Changes in mortality trends: convergence between regions and changes in the contribution of causes of death to life expectancy in Europe

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Abstract

Background and objective

Because of positive health trends in the 20th century, a worldwide convergence between countries and regions to low levels of mortality was projected, however, diverging trends occurred recently. The objective of this research is to assess to what extent mortality trends are converging or diverging between regions in Europe, and to assess which causes of death contribute most to the change in all cause mortality. The epidemiologic transition theory was used and trends of convergence and divergence were discussed. By assessing convergence between regions in Europe, new insights can be provided in order to reduce health inequalities between and within countries.

Data and methods

All-cause mortality data and data on seven causes of death for 224 NUTS-2 regions for males, females and both sexes for the years 1994-1996 and 2008-2010 was obtained through Eurostat and the WHO European detailed mortality database and was directly standardised using the EU-27 as the standard population. Life table data was obtained from the Human Mortality Database. Convergence was measured by assessing sigma and beta convergence, decomposition by cause was used to assess the contribution of causes of death to the change in life expectancy.

Results

Sigma and beta convergence was observed for all causes of death and all cause mortality for males, females and both sexes. For both sexes sigma convergence was -0.629 and beta convergence was -0.026; indicating that not only mortality levels between regions are becoming more equal, but regions with initially the highest levels of mortality decline faster than those with initially lower levels of mortality. Divergence (sigma divergence) was only observed for females for lung cancer and COPD, this was however not statistically significant. Ischaemic Heart Disease and Cerebrovascular diseases contribute most to the change in all cause mortality and life expectancy.

Conclusion

Mortality levels between regions in Europe between 1994-1996 and 2008-2010 have converged.

Keywords: convergence, all-cause mortality, causes of death, contribution to change in life expectancies, trend-analysis

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List of abbreviations

ICD	International Classification of Diseases
CVD	Cardiovascular diseases
IHD	Ischaemic Heart Disease
COPD	Chronic Obstructive Pulmonary Disease
ASCDR	Age- and sex-Standardised Crude Death Rate
NUTS	Nomenclature of territorial nits for statistics
WHO	World Health Organization
HMD	Human Mortality Database
DMDB	European Detailed Mortality Database

1 Introduction

1.1 Background

In the 20th century health trends were generally positive with a rise in life expectancy and a decline in mortality rates in developed and developing countries (McMichael et al., 2004). The rise in life expectancy however, was not a linear process as it first increased, but was followed by stagnation and later by a renewed increase, similar to phases of the epidemiologic transition (Mackenbach, 2013). Because of these positive health trends, many demographers projected a worldwide convergence towards low mortality rates between countries and an increase in life expectancies (Omran, 2005; McMichael et al., 2004).

Convergence is often accompanied by stagnation and divergence, as innovations that reduce mortality are implemented in some countries first, but spread to other countries slowly, thus leading to increased mortality differences between countries first, followed by convergence (Mackenbach, 2013). Actual mortality reversals (increasing death rates after a period of lower death rates) before the 1980s only occurred in periods of war and famine (Vallin & Mesle, 2004; McMicheal et al., 2004). Yet, recently there have been diverging trends on the global level due to mortality reversals with increasing mortality rates and declining life expectancies for several countries and regions. These mortality increases mainly occurred in sub-Saharan Africa, central and Eastern Europe and in countries of the former Soviet Union (McMichael et al., 2004; Vallin & Meslé, 2004).

These converging and diverging trends are not only visible on the global level, but also occur within Europe and within countries. Within Europe, a clear divide between mortality levels between East and West exists, this can be ascribed to different social and political systems in eastern and western Europe (Vallin & Meslé, 2004). This diverging trend started around 1965, countries in central and eastern Europe experienced an increase in life expectancy after World War II, but was followed by stagnation in 1965 or even a decline in life expectancy after 1965, whereas life expectancy in all western countries continued to increase after the 1960s (Vallin & Meslé, 2004). There is also a difference between males and females, life expectancy differences in Europe started to increase after the 1960s for men, whereas this after the 1970s for women (Mackenbach, 2013).

The diverging and converging trends are not only visible for all cause mortality and life expectancy, but also occur for different causes of death. The diverging life expectancy trend between countries of the former Soviet Union and the rest of Europe after World War II was mainly caused by alcohol related deaths, as an anti-alcohol campaign introduced in the 1980s in the Soviet Union has led to slightly increasing life expectancy again in these regions (McMichael et al., 2004; Vallin & Meslé, 2004). When examining cancer mortality in Europe, four sub-regions can be observed: overall, cancer mortality in north, west and south (excluding a few countries) reached its top in the 1980s and started to decline afterwards, for eastern Europe, cancer mortality continued to rise until the 1990s (Avdeev et al., 2011), thus causing a divergence in mortality between Eastern- and the rest of Europe in cancer related deaths. This same pattern occurs for cardiovascular mortality (CVD's), which has shown a steady decline in north, west and south since the 1980s (Monnier, 2006 in Avdeev et al., 2011). Whereas central and eastern Europe experienced an increase in CVD's until the 1990s, followed by a decline afterwards (excluding a few countries), the high prevalence of CVD's

in central and eastern Europe is one of the main reasons why life expectancy is lower in these regions compared to the rest of Europe (Avdeev et al., 2011).

Convergence also occurs within countries and between regions. Many studies on within country convergence were conducted in large countries, which encompass more heterogeneous regions, depending on the size of the country, a study in the United States found both converging and diverging trends between regions (Gächter & Theurl, 2011). Whereas research in Austria, which is a relatively small country and consists of more homogeneous regions, found converging trends (Gächter & Theurl, 2011).

Although studies have looked at differences between and within countries, (Gächter & Theurl, 2011: for regions in Austria; Montero-Grenados, 2007: for regions in Spain; Mackenbach, 2013: for countries in Europe), there have not been many studies to assess convergence and divergence between the regions of different countries, thus by overstepping country boundaries. Depending on the size of the country and other factors, some countries are more heterogeneous than others (Gächter & Theurl, 2011), when one would compare differences between countries, the regional differences such as gender differences and internal geographical variations within countries are lost (Vallin & Meslé, 2004). By researching convergence across regions in Europe by overstepping country boundaries and adding this to the existing literature, new insights in convergence and divergence can be obtained. By gaining insight in converging and diverging mortality trends on a regional level in Europe, this might also be important for policymakers in order to reduce health inequalities between regions.

1.2 Objective and research questions

The objective of this paper is to assess to what extent mortality trends are converging or diverging between regions in Europe, and to assess which causes of death contribute most to the change in all cause mortality. The main research question of this paper is:

> *To what extent are mortality trends converging or diverging between regions in Europe and to what extent can mortality changes be ascribed to certain causes of death?*

Sub questions:

- What are the converging and diverging trends in all-cause mortality between regions in Europe?
- What are the converging and diverging trends in cause-specific mortality between regions in Europe?
- To what extent do different causes of death contribute towards all cause mortality levels in Europe?

1.3 Structure of the thesis

The second chapter will discuss the theory and literature that is of importance to this study, and will provide a conceptual model and hypothesis for each research question. Chapter three will discuss the methods. In the fourth chapter, the results of this research will be discussed. The final chapter will provide conclusions and answers to the research questions, and there is a discussion.

2 Theoretical framework

2.1 The epidemiologic transition theory

Because this research will mainly focus on mortality trends in Europe, it is important to understand how mortality trends have changed over time. Therefore, the theory of the epidemiologic transition will be explained first. The epidemiologic transition theory was developed by Omran in 1971 and describes mortality patterns and disease patterns over time, where the high prevalence of infectious diseases is replaced by the prevalence of degenerative and man-made diseases (Omran, 2005).

The transition describes three stages: the age of pestilence and famine, the age of receding pandemics, and the age of degenerative and man-made diseases (Omran, 2005). The age of pestilence and famine is marked by high and fluctuating mortality levels, a life expectancy at birth that varies between 20 to 40 years, and a high prevalence of infectious diseases (Omran, 2005). The age of receding pandemics marks a transition, there is a decline in mortality rates and life expectancy at birth rises to 50 years, at the same time there is a decline in infectious diseases with less frequent epidemics and a rise in cancers and cardiovascular diseases (CVD)(Omran, 2005). In the final stage, the age of degenerative and man-made diseases, mortality reaches a low stable level and life expectancy increases to 70 years, the diseases are mainly non-communicable and degenerative (Omran, 2005). These three stages form the Classical model, which is mainly applicable to Western Europe, it started in the late 18th century and was completed around 1965 (Van de Kaa, 1994; Vallin & Mesle, 2004). The process was rather slow and was mainly the result of the social-economic change with improved hygiene and living standards, and later through medical and public health developments (Kirk, 1996; Omran, 2005). For Eastern Europe, the Accelerated model is applicable, which is similar to the Classical model, the transitions however occurred later and stages were completed faster. Unlike the Classical model, the processes in the Accelerated model were because of both the socio-economic improvements and the medical and public health developments (Omran, 2005). At the end of the epidemiologic transition theory in the 1960s diverging trends in life expectancy between East and West started to emerge and was highly related to CVD mortality, as countries in western Europe were able to reduce CVD mortality, whereas this was not the case for eastern Europe until the 1990s (Vallin & Meslé, 2004). This East and West divide was also more clear for males than for females (Vallin & Meslé, 2004).

The stages of the epidemiologic transition theory described above are mainly applicable to countries in Europe and other developed countries, but not all countries worldwide enter these stages at the same time, and some countries do not experience all these stages, but rather have other changes in cause of death mortality (Vallin & Meslé, 2004). For some countries in sub-Saharan Africa increases in life expectancy after the 1950s were very slow, and even slower after the 1980s due to economic regression, other countries in sub-Saharan Africa experienced an AIDS epidemic around the 1980s (Vallin & Meslé, 2004).

2.2 Global convergence and divergence in all cause mortality and life expectancy

As described in the previous paragraph, health trends have been generally positive over the past decades. Death rates continued to decline in developed and some developing countries (McMichael et al., 2004). These changes in health towards low levels of mortality however, did not occur linearly in all regions, but were accompanied by stagnation and renewed mortality decline (Mackenbach, 2013). Because of these positive health trends, the main expectation was that of a worldwide convergence between countries to low levels of mortality and fertility, and increased life expectancy (Omran, 2005; McMichael et al., 2004).

When convergence between countries occurs, this is often accompanied by divergence, because innovations that reduce mortality are not implemented in all countries at the same time, but are rather implemented in a few countries and slowly spread to other countries, thus widening the mortality gap between these countries first (Vallin & Meslé, 2004; Mackenbach, 2013). Actual reversals in mortality (increasing mortality levels after a period of lower mortality levels) only occurred during wars and times of famine before the 1980s (McMichael et al., 2004). Between 1965 and 2000 converging trends in life expectancy on the global level occurred, however, diverging trends also occurred due to mortality increases: life expectancy increased from 71 to 81 in Japan (both sexes), but decreased in Russia (from 69 to 66) in this period (Vallin & Mesle, 2004). From the 1980s to 2000, life expectancy has declined for some regions, and these global setbacks mainly occurred in sub-Saharan Africa, central and Eastern Europe, and the former countries of the Soviet Union (McMichael et al, 2004; Vallin & Meslé, 2004).

2.2.1 Age-groups

When examining age-specific death rates, it turns out that infant mortality was declining and adult mortality was increasing for the 1970s in countries of the former Soviet Union, contrary to countries in western Europe (McMichael, 2004; Vallin & Meslé,2004). Thus indicating that diverging trends in life expectancy and mortality rates are mainly because of increases in adult mortality (Moser et al., 2005). Montero-Grenados et al. (2007), who studied beta- and sigma convergence between regions in Spain, found beta convergence in life expectancy and infant mortality between 1981 and 1995, whereas sigma convergence only occurred for life expectancy, and infant mortality had diverged. Beta convergence occurs when regions with initially higher levels of mortality have a greater decline in mortality than regions with initially lower levels of mortality and sigma convergence measures the spread of mortality through the standard deviation (Montero-Grenados et al., 2007; Gächter & Theurl, 2011).

Moser et al. (2005) who used the dispersion measure of mortality (DMM) found worldwide convergence for infant mortality and under five mortality since the 1990s. Life expectancy at birth has increased since the1980s on a global level, this however was accompanied by divergence (Moser et al., 2005). This global divergence in life expectancy was mainly due to decreases in life expectancy at birth in countries in sub-Saharan Africa, a few countries in Asia and countries of the former Soviet Union and Central and Eastern Europe (Moser et al., 2005). Clark (2011) - who measured convergence using the Coefficient of variation (CV), which is the standard deviation adjusted by the mean, and the Gini, and the Theil index - also found that between 1955 and 1990, life expectancy at birth has converged between countries worldwide, and found a divergence after the 1990s. For infant mortality however, different

results were found. Contrary to other research findings, worldwide infant mortality rates have diverged in the period 1955 to 2005 (Clark, 2011). Clark (2011) mentions that this divergence in infant mortality could be explained by the state of economic development. For poor regions, life expectancy increases more than it reduces infant mortality rates because of economic development (Clark, 2011). Whereas this is the opposite in wealthier regions. Hence economic development also seems to have an impact on the worldwide convergence in life expectancy and divergence in infant mortality (Clark, 2011).

2.2.2 Differences in convergence between men and women

Diverging and converging trends in life expectancy and mortality trends can also be visible within societies for subgroups such as males and females, different ethnic groups or socioeconomic status groups (Vallin & Meslé, 2004). As previously discussed, convergence is often accompanied by divergence, because innovations that reduce mortality are implemented in some regions or countries first and spread slowly to others (Mackenbach, 2013), this is also the case within societies as major improvements in health first occur in the most favoured parts of the society, such as high-income groups (Vallin & Meslé, 2004).

Mortality differences are more clear for males than for females, as the range for life expectancy at birth for males is approximately 70 to 73.5 years in 1980, and for females approximately 77.6 to 79 years between the USA, Japan, Sweden, Italy, the Netherlands, England, France and Denmark (Vallin & Meslé, 2004). After 1980, although life expectancy continued to increase in the eight countries for males and females, a diverging trend in life expectancy at birth for females emerged, whereas the differences for males remained stable. This is due to females being ahead of males in terms of health progress, and when a new stage of health occurs, females are more likely to enter first, thus causing a divergence due to health differences between regions, whereas this process is less clear for males (Vallin & Meslé, 2004). When examining life expectancy differences within Europe, it shows that the differences between countries were the lowest in 1960 for males, whereas this was 1970 for females (Mackenbach, 2013).

When looking at inequalities between males and females, research in Austria showed that from 1969-1984 to 1988-2004 mortality rates for men and women became more equal, thus indicating a converging trend between both sexes (Gächter & Theurl, 2011).

2.3 Convergence and divergence in Europe

2.3.1 All-cause mortality

For countries in central and eastern Europe there has been an increase in life expectancy after World War II, followed by a stagnation in 1965 and declining life expectancies after that for countries of the former Soviet Union (life expectancy in Poland stagnated after 1965) (McMichael et al., 2004; Vallin & Meslé, 2004). In the rest of Europe, life expectancies continued to increase after 1965, resulting in diverging trends between countries in eastern and western Europe, which can partly be ascribed to different social and political systems in east- and west-Europe (Vallin & Meslé, 2004). Lower health levels in central and eastern Europe can be ascribed to the switch to a market economy, dietary problems, excessive alcohol consumption, tobacco use, low income, level of health care and psychosocial stress (Vallin & Meslé, 2004; Mackenbach, 2013).

At the end of the 1980s the Czech Republic was one of the first countries in Europe to experience increases in life expectancy again, followed by Poland, Hungary and Slovakia at the start of the 1990s and Romania and Bulgaria thereafter, life expectancies started to increase to the levels of western Europe, indicating convergence between these countries, however diverging trends for some countries are still visible (McMichael et al., 2004; Vallin & Meslé, 2004). Not only did these east-European countries started to increase in life expectancy, the gains in life expectancy are also greater in some countries (Poland and Czech Republic) than in countries of western Europe (McMichael et al., 2004; Vallin & Meslé, 2004).

2.3.2 Convergence and divergence for causes of death

As discussed before, during the epidemiologic transition there was a shift from a high prevalence of infectious diseases, to a decline in infectious diseases and an increase in cancers and cardiovascular diseases, to an age with degenerative (chronic) and man-made diseases (diseases of affluence (Omran, 2005; Mackenbach, 2013). Because of the declining death rates for infectious disease, a greater percentage of people grow old which is accompanied by an increase in the number of chronic diseases (McMichael et al., 2004). This also means a shift in the causes of death that contribute most towards all-cause mortality levels. Nusselder & Mackenbach (2000) researched the contribution of causes of death to the change in life expectancies, they found that for the Netherlands, an increase in Chronic Obstructive Pulmonary Disease, mental disorders and diabetes mellitus mortality a decline in life expectancy caused, whereas decreases in CVD's lead to an increase in life expectancy.

The diverging and converging trends are not only visible for all cause mortality and life expectancy, but also occur for different causes of death and can often be explained by them. The diverging life expectancy trend between countries of the former Soviet Union and the rest of Europe after World War II was partly caused by alcohol related deaths, as an anti-alcohol campaign introduced in the 1980s in the Soviet Union has led to slightly increasing life expectancy again in these regions (McMichael et al., 2004; Vallin & Meslé, 2004). But the former Soviet Union countries also experienced changes in deaths from heart diseases, injuries and violence (McMichael et al., 2004).

When examining cancer mortality in Europe, four sub-regions can be observed: overall, cancer mortality in north, west and south reached its top in the 1980s and started to decline afterwards, for eastern Europe, cancer mortality continued to rise until the 1990s (Avdeev et al., 2011), thus causing a divergence in mortality between Eastern- and the rest of Europe in cancer related deaths. However, high cancer mortality rates were also experienced in Ireland, Spain, Greece and Portugal in this period (Avdeev et al., 2011), indicating that mortality decline is not an uniform process across these sub-regions. These differences within western Europe can be related to anti-smoking campaigns that were introduced at different times in different countries (Avdeev et al., 2011) as among cancer mortality, lung cancer is generally the most frequent cause of death for males and females in many European countries, of which 80 to 90% is attributable to smoking (Spijker, 2004; Zatonski et al., 2007).

This same pattern across Europe occurred for cardiovascular mortality which has shown a steady decline in the northern, western and southern parts of Europe since the 1980s

(Monnier, 2006 in Avdeev et al., 2011). Whereas central and eastern Europe experienced an increase in CVD's until the 1990s, followed by a decline afterwards (excluding Bulgaria, Moldova, Russia, and Romania), which lead to a divergence between east- and west-Europe until the 1990s (Vallin & Meslé, 2004; Avdeev et al., 2011) the high prevalence of CVD's in central and eastern Europe is one of the main reasons why life expectancy is lower in these regions compared to the rest of Europe (Avdeev et al., 2011). This diverging trend in CVD mortality is one of the main reasons life expectancy at birth diverged between eastern and western Europe (Vallin & Meslé, 2004).

2.4 Convergence and divergence within countries

There are several studies focussing on converging and diverging trends within countries, some studies have been done in rather large and heterogeneous countries (such as the United States, Canada, India and Spain) and find signs of convergence, as well as divergence between regions. Gächter & Theurl (2011) researched health trends within Austria, which is a more homogeneous country, and found convergence in life expectancy between the regions. Goli & Arokiasamy (2014) found that infant mortality rates between regions are converging, life expectancy at birth shows diverging trends between the 1990s and the 2000s. For the 1990s they found a convergence in health inequalities, however this was later replaced by divergence and was ascribed to an unequal decline in adult mortality for different regions (Goli & Arokiasamy, 2014). Goli & Arokiasamy (2014) conclude that divergence and convergence can replace each other at any time between regions depending on different health policies and other factors.

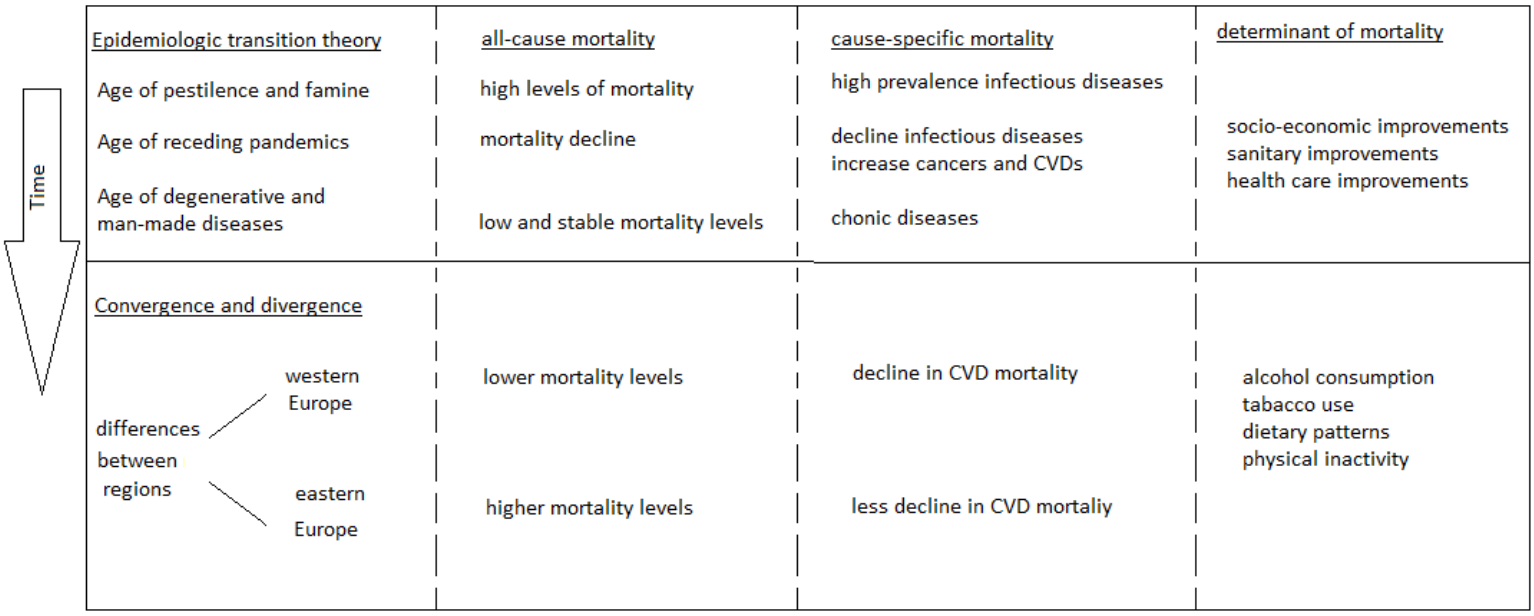
2.5 Assessing convergence across regions

There are several ways of assessing convergence across regions. The studies of Gächter & Theurl (2011) and Montero-Grenados et al. (2007) measured convergence by assessing sigma- and beta convergence. Where sigma convergence measures the spread of dispersion by looking at the change in standard deviation (Moser et al., 2005; Gächter & Theurl, 2011; Montero-Grenados et al., 2007). This can be assessed among others through the DMM, the CV, the Gini index, and Theil index as was mentioned in previous paragraphs. Beta convergence measures whether regions with initially the lowest health levels increase more than the regions with initially the highest levels (Gächter & Theurl, 2011; Montero-Grenados et al., 2007). Montero-Grenados et al. (2007) found beta and sigma convergence between regions in Spain for life expectancy at birth. For infant mortality they found only beta convergence, but showed sigma divergence. Indicating that although the regions with initially the lowest health levels increased more, the inequalities between regions has widened (Montero-Granados et al., 2007). Gächter & Theurl (2011) also discussed the relationship between sigma and beta convergence: beta convergence can occur without sigma convergence. Whereas sigma convergence cannot occur without beta convergence (Gächter & Theurl, 2011). This was also shown in the research between regions in Spain for infant mortality (Montero-Grenados et al., 2007).

Another concept linked to convergence is the so-called 'Mattew effect', where – contrary to beta convergence – regions with the highest levels of health, have higher health improvements than regions with lower levels of health (Gächter & Theurl, 2011). However, this effect is not visible in all countries. Some studies suggest it mainly occurs in countries with low infant, child and maternal mortality rates. Other studies did not find this Matthew effect for studies with low infant mortality rates (Gächter & Theurl, 2011).

2. 6 Conceptual model

Figure 1: Convergence and divergence in mortality trends across regions



Based on: Omran (2005); Vallin & Meslé (2004).

This research will focus on convergence and divergence between regions in Europe. Figure 1 shows the conceptual model for this research. During the ages of the epidemiologic transition different mortality levels (high and low) and differences in the causes of death occurred. The stages of the epidemiologic transition theory started due to improvements in socio-economic factors and due to hygiene and health care improvements. As stated by Vallin & Meslé (2004) after the third stage of the epidemiologic transition theory, rather than a fourth stage emerging, converging and diverging trends between regions play a major role. Within Europe there is a clear distinction between mortality levels both for all-cause mortality and causes of death between eastern and western Europe, lifestyle factors as alcohol consumption, smoking and nutrition and physical inactivity are determinants for differences in cause-specific and all-cause mortality.

2.6 Hypothesis

What are the converging and diverging trends in all-cause mortality between regions in Europe?

Overall convergence in all-cause mortality between regions for the period 1994-2010 in Europe, with lower levels in eastern Europe than western Europe, east-European countries however experience greater mortality decreases than west-European countries (Vallin & Mésle, 2004; McMichael et al., 2004; Mackenbach, 2013).

What are the converging and diverging trends in cause-specific mortality between regions in Europe?

In general convergence between regions for CVD and cancer mortality, as this started to decline after the 1990s (Vallin & Mésle, 2004; McMichael et al., 2004; Mackenbach, 2013).

To what extent contribute different causes of death towards all cause mortality in Europe?

Changes in the causes of death result in changes in all cause mortality levels, the greatest contribution is expected for cancer mortality and CVD's as they are mentioned as the diseases that mainly explain the diverging and converging trends in life expectancy at birth (Vallin & Meslé, 2004; Avdeev et al., 2011; Nusselder & Mackenbach, 2000).

3. Data and methods

3.1 Data

3.1.1 Study design

This study is a trend analysis and is mainly explanatory. In order to assess convergence between regions, data on NUTS-2 regions in Europe was used. Population numbers on January 1, number of deaths for all-cause mortality and seven causes of death for 5 year age-groups, with 85+ being the open ended age group, was used for the years 1994-1996 and 2008-2010 for both sexes and for males and females separately. The death rates were age- and sex-standardised using the EU-27 in 2008-2010 as the standard population. In order to assess the contribution of causes of death to all-cause mortality, life table data including life expectancy for 27 countries in Europe for the years 1994-1996 and 2008-2010 was used. Regions of the following 27 countries were used in this research: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom, encompassing a total of 224 regions.

3.1.2 Data sources

Data on population numbers, all-cause mortality and seven causes of death for 1994-1996 and 2008-2010 for regions in Europe were obtained from several data sources. See table 1 for an overview of the data sources that were used.

3.1.2.1 Population numbers and total deaths

Data on population numbers on and numbers of death per 5 year age-group and 85+ was obtained from Eurostat for the years 1994-1996 and 2008-2010 for both sexes and males and females separately. Eurostat obtained its data from the national Statistical Institutes from each country on a voluntary basis, before the data is made public, checks are being made to ensure the data is consistent and can be compared between years (Eurostat, 2013). Population data is the population on January 1 in a certain year and refers to usual residence (Eurostat, 2013).

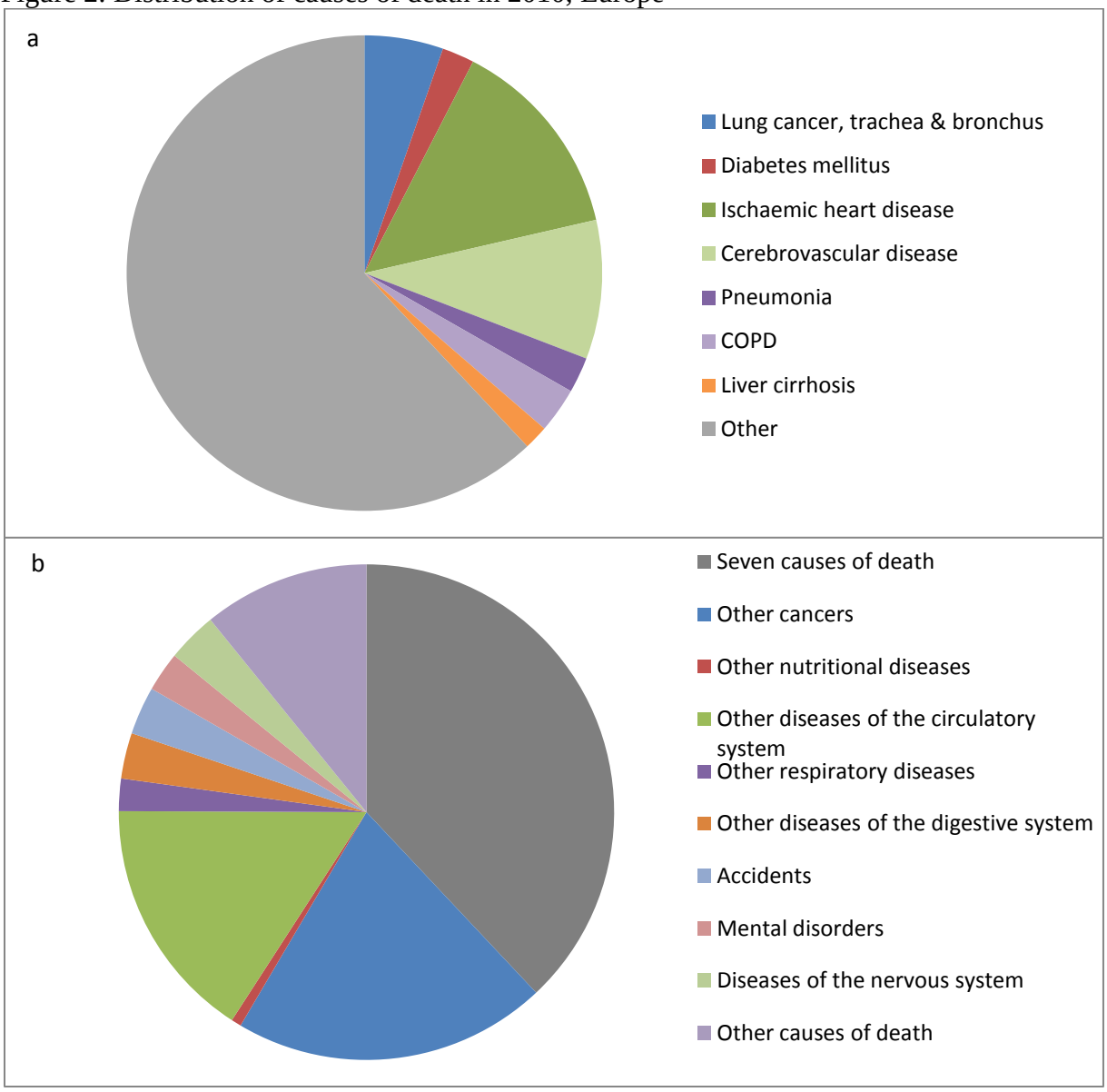
Data for regions in Germany for the years 1995-1996 were obtained from the statistical bureau of Germany (Regionaldatenbank Deutschland, 2014) due to overestimating (50% for Sachsen and underestimating (111% for Saarland and 50% for Sachsen-Anhalt)the number of deaths in several regions for these years by Eurostat (Eurostat,2014b), the statistical bureau of Germany however, provided only data for 1995-1996 (Regionaldatenbank Deutschland, 2014), which was averaged in this research.

3.1.2.2 Causes of death

According to the fact sheet of the World Health Organization (2014a) of the top 10 causes of death worldwide and for different income groups in 2012, there are several leading causes of death in Europe. Because the European Union consists of both high-income and middle-income countries, the diseases that are prominent in these income groups are taken into

account. The causes of death that are used in this research are: 1) trachea, bronchus and lung cancer, 2) diabetes mellitus, 3) ischaemic heart disease, 4) cerebrovascular diseases, 5) pneumonia, 6) chronic obstructive pulmonary disease, and 7) liver cirrhosis. These causes of death also account for leading cause of death within their respective group (e.g. lung cancer, trachea and bronchus is most prevalent in the category neoplasms), see also figure 2. Figure 2a shows the distribution of the seven causes of death that were assessed in this research, the figure shows that most deaths are due to ischaemic heart disease and cerebrovascular disease, followed by lung cancer, trachea and bronchus, these seven causes of death account for 40% of the total deaths in 2010. Figure 2b shows the distribution of other causes of death, other cancers and other diseases of the circulatory system account for most deaths in the category other.

Figure 2: Distribution of causes of death in 2010, Europe



Source data: WHO (2014a)

The seven causes of death can also be attributable to different underlying causes: by gaining insight in lung cancer and COPD mortality, this might give an indication of the effect of smoking in Europe. Diabetes mellitus is mainly caused by being overweight and physically inactive, pneumonia is caused by an infection and liver cirrhosis is caused by excessive alcohol consumption (Spijker, 2004). Ischaemic heart disease and cerebrovascular diseases can have multiple underlying causes, and can be ascribed to smoking, alcohol consumption, physical inactivity and fruit- and vegetable consumption (Spijker, 2004). The category other causes of death was calculated as the total number of deaths minus the deaths due to the seven causes of death mentioned here.

Data on the causes of death with their respective ICD-10 code was obtained through Eurostat (see also appendix 1 for an overview of the used ICD-codes and their description). Eurostat acquired its data through the statistical offices of the different countries, who provide the underlying causes of death for diseases on the European Shortlist (Eurostat, 2014c). In general the statistical offices of the countries follow the standards that were set in the ICD, however sometimes different interpretations can exist for different countries, leading to some quality issues (Eurostat, 2014c). The cause of death data is based on the information on cause of death certificates and refers to the underlying cause of death which is "the disease or injury which initiated the train of morbid events leading directly to death, or the circumstances of the accident or violence which produced the fatal injury" as described by the World Health Organization (WHO, 2014c; Eurostat, 2014c). Consistency checks for age, sex and causes of death were made and the 3 years averages for 1994-1996 and 2008-2010 were calculated from the number of occurred deaths during a year (Eurostat, 2014c).

For lung cancer, trachea and bronchus, there was less data available in Eurostat on both the regional and the national level. However, data on the country level for the number of deaths due to lung cancer was obtained from the European Detailed Mortality Database (DMDB) from the World Health Organization for Belgium, Finland, Germany, Iceland, Ireland, Italy, the Netherlands, Poland, Portugal and Switzerland (WHO, 2014b). The DMDB provides the raw detailed files of the global mortality database of the WHO, data was obtained from the official registers of the different countries, when data is not available these are estimated through census data (NSD, 2014).

3.1.2.3 Regions

Because this research assessed whether there is convergence or divergence in mortality trends across regions in Europe, NUTS-2 regions were used. Europe can be divided into statistical regions, called the nomenclature of territorial units for statistics (NUTS). There are several NUTS levels, NUTS-0 is the country level, NUTS-1 are smaller areas (e.g. Scotland), and NUTS-2 are even smaller areas. NUTS-2 regions are the size of provinces for The Netherlands and Germany (Eurostat, 2012). For small countries like Iceland and Estonia, NUTS-2 is also the country level. Data on all-cause mortality, causes of death and population numbers was not available for all NUTS-2 regions in Europe, for some countries and regions NUTS-0 or NUTS-1 data will be used, this was the case for regions in Germany and Scotland (=NUTS-1), and for Slovenia, Denmark and Finland (=NUTS-0). In total there are 270 NUTS-2 regions in Europe, in this research 224 regions were used, for lung cancer only 143 regions were used.

3.1.2.4 Life tables

In order to assess which causes of death contribute the most to changes in life expectancy and thus all-cause mortality, life table data was used. Life expectancy at birth indicates "the overall mortality level of a population, as it summarizes the pattern that pattern that prevails across all age groups" (WHO, 2007).

Abridged period life tables for the years 1994-1996 and 2008-2010 for both sexes and males and females separately for 26 countries were obtained from the Human Mortality Database (HMD, 2014), data for Greece was obtained through Eurostat. The data of the HMD is obtained from raw data from vital statistics of the different countries (HMD, 2014). Data on population size and number of deaths were used by the HMD to further calculate the values of the different columns in the life tables (HMD, 2014).

Table 1: Overview of data and data sources

<table>
<tr><th></th><th>Data</th><th>Database</th><th>Years</th></tr>
<tr><td>Population</td><td>Number of inhabitants per 5 year age group: total, females & males</td><td>Eurostat: Population on 1 January by five years age groups and sex - NUTS 2 regions</td><td rowspan="2">1994,1995,1996
2008,2009,2010</td></tr>
<tr><td>All-cause mortality</td><td rowspan="9">Number of deaths per 5 year age group: total, females & males</td><td>Eurostat: Deaths by age at last birthday and sex - NUTS 2 regions
Statistics Germany: Deaths</td></tr>
<tr><td>Trachea, bronchus & lung cancer</td><td rowspan="8">Eurostat: Causes of death by NUTS 2 regions - absolute Number, 3 years average – total

Eurostat: Causes of death by NUTS 2 regions - absolute Number, 3 years average – females

Eurostat: Causes of death by NUTS 2 regions - absolute Number, 3 years average – males

WHO: European Detailed Mortality Database: Comparisons betweeen countries for one selected (group of) cause(s) of death</td><td rowspan="8">1994-1996
2008-2010</td></tr>
<tr><td>Diabetes mellitus</td></tr>
<tr><td>Ischaemic heart disease</td></tr>
<tr><td>Cerebrovascular disease</td></tr>
<tr><td>Pneumonia</td></tr>
<tr><td>Chronic obstructive pulmonary disease</td></tr>
<tr><td>Liver cirrhosis</td></tr>
<tr><td>Abridged period life tables</td><td>Life tables per country
total, females & males</td><td>Eurostat: Life table
Human Mortality Database</td><td>1994,1995,1996
2008,2009,2010</td></tr>
</table>

Sources: Eurostat (2014a; 2014b); WHO (2014b); Regionaldatenbank Deutschland (2014); HMD (2014).

3.1.4 Missing data

Although Eurostat provides the information on population, total deaths and causes of deaths for the total population and for males and females. There are some differences in available data for different countries and years. For a few regions in France (4 regions), Italy (2 regions) and the United Kingdom (2 regions) there is no data available on population distribution, all cause mortality and causes of death. Therefore these 8 regions were excluded from the analysis.

The population data for the regions in Bulgaria in Eurostat doid not provide information for age-groups 80-84 and 85+, a value for unknown age group was however available and population data for the ages 80-84 and 85+ for Bulgaria as the whole country were also available. The population for the age-groups 80-84 and 85+ for the different regions were estimated, by applying the population proportion for the two age groups on the country level to the unknown values of the different regions.

For the Netherlands, regional data on total numbers of deaths in the demography database mentioned in paragraph 3.1.2.1 for the years 1994-1996 and 2008-2010 were not available. Data for the summation on different causes of death (exluding a few causes) however was available through the cause of death database, mentioned in paragraph 3.1.2.2. Because Eurostat provided data on the national scale for total deaths, the number of deaths per region were estimated by applying the proportion of the summation of the causes of death (excluding a few causes) per region, to the national total numbers of death.

3.2 Methods

3.2.1 Death rates

Data on population size on January 1, total number of deaths and number of deaths per cause per 5 year age-groups and open ended age-group 85+ were used to calculate the age-specific death rates. Causes of death data was obtained as three years averages from Eurostat. The number of total deaths and population numbers for both sexes and males and females separately for the years 1994, 1995, 1996 were averaged, this was also done for 2008, 2009, 2010 in order to be able to compare the all-cause mortality rates with the cause-specific mortality rates.

3.2.2 Standardisation

The age-specific death rates mentioned above, were directly age- and sex- standardised using the EU-27 in 2008-2010 as the standard population, in order to compare between regions who have different age structures and between sexes. Summating these age-specific death rates gives the age- and sex-standardised crude death rates (ASCDR), which was used as a measure for all-cause mortality and cause-specific mortality.

3.2.1 Convergence

3.2.1.1 Sigma convergence

By assessing sigma convergence, the change in standard deviation over time is used. Sigma convergence occurs when the standard deviation significantly decreases over time. Meaning, if there is a drop in the mean of health differences of different regions, there is a reduction in the differences. Thus if the standard deviation falls over time, this means convergence. An increase in standard deviation means divergence (Montero-Grenados et al., 2007). Thus sigma convergence measures the overall spread of the mortality distribution (Gächter & Theurl, 2011).

Sigma convergence occurs when the standard deviation of the mean mortality levels significantly decreases over time. Meaning, if there is a drop in the mean of health differences of different regions, there is a reduction in the differences. Thus if the standard deviation (σ) falls over time, this means sigma convergence. An increase in standard deviation means sigma divergence and regions are becoming less equal (Montero-Grenados et al., 2007; Gächter & Theurl, 2011). By using the standard deviation, the overall spread of the mortality distribution is measured (Gächter & Theurl, 2011). The means and standard deviations are being weighted by population size in order to adjust for differences in size between regions.

As described by Montero-Grenados et al. (2007), to assess whether this fall or rise in standard deviation over time is significant, a F-test can be used. A F-test is a test of variance (standard deviation squared: σ^2), thus testing whether the variance of both means (in this case the initial mortality levels: 1994-1996, and the final mortality levels: 2008-2010) are the same. The nullhypothesis for this is thus H0: $\sigma^2_t = \sigma^2_{t+1}$. Because this is an one tailed F-test the alpha level for the p-value is 0.025.

3.2.1.2 Beta convergence

Beta convergence is another method of assessing convergence and it looks at the differences between the regions. When regions with lower health levels improve their situation relative to the rest, convergence has occured. In this research, when regions with initially higher mortality levels decline more than regions with initially lower mortality levels, beta convergence has taken place (Montero-Grenados et al., 2007; Gächter & Theurl, 2011). As described by Montero-Grenados et al. (2007) and Barro & Sala-i-Martin (1992) Beta convergence can be measured through the following equation:

$$\frac{1}{T} * (S_{i,t+T} - S_{i,t}) = a + b*S_{i,t} + \varepsilon_{i,t}$$

T = total period of the study
Si,t = initial state of mortality level
Si,t+T = final state of mortality level

a: constant
b: implies Beta convergence/divergence
ε: other influences

The equation above is a linear equation, where the mortality levels in the final state is dependent on mortality levels in the initial state. The a and b parameters can be estimated by a linear regression. With a being the constant and b implying the presence of beta convergence or divergence (Montero-Grenados et al., 2007). When the b value is positive and significant this means β divergence, when the b value is negative and significant this means β

convergence. When using a linear regression, this will also give the p-values for the b coefficients. When the p-value for b <0.05, the coefficient for b is significant.

There also exists a relationship between sigma and beta convergence. Sigma convergence occurs when beta convergence also occurs. However, beta convergence can occur without sigma convergence (Gächter & Theurl, 2011).

3.2.3 Contribution of causes of death towards all cause mortality

A decomposition measure was used in order to assess the contribution of cause-specific mortality towards all-cause mortality. The change in all-cause mortality is measured as the change in life expectancy between 1994-1996 and 2008-2010. As discussed by Nusselder & Mackenbach (2000; Nusselder & Looman, 2004) who used the decomposition method by Arriaga (1984; 1989), this method assesses the contribution of different ages and causes of death to the change in life expectancy over time. Although, this method also assesses the contribution at different ages, the focus of this research is on the decomposition by cause for life expectancy at birth.

The decomposition method uses life expectancy data (Arriage, 1984; Nusselder & Mackenbach, 2000), whereas convergence was assessed using age standardised crude death rates. Because both indicators are measures of mortality, as an increase in all-cause mortality would lead to an decrease in life expectancy and vice versa (Silcocks et al, 2001), both measures are used in this research. Although convergence was assessed between regions for Europe, the contribution of causes of death towards the change in life expectancy is assessed for the average life expectancy of Europe.

Decomposition of life expectancy by causes of death was done for both sexes and males and females separately, in order to assess whether different causes of death contribute differently towards all-cause mortality for men and women. This research needs one average life table for the countries and regions used in this research, to assess the contribution of the causes of death to the change in life expectancy, this was calculated by averaging the 27 life tables by using the ${}_nm_x$ and ${}_na_x$ values, and was weighted over population size. The age groups <1 and 1-5 were averaged using the ${}_nL_x$ and ${}_nd_x$ values, the same was done for the age-groups above 85, in order to obtain 5 year age-groups and open ended age group 85+.

Decomposing of life expectancy for different causes, as described by Arriaga (1984; 1989) and Nusselder & Looman (1984) encompasses direct, indirect and interaction effects.The direct effect will measure the effect that a mortality change in age group x, x+i has on the life expectancy at age a (in this case: life expectancy at birth). The direct effect will be calculated using the difference in *temporary* life expectancies (e_x^t). The l_a^t refers to the ages at which the change in life expectancy and the contribution of a specific cause of death will be measured. In this study this will be done for life expectancy at birth (a=0).

Direct effect:
$DE_x = (l_x^t/l_a^t) * (e_x^{t+n} - e_x^t)$

The indirect effect will measure the change in survivors (CS_x), which affects life expectancy at older ages. The indirect effect is calculated as:
$IE_x = (CS_x/l_a^t) * e^t_x$ $\quad\quad$ $CS_x = (l_x^t * (l_{x+i}^{t+n}/l_x^{t+n})) - l_{x+i}^t$

Although the direct effect uses temporary life expectancies (${}_{x}e^{t}$) between two ages. The indirect effect uses the actual life expectancy (${}^{t}e_{x}$).

Interaction effect:
$I_x = ({}_{x+i}T^{t+n} / {}_{a}l^{t}) * (({}_{x}l^{t} / {}_{x}l^{t+n}) - ({}_{x+i}l^{t} / {}_{x+i}l^{t}))$

By adding all these effect, the total effect is calculated.
Total effect: $TOT_x = DE_x + IE_x + I_x$

For the open ended age grouped, there are no indirect and interaction effects. Therefore this is only measured by the direct effects, calculated differently from the direct effect mentioned above.

$$DE\infty = ({}_{x}l^{t}/{}_{a}l^{t}) * (({}^{t+n}e_{x}) - ({}^{t}e_{x}))$$

The formulas above only decompose by age. This needs to further include the causes of death. The contribution of changes in causes of deaths towards all cause mortality is assumed to be proportional. Therefore:
${}_{c}TOT_x = TOT_x * {}_{c}C$

Where ${}_{c}C$ is the mortality of a specific cause of death.
${}_{c}C = ((Rt+nc * Mt+n) – (Rtc * Mt)) / (Mt+n - Mt)$

With R being the proportion of a specific cause of death and M being the central mortality rate.

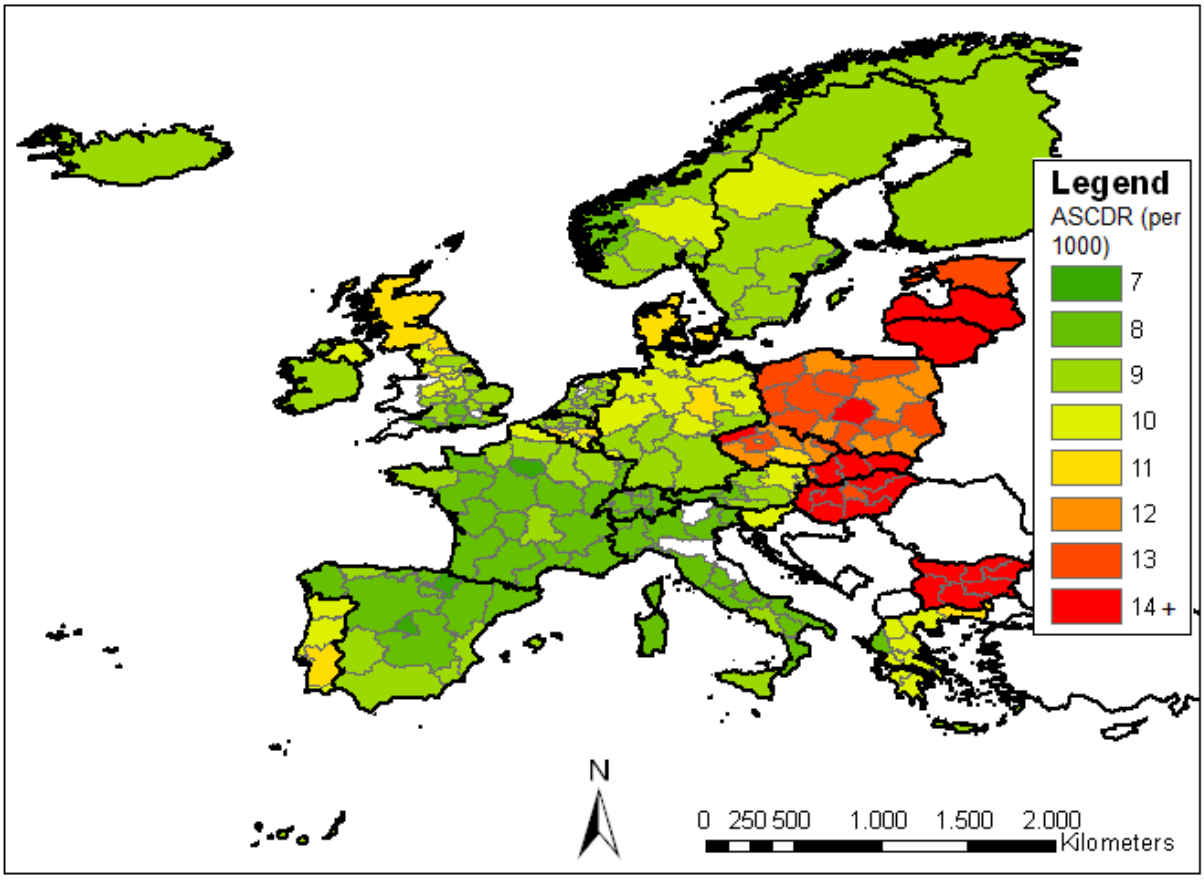
4. Results

4.1 All cause mortality

4.1.1 Regional mortality differences

In total, 224 regions in Europe were used in the analysis for all cause mortality. Figure 3 shows the age standardised crude death rates (per 1000 population) for males and females combined per region in Europe that were analysed in this research. The weighted mean ASCDR for the regions in Europe for the period 2008-2010 is 9.81 per 1000 population, the green areas in the map show regions who have lower mortality levels than the mean, orange and red areas have higher mortality levels. When looking at the map, it shows that there are some differences in mortality between the regions across Europe, as well as between regions in a country. The overall picture shows the highest levels of mortality in eastern Europe, the lowest levels of mortality are found in northern, western and southern Europe. This corresponds with the results of Avdeev et al. (2011) who found lower levels of life expectancy in eastern Europe. One of the main reasons of this higher life expectancy in northern, western and southern Europe was due to mortality decline in cardiovascular mortality in these regions since 1980 (Monnier, 2006 in Avdeev et al., 2011). Other reasons for the lower health levels in eastern Europe are dietary problems, excessive alcohol consumption, tobacco use and stress and the switch to a market economy after the Cold War (Vallin & Meslé, 2004; Mackenbach, 2013).

Figure 3: Age standardised Crude Death Rate (per 1000) for 224 regions in Europe, 2008-2010, males and females combined



Source data: Eurostat (2014a).

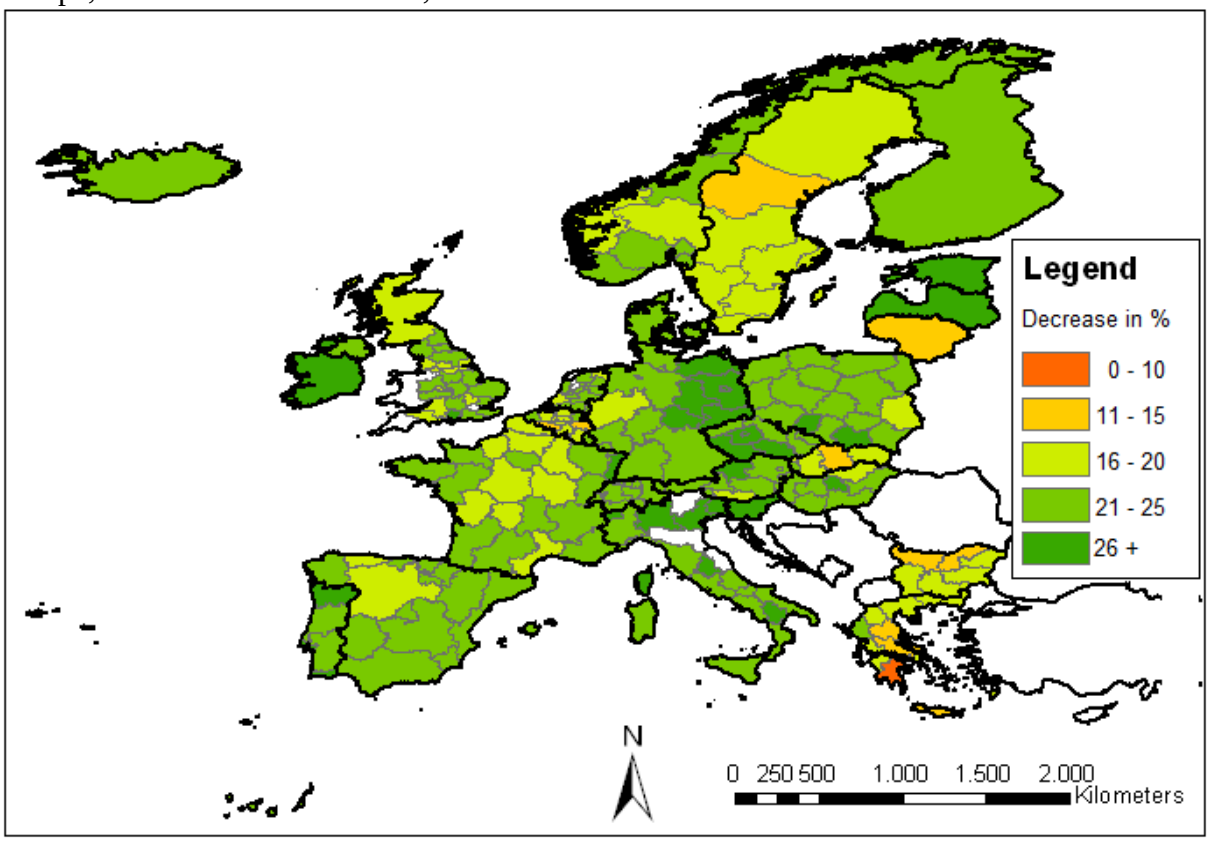
The lowest mortality levels were found in Île de France (the urban area around Paris) with an ASCDR of 7.26 per 1000 population, the highest mortality levels were found in Severozapaden (Bulgaria) with an ASCDR of 16.29 per 1000 population, Severozapaden also has the poorest economy among the regions of the European Union (Eurostat, 2013b).
The highest regional variation in mortality levels within countries occur in the United Kingdom and Germany, with mortality levels that vary between 7, respectively 8 deaths per 1000 inhabitants and 11 deaths per 1000 inhabitants. Within country variation between regions is also high for Czech Republic and Poland, which experience mortality levels between 11, respectively 12 deaths per 1000 inhabitants and 14 deaths per 1000 inhabitants. When looking at the ASCDR for males and females separately in 2008-2010 (see appendix 2), a different picture emerges. The mortality levels for males range between 9 and 21 deaths per 1000 population and the map shows less regional variation within countries: mortality levels in eastern Europe are mainly homogenous across regions with an ASCDR of 15 and higher per 1000 population. Whereas more regional variation exists in west-Europe, especially within the United Kingdom, Belgium, France and in the Scandinavian countries. For females the picture is reversed: mortality levels are mainly uniform across western, northern and southern Europe (excluding regions within the United Kingdom), whereas eastern Europe shows more variation between the regions, but also within countries (Poland and Czech Republic). The east-west divide is less pronounced for females than for males, this also corresponds with the research of Vallin & Meslé (2004). The mortality levels for females range between 6 and 13 deaths per 1000 population in 2008-2010.

4.1.2 Trends in all cause mortality

All cause mortality for both sexes between 1994-1996 and 2008-2010 has decreased over time. The weighted mean ASCDR for Europe in 1994-1996 was 12.69 deaths per 1000 population, for 2008-2010 this was 9.81 deaths per 1000 population. For females this has decreased from 10.05 to 7.81 deaths per 1000 population and from 16.30 to 12.16 deaths per 1000 population for males.

Figure 4 shows the relative change in ASCDR in the period 1994-1996 to 2008-2010 (see appendix 3 for males and female separately). In this period death rates for all cause mortality have dropped in all regions in Europe. The map shows that the greatest decreases between 1994-1996 and 2008-2010 in all-cause mortality have occurred in Ireland, eastern Germany, Estonia, Latvia and in regions in Italy and the Czech Republic, with a drop of more than 25% in all cause mortality rates for both sexes. This is in line with the research of Vallin & Meslé (2004) who found that some east-European countries (Czech Republic and Poland) had greater gains in life expectancy than west-European countries after the 1990s. Although Poland did not have the greatest decrease in mortality in this research, mortality decline is still high (varying between a decrease of 20% to 27%), this is also the case for Hungary (decrease of 20% to 26%). Although Slovakia belonged to one of the first east-European countries (together with Czech Republic, Poland and Hungary) to experience increases in life expectancy at the start of the 1990s after a period of life expectancy decline (Vallin & Meslé, 2004), the decline in mortality between 1994-1996 and 2008-2010 is lower compared to the other countries.

Figure 4: Relative change in age-standardised crude death rate (per 1000) for 224 regions in Europe, 1994-1996 to 2008-2010, males and females combined.



Source data: Eurostat (2014a).

The differences in Germany, with eastern Germany having greater mortality decreases than western Germany is similar to the findings of Kibele (2012), who found that life expectancy in East-Germany had increased more than in West-Germany, and could be explained by the Reunification of East- and West-Germany in 1989/1990. Due to these greater increases in life expectancy in the eastern part of Germany, convergence in life expectancy between these two regions occurred (Kibele, 2012).

Although Estonia and Latvia belong to the regions with the highest mortality decline between 1994-1996 and 2008-2010, mortality levels are still high in 2008-2010. This could be ascribed to excessive alcohol consumption in the Baltic States due to easy access and lack of legislation, and in 2007 alcohol consumption reached its top in Estonia and Lithuania (Karanikolos et al., 2012). In 2008 alcohol taxes and restrictions on sales and advertising were introduced in Estonia and Lithuania, Latvia introduced a programme to reduce alcohol consumption by raising public awareness and combating illegal alcohol, due to these measures life expectancy started to increase again (Karanikolos et al., 2012). Figure 4 shows that Lithuania has the lowest mortality decline of the three Baltic States between 1994-1996 and 2008-2010. Previous research indicate that differences between the three Baltic states and western Europe had increased since the 1990s: Karanikolos et al. (2012) researched changes in life expectancy between the three Baltic States and Finland and found that between 1985 and 1995 the difference in life expectancy had increased. Estonia and Latvia experienced great mortality decreases after the mid-1990s, indicating convergence between the two countries and Finland (Karanikolos et al., 2012). Lithuania however, experienced less mortality decline after 1999, which was mainly ascribed to CVD's, cancers and deaths from external causes, mainly for males (Karanikolos et al., 2012).

4.1.3 Convergence in all cause mortality

Sigma and beta convergence has been assessed for the 224 regions in Europe. The results are shown in table 2. As mentioned in paragraph 4.1.2, all-cause mortality has declined in the period 1994-1996 to 2008-2010 for both sexes and for males and females separately.

Sigma convergence was measured by a change in standard deviation and has declined for both sexes and for males and females separately. The standard deviation has declined by 0.371 for both sexes, for females by 0.419 and for males by 0.436, this is also reflected in the change in variance, as the variance is standard deviation squared, indicating that the mortality differences between regions in 1994-1996 to 2008-2010 has lessened. Whether this change in standard deviation is statistically significant was determined by using an one-tailed F-test over the variance of the mortality levels in 1994-1996 and 2008-2010. The change in standard deviation is statistically significant ($p<0.025$) for total change and for the change in the male and female population. The change in standard deviation in the male population is slightly higher than in the female population, indicating that all cause mortality for males has converged more between the regions in Europe, although the overall spread of mortality levels is still higher for males.

Table 2 also shows beta convergence. Beta convergence was measured by applying a linear regression technique on the formula mentioned in chapter 3.2.2. As mentioned before, beta convergence occurs when regions with initially higher mortality rates decline more than regions with initially lower mortality rates. When the b-value is positive and significant, this indicates beta divergence, when the b-value is negative and significant, this indicates beta convergence (Montero-Grenados et al., 2007; Gächter & Theurl, 2011). The output table of the linear regression analysis also provides a significance measure at the a=0.05 level. In this research, besides sigma convergence, beta convergence also occurred. The total β is -0.0158, for females this is -0.0198 and for males this is -0.0127 and all three p-values are statistically significant. The beta convergence for males is lower than for females, indicating that not only have regions become more equal, regions with initially lower health levels have increased more between regions in Europe.

Table 2: Sigma and Beta convergence in all-cause mortality across 224 NUTS-2 regions in Europe between 1994-1996 and 2008-2010

ASCDR (per 1000)	Total		Females		Males	
	1994-1996	2008-2010	1994-1996	2008-2010	1994-1996	2008-2010
Mean*	12.69	9.81	10.05	7.81	16.30	12.16
stdev (σ)	2.449	2.078	1.978	1.559	3.112	2.676
change in σ		-0.371		-0.419		-0.436
variance (σ^2)	6.00	4.32	3.91	2.43	9.69	7.16
F-ratio		1.39		1.61		1.35
p-value (a=0.025)		0.0067		0.0002		0.0115
β		-0.0158		-0.0198		-0.0127
p-value β (a=0.05)		0.0000		0.0000		0.0000

*the mean is weighted over the population size

This study solely found convergence for all-cause mortaliy in Europe, which is contrary to other studies. Mackenbach (2013) who looked at divergence using the inter-quartile range as a measure found that differences between countries in terms of life expectancy were the lowest in 1960 for males and in 1970 for females, thereafter the differences increased again, indicating divergence. The research of Vallin & Meslé (2004) also found diverging trends, mainly between east and west, with eastern Europe mainly being represented by declining life expectancies in Russia and Ukraine at least until 2000.

This difference in results could partly be explained to the selected regions, the research of Mackenbach (2013) focused on convergence between countries, whereas this study focused on convergence between regions, when convergence would be assessed on the country level, different results occur as shown in table 3. Table 3 compares the results of convergence between regions (n=224) and countries (n=28), the differences in the mean are because of missing regions in the regional analysis, whereas the national analysis encompassed national data. The table clearly shows that for the analysis between countries, the level of sigma convergence is lower compared to the regional analysis, the change in standard deviation of -0.085 is however, not statistically significant (p=0.421). This suggests that when assessing convergence between countries, less variation exists than when assessing convergence between regions, and regional differences get lost when analyzing countries. Beta convergence however, shows more or less the same results, although the convergence is slightly higher in the analysis between countries (b= -0.017) and is statistically significant.

Table 3: Convergence for all cause mortality for the total population, 1994-1996 to 2008-2010, between regions and countries in Europe

Regions	1994-1996	2008-2010
Mean	12.69	9.81
σ	2.45	2.08
Change σ	-0.3710	
p-value σ	0.0067	
β	-0.0158	
p-value β	0.000000	

n=224

Countries	1994-1996	2008-2010
Mean	12.55	9.58
σ	2.25	2.16
Change σ	-0.0854	
p-value σ	0.4210	
β	-0.0171	
p-value β	0.00007	

n=28

Another reason for finding convergence in this study contrary to the studies of Vallin & Meslé (2004) and Mackenbach (2013), is the selection of countries. Both studies included Russia in its analysis, whereas this was not the case in this study. When Russia would be included in the analysis, a different result may occur.

4.2 Cause specific mortality

4.2.1 Trends in cause specific mortality

When looking at changes in causes of death mortality, between 1994-1996 and 2008-2010 the weighted mean over population size for males and females combined has decreased for all causes of death (see also table 3). For lung cancer only 143 regions were used (instead of 224 regions), due to missing data, therefore two categories for "other" causes of death were calculated (including and excluding lung cancer mortality).

For all categories, mortality rates have dropped for the total population in this period. The highest relative mortality declines occurred in Ischaemic Heart Disease (from 216 to 134 deaths per 100,000 population), Cerebrovascular diseases (from 152 to 88 deaths per 100,000 population), Pneumonia (from 38 to 25 deaths per 100,000 population) and in liver cirrhosis (from 20 to 14 deaths per 100,000 population). When examining differences between males and females, there has been an increase in lung cancer mortality and a very small decrease in Chronic Obstructive Pulmonary Disease (COPD) for females. This increase in lung cancer and COPD mortality is mainly attributable to smoking, as females started to smoke more in the second half of the 20th century, whereas this declined for males (Zatonski et al., 2007). For males, all causes of death mortality has decreased, expect deaths from diabetes mellitus, which have increased in this period.

4.2.2 Convergence in cause specific mortality

In the period examined in this research sigma convergence occurred. When looking at the total population, the standard deviation has fallen for all causes of death. Table 4 provides the change in standard deviation for the period 1994-1996 to 2008-2010. It shows, that the standard deviation has fallen for almost all causes of deaths. Also when looking at the significance levels for sigma convergence, this is statistically significant for these causes of death.

Sigma convergence was however not found for lung cancer and COPD for females which has increased by 0.741 for lung cancer, trachea and bronchus, and 1.537 for COPD, thus indicating sigma divergence in these causes of death. These however, were not statistically significant: lung cancer mortality had a p-value of 0.21 and COPD a p-value of 0.98. For males no increases in standard deviation occurred, however diabetes mellitus mortality had increased between 1994-1996 and 2008-2010. This indicates that although mortality had increased, the differences between countries had not increased, but rather decreased. Sigma convergence for males however for diabetes mellitus, was not statistically significant (p=0.08). The decreases in standard deviation were the greatest for IHD and cerebrovascular disease mortality, followed by Pneumonia.

When looking at beta convergence, this shows approximately the same pattern as sigma convergence. Beta convergence was found for all causes of death for both sexes and for males and females separately. Beta convergence for females was found for lung cancer (b=-0.0005), but was not statistically significant (p=0.80). This is also in line with Gächter & Theurl (2011), who mention that beta convergence can occur without sigma convergence, but sigma convergence cannot occur without beta convergence.

Untill the 1990s, converging and diverging trends were visible for CVDs, such as cerebrovascular diseases and ischaemic heart disease, and cancer mortality (Vallin & Meslé, 2004; Avdeev et al., 2011). In this research mainly a converging trend was found between regions from 1994-1996 to 2008-2010, indicating that differences between regions for cerebrovascular disease and ischaemic heart disease mortality has decreased.

Table 4: Sigma and beta convergence for causes of death between NUTS-2 regions in Europe between 1994-1996 and 2008-2010.

Sigma and beta convergence for causes of death		Total		Females		Males	
		1994-1996	2008-2010	1994-1996	2008-2010	1994-1996	2008-2010
Lung cancer trachea & bronchus*	Mean	56.33	51.03	20.03	25.77	107.04	86.92
	StdevP σ	16.11	9.83	10.55	11.29	23.42	16.86
	Change in σ		-6.285		0.741		-6.565
	F ratio		2.69		1.15		1.93
	P-value (a<0.025)		0.0000		0.2100		0.0001
	β		-0.0640		-0.0005		-0.0297
	P-value (a<0.05)		0.0000		0.7989		0.0000
Diabetes mellitus	Mean	23.86	21.63	23.67	19.40	23.92	24.07
	StdevP σ	13.12	10.22	13.77	9.97	11.52	10.51
	Change in σ		-2.892		-3.806		-1.015
	F ratio		1.25		1.91		1.20
	P-value (a<0.025)		0.0491		0.0000		0.0846
	β		-0.0293		-0.0276		-0.0185
	P-value (a<0.05)		0.0000		0.0000		0.0000
Ischaemic Heart Disease	Mean	216.82	134.93	159.39	100.63	298.34	183.50
	StdevP σ	140.39	86.16	99.02	73.30	155.24	107.93
	Change in σ		-54.23		-25.72		-47.31
	F ratio		2.66		1.82		2.07
	P-value (a<0.025)		0.0000		0.0000		0.0000
	β		-0.0453		-0.0321		-0.0299
	P-value (a<0.05)		0.0000		0.0000		0.0000
Cerebrovas. Disease	Mean	152.02	88.01	139.56	81.39	167.01	96.11
	StdevP σ	74.09	46.76	65.43	42.62	77.22	53.45
	Change in σ		-27.330		-22.807		-23.774
	F ratio		2.51		2.36		2.09
	P-value (a<0.025)		0.0000		0.0000		0.0000
	β		-0.0395		-0.0321		-0.0314
	P-value (a<0.05)		0.0000		0.0000		0.0000
Pneumonia	Mean	38.22	25.07	31.38	20.34	50.03	32.94
	StdevP σ	34.50	14.99	27.80	13.43	36.42	18.11
	Change in σ		-19.507		-14.375		-18.315
	F ratio		5.30		4.29		4.05
	P-value (a<0.025)		0.0000		0.0000		0.0000
	β		-0.0559		-0.0448		-0.0462
	P-value (a<0.05)		0.0000		0.0000		0.0000

COPD	Mean	36.73	29.97	19.87	19.21	66.82	48.30
	StdevP σ	15.31	12.34	10.24	11.78	27.46	17.08
	Change in σ		-2.973		1.537		-10.379
	F ratio		1.54		0.76		2.58
	P-value (a<0.025)		0.0007		0.9814		0.0000
	β		-0.0310		-0.0111		-0.0386
	P-value (a<0.05)		0.0000		0.0011		0.0000
Liver cirrhosis	Mean	20.49	14.51	12.23	8.41	30.34	21.57
	StdevP σ	14.02	7.40	7.79	4.18	21.43	11.93
	Change in σ		-6.620		-3.610		-9.496
	F ratio		3.59		3.48		3.22
	P-value (a<0.025)		0.0000		0.0000		0.0000
	β		-0.0417		-0.0429		-0.0374
	P-value (a<0.05)		0.0000		0.0000		0.0000
Other (excl. lung cancer)*	Mean	726.33	598.83	595.39	503.61	885.87	725.46
	StdevP σ	217.63	86.81	136.68	65.54	218.09	127.46
	Change in σ		-130.823		-71.140		-90.626
	F ratio		39.86		4.35		2.93
	P-value (a<0.025)		0.0000		0.0000		0.0000
	β		-0.0704		-0.0492		-0.0364
	P-value (a<0.05)		0.0000		0.0000		0.0000
Other (incl. lung cancer)	Mean	779.91	650.24	619.70	531.23	994.43	809.77
	StdevP σ	217.65	99.14	151.35	74.60	252.91	150.73
	Change in σ		-118.514		-76.756		-102.183
	F ratio		4.82		4.12		2.82
	P-value (a<0.025)		0.0000		0.0000		0.0000
	β		-0.0590		-0.0450		-0.0328
	P-value (a<0.05)		0.0000		0.0000		0.0000

Mean is weighted over population size
*n=143

4.3 Contribution of causes of deaths to changes in all cause mortality

The causes of death that were examined in this research accounted for 40% of the total deaths in Europe in 2010. In the previous chapters, mortality was assessed by changes in the age standardized crude death rates. In order to use the decomposition method, described in chapter 3, data on life expectancy was needed. Because life expectancy is also a measure of mortality and can be calculated by having population size and number of deaths per age groups.

When looking at the contribution of causes of deaths to the change in life expectancy in table 5. It is shown that the overall change in life expectancy at birth is positive with an increase of 2.27 years for the total population, and an increase of 2.86 for females and 4.10 for males between 1994-1996 and 2008-2010. Overall, most causes have a positive contribution to the change in life expectancy at birth. Meaning that a reduction in a specific cause of death leads to an increase in life expectancy (Nusselder & Mackenbach, 2000). For lung cancer for females however, there is a negative contribution. Thus an increase in lung cancer mortality

leads to a decrease in life expectancy (Nusselder & Mackenbach, 2000). Although overall life expectancy is still increasing for the female population this means, that lung cancer is not responsible for the change in life expectancy.

Table 5: Decomposition by cause of death for the change in life expectancy at birth in Europe, 1994-1996 to 2008-2010

	Total	**Females**	**Males**
e^0			
Lung cancer	0.001	-0.085	0.242
Diabetes mellitus	0.023	0.055	0.013
Ischaemic Heart Disease	0.796	0.694	1.005
Cerebrovascular disease	0.514	0.584	0.439
Pneumonia	0.126	0.136	0.113
COPD	0.058	0.010	0.126
Liver cirrhosis	0.042	0.057	0.109
Other	0.713	1.413	2.052
Total change	**2.274**	**2.864**	**4.101**

When examining the causes that contribute the most to a change in life expectancy and thus overall mortality in Europe. These are Ischaemic heart Disease and Cerebrovascular disease for both sexes, which would seem logical as they also provide for a great share in total number of deaths. The research of Vallin & Meslé (2004) also found a high positive contribution of cardiovascular mortality for the Denmark, the Netherlands and France between 1980-1999. Meaning the reductions in CVD mortality, lead to an increase in life expectancy in Europe. The research of Vallin & Meslé (2004) also showed a high contribution of cancer mortality (Denmark) and respiratory diseases (Denmark and the Netherlands) in 1980-1999. In this research Pneumonia is the third largest cause that contributes most to changes in life expectancy between 1994-1996 and 2008-2010 (besides other causes of deaths), although Pneumonia is a relatively small cause of death (2.7% of total mortality) in 2008-2010. Changes in lung cancer, diabetes mellitus, COPD and liver cirrhosis are least responsible for the rise in life expectancy at birth for females, with lung cancer having a small negative contribution. For males diabetes mellitus contributes the least to an increase in life expectancy.

Because different causes of death can have different impacts at different ages, the results for the contribution of causes of death towards remaining life expectancy at ages 40+, 65+ and 85+ are shown in appendix 4. It shows that at older ages, the positive contribution of Pneumonia increases. Diabetes mellitus rather has a negative contribution at the oldest age groups.

5. Conclusion & discussion

5.1 Summary of results

The objective of this paper was to assess to what extent mortality trends are converging or diverging between regions, and to assess which causes of death contribute most to the change in all cause mortality.

Overall sigma and beta convergence was found for all cause mortality and for causes of death for both sexes and for males and females separately. Diverging trends were observed for causes of death related to smoking (lung cancer & COPD) for females, these were however not statistically significant. Sigma convergence was the strongest for cardiovascular diseases: Ischaemic Heart Disease and Cerebrovascular disease, followed by Pneumonia. This is partly in line with the hypothesis 2 made in chapter 2, which is true for CVD mortality, but not for cancer mortality.

Decreases in Ischaemic Heart Disease and Cerebrovascular disease also contribute the most to an increase in life expectancy, for both males and females. Which was also the case for Pneumonia. For males a reduction in lung cancer also increased the life expectancy, whereas for females lung cancer mortality has increased, thus decreasing life expectancy.

5.2 Limitations of the study

Missing data is one of the limitations of this study, as not all regions and countries in Europe were included in this analysis. Regions in Romania and Croatia were not taken into account in this study as data was not available, because both these regions generally have lower health levels than western Europe, this may affect the results. Also Russia was not included in the analysis for Europe, where many alcohol related deaths. Research by Vallin & Meslé (2004) and Mackenbach (2013) found a divergence in Europe between east and west, with a decline in life expectancy in Russia as one of the main reasons for this diverging trend. By including Russia, Romania and Croatia in the analysis, the level of convergence may be lessened or even diverge.

5.3 Evaluation data and methods

A point of discussion is the timeframe of this study, this study covers a period of 14 year, with the initial period an average of mortality levels 1994-1996 and a final period of an average of mortality levels 2008-2010. Other studies however studied longer periods of time. Gächter en Theurl (2011) did their research for 1969-2004 between regions in Austria. A period of 21 years (1980-2001) was researched by Montero-Grenados et al. (2007). Goli & Arokiasamy (2014) assessed convergence for the periods 1981-2011. Mackenbach (2013) who looked at convergence and divergence in life expectancy between countries between 1900 and 2008, found recent diverging trends in life expectancy for Europe.

Not all causes of death were examined in this study, but rather those who account for most deaths in their respective category (e.g. lung cancer, trachea & bronchus for cancer mortality; IHD and cerebrovascular disease for diseases of the circulatory system) and for which different determinants could be assessed (e.g. converging or diverging trends in lung cancer mortality could gain insight in smoking habits). The research could give different results when studying the overall cause of death groups such as neoplasm, respiratory diseases etc. It would also be interesting for policy makers to further conduct research on convergence and

divergence for smoking related causes of death, as this research finds diverging trends for smoking related mortality, although these were not statistically significant.

5.4 Policy implications

Although converging trends are visible, many countries in mainly eastern Europe still have high mortality rates. Policies should focus on health care and lifestyle factors, as smoking-related deaths as lung cancer and COPD mortality for females and diabetes mellitus mortality for males have increased the past couple of years due to dietary patterns and physical inactivity. Alcohol consumption in Europe is the highest worldwide, and poses a risk factor not only for liver cirrhosis and other alcohol related diseases, but also for cardiovascular mortality (WHO, 2014d). Developing policy in order to reduce tobacco and alcohol use and promoting physical activity across all regions in Europe, can improve life expectancy and reduce mortality.

5.5 Overall conclusion

In general, it can be concluded that mortality levels between regions in Europe in the period 1994-1996 to 2008-2010 have converged, for all cause mortality and most causes of death researched in this study. Reductions in Ischaemic Heart Disease and Cerebrovascular diseases contribute the most to changes in life expectancy, and showed most convergence between regions, followed by Pneumonia.

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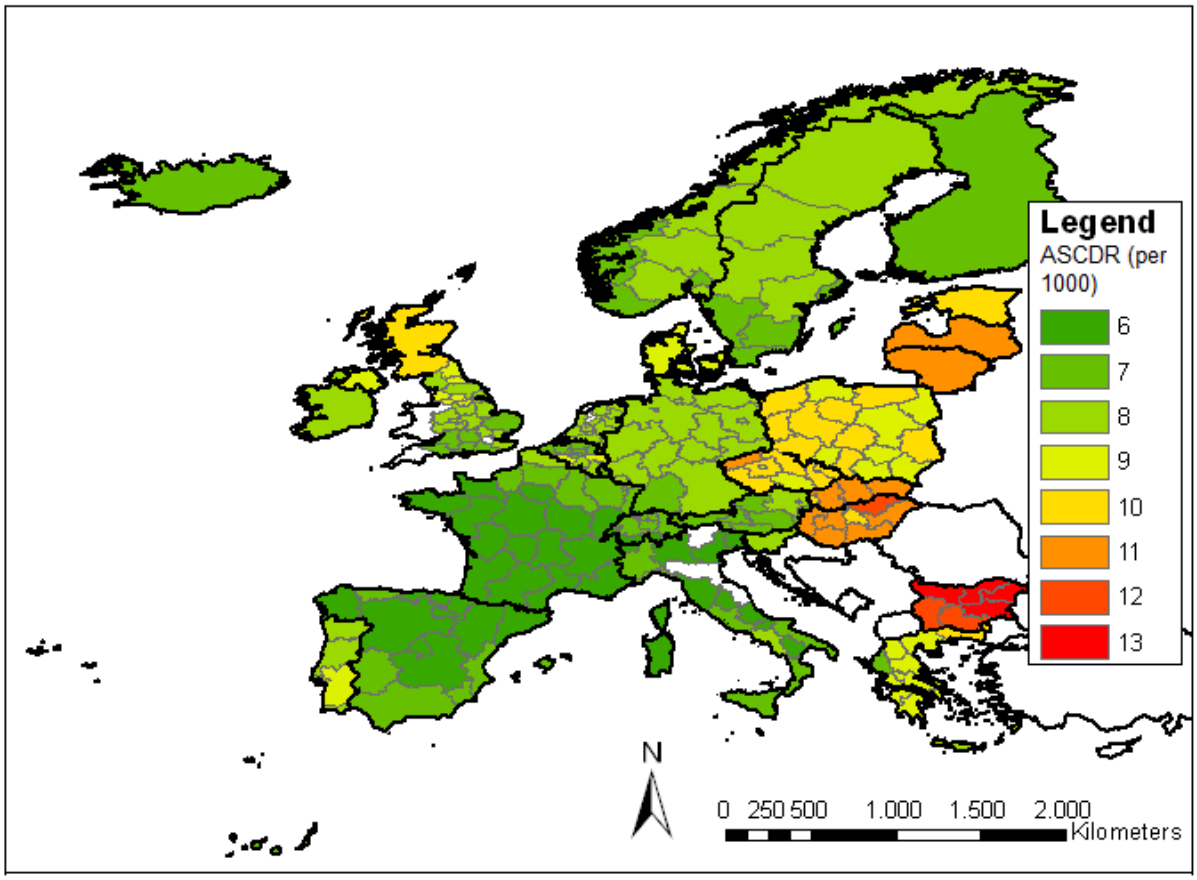
Appendix 1: Causes of death and their ICD-10 classification

Causes of death	ICD-10 classification
Lung cancer, trachea & bronchus	C33: Malignant neoplasm or trachea C34: Malignant neoplasm of bronchus and lung
Diabetes mellitus	E10-E14: Diabetes mellitus
Ischaemic heart diseases	I20-I25: Ischaemic heart diseases
Cerebrovascular diseases	I60-I69: Cerebrovascular diseases
Pneumonia	J12-J18 Pneumonia
Chronic Obstuctive Pulmonary disease	J40-J42: Chronic bronchitis J43: Emphysema J44: Other chronic obstructive pulmonary disease J47: Bronchiectasis
Liver cirrhosis	K70: Alcoholic liver disease K73: Chronic hepatitis K74: Fibrosis and cirrhosis of liver
Other causes of death	Remaining causes of death

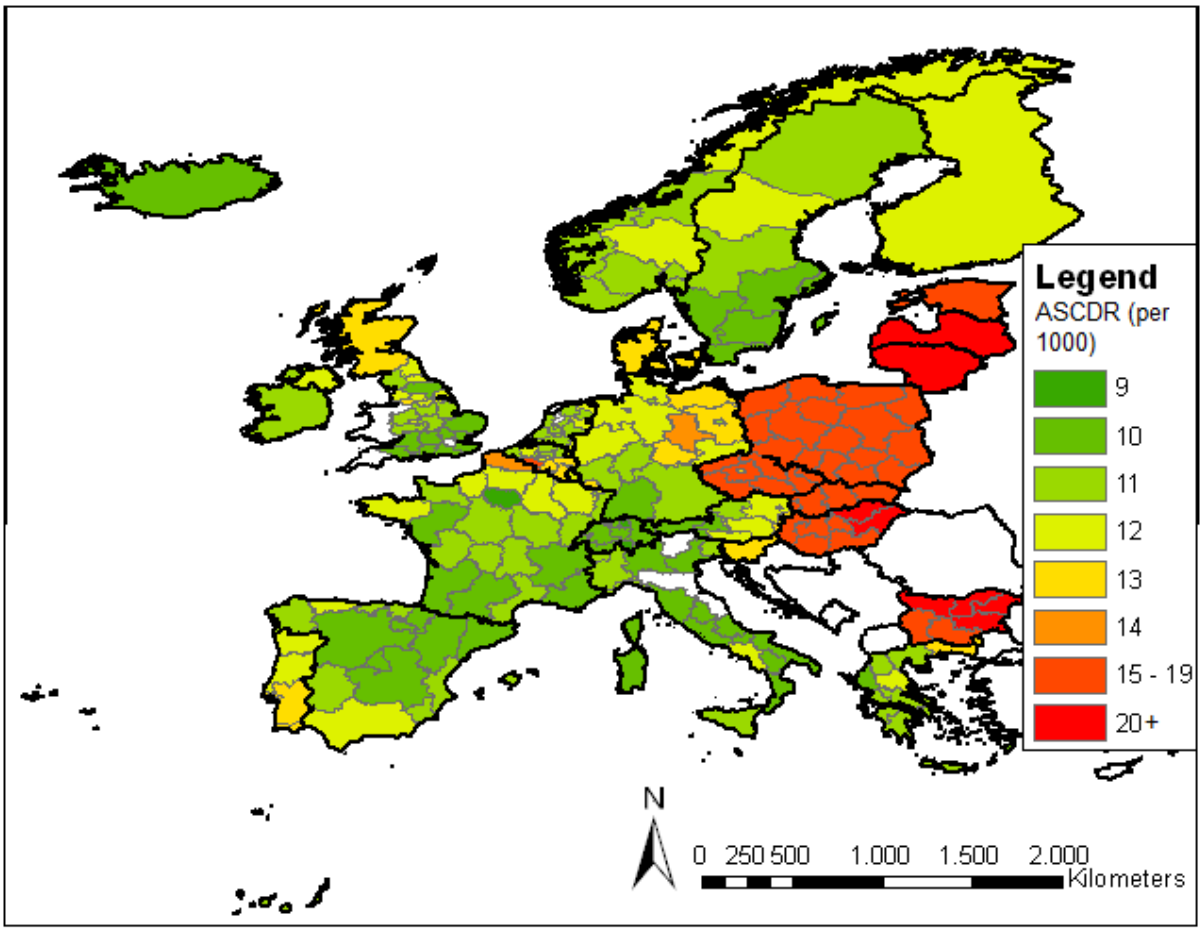
Source: WHO (2010)

Appendix 2a: Age standardised Crude Death Rate (per 1000) for 224 regions in Europe, 2008-2010, females



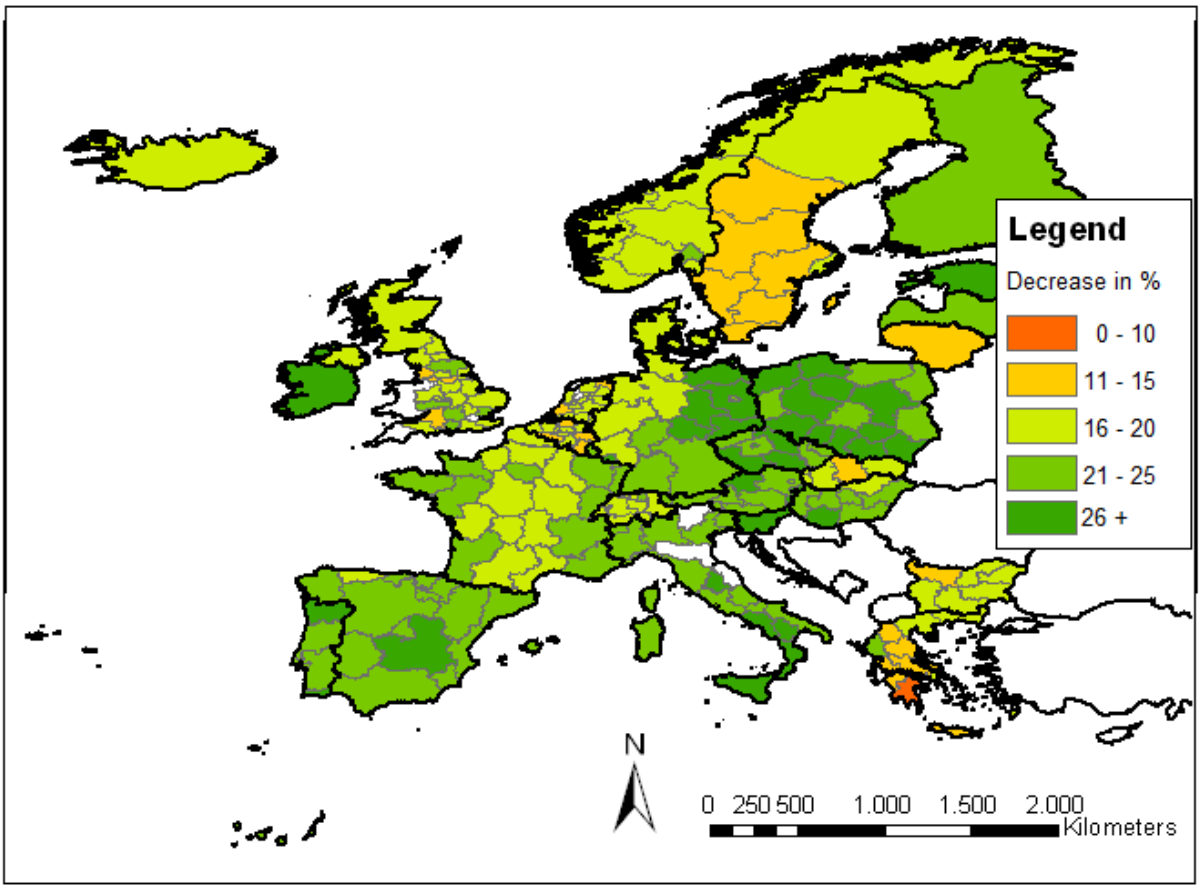
Source data: Eurostat (2014a).

Appendix 2b: Age standardised Crude Death Rate (per 1000) for 224 regions in Europe, 2008-2010, males



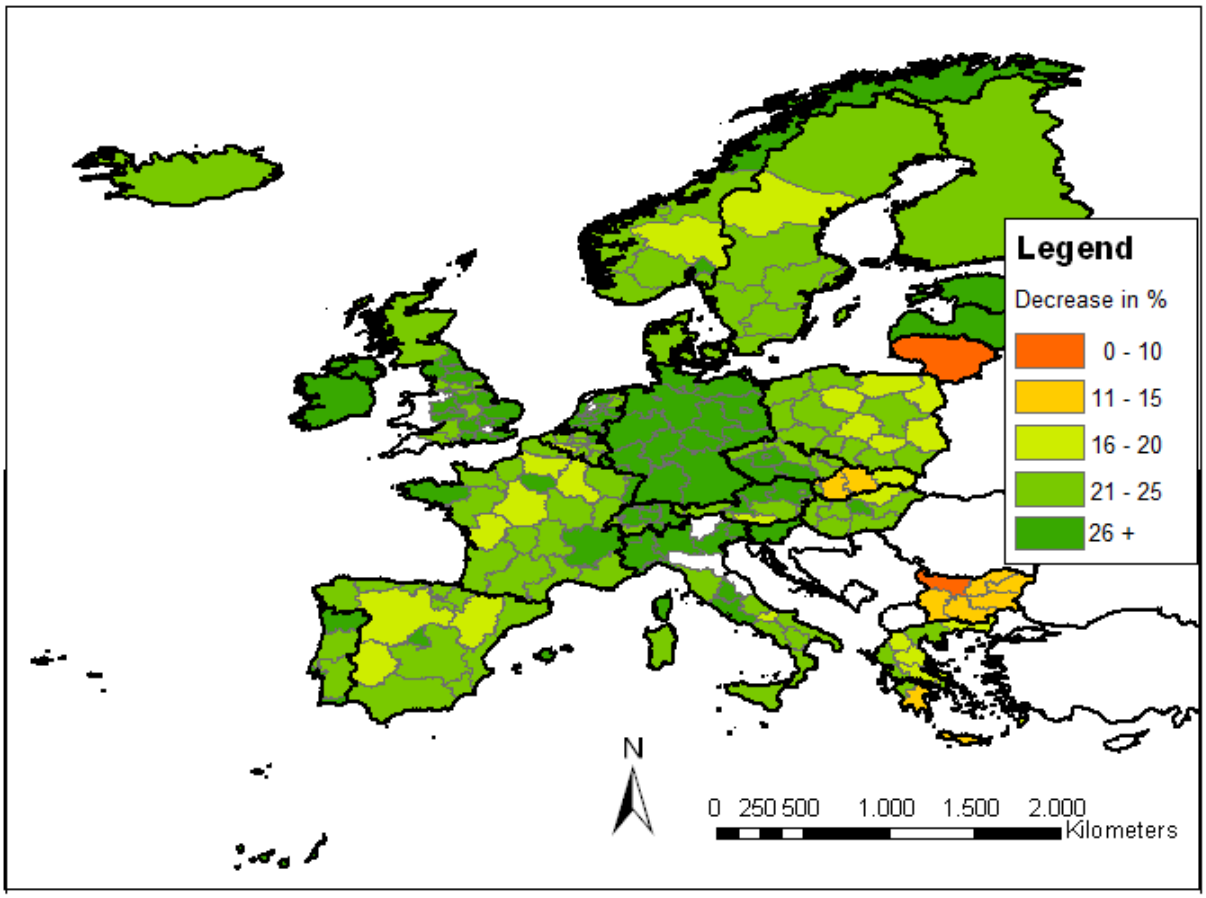
Source data: Eurostat (2014a).

Appendix 3a Relative change in age-standardised crude death rate (per 1000) for 224 regions in Europe, 1994-1996 to 2008-2010, females



Source data: Eurostat (2014a).

Appendix 3b Relative change in age-standardised crude death rate (per 1000) for 224 regions in Europe, 1994-1996 to 2008-2010, males



Source data: Eurostat (2014a).

Appendix 4: Decomposition of causes of death to changes in remaining life expectancy between 1994-1996 and 2008-2010 at ages 40+, 65+ and 85+

e^0=40			
Lung cancer	0.001	-0.089	0.248
Diabetes mellitus	0.025	0.055	0.011
IHD	0.809	0.704	1.027
Cerebrov. Disease	0.523	0.584	0.446
Pneumonia	0.126	0.128	0.102
COPD	0.059	0.009	0.131
Liver cirrhosis	0.041	0.051	0.093
Other	0.789	0.947	1.177
SUM	2.372	2.388	3.235
e^0=65			
Lung cancer	-0.007	-0.035	0.153
Diabetes mellitus	0.021	0.042	0.004
IHD	0.687	0.645	0.793
Cerebrov. Disease	0.523	0.561	0.428
Pneumonia	0.141	0.137	0.112
COPD	0.065	0.016	0.139
Liver cirrhosis	0.018	0.027	0.040
Other	0.651	0.644	0.773
SUM	2.099	2.037	2.441
e^0=85			
Lung cancer	0.009	-0.012	0.002
Diabetes mellitus	0.007	-0.020	-0.021
IHD	0.388	0.224	0.193
Cerebrov. Disease	0.458	0.350	0.267
Pneumonia	0.187	0.147	0.125
COPD	0.050	0.002	0.047
Liver cirrhosis	0.008	0.005	0.007
Other	0.808	0.042	0.159
SUM	1.915	0.738	0.779