2001; Caselli, Meslé, and Vallin 2002; Vallin and Meslé 2004). In economic literature, however, a clear distinction is being made between sigma convergence and beta convergence following the work by Barro (e.g., Barro and Sala-i-Martin 1990, 1992) and with recent applications to the study of health convergence (Nixon 2000; Montero-Granados, de Dios Jiménez, and Martín 2007; Gächter and Theurl 2011). Where sigma convergence concerns the formal study of trends over time in cross-sectional dispersion measures, beta convergence formally explores regression towards the mean of the different values over time (Barro and Sala-i-Martin 1992; Nixon 2000; Montero-Granados, de Dios Jiménez, and Martín 2007; Gächter and Theurl 2011).

Within demography, no formal analysis of beta convergence has been applied before, nor have sigma convergence and beta convergence been studied together. Sigma and beta convergence, however, highlight different aspects and have relevance for demographers and policymakers in distinctive ways. Sigma convergence shows whether regional differences in health have become smaller over time. However, it does not show the underlying changes in mortality for individual regions. For example, it does not show whether regions that were lagging behind are catching up with regions that were forerunners. Beta convergence provides more insight as it measures whether regions that experienced relatively high mortality in the past have shown more improvement since then compared with regions where mortality was relatively low. However, beta convergence does not always result in sigma convergence. Beta

convergence is a necessary but not sufficient condition for sigma convergence (Gächter and Theurl 2011). Vice versa, when no sigma convergence is measured this does not necessarily imply that regions with low life expectancy are in a persistently disadvantaged position. Beta convergence tests are necessary to examine whether disadvantaged regions are catching up or whether improvements in advantaged regions are stalling. In addition, to examine which type of convergence (or divergence) occurred, it is essential to also examine the trajectories of regions in the tails of the distribution. While upward convergence implies that regions with low life expectancy move to a more favourable position in the regional distribution, downward convergence means that well-off regions lose (part of) their advantage. For policymakers, the former is probably more important than the latter.

To aid the debate of convergence/divergence in health, we demonstrate and evaluate the application of the economic concepts of sigma and beta convergence tests to the study of regional mortality. As a case study, we formally assess both sigma and beta convergence of regional mortality levels over time and examine trajectories of regions in the tails of the distribution for the Netherlands. Even though the Netherlands is a small country, there have been significant differences in the level of mortality across regions. For 2004–2008, for example, 12 out of 40 NUTS-2 regions had statistically significant higher age-standardised mortality than the average level of 81.0 deaths per 10,000 population for males and 84.4 for females, and 15 regions had lower age-standardised mortality than average (Janssen and Spriensma 2012). Furthermore, a renewed increase in life expectancy at the national level has occurred since 2002 (Mackenbach and Garssen 2011), which could potentially affect the existence and level of convergence.

2. Data and methods

2.1 Setting

For the total population of the Netherlands we study regional mortality trends over the period 1988 to 2009, for 40 NUTS-3 regions. These so-called COROP regions are designed as nodal regions (i.e., one city plus its hinterland). See Appendix I for the distinguished regions. The administrative borders remained unchanged during the observation period.

2.2 Outcome measure

In previous studies, different mortality measures have been used to assess trends in regional mortality differences. Most often, life expectancy at birth is used (e.g., Moser, Shkolnikov, and Leon 2005; Ram 2006; Vallin and Meslé 2004; Meslé and Vallin 2002; Happich and von Lengerke 2007; Nixon 2000; Ezzati et al. 2008; Manuel and Hockin 2000; Trovato and Lalu 2001; Valkonen 2001; Goesling and Firebaugh 2004), but also (un)standardised (logged)(premature) mortality (Gächter and Theurl 2011; Leyland 2004; Mustard, Derksen, and Black 1999; Valkonen 2001; Vallin et al. 2005) and infant mortality (Moser, Shkolnikov, and Leon 2005; Joseph 1989; Nixon 2000; Agrawal 2010). To provide a complete picture, we analysed both life expectancy at birth (e0) and logged standardised mortality, implementing commonly used measures. Because the overall results proved similar, we only show the results for e0.

2.3 Data

To calculate the underlying age-specific mortality rates, we obtained mortality and population data from Statistics Netherlands (2010a; b), by year (1988–2009), age (mortality data by five-year age groups 0, 1–4, 5–9, …, 90–94, 95+, and population data by single year of age), sex, and region. Demographic data are obtained in the Netherlands by means of a population register and are therefore considered of good quality. Registration of deaths in the Netherlands occurs according to the place of residence.

The mortality data we obtained were based on period-cohort observations. We rescaled the estimated period-cohort mortality rates into the more conventionally used age-period rates. For this we used Dutch deaths by age, period, and cohort from the Human Mortality Database (2011a) and calculated a rescaling factor (by sex and age group), taking an unweighted average over 2005 to 2008. The rescaled age-specific mortality rates were smoothed over time by subsequently applying a three-year running median and a three-year running mean (Goodall 1991). The rescaling and smoothing did not affect the outcomes much.

2.4 Life table calculations

Life expectancy at birth (e0) by sex, region, and year was calculated using abridged life tables (Preston, Heuveline, and Guillot 2000). For age groups 0–1 and 1–4 we estimated the time spent in the age interval by those dying in the interval ($_na_x$) using the formulas

by Coale and Demeny (1983) as reported in Preston, Heuveline, and Guillot (2000). For the remaining age groups, we used the Dutch 2008 $_na_x$ values by sex of the Human Mortality Database (2011b).

2.5 Sigma convergence

To examine sigma convergence, i.e., the decline of the dispersion of the regional distribution of mortality, different dispersion measures from the available economic, health, and demographic literature can be used (see, respectively De Maio 2007, Mackenbach and Kunst 1997 and Shkolnikov et al. 2001 for relevant reviews). It is important to note, however, that most of the dispersion measures in the health-related literature focus on measuring health inequalities linked to socioeconomic differences, and are therefore not all suitable for our approach of studying dispersion of mortality between administrative regions. Overall, dispersion measures exist that either focus on the difference to the average or on the underlying regional differences. Examples of the latter are the Dispersion Measure of Mortality (Shkolnikov et al. 2001; Moser, Shkolnikov, and Leon 2005) and the Theil index of inequality (Gächter and Theurl 2011; Ram 2006; Goesling and Firebaugh 2004). These 'entropy measures' seem more relevant when differences between the different subpopulations are large, whereas looking at the difference to the average is more informative when differences tend to be less. The dispersion can be expressed as either absolute or relative. Commonly used absolute measures are the range, variance, standard deviation, and the average deviation. These measures are turned into relative measures by dividing them by the average. The relative standard deviation is similar to the often-used coefficient of variation (Gächter and Theurl 2011; Nixon 2000; Appleby et al. 2011; Ram 2006). In most demographic studies, but also in epidemiological studies, changes in the relative sizes of the subgroups are taken into account through weighting. The measure used most often in epidemiology, e.g., the index of dissimilarity (Mackenbach and Kunst 1997), is actually the weighted average deviation (Valkonen 2001). In economic studies the standard deviation and the coefficient of variation are used most often.

   In our application, we focused on the difference to the average and compared different weighted and unweighted dispersion measures, both absolute and relative; i.e., variance, standard deviation, average deviation (= index of dissimilarity), relative variance, coefficient of variation (= relative standard deviation), and relative average deviation. It turned out that the absolute dispersion measures revealed similar trends to the relative dispersion measures. Therefore we only show the results for the absolute dispersion measures.

Differences proved to be largest as regards the use of weighted versus unweighted measures. The weighted measures not only take into account changes in the relative size of subgroups over time, but also the relative size of the subgroups themselves. Larger subgroups therefore have a larger effect on the calculation of the standard deviation than smaller subgroups. Also, the dispersion of the larger subgroups alone has an influence on the overall sigma convergence. For the descriptive results, we choose to depict the trends purely for the unweighted dispersion measures because (i) when studying regional differences in mortality, policymakers are especially interested in whether differences between the regions have become smaller or bigger, irrespective of the population size of the regions, and (ii) unweighted measures could be considered more easy to interpret than weighted measures. However, because population size does matter and the weighted dispersion measures could provide additional information, our formal analysis of sigma convergence (see below) included both weighted and unweighted variance.

To examine whether sigma convergence is statistically significant we performed an F-test for the difference in weighted and unweighted variance over time (see Nixon 2000 and Montero-Granados, de Dios Jiménez, and Martín 2007). Choosing the F-test over Levene's test we assume that the data are more or less normally distributed, which indeed proved to be the case in over 95% of the cases according to the Kolmogorov-Smirnov test for normality.

2.6 Beta convergence

In a context of declining mortality, beta convergence in regional mortality occurs when regions with relatively low life expectancy have experienced a stronger increase in life expectancy than regions with high life expectancy. Thus we can assess convergence of mortality between t=0 and t=1 by examining whether there is a negative relationship between the level of life expectancy at t=0 and the change in life expectancy between 0 and 1. This can be done by regressing the difference between 0 and 1 on the level in t=0, following Barro and Sala-i-Martin in 1990:

$$Y_{i,1} - Y_{i,0} = \alpha + \beta_{(0)} Y_{i,0} + \varepsilon \tag{1}$$

where $Y_{i,t}$ represents e0 of region i at time t. Beta convergence is observed if the rate of change in e0 negatively correlates with the initial e0 levels, and therefore occurs when $\beta_{(0)} < 0$.

If there are more years in between measurements it is also convenient to scale the difference with the number of years (e.g., Montero-Granados, de Dios Jiménez, and Martín 2007):

$$(1/t)\,(Y_{i,t}-Y_{i,0})=\alpha+\beta Y_{i,0}+\varepsilon \tag{2}$$

in which case $\beta = \beta_{(0)}/t$.

We use expression (2) in our calculations, which means that beta convergence is present if $\beta<0$ (Montero-Granados, de Dios Jiménez, and Martín 2007). To visualize the presence of beta convergence we show scatterplots with the annual increase over the period $(1/t)(Y_{i,t}-Y_{i,0})$ against the value in the starting year $(Y_{i,0})$, by region.

2.7 Difference between beta and sigma convergence

If there is beta convergence, the expectation would be that the variation in death rates across regions would become smaller. Thus one would expect sigma convergence. From expression (1) we can derive that beta convergence is a necessary condition for sigma convergence (Gächter and Theurl 2011). Sigma convergence is the case when *Var $(Y_1)<Var (Y_0)$*. From expression (1) the variance of the outcome measure in the final year (Y_1) can be expressed as: *$Var(Y_1)=(1+\beta_{(0)})^2 Var(Y_0)+Var(\varepsilon)$, thus $Var(Y_1)-Var(Y_0)=[(1+\beta_{(0)})^2-1]Var(Y_0)+Var(\varepsilon)$*. Hence sigma convergence implies *$[(1+\beta_{(0)}^2)-1]Var(Y_0)<Var(\varepsilon)$*. Since Var($\varepsilon$) is larger than 0 (unless Y_0 and Y_1 are perfectly correlated) this is only possible when *$(1+\beta_{(0)}^2)<1$* and thus *$\beta_{(0)}<0$*. So beta convergence is a necessary condition for sigma convergence to occur.

However, beta convergence is not a sufficient condition for sigma convergence (Gächter and Theurl 2011). One reason why beta convergence does not necessarily result in sigma convergence is that random fluctuations in the final year 1 may be relatively large compared to the change that can be contributed to the converging trend; i.e., Var(ε) compensates for $\beta < 0$. Another reason why beta convergence may not result in sigma convergence is that random fluctuations in the starting year may be behind the observed beta convergence. If the life expectancy in a given region in the starting year is very different from the mean due to a random fluctuation, the life expectancy in the end year is expected to be closer to the mean than in the starting year. Thus random fluctuations may result in regression toward the mean. This is called Galton's fallacy (Quah 1993). In order to limit the risk of Galton's fallacy and to eliminate random fluctuations, one approach is to smooth the data in successive years, which we did in our application (see 2.3). Another approach would be to correlate the intercepts and the slopes.

Next to the effects of random fluctuations in the beginning and final observation years, differences between sigma and beta convergence can result from systematic differences. The size of the beta is more strongly influenced by the changes that occur among regions that differ largely from the mean as compared to regions that are close to the mean in the first year. When regions in the tail of the distribution experience changes towards the mean (i.e., convergence) while at the same time regions close to the mean experience changes away from the mean (i.e., divergence) this may lead to significant beta convergence without significant sigma convergence. This can be explained by the fact that size of beta depends on the covariance of the value in year 0 and the change between year 0 and year 1. In the calculation of the covariance the deviance from the mean in year 0 for each region is multiplied by the change between year 0 and year 1. Thus large changes in regions for which the difference from the mean in year 0 is small have a small weight in the calculation of the covariance.

Thus absence of sigma convergence does not imply that there are no converging regions, while, by contrast, significant beta convergence does not necessarily imply that all or most regions are converging. The simultaneous study of both sigma and beta convergence is therefore necessary. Moreover, studying the trajectories of the regions in the tails of the distribution is essential to obtain a complete picture of convergence.

2.8 Trajectories of regions

Studying the trajectories of regions in the tails of the distribution is beneficial to the study of convergence/divergence in different ways. First, it can shed light on the importance of random fluctuations. If there is a gradual consistent movement of mortality in a region towards the mean it seems unlikely that this is caused by random fluctuations only. Second, it can shed light on the existence or amount of convergence for the different regions. Using expression (2) to assess beta convergence is based on the assumption that the same value of beta applies to all regions. However, some regions may converge at a faster rate than others and it is also possible that even though some regions convergence, others do not, or they even diverge. Thus a low value of beta may either indicate that there are no converging regions or that some regions converge towards the mean while others move away from it. Third, the analysis of the trajectories of regions in the tails of the distribution will also shed light on the occurrence of upward convergence (catching-up of disadvantaged regions) and downward convergence (advantaged regions losing their lead).

In our application, we examined the time path of mortality changes between year 0 (1988) and year t (2009) in regions with high or low mortality in 1988. More specifically, we examined the development of the deviation of the unweighted average

of e0 from the overall mean in regions with relatively low and high e0 in 1988. We regard regions where the deviation of e0 from the mean exceeds one standard deviation as regions with low or high e0. In addition, we assessed downward divergence (regions that move from an average position to a disadvantaged position) and upward divergence (regions that move from an average position to an advantaged position) by examining the trajectories of regions with high or low e0 in 2009. We also examined whether individual regions moved towards the mean or not.

2.9 Conditional beta convergence

The assessment of beta convergence by means of expression (2) assumes that all regions converge towards the same average level. This is called absolute beta convergence. However, due to structural differences across regions at the onset caused by, e.g., differences in education, income, life style, health care provision, urbanization, and environment (Gächter and Theurl 2011), the initial mortality levels in different regions may converge towards different levels. Conditional beta convergence takes these different average levels of convergence – according to the different characteristics at onset – into account. It is measured by controlling convergence for differences in the regions' structural characteristics at the onset (Montero-Granados, de Dios Jiménez, and Martín 2007; Gächter and Theurl 2011) by multivariate linear regression:

$$(1/t) \, (Y_{i,t} - Y_{i,0}) = \alpha + \beta Y_{i,0} + \gamma z_{i,0} + \varepsilon \tag{3}$$

where $z_{i,0}$ indicates the different characteristics at t=0.

The analysis of conditional beta convergence, although important in determining whether complete convergence occurred or whether structural differences across regions remain, should certainly not be regarded as a tool for a full explanatory analysis of the trends. An important advantage of (conditional) beta convergence over a full explanatory analysis of the trends is its capability of summarizing the information into one single measure to assess convergence.

In our application, we assessed both absolute and conditional beta convergence. To assess conditional beta convergence we obtained information on population density, immigration rate, total inflow of migrants (rate), % Roman Catholics, % Protestants, % no religion, net labour force participation, % unemployed, % low education (= with primary and/or lower secondary education), % high education (= with tertiary education), % low income (= with <=40% of the national income level (23,800 guilders)), % high income (= with >=80% of the national income level (23,800 guilders)), % non-Western population, from Statistics Netherlands. The chosen

characteristics represent the most likely candidates for the explanation of regional mortality differences and trends therein for the Netherlands (Spijker 2007; Mackenbach, Kunst, and Looman 1991). We obtained the data for the year 1988, except for religion (1987), education (1990), income (1989), and % non-Western population (1990). The data were obtained by region and sex. Density, however, was based on the total population in the region, and for religion and income only information for males and females combined were available.

We first ran a full model for males to identify multi-collinearity through the variance inflation factor (VIF) measure. We dropped characteristics that showed high collinearity with other variables (VIF >= 6) and characteristics with high pair-wise correlations ($r > 0.5$; $p < 0.05$), thereby checking their effect on the adjusted R-squared. The final model consisted of the following characteristics: population density, total inflow of migrants (rate), % Roman Catholics (for males and females combined), % unemployed, % low education, and % non-Western population. Note that for religion we expect only marginal differences between the two sexes, judging by more recent data on the Netherlands as a whole.

3. Results

Between 1988 and 2009, Dutch life expectancy at birth (e0) increased from 73.7 to 78.5 years for males and from 80.2 to 82.5 years for females. Both males and females experienced a stronger increase after 2002. This elevated increase in e0 is especially evident for females, who showed a much less rapid increase up until 2001 as compared to males. From 2008 onwards a levelling-off of the increase is shown (Figure 1).

Looking at the trends in e0 for the 40 NUTS-3 regions, it is clear that in general the regions followed the national trend (Figure 1). That is, the regions shared the same timing of an elevated increase in e0 since 2002 as observed for the Netherlands as a whole.

Figure 2 shows the trends in different unweighted dispersion measures, to obtain some first insights into sigma convergence. For males, the range between regions with the highest and lowest e0 declined (from 3.3 to 2.1 years), whereas for females hardly any change in the range occurred (e0 from 2.1 to 2.0 years). For males, a small decline over time in the average and standard deviation can be observed. For females there was no clear overall downward or upward trend in these dispersion measures (Figure 2). For both males and females there was no marked change in the trend of the dispersion measures around 2002, when the average mortality trend changed markedly. The comparison between the sexes also reveals higher regional mortality differences for males as compared to females.

Figure 1: **Trends in life expectancy at birth (e0), the Netherlands, 1988-2009, by region (40 NUTS-3 regions) and sex**
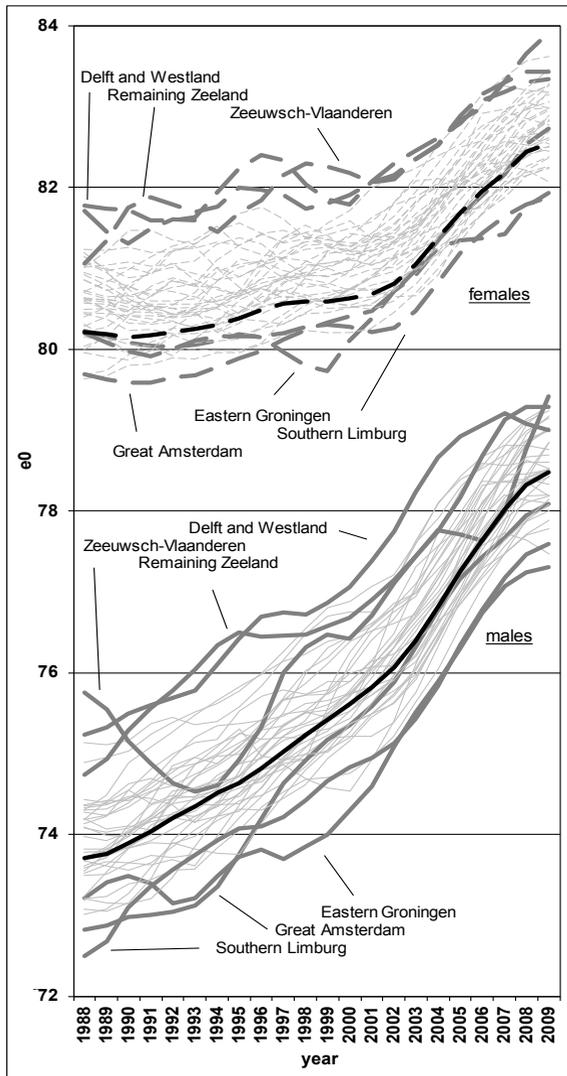
Figure 2: **Trends in dispersion of life expectancy at birth (e0) between 40 NUTS-3 regions by means of selected (unweighed) measures, the Netherlands, 1988-2009, by sex**
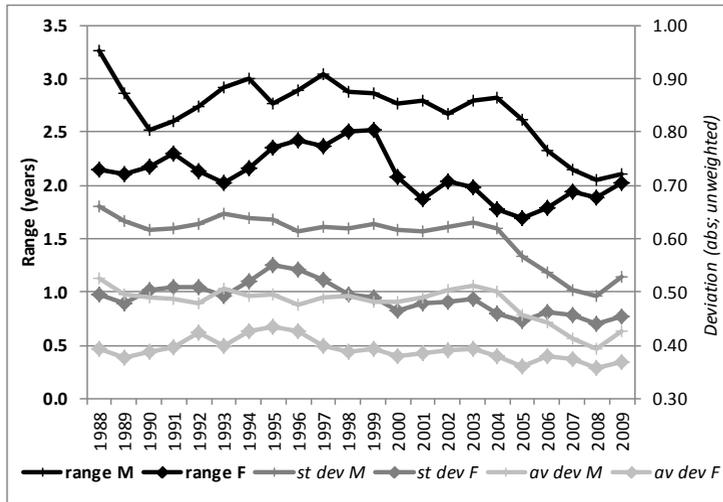
Source data: Statistics Netherlands (2010a;b); own calculations

M = males   st dev = standard deviation

F = females   av dev = average deviation

The results of the formal analysis of sigma convergence, by means of the F-test for the difference over time in weighted and unweighted variance, are depicted in Table 1. For both males and females a tendency towards sigma convergence can be observed, which is stronger for males. The changes in variance over time, however, are not statistically significant, indicating no statistically significant sigma convergence. Also, for the periods 1988–2002 and 2002–2009, no statistically significant sigma convergence or divergence occurred. The use of different sigma dispersion measures led to the same overall conclusion of no statistically significant sigma convergence.

Table 1: **Sigma convergence and divergence – F-test for difference over time (1988-2009) in weighted and unweighted variance in life expectancy at birth (e0) between 40 NUTS-3 regions, the Netherlands, by sex**

Dispersion measure	Males F value	Males p-value	Females F value	Females p-value
Unweighted variance	1.56	0.08	1.19	0.29
Weighted variance	1.56	0.09	1.31	0.20

Source data: Statistics Netherlands (2010a;b); own calculations

The scatterplots of the annual increase over the period 1988–2009 against mortality levels in 1988 (Figure 3) can provide an indication of the presence of absolute beta convergence. For both males and females they clearly show that regions with the lowest e0 in 1988 experience the highest increase in e0 during the period 1988–2009, and vice versa. 'Delft and Westland' (region 27) exhibited a high e0 combined with a low increase, whereas 'Northern Limburg' (region 37) and 'Mid Limburg' (region 38) experienced low e0 with a high annual increase.

Figure 3: **Scatterplots of life expectancy at birth (e0) in 1988 against the annual change over the period 1988 – 2009, the Netherlands, 40 NUTS-3 regions, by sex**
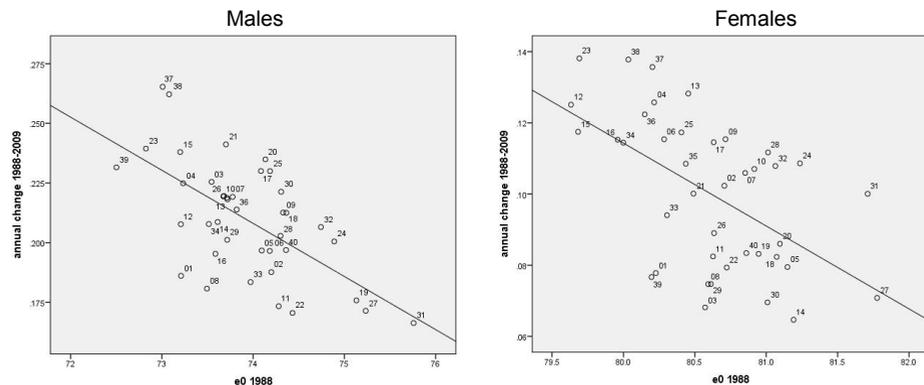
Source data: Statistics Netherlands (2010a;b); own calculations

The formal analysis of absolute beta convergence (Table 2) confirms the observed relationships. Judging from the adjusted R-squared values, the relationship is stronger for males than females. The values for β are negative and statistically significant for both males and females. Also, for the periods 1988–2002 and 2002–2009, beta convergence was statistically significant.

Table 2: **Beta convergence and divergence in regional life expectancy at birth (e0) (NUTS-3 level), over the period 1988-2009, the Netherlands, by sex**

	Males			Females		
	estimate	p-value	adj R^2	estimate	p-value	adj R^2
Absolute beta convergence *						
(constant)	**1.856**	0.000	0.372	**1.977**	0.000	0.285
beta coefficient β	**-0.022**	0.000		**-0.023**	0.000	
Conditional beta convergence *						
(constant)	**2.61969**	0.000	0.474	**2.48269**	0.000	0.341
beta coefficient β	**-0.03159**	0.000		**-0.02883**	0.000	
density**	0.00000	0.776		-0.00001	0.199	
total inflow of migrants (rate)	0.00018	0.604		0.00010	0.777	
% Roman Catholics**	0.00005	0.738		0.00004	0.776	
% unemployed	-0.00356	0.087		**-0.00223**	0.015	
% low education	**-0.00147**	0.041		-0.00050	0.482	
% non-Western population	-0.00032	0.807		-0.00063	0.652	

* unstandardised coefficients; ** for males and females combined
Bold = statistically significant at the 0.05 level

Our analysis of conditional beta convergence – in which we controlled for structural characteristics of the regions at the onset – revealed the same picture of statistically significant beta convergence for both males and females (Table 2). For males, % low education at onset proved a statistically significant predictor of convergence. That is, in regions where relatively many people have low education, life

expectancy of males tends to converge to a lower level than in regions with few people with low education. For females, % unemployed at onset proved a statistically significant predictor of convergence. Thus, in regions with high unemployment, e0 for females does not converge to the same level as in regions with low unemployment. For both predictors, however, effect sizes are low.

Figure 4 shows the trajectories of regions in the tails of the distribution. For both males and females, the average e0 of regions where e0 was low in 1988 moved closer to the mean in a gradual manner. Even though in 2009 their e0 was still lower than the average, the difference was less than the standard deviation from the mean. This indicates that there has been upward convergence. In addition, downward convergence occurred, although in a less gradual manner: regions with high e0 in 1988 lost part of their lead.

Regions with low average e0 in 2009 had a higher average e0 in 1988 and thus moved away from the mean. Especially for females a downward divergence can be observed, with regions with a more average position in 1988 ending up in a disadvantaged position in 2009. Neither males nor females exhibited upward divergence. Regions with high e0 in 2009 already had high e0 in 1988 and the difference with the mean has not increased.

Looking more closely at the individual regions that constitute the tails of the distribution in 1988, it can be observed that many similar regions are included for males and females. Upward convergence is observed among 6 out of 8 regions with low e0 in 1988 among males and all 6 regions with low e0 in 1988 among females. Downward convergence occurred as well often, for both males and females, but more often the regions did not end up within one standard deviation from the average. Whereas for males three regions remained in the lower tail of the distribution (1,12,39) and three regions remained in the upper tail of the distribution (24,31,32), for females only one region with low e0 in 1988 had also low e0 in 2009 (15) and – similar to males – three regions remained in the upper tail of the distribution (24,27,31).

See Appendix II for the results for (logged) standardised mortality, demonstrating the same general outcomes.

Figure 4: **Development of the deviation of the average life expectancy at birth (e0) from the overall mean in regions that had high or low e0 in 1988 or 2009**
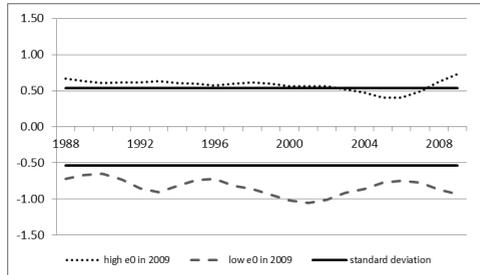
Males
Average e0 in regions where e0 in 1988 was one standard deviation higher or lower than the average
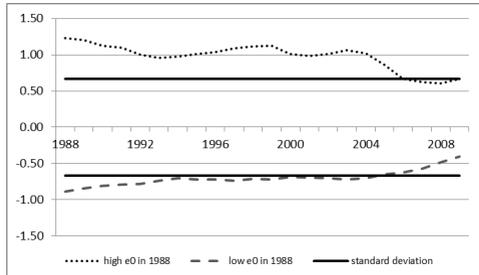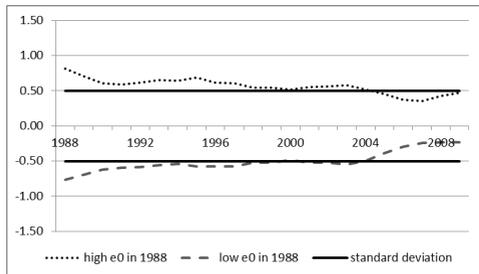
Males
Average e0 in regions where e0 in 2009 was one standard deviation higher or lower than the average

Females
Average e0 in regions where e0 in 1988 was one standard deviation higher or lower than the average

Females
Average e0 in regions where e0 in 2009 was one standard deviation higher or lower than the average
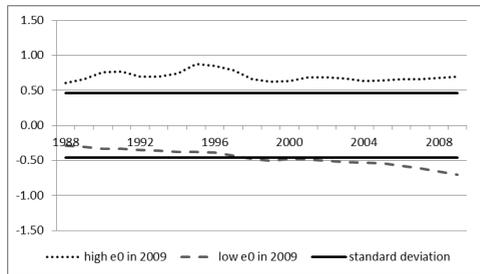
Males
Regions with low e0 in 1988: 1,**4**,12,**15**,**23**,**37**,**38**,**39***
Regions with high e0 in 1988: **19**,**24***,**27**,**31***,**32***
Females
Regions with low e0 in 1988: **12**,**15***,**16**,**23**,**34**,**38**
Regions with high e0 in 1988: **5**,**14**,24,**27***,**31***
Bold region numbers indicate movement towards the mean
* no movement inside one standard deviation from the average

Males
Regions with low e0 in 2009: 1, 8, 12, 16, 39
Regions with high e0 in 2009: 17, 20, 24, 25, 30, 31, 32
Females
Regions with low e0 in 2009: 1,3,8,15,29,39
Regions with high e0 in 2009: 10,13,24,27,28,31,32

Source data: Statistics Netherlands (2010a;b); own calculations

4. Discussion and conclusion

Our application of the economic concepts of sigma and beta convergence to regional mortality in the Netherlands over the period 1988 to 2009 revealed some interesting findings.

The trends in dispersion of regional mortality in the Netherlands over the period 1988 to 2009 displayed no statistically significant sigma convergence. However, both absolute and conditional beta convergence were statistically significant, for both males and females. The regions with the lowest e0 in 1988 generally showed the highest increase over the period 1988–2009, and vice versa. Closer examination revealed that, for females, upward convergence for disadvantaged regions was combined with downward divergence for some average regions.

4.1 Evaluation of the methodology

In this paper we demonstrated the application of the economic concepts of sigma and beta convergence to the study of regional mortality. Our application clearly showed the added value of simultaneously applying sigma and beta convergence tests: i.e., a finding of no statistically significant sigma convergence does not necessarily mean no convergence at all. See as well sections 2.7 and 4.2.

One key property of both sigma and beta convergence tests is that they provide us with one single measure to assess convergence. This, however, is also a drawback of the methodology. When beta convergence occurs, this does not necessarily apply to all regions. Since the beta convergence test is based on a regression method, the outcome is heavily influenced by what happens in the tails of the distribution. Whereas this is an important limitation of regression techniques in general, for convergence issues and for policymakers what is happening in the regions in the tail of the distribution is especially relevant. However, significant beta convergence may hide the fact that some regions may diverge from the mean.

Both sigma and beta convergence rely on a symmetric approach; that is, equal weight is given to convergence for the most disadvantageous regions (upward convergence) and convergence for the most advantageous regions (downward convergence). For policymakers, however, what the convergence trends are for disadvantageous regions is especially interesting. This issue, and also the two above-mentioned issues, warrant additional analysis: the examination of the trajectories of separate regions.

An additional potential drawback of the used approach is the potential effect of random fluctuations on both sigma and beta convergence. Smoothing is therefore

essential. In our analysis, our results did not prove very sensitive to the smoothing applied (see the methods section). It should be noted, however, that the likelihood of a potential outlier in the trend to occur differs based on the size of the regional differences and the number of regions being compared.

It should be noted that different results would be obtained by selecting a different observation period, especially when there are important year-specific effects or important trends over time. In our case study, additional analyses for the period 1992 to 2009 – excluding the initial increase in dispersion among females – showed the same outcome of non-significant sigma convergence with significant beta convergence. In previous work, data for consecutive years were aggregated (e.g., Gächter and Theurl 2011) to exclude year-specific effects. Whereas the aggregating of data for consecutive years could indeed be beneficial when examining long-term trends, showing the results for the different years will provide more information on what happened around a particular year of interest. For example, in our case study the year 2002 proved interesting because of the renewed increase in Dutch life expectancy (Mackenbach and Garssen 2011)(see as well 4.2.5).

In our application we focussed on overall mortality, and consequently neglected age- and cause-specific mortality trends. However, the same analysis can be applied to different age groups to see whether certain patterns are only observed for some age groups, and to different causes of death to obtain more insight into likely underlying determinants of the results for all-cause mortality. Additional analysis for our study population, distinguishing the age groups 0–19, 20–64, and 65+ for ln(SDR), showed, for example, that sigma convergence again was not statistically significant, except for males aged 0–19 (unweighted variance only). Absolute beta convergence was again statistically significant for all age groups among males (although only at a significance level of 0.1 for age group 20–64). For females, however, absolute beta convergence proved not statistically significant for the different age groups. Thus, apparently, for males, mortality at the young age groups particularly contributes to convergence. For females, beta convergence seems less solid and less clear as compared to males, which can be linked to our observation of important downward divergence among females.

4.2 Interpreting the outcomes

4.2.1 Evidence of beta convergence but not of sigma convergence

The simultaneous and formal analysis of both sigma and beta convergence for the Netherlands interestingly revealed statistically significant beta convergence, i.e., a negative correlation between the rate of change and the initial mortality levels, without

statistically significant sigma convergence, i.e., a significant decline in dispersion between 1988 and 2009.

Previous studies that assessed both sigma and beta convergence found different correlations between the results for beta and sigma convergence. Mostly, sigma convergence and beta convergence were both statistically significant (Montero-Granados, de Dios Jiménez, and Martín 2007; Nixon 2000). However, studying infant mortality over the period 1980–2001 in 50 Spanish provinces, Montero-Granados et al. (2007) observed statistically significant beta convergence combined with statistically significant sigma divergence. The authors linked this finding to the 'change of role' scenario: some selected regions obtained a much better situation, but still dispersion increased overall (Montero-Granados, de Dios Jiménez, and Martín 2007). Our result of statistically significant beta convergence without statistically significant sigma convergence has also been observed for e0 among women in 15 European countries from 1960 to 1995 (Nixon 2000). Also, the statistically significant beta convergence that Gächter and Theurl observed for standardised mortality across 2,381 Austrian communities between 1969–1984 and 1988–2004 was not linked to declines in the coefficient of variation and the Theil index. Beta convergence without sigma convergence, although less frequently observed than beta convergence combined with sigma convergence, and perhaps less intuitive, is a likely outcome if either large random fluctuations occur in the first or last year of the observation period, or in the case of heterogeneity of trends between regions, and therefore should not be disregarded.

In our analysis, we controlled for random fluctuations by smoothing the data. Instead, behind our observations lies the fact that beta convergence is more heavily influenced by what happens in the tails of the distribution as compared to what happens around the mean. From our examination of the trajectories of regions in the tails of the distribution, it can indeed be observed that there is clear convergence towards the mean for regions with high and low e0 in 1988, which resulted in significant beta convergence.

The two convergence measures thus clearly measure something different, and as a consequence also have different interpretations. In our analysis, the result of significant beta convergence without significant sigma convergence indicates that even though overall regional mortality differences have not declined, still the life expectancy levels of some – but not necessarily all – regions have moved towards the mean. Below, we elaborate on the interpretation of the observed absolute and conditional beta convergences.

4.2.2 Observed absolute beta convergence

The statistically significant absolute beta convergence we observed indicates the important role of the mortality levels at the beginning of the observation period (1988) in the subsequent mortality change. Our scatterplots indeed showed that the regions with the lowest e0 in 1988 generally showed the highest increase over the period 1988-2009. Beta convergence, however, does not necessarily mean that the underlying processes all point in the same direction. A more detailed examination of the trajectories of regions in the tails of the distribution showed the predominance of upward convergence over downward convergence, but also demonstrated the importance of downward divergence for females. Thus beta convergence is not always only good news. Furthermore, our examination of the trajectories of individual regions showed that especially regions in the east of the Netherlands (in particular Twente (=12)) have a structural disadvantage, whereas the province of Zeeland (31,32) and The Gooi and Vechtstreek (24) have been successful in maintaining more favourable positions compared to the average.

A negative correlation between initial levels and subsequent mortality change could point to a limit to life expectancy (e.g., Manton, Stallard, Tolley 1991). The idea of a limit to life expectancy is, however, much debated. Moreover, our observation of the high increase in e0 among males in Utrecht who already exhibited very high values in 1988, and the large increase in e0 since 2002 that was observed for the Netherlands as a whole, seem not to be in line with this paradigm.

4.2.3 Conditional beta convergence

Next to statistically significant absolute beta convergence, we observed statistically significant conditional beta convergence. This indicates that beta convergence is actually made up of different groups that converge to different levels.

Our analysis of conditional beta convergence showed that socio-economic conditions around 1988 (% low education for males, % unemployed for females) determine the different groups that converge to different levels. Appendix III illustrates this for low education for males. Both of these sex-specific variables had a strong negative correlation with % high income (-0.639 for % unemployed for females; -0.539 for % low education for males). Therefore, the results indicate that those NUTS-3 regions with a lower share of people with a high income – and thus in general lower e0 and higher mortality – are likely to converge to a lower life expectancy level, whereas those NUTS-3 regions with a higher share of people with a high income are likely to experience convergence to a higher life expectancy level.

Our analysis also showed that the beta parameter is more negative for conditional beta convergence than for absolute beta convergence. Indeed, conditional beta convergence indicates stronger convergence (higher absolute value of beta, i.e., a shorter period before convergence is reached), but not to the same level. Phrased differently, the value of beta is smaller for absolute beta convergence than for conditional beta convergence because regions converge, but not to the same level.

For policymakers this is relevant, as it indicates that as a consequence of structural differences across regions, complete convergence will not be reached. Disadvantaged regions may develop in the direction of the mean, but they remain disadvantaged. Specifically for the Netherlands, the results indicate that mortality differences between more economically advantaged and disadvantaged regions are not only important but are likely to be persistent, even though the mortality differences within the groups might become smaller.

The regions that kept low e0 levels are indeed regions with an economic disadvantage in the Netherlands, whereas 'Gooi en Vechtstreek', with its consistently high e0 over time, is one of the wealthiest regions in the Netherlands (Statistics Netherlands 2011).

The other health determinants we included proved not significant when assessing conditional beta convergence. This, however, does not necessarily mean that these variables are not important in influencing trends in mortality, but merely that – based on their levels in 1988 or close by – no distinct groups with different levels of convergence could be assessed.

Trends in the role of religion in mortality, for example, might still have played a role. Mackenbach, Kunst, and Looman (1991) showed that the convergence towards the mean of regions in the southeast in the Netherlands could be related to a decrease in excess mortality due to unhealthy behaviours among Roman Catholics. Selective migration is also likely to have an effect on the convergence process, as healthy people tend to move to regions with more favourable living conditions, and vice versa (Bentham 1988; Boyle 2004; Gächter and Theurl 2011; Valkonen 2001). This would, however, result in divergence rather than convergence. And, although it was demonstrated for the Netherlands that internal migration in late life can distort regional old-age mortality levels and patterns (Kibele and Janssen 2013), this was mostly observed at the municipal level, but barely at the NUTS-3 level.

Factors that we did not consider but that could also have an effect are different trends for different regions in determinants originating in earlier phases of the life course (see e.g., Ben-Shlomo and Kuh 2002). For the Netherlands, for example, a long-lasting effect of infant mortality and socio-economic circumstances at infancy or in childhood on later life mortality has been observed (Amiri et al. 2006; Janssen, Kunst, and Mackenbach 2006; van den Berg, Lindeboom, and Portrait 2006).

4.2.4 Different outcomes by sex

Convergence proved less clear for females compared to males. The larger variation in life expectancy in 1988 among males as compared to females is likely behind this. With a larger initial variation, a decline in dispersion or a movement towards the mean is more likely to occur. This is in line with observations in the literature that a period with divergence – resulting in more variation – is often followed by convergence, and vice versa (see as well the introduction).

Previous research has shown that the larger differences in regional mortality among males as compared to females can largely be explained by smoking (Janssen and Spriensma 2012). Actually, for non-smoking-related mortality, regional differences in 2004–2008 were slightly larger for females as compared to males.

4.2.5 The importance of the trend at the national level

Since 2002 the Netherlands has experienced a renewed increase in life expectancy at the national level (see as well Mackenbach and Garssen 2011). A sudden change in the trend at the national level as a result of a determinant that might give way to regional differences could either result in a new phase of divergence or a continuation of the convergence, and is therefore a very relevant context for the study of the convergence of regional mortality.

Our analysis for the Netherlands showed that the different regions generally followed a rapid increase in e0 from 2002 onwards. No marked change in dispersion occurred around 2002, and both before and after 2002 sigma convergence or divergence was not statistically significant. Results for absolute beta convergence were also generally the same for the two periods and no longer statistically significant.

These results seem to indicate that the factors that are responsible for the trend at the national level influence the regions grossly in a similar manner. According to Mackenbach and Garssen (2011), the strong increase in life expectancy after 2002 was especially due to a renewed decline in old-age mortality and could be linked to changes in health care, especially acceleration in hospital admission and growth of health care expenditure. Thus these changes in health care, in general, seem to have had an equal impact on the different provinces and regions in the Netherlands.

4.3 Overall conclusion and implications

Our paper clearly shows the value of simultaneously studying sigma and beta convergence formally.

Our case study of the Netherlands revealed no statistically significant sigma convergence, and thus no overall decline in mortality differences between regions, combined with statistically significant beta convergence, indicating that disadvantaged regions still moved towards the mean. Mortality differences between more economically advantaged and disadvantaged regions proved likely to be persistent, even though the mortality differences within both groups might become smaller. Also, changes in health care, which were behind the improved mortality at the national level, seem essential. Thus, next to the further improvement of mortality at the national level, attention still needs to be drawn to those regions that are economically disadvantaged and that remain in the lower tail of the distribution.

Our analysis also shows that the outcomes of sigma and beta convergence tests should be interpreted with caution. Where absence of sigma convergence does not imply that disadvantaged regions did not improve, beta convergence does not necessarily mean that the underlying processes all point in the same direction, nor does it always indicate complete convergence due to structural differences across regions. By examining trajectories of regions in the tails of the distribution, not only can the regions with a structural disadvantage be identified, but also those regions which have been successful in obtaining or maintaining more favourable positions compared to the average. Policymakers could potentially use the experiences of the latter group to improve the situation of the former group. The mutual occurrence of both convergence and downward divergence – which we observed for females – should warn policymakers that beta convergence is not always only good news.

All in all, the economic concepts of sigma and beta convergence, especially when combined with an examination of the trajectories of regions in the tails of the distribution, have strong potential not only for the demographic study of health but also for policymaking.

5. Acknowledgement

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Appendix I: The 40 NUTS-3 regions in the Netherlands

1.	Eastern Groningen	11.	South-western Overijssel	21.	Agglomeration Haarlem	31.	Zeeuwsch-Vlaanderen
2.	Delfzijl and surroundings	12.	Twente	22.	Zaanstreek	32.	Remaining Zeeland
3.	Remaining Groningen	13.	Veluwe	23.	Great Amsterdam	33.	Western Noord-Brabant
4.	Northern Friesland	14.	Achterhoek	24.	The Gooi and Vechtstreek	34.	Mid Noord-Brabant
5.	South-western Friesland	15.	Arnhem and Nijmegen	25.	Agglomeration Leiden and Bollenstreek	35.	North-eastern Noord-Brabant
6.	South-eastern Friesland	16.	South-western Gelderland	26.	Agglomeration The Hague	36.	South-eastern Noord-Brabant
7.	Northern Drenthe	17.	Utrecht	27.	Delft and Westland	37.	Northern Limburg
8.	South-eastern Drenthe	18.	Upper north Noord-Holland	28.	Eastern Zuid-Holland	38.	Mid Limburg
9.	South-western Drenthe	19.	Alkmaar and surroundings	29.	Great Rijnmond	39.	Southern Limburg
10.	Northern Overijssel	20.	IJmond	30.	South-eastern Zuid-Holland	40.	Flevoland

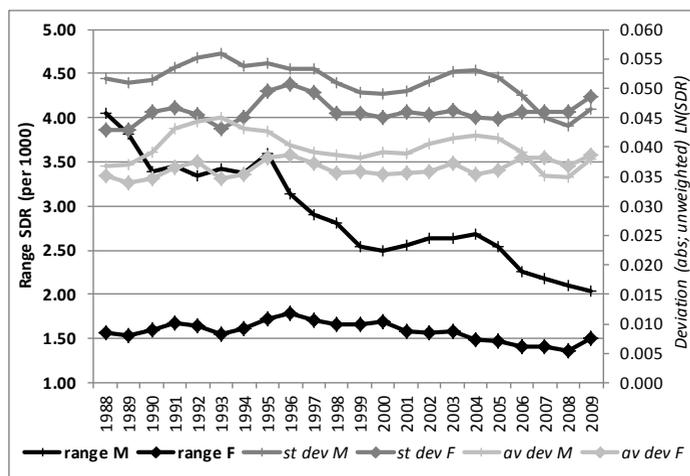*Source*: Statistics Netherlands (2008)

Appendix II: Results for standardised mortality instead of life expectancy at birth

a) Trends in age-standardised mortality (SDR), the Netherlands, 1988-2009, by region (40 NUTS-3 regions) and sex
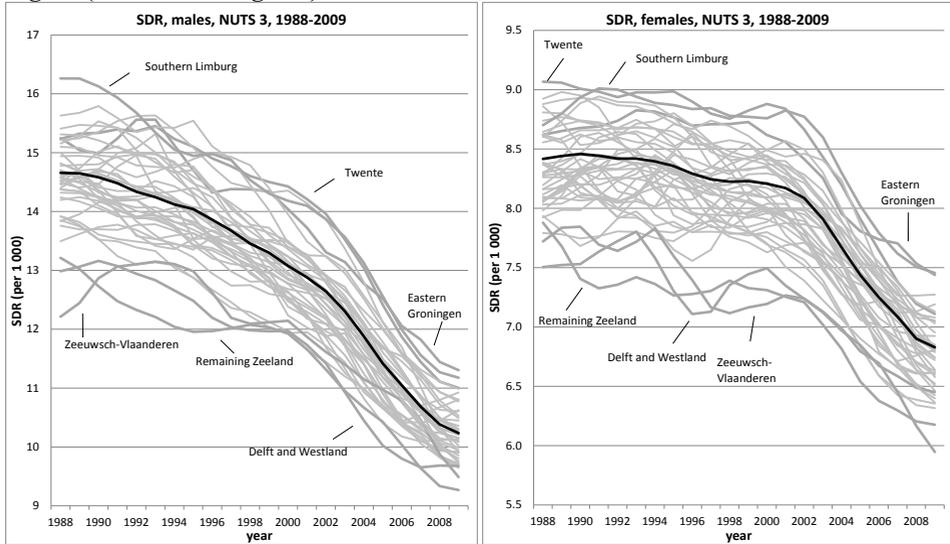
Source data: Statistics Netherlands (2010a;b); own calculations
Black line = trend for the Netherlands

b) Trends in dispersion of (logged) standardised mortality (SDR, LN(SDR)) between 40 NUTS-3 regions by means of selected (unweighed) measures, the Netherlands, 1988-2009, by sex

Source data: Statistics Netherlands (2010a;b); own calculations

M = males   st dev = standard deviation
F = females   av dev = average deviation

c) Sigma convergence and divergence – F-test for difference over time (1988-2009) in weighted and unweighted variance in logged standardised mortality between 40 NUTS-3 regions, the Netherlands, by sex

Dispersion measure	Males F value	Males p-value	Females F value	Females p-value
Unweighted variance	1.23	0.26	1.29*	0.22
Weighted variance	1.09	0.39	1.02*	0.47

* F value calculated through var(2009)/var(1988) instead of var(1988)/var(2009). The positive value therefore indicates an increase in variance instead of a decline in variance
Source data: Statistics Netherlands (2010a;b); own calculations

d) Scatterplots of logged standardised mortality (ln(SDR)) in 1988 against the annual change over the period 1988 – 2009, the Netherlands, 40 NUTS-3 regions, by sex
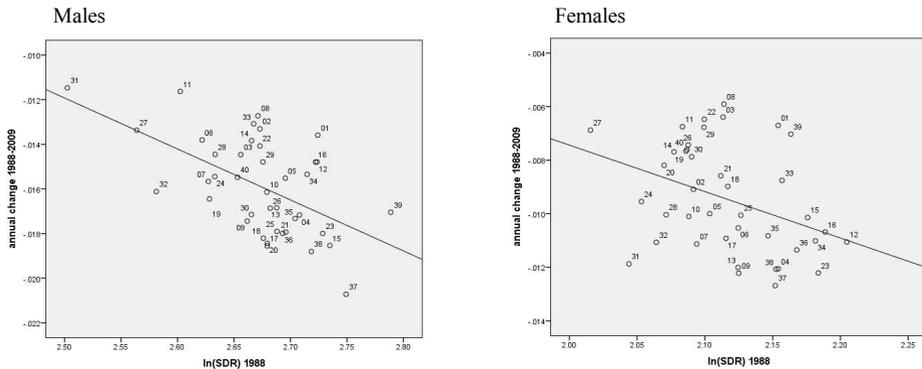
Males

Females

Source data: Statistics Netherlands (2010a;b); own calculations

e) Beta convergence and divergence in regional logged standardised mortality (NUTS-3 level), over the period 1988-2009, the Netherlands, by sex

	Males			Females		
	estimate	p-value	adj R^2	estimate	p-value	adj R^2
Absolute beta convergence *						
(constant)	**0.045**	0.004	0.291	0.027	0.074	0.116
beta coefficient β	**-0.023**	0.000		**-0.017**	0.018	
*Conditional beta convergence**						
(constant)	**0.05315**	0.001	0.405	0.02878	0.104	0.200
beta coefficient β	**-0.02845**	0.000		**-0.02077**	0.012	
density**	0.00000	0.907		0.00000	0.076	
total inflow of migrants (rate)	-0.00001	0.718		-0.00001	0.809	
% Roman Catholics**	0.00000	0.703		0.00000	0.756	
% unemployed	0.00027	0.100		**0.00022**	0.020	
% low education	**0.00014**	0.036		0.00005	0.531	
% non-Western population	-0.00003	0.780		0.00003	0.820	

* unstandardised coefficients; ** for males and females combined
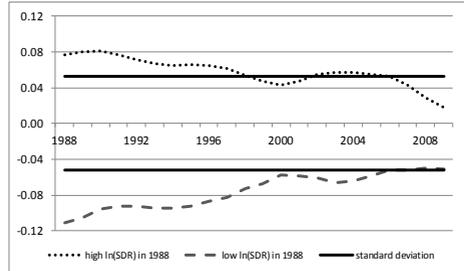Bold = statistically significant at the 0.05 level
Source data: Statistics Netherlands; own calculations

f) Development of the deviation of logged standardised mortality (LN(SDR)) from the overall mean in regions that had high or low LN(SDR) in 1988 or 2009
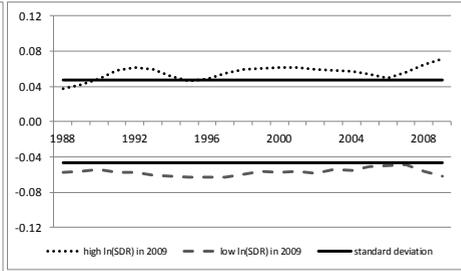
Males
Average LN(SDR) in regions where LN(SDR) in 1988 was one standard deviation higher or lower than the average
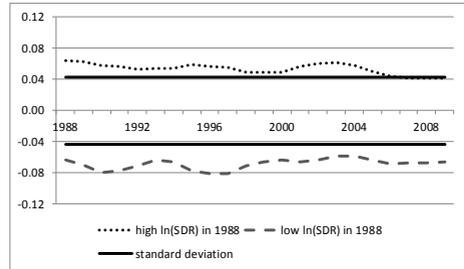

Males
Average LN(SDR) in regions where LN(SDR) in 2009 was one standard deviation higher or lower than the average
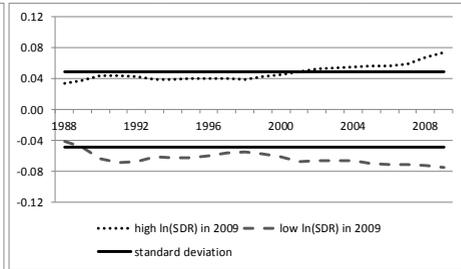

Females
Average LN(SDR) in regions where LN(SDR) in 1988 was one standard deviation higher or lower than the average

Females
Average LN(SDR) in regions where LN(SDR) in 2009 was one standard deviation higher or lower than the average

Males
Regions with high LN(SDR) in 1988: **15,23,37,39***
Regions with low LN(SDR) in 1988: **11,27***,**31***,32
Females
Regions with high LN(SDR) in 1988: **12***,**15***,**16***,**23,34,36,39**
Regions with low LN(SDR) in 1988: **20**,24,**27***,28,31,32
Bold region numbers indicate movement towards the mean
* no movement inside one standard deviation from the average

Males
Regions with high LN(SDR) in 2009: 1,2,8,12,16,33,34,39
Regions with low LN(SDR) in 2009: 17,18,19,20,27,31,32
Females
Regions with high LN(SDR) in 2009: 1,3,8,12,33,39
Regions with low LN(SDR) in 2009: 7,9,24,28,31,32

Source data: Statistics Netherlands (2010a;b); own calculations.

Appendix III: Illustration of the difference between absolute and conditional convergence for males in the Netherlands (NUTS-3) based on percentage with low education.

Two groups of regions are distinguished: 50% with a high percentage of people with low education and 50% with a low percentage. Using a dummy variable in the regression for conditional beta convergence, we can estimate to which levels of life expectancy (deviation from the mean) both groups of regions converge.