LISBON
SCHOOL OF
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MASTER

MASTER'S IN ACTUARIAL SCIENCE

MASTER´S FINAL WORK

DISSERTATION

NEW INSIGHTS INTO MORTALITY AND LONGEVITY
THE CASES OF FRANCE, CZECH REPUBLIC, AND USA

ANDREY UGARTE MONTERO

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Abstract

The idea that human lifespan is limited by our own biological condition seems to be very well accepted in all cultures, but this belief has not stopped human beings from trying to push the limits to extend life as much as possible. In this sense, the natural human desire to fight death has seen tangible results, changing throughout history the way humans live and die. Because of this, human intervention through science has led mortality to become a very dynamic phenomenon that is re-shaping societies and the challenges they face.

In this context, the main objective of this work is to create more knowledge on the dynamics behind longevity changes. France, Czech Republic and the United States haven been chosen as case studies. This knowledge focuses not only on quantifying the changes but also on estimating the attributable contributions for different age groups and mortality chapters, as defined by the International Classification of Diseases (ICD). In order to achieve this, an actuarial analysis of mortality data is carried out by making use of algorithms developed by Andreev (2002) and Arriaga (1984,1989) that allow to transform raw information into answers about the origin of the longevity changes experienced in these three countries.

Since this work is linked to a project developed by the author for the Society of Actuaries - the creation of the Mortality Analysis Calculator (MAC) – the following pages depict some of the questions that can be answered using MAC for every country with information available in the Human Mortality Database and the Cause of Death Mortality Database.

After providing all general details to understand the problem and the methodology used, an extensive analysis of results, separated in three chapters, is presented for the time period going from 1970 to 2012. Firstly, the estimated decomposition of changes in life expectancy at birth is analyzed for each country. After this, attention will be placed on the gender gap in life expectancy at birth: its evolution in time, and origin in terms of age groups and mortality chapters. Finally, in order to understand longevity evolution at a more senior age, the emerging concept of life preparancy is introduced and analyzed for the 25th percentile and age 60.

Keywords: mortality, longevity, life expectancy, life preparancy, gender gap, mortality chapter, Human Mortality Database, MAC (Mortality Analysis Calculator).

Resumo

A noção de que a vida humana está limitada pelas suas condições biológicas parece um facto aceite em todas as culturas, mas tal não faz com que o homem deixe de tentar prolongar a duração da sua vida tanto quanto possível. Nesse sentido, o desejo natural do homem de lutar contra a morte tem mostrado resultados tangíveis e, consequentemente, ao longo da história, a forma como o homem vive e morre. Ou seja, a intervenção e a vontade humana têm feito da mortalidade um fenómeno dinâmico, reformulando as sociedades e os desafios que estas enfrentam.

Neste contexto, o objetivo principal do trabalho é compreender melhor a dinâmica por detrás das alterações na longevidade. França, República Checa e Estados Unidos da América foram os países selecionados para o estudo. O objetivo em vista é não só quantificar as alterações, mas também estimar as contribuições atribuíveis aos diferentes grupos etários, em função da causa de morte e de acordo com a classificação das doenças estabelecida na *International Classification of Diseases (ICD)*. Para tal, com base nos algoritmos desenvolvidos por Andreev (2002) e Arriaga (1984,1989), foi efetuada uma análise atuarial que permitiu, a partir de dados em bruto, obter algumas respostas sobre a origem das mudanças na longevidade experienciadas nestes três países.

Uma vez que este trabalho foi desenvolvido a partir de um projeto do autor para a *Society of Actuaries* (a *Mortality Analysis Calculator* (MAC)), as páginas seguintes descrevem algumas das questões que podem ser respondidas por recurso à MAC, tendo por base a informação disponível nas bases de dados de cada país relativas à mortalidade e às causas de morte associadas (*Human Mortality Database* e *Cause of Death Mortality Database*).

Depois de descrito e identificado o problema bem como a metodologia aplicada, é apresentada uma análise exaustiva dos resultados, distribuída em três capítulos, para o período compreendido entre 1970 e 2012. No primeiro, são decompostas as alterações evolutivas da esperança de vida à nascença, por país. No segundo, dá-se especial atenção à forma como a diferença de género afeta a esperança de vida à nascença: evolução temporal em função do género e causa de morte. Por fim, no terceiro, com o objetivo de perceber melhor a evolução da longevidade nas idades mais avançadas, é apresentado e analisado o novo conceito de *life preparancy* para o percentil 25, à idade de 60 anos.

Palavras-chave: mortalidade, longevidade, esperança de vida, *life preparancy,* diferença por género, mortalidade por doença, *Human Mortality Database*, MAC.

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A mi familia, por siempre brindarme su apoyo incondicional y creer en mí. En particular, a mi madre por todo su trabajo y esfuerzo ¡Gracias por hacer de mi educación siempre una prioridad!

Ao professor Onofre: muito obrigado pelo apoio e todo o tempo investido neste projeto. Este documento não seria o que é sem a vossa dedicação e esforço por fazer-me dar o melhor de mim enquanto o escrevia.

To Dale Hall and Lisa Schilling from the Society of Actuaries for trusting me with this project, for their guidance, and for being very active collaborators throughout the development of MAC.

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Chapter I - Introduction

Understanding and explaining the sources of change in demographic indicators such as life expectancy at different ages has been in the interest of the scientific community for several decades by now. However, the topic starts gaining relevance now more than ever due to the financial complications that have affected, or are expected to affect, pension fund schemes and social security systems in general. Because of this, attention has increasingly turned to better understanding mortality, the patterns shown in the past, and how they have been evolving in time as a way of enhancing the scientific knowledge that will enable the community to better predict the future. In this sense, several authors, such as Andreev (2002) and Arriaga (1984,1989), have dealt with the mathematics behind these issues, presenting formulas that contribute to better understand the composition of changes of demographic indicators.

The Society of Actuaries (SOA) is one of the organizations making important efforts to create more knowledge and understanding about mortality and its evolution. In this context, they have supported the Human Mortality Database (HMD - https://www.mortality.org/) to work on the expansion of their information to include data about Cause of Death (COD), which has led to the creation of the Cause of Death Database (https://cod.mortality.org/). On one hand, in the case of the Human Mortality Database, the user has access to general mortality information from 40 different countries. On the other, the Cause of Death database provides more specific information about eight countries (referred to as of now as the "COD Countries"). These countries have in common high income levels, ranging from gross national income per capita of USD34.450 to USD63.980 (all corresponding to 2017 values in current US Dollars according to the World Bank Databank[1]). The COD information classifies deaths in one out of 92 possible causes, which are grouped in 20 mortality chapters (or groups of "similar" diseases) that are determined to "minimize the disruptions associated with revisions of the international classification system (ICD)" (Barbieri, 2017). These mortality chapters are presented in Table 1.1 and will be used extensively throughout this work.

In this sense, the following work analyzes in depth the changes in life expectancy at birth, the gender gap in life expectancy at birth, and life preparancy at age 60 at the 25th percentile (in Chapter II this concept is formally introduced). The main purpose of this work is to help enhance the comprehension of mortality changes and their origin. In order to achieve this, mortality variations are decomposed considering not only age, but also the different mortality chapters.

[1] https://data.worldbank.org/indicator/ny.gnp.pcap.pp.cd

Moreover, given the range of mortality indicators considered, the analysis captures a wider range of the phenomena, allowing the reader to understand mortality changes at young and senior ages, as well as the historical differences between men and women, and among countries. Because of this, this text is expected to contribute in the generation of knowledge about the dynamics of mortality and longevity in a way that is not normally seen: through a very thorough analysis considering the evolution in time of the indicators, temporal patterns and the historical change in the decomposition of those patterns considering factors such as age, cause of death and the relationship between them - all for very different nations. To the best of our knowledge, this has not been done before in one paper.

Table 1.1

	Mortality Chapter		**Mortality Chapter**
I	Certain Infectious Diseases	XI	Respiratory Diseases
II	Malignant Neoplasm	XII	Diseases of the Digestive System
III	Other Neoplasm	XIII	Diseases of the Skin
IV	Diseases of the Blood	XIV	Diseases of the Musculoskeletal System
V	Endocrine, Nutritional and Metabolic diseases	XV	Diseases of the Genitourinary System
VI	Mental and behavioral disorders	XVI	Complications of Pregnancy, Childbirth
VII	Diseases of the nervous systems	XVII	Certain Conditions in the Perinatal period
VIII	Heart Disease	XVIII	Congenital malformations/anomalies
IX	Cerebrovascular Disease	XIX	Ill-defined or unknown
X	Other Disorders of the Circulatory System	XX	External Causes

Source: Barbieri, 2017

This thesis portraits the type of analysis that can be done with the Mortality Analysis Calculator (as of now referred to as MAC), a programmed tool that the author developed to analyze mortality information from the HMD and COD databases as part of a parallel and related project carried out for the Department of Research of the Society of Actuaries. This tool is also one of the original elements involved in this work since it may be the first time that such an application is developed.

In order to provide a deeper analysis of each variable, the work will focus on analyzing the previously mentioned phenomena for three different countries: France, Czech Republic, and the United States of America. These three nations were selected because of three major reasons: they belong to the group of COD countries, they cover the entire range of gross national income of the group, and they have populations with three very different sizes. On one hand, Czech Republic is the country with the lowest income in the COD countries (USD 34.450), France is very close to the COD countries' mean (with an income of USD43.790), and the United States is very close to the upper limit with its income of USD60.200. On the other, Czech Republic had an estimated

population of 10.58 million in 2017, whereas France had 66.95 million inhabitants and USA had 325.7 million. Having such diverse characteristics, it is enriching to study how the indicators of interest have evolved in time according to each geography.

The information available in the Cause of Death Database goes from 1959 to 2013 for USA, 1958 to 2012 for France, and 1968 to 2013 for Czech Republic. In order to make the results comparable, a common time interval for all three countries is necessary. Because of this, to break the timeline in three equidistant periods with information available in all three countries, the following analysis goes from 1970 to 2012, dividing the time horizon from 1970 to 1984, from 1984 to 1998, and from 1998 to 2012.

The following chapter (Chapter II) will focus on providing not only some context to understand the research problem, but also all the necessary concepts and formulae to comprehend the methodology used. Regarding the metrics of interest, attention is first placed on analyzing the changes in life expectancy at birth as presented in Chapter III. Secondly, an analysis of the gender gap in life expectancy at birth is presented in Chapter IV. Finally, in Chapter V, the concept of life preparancy at age 60 at the 25th percentile is presented and analyzed more in depth. Chapter VI highlights the general conclusions obtained from the work.

Chapter II - Background

2.1- Understanding the problem

Humans have long been collecting mortality information attempting to use it to improve the future quality of life. Today, more than ever, understanding mortality becomes relevant as some countries start to face the consequences of mortality changes and the world heads towards having a much older population.

In this context, the concept of life expectancy is one of the most popular to use when analyzing mortality, and - in general - it is taken as an indicator of human health due to its capacity to "summarize mortality in a single measure" (Auger *et al.*, 2014). Whether a researcher uses this indicator or any other, it is evident that mortality improvements are real in most of the world, leading people to live longer.

For example, by 2017 the amount of people who were 60 or older had doubled in the world (when compared to 1980) after reaching 962 million, and it is expected that their number worldwide will amount to over 2 billion by 2050 (United Nations, 2017). In addition, global life expectancy at birth for both sexes went from 66.5 years in 2000 to 72 years in 2015 according to the World Health Organization (2019).

However, this is not a phenomenon that has appeared in recent times only. For example, in the developed economies, the improvements in life expectancy have been present since 1850 (Rischatsch *et al.*, 2018), and increases in longevity are not limited to rich nations. Even though the length of human life still shows discrepancies based on geography and levels of social and economic development, the gaps in life expectancy between developed and developing countries seems to be diminishing in certain regions (Rischatsch *et al.*, 2018). One reason for this is that, during the XXI century, life expectancy improvements have presented slowdowns in many developed nations (Office for National Statistics, 2018). It is believed that the magnitude of changes in life expectancy at a specific age is dependent on how high the indicator already is, responding to a sort of upper bound given by the biological limits of human life (Arriaga, 1984). This situation would eventually make it harder for countries with higher life expectancies - like in the case of the developed nations - to continue improving the indicator at the same pace registered in the past, but the trends are still unclear to determine if the slowdowns have come to stay.

Examples of individuals living really long lives are not uncommon. For instance, it was just in early 2017 that Emma Morano, back then the last person alive that had been born in the XIX century, died in Italy at age 117 (Hall, 2017). Moreover, there seems to be a growing interest in

the so-called “Blue Zones”: a selected group of places in the world with an extraordinarily high concentration of people living to ages over 100. According to the World Economic Forum (2017), Loma Linda in California (USA), Nicoya in Costa Rica, Sardinia in Italy, Icaria in Greece, and Okinawa in Japan are the members of this selective group that has driven researchers to try to understand the factors behind these high levels of longevity.

It becomes evident that, in general terms, people are enjoying a much longer life now than they were expected to decades ago. The drivers behind this, as well as the consequences of it, are of great interest to society. Longer lives come as very good news, yet they also bring important challenges to individuals, governments and even private organizations. Advanced ages can bring with them financial challenges, health complications, and an increasing dependency on other people to perform tasks that once were taken for granted.

In this context, actuaries have become protagonists in the search of solutions and contingency plans for countries to face the issues of having a much older population. The uncertainty of not knowing exactly how much further the improvements in mortality may go, and how deep the financial cost of the phenomena may be, has received the name of Longevity Risk, one of the key actors in the actuarial scene nowadays.

One of the main concerns about Longevity Risk is that it represents an aggregated risk that is non-diversifiable, magnifying its effects for the societies that face it (Rischatsch, 2018). It is at this point that understanding mortality becomes a key component of ensuring social and economic stability and development for the future. In particular, the stability of Social Security Systems can be in danger if the magnitude of mortality changes is not properly quantified and understood. Overestimating mortality improvements would lead to unfair prices to access health insurance, long-term care systems or defined benefit pension schemes whereas underestimating them could lead to the insolvency of these systems with all the implications coming from it. Actuarial Models, depending on its nature, can be very sensitive to mortality hypothesis. For example, the Organization for Economic Cooperation and Development has established that every year of additional life expectancy not accounted for in a model could generate liabilities from 3% to 5% higher (Rischatsch, 2018). Moreover, the Actuarial Association of Europe (2019) found that in this continent, in the context of its aging population, “costs are projected to rise in every country on health and long-term care spending. These projections depend not only on the population projections but also on how life expectancy increases translate into healthy life expectancy and how the demand for health and long-term care services evolve”.

Because of this, it is imperative to better understand the drivers of longevity changes in order to anticipate their future development. Even the gender gap that has historically characterized mortality is likely to show material changes in patterns. For example, Trovato and Heyen (2006) found that in the 1990s in six of the seven countries belonging to the denominated G7 (Japan being the one exception), the gender gap was narrowing. This puts in evidence that mortality dynamics are complex and in constant evolution, even in aspects that have traditionally been taken for granted, bringing on extra risk to actuarial models used for pricing and reserving.

2.2. Main Concepts Involved

2.2.1 Life Expectancy

Let T_x be the random variable representing the future lifetime of a life aged *x*. Then, we define life expectancy at age *x*, denoted as e_x, as

$$e_x = E[T_x] = \int_0^{\omega - x} {}_t p_x \mu(x+t) dt \,, \tag{2.1}$$

where

ω represents the maximum age attainable according to a life table

${}_t p_x$ represents the probability of survival for the next *t* units of time of a life currently aged *x*

$\mu(x)$ represents the force of mortality to which a life aged *x* is exposed

Intuitively, life expectancy at a certain age *x* is the number of future years a person is expected to live, given that they have reached age *x*. From (2.1), it should be clear that life expectancy at age *x* depends on the chances to survive in the future; i.e., for all other subsequent ages. Because of this, changes in life expectancy at age *x* can be explained not only by changes in the mortality levels of age *x*, but also by the mortality changes associated to all other posterior ages. This is one of the features that make life expectancy at birth a relevant indicator to summarize mortality in a country.

2.2.2 Life Preparancy

Life Preparancy is a concept that is believed to have been recently introduced by the Society of Actuaries to analyze longevity in a way that goes beyond average scenarios. As explained by Dale Hall, the concept is used to reinforce the idea of "retirement preparedness" over life expectancy "borrowing the comfortable sound of the phrase 'life expectancy' but also injecting the need for preparing for the future" (Hall, 2017).

For the purposes of this text and the Mortality Analysis Calculator, the concept of life preparancy for age *x* at the *z*-th percentile will be formalized as the age *y* satisfying

$$y: P(T_0 > y \,|T_0 \geq x) = 1 - z\,, \tag{2.2}$$

where T_0 represents the future lifetime at birth.

In this sense, life preparancy at age *x* at the *z*-th percentile should be thought of as the survival age of (1-*z)%* of the individuals who reach age *x.* As of now, in order to reinforce the fact that life preparancy levels depend not only on the age for which it is calculated, but also on the percentile used, life preparancy at age *x* at the *z*-th percentile will be denoted as $\lambda_{x,z}$ instead of *y*.

2.3. General Formulae

2.3.1 Calculation of Life Preparancy levels

Following standard actuarial notation, denote l_x the number of individuals surviving to age *x* from an initial cohort. For an age *x*, given the percentile *z*, let $l_x^z = (1-z)l_x$. Because mortality tables are given in discrete years of life, an interpolation becomes necessary in order to obtain a more exact estimation of life preparancy levels.

Since the objective is to find the survival age $\lambda_{x,z}$ of (1-*z)%* of individuals who have attained age *x*, denote $x_g = max\{a: l_a \geq l_x^z\}$ and $x_s = min\{a: l_a \leq l_x^z\}$. Then, let us define $\mathrm{d}_1 = l_{x_g} - l_x^z$, $\mathrm{d}_2 = l_x^z - l_{x_s}$, and $d = \mathrm{d}_1 + \mathrm{d}_2$. This way, life preparancy for age *x* at the *z-th* percentile (in a particular year) is computed as

$$\lambda_{x,z} = \frac{d_1}{d} x_s + \frac{d_2}{d} x_g\,. \tag{2.3}$$

Determining the levels of life preparancy is of critical importance not only to decompose the changes of the indicator between two specific points in time, but also to study its historical evolution. Notice that since life expectancy levels are already given in the information provided by the Human Mortality Database, there is no need to estimate this indicator for the life expectancy analysis.

2.3.2 Calculation of decomposition of changes

One of the main features of the Mortality Analysis Calculator (MAC) is that it decomposes the changes registered in a mortality indicator by the contributions attributable per age group and mortality chapter, when applicable. In order to decompose the variations, the tool makes use of algorithms already present in the literature, relying mostly on the contributions of Andrev *et al.* (2002) and Arriaga (1984, 1989).

2.3.2.1 Decomposition of the changes in a mortality indicator per age group

Consider the changes registered between years t_1 and t_2 ($t_2 > t_1$) in a mortality indicator estimated for a specific age *a*. When computing the attributable contribution to changes associated to an age/age group, the algorithm presented by Andreev *et al.* (2002) is used in the development of MAC. The original paper presents the formula to decompose changes between two periods in time, but in general it applies to compare two different "experiences" in an indicator - whether the change comes from time, gender or an ethnic group, for example. The notation presented here is slightly different from that used in the original paper, but the underlying principles remain intact.

Denote a mortality indicator - be it life expectancy or life preparancy - for age *a* as Ind_a. Then the attribution of change in the mortality indicator between years t_1 and t_2 at age a associated to a contributing age *x*, ${}^{a}_{x}\delta^{2-1}$, is given by

$$ {}^{a}_{x}\delta^{2-1} = \frac{l_x^2}{l_a^2}\underbrace{(Ind_x^2 - Ind_x^1)}_{Variation\ age\ x} - \frac{l_{x+1}^2}{l_a^2}\underbrace{(Ind_{x+1}^2 - Ind_{x+1}^1)}_{Variation\ age\ x+1} \quad , \tag{2.4} $$

where

l_x^j represents, for year t_j *(j=1,2)* the number of survivors aged *x*

Ind_x^j represents the level of the indicator for *x* in year t_j *(j=1,2).*

Let us analyze the formula more in depth: the terms underlined with brackets correspond to the variation (justifying the minus sign) registered in the indicator for ages *x* and *x+1*, respectively. As mentioned before, mortality indicators - such as life expectancy or life preparancy at a certain age *a* - contain information about that age and all posterior ages (*x* ≥ *a)*. Because of this, the difference $(Ind_x^2 - Ind_x^1)$ contains information about the change attributable to age x and all subsequent ages. By subtracting then $(Ind_{x+1}^2 - Ind_{x+1}^1)$ one is finally able to isolate the change attributable to age *x* (since we are removing the effect of all other posterior ages). Finally, notice how $(Ind_x^2 - Ind_x^1)$ represents the change in the indicator for one life, so multiplying by l_x allows to obtain the total change for all survivors to age *x*, and then dividing by l_a yields the proportion of change attributable to the lives that were alive at the age of interest *a.*

As established by Andreev (1982) and R. Pressat (1985), the result of computing ${}^{a}_{x}\delta^{2-1}$ for the decomposition by age does not necessarily have to be the same as that of $-{}^{a}_{x}\delta^{1-2}$, so they suggested to use instead ${}^{a}_{x}\delta = 0.5({}^{a}_{x}\delta^{2-1} - {}^{a}_{x}\delta^{1-2})$ to obtain the attributable contribution coming from age *x* to the change in the indicator for age *a*, so that

$$(Ind_a^2 - Ind_a^1) = \sum_{x=a}^{\omega} {}_x^a\delta \ . \qquad (2.5)$$

2.3.2.2 Decomposition of changes associated to causes of death

It is now of interest to compute the contribution of the evolution of causes of death in the mortality indicators. Just like in the previous section, consider ${}_x^a\delta$ as the contribution to change attributable to age *x* in the mortality indicator at age *a* between years t_1 and t_2. Assume that the environment is affected by *n* diseases, so that we denote the change in the indicator at age *a* between years t_1 and t_2 due to disease *i* (*i*=1,2,3,…,n) as ${}_a^i\alpha^{2-1}$. Following the reasoning in Arriaga's method, one can compute the change associated with disease *i* as

$$(2.6) \qquad {}_a^i\alpha^{2-1} = \sum_{x=a}^{\omega} {}_x^a\delta \ {}^i\Lambda_x^{2-1} \text{ with } \quad {}^i\Lambda_x^{2-1} = \frac{{}^iq_x^2 - {}^iq_x^1}{q_x^2 - q_x^1} \ , \qquad (2.7)$$

where ${}^iq_x^k$ denotes the mortality rate associated with disease *i* for age *x* during year t_k. Similarly, q_x^k represents the total mortality rate for age *x* (i.e, including all *n* diseases) during year t_k.

Analyzing the formula, it becomes evident that it distributes the changes in the indicator attributable to the different ages involved using the changes registered in mortality rates per cause. In this sense, ${}^i\Lambda_x^{2-1}$ is just the proportion of the overall change in mortality for age *x* that was registered between times t_1 and t_2 that is attributable to cause *i*.

Because of the nature of the formula, the underlying assumption is that the contributions to changes associated to a cause are directly proportional to the variations registered in the respective mortality rates.

Then, clearly $\alpha_a^{2-1} = \sum_{i=1}^{n} {}_a^i\alpha^{2-1} = \sum_{i=1}^{n} \sum_{j=a}^{\omega} {}_j^a\delta {}^i\Lambda_j^{2-1}$ is the overall change in the mortality indicator for age *a* between years t_1 and t_2.

When it comes to estimating the attribution of a disease *i* for a specific age *x* in the gender gap, it is common to use, instead of (2.7), the formula suggested by Arriaga (1989)

$${}^i\Lambda_x = \frac{{}_nFr_x^{i,F} q_x^F - {}_nFr_x^{i,M} q_x^M}{q_x^F - q_x^M} \ , \qquad (2.8)$$

with ${}_nFr_x^{i,G}$ denoting the proportion of deaths, between ages *x* and *x+n*, that were caused by disease *i*, out of all the deaths registered in the age group, for gender *G* (*G=F* for females or *G=M* for males). In this sense, formula (2.8) is adopted in the case of the gender gap.

Chapter III – Age Groups, Mortality Chapters, and Life Expectancy

As it will be shown in this chapter, life expectancy at birth has been evolving greatly in France, Czech Republic and United States. In all three countries life expectancy at birth has increased as mortality dynamics evolve at different stages of human life and the effect of diseases vary in time. In this chapter, the decomposition of changes in life expectancy at birth per age group was obtained using equation (2.5) whereas the contributions attributable to the different mortality chapters were calculated using equation (2.6) and (2.7).

3.1 Life Expectancy at Birth in France

France has experienced a sustained growth in life expectancy at birth in the period of interest. This indicator went from 68.37 years for males and 75.81 years for females in 1970 to 78.5 years and 84.85 years (respectively) in 2012. This represents a change of 10.13 years for males and 9.04 years for females in the entire period. These changes, however, did not occur in a "uniform" manner and can be explained in different ways along this time interval.

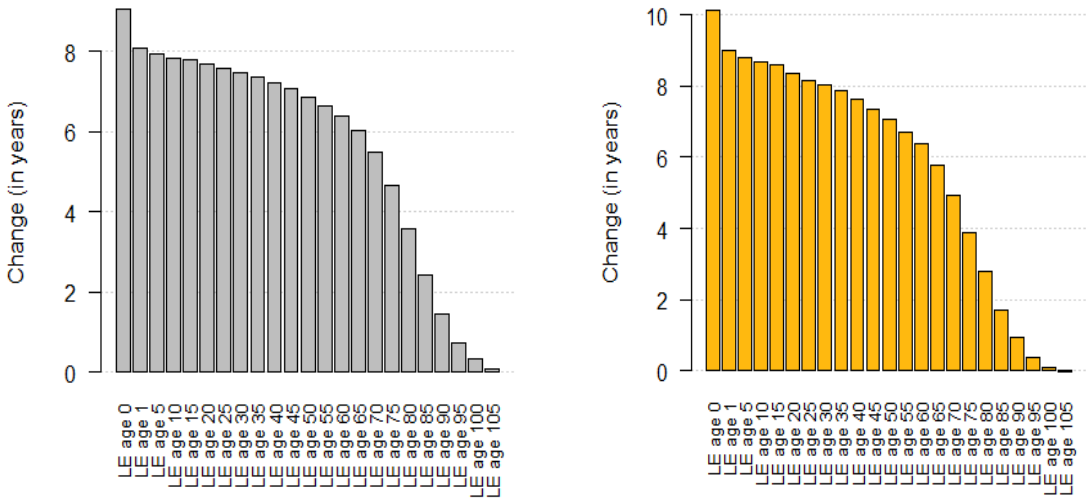

Figure 3.1. Changes in life expectancy (LE) for all age groups from 1970 to 2012. France. Females vs Males
Sources: Human Mortality Database and MAC

3.1.1 Period 1970-1984

During this term, females experienced a bigger increase in their life expectancy at birth, and registered a total change of 3.54 extra years against 2.77 extra years for males. Per age group, the changes experienced in life expectancy at birth during this period are characterized by a very important increase due to mortality changes at early ages. For example, the contribution to the

change attributed to the first year of life alone amounts to around 29% of the total change for males and 19% for females. In general, during this time period, when considering the changes attributable to ages younger than 65, mortality changes in these age groups contributed with almost 64% of the total increase (1.76 years) in the case of males whereas for females they amount to 51% (or 1.81 years). In the case of males, estimations show that only 1 year is attributable to changes in mortality at ages 65 and older (out of the 2.77 years), while the number increases to 1.73 years when considered the total change of 3.54 years for females. From this information, it seems that women at older ages saw a much more significant improvement in their mortality prospects than men, who were experiencing a greater mortality enhancement at young ages.

When analyzing the results and estimated changes attributed to the different mortality chapters, estimations show that the most relevant increment in life expectancy, for both genders, took place due to improvements in Cerebrovascular Diseases (Mortality Chapter IX). The changes in mortality due to this group of diseases represented an estimated improvement in life expectancy at birth of half a year for males and 0.64 years for females, between 1970 and 1984. Changes in mortality due to Heart Diseases (Mortality Chapter VIII) also played a central role in improving the indicator for both genders, but the effect is much higher in the case of females since it is estimated that women gained over half a year in life expectancy at birth (against 0.35 years for males). Similar results are obtained for Mortality Chapter XIX, Ill-defined or Unknown Causes, registering an improvement of 0.52 years for females and 0.38 years for males.

Moreover, Mortality Chapter XX - External Causes - including death due to accidents, homicides, poisoning, and the like, contributes considerably to the improvement in life expectancy at birth for men (0.34 years), but not for women (0.14 years). Finally, it is worth noting that results show an important decrease in life expectancy at birth for males due to Chapter II, Malignant Neoplasm, which caused an estimated loss in life expectancy of 0.55 years for men. Table A.1 in the annex shows all the details of the composition of changes in life expectancy per cause of death.

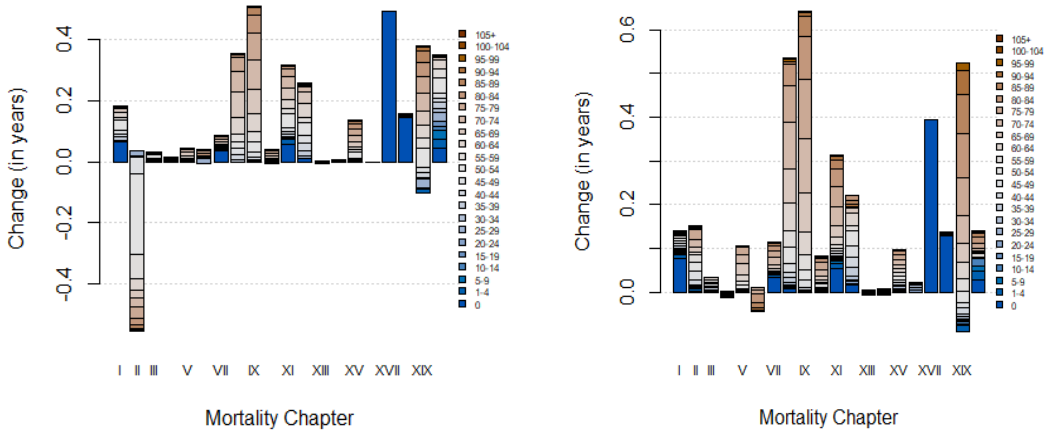

Figure 3.1.1. Contributions to changes in Life Expectancy at birth in France per Cause of Death and Age between Years 1970 and 1984. Males vs. Females.
Sources: Human Mortality Database, Cause of Death Mortality Database and MAC

Figure 3.1.1 shows the estimated changes in life expectancy at birth per mortality chapter for the time interval being analyzed. The overall size of the bars represents the total variations estimated (axis *y*) for the mortality chapters (axis *x*). Every bar is divided in smaller segments with changing colors, representing where the overall change comes from in terms of contributing age groups. When a particular bar has a section in both the positive and negative quadrants, it shows that some ages contributed to a decrease in life expectancy for that mortality chapter whereas other age groups contributed to a gain. An example of this is Mortality Chapter XIX for females (with an overall gain of 0.525 years).

3.1.2 Period 1984-1998

Contrary to what happened in the previous term, from 1984 to 1998 life expectancy at birth increased more for males than for females in France (with increments of 3.58 years for men and 3.06 years for women). The variation in life expectancy at birth attributable to each age group suffered several changes in structure: the contribution attributable to the first year of life decreased greatly in both absolute and relative numbers and represented less than 9% of the overall change in both genders. Moreover, between 1984 and 1998, the structure of changes is inverted per gender: the total change in life expectancy at birth for men coming from ages younger than 65 consists of 61% (2.18 years) of the total variation whereas 39% comes from ages older than 65. For women, it is the opposite, since 37% of changes (1.14 years) comes from age groups younger than 65 and 63% from seniors.

Regarding gains and losses in life expectancy at birth, it seems that from 1984 to 1998 France saw, with great success, improvements in the treatments of diseases of the Circulatory System, which caused Mortality Chapter VIII to improve the indicator in 0.72 and 0.73 years for men and

women, respectively. This puts in evidence an improvement in this cause of death much more significant than that registered in the previous 14 years. The estimated increases in life expectancy at birth attributable to Cerebrovascular Diseases, which had registered a very prominent role in the previous term for both genders, continue to be relevant. In this period, this mortality chapter placed itself as the second and third main cause contributing to the enhanced indicator for women and men (respectively). The estimations of gains due to this chapter yield half a year increment in life expectancy at birth for males and 0.66 years for females. The mortality experience registered during this period also suggests important improvements in deaths caused by external causes, completing the top 3 contributors per mortality chapter. In this case, the gain years in life expectancy are more relevant in the masculine case than in the feminine. These three causes of death are estimated to be responsible for about 52% and 59% of the overall change in life expectancy during this period. Figure 3.1.2 shows graphically this and other results.

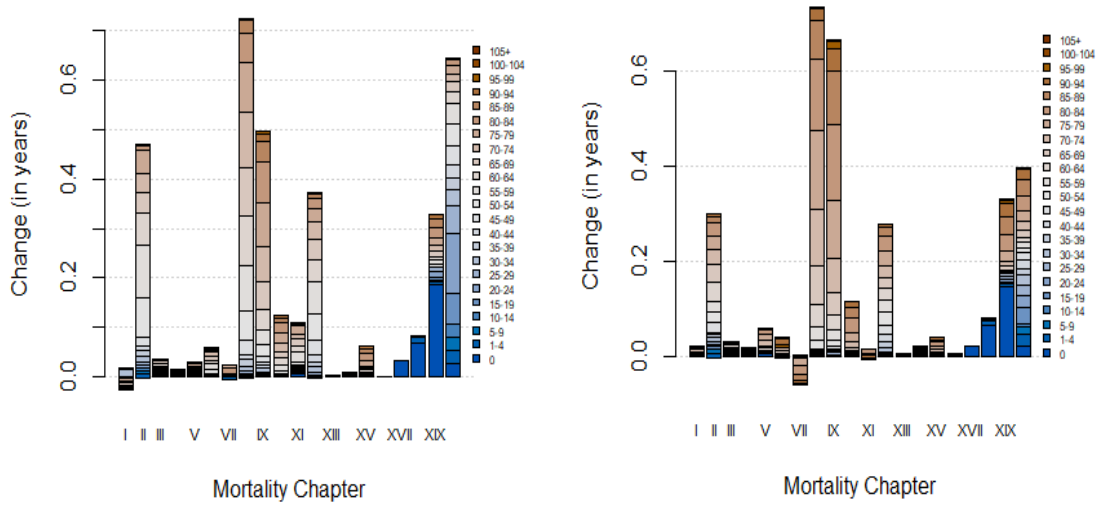

Figure 3.1.2. Contributions to changes in Life Expectancy at birth in France per Cause of Death and Age between Years 1984 and 1998. Males vs. Females.
Sources: Human Mortality Database, Cause of Death Mortality Database and MAC

3.1.3 Period 1998-2012

From 1998 to 2012, once again, the French saw an important improvement in their life expectancy at birth. By the end of this time period, like in the previous term, French men experienced a more significant increase than French women - men improved their life expectancy at birth in 3.78 years whereas women did so by 2.44 years. Moreover, not only did men see a more prominent improvement in the indicator for the second consecutive term, but also the difference when compared with the gains in the case of women are much more notable: 1.34 years higher than that of French women (as opposed to half a year of the previous term). This certainly contributed to a reduction in the gender gap, the difference in life expectancy between

males and females, but this phenomenon will be studied and explained more in depth in Chapter III.

The changes in life expectancy at birth during this period confirm the tendency detected previously: the improvements attributable to young ages start to lose relative importance as the mortality improvements start to come from the treatment and longevity of the elderly. During these 14 years, only 3% of the variation is attributable to changes in mortality of newborns for males (4% for females) whereas ages younger than 65 contributed with 47% of the overall change in the case of males and 30% in the case of females. Moreover, the variations attributable to senior ages amount to 2 years for males and 1.7 years for females. In this sense, the change in the structure becomes more relevant in the case of French men as they seem to keep up better with female mortality at older ages during this period.

During these years, life expectancy was primarily improved due to the influence of Mortality Chapter II, Malignant Neoplasm, which generated an improvement of 1.14 years in life expectancy at birth for men. The evolution of mortality due to Heart Diseases continued to affect positively life expectancy for both genders (with an estimated attribution of 0.87 years of increase in the indicator for men and 0.75 years for women). Deaths due to external causes (Mortality Chapter XX) also helped increase life expectancy at birth during this period. Improvements related to Respiratory Diseases started to be more prominent during this term whereas causes such as Mental Disorders and Nervous System Disorders (Mortality Chapters VI and VII) caused subtle decreases in life expectancy according to estimations.

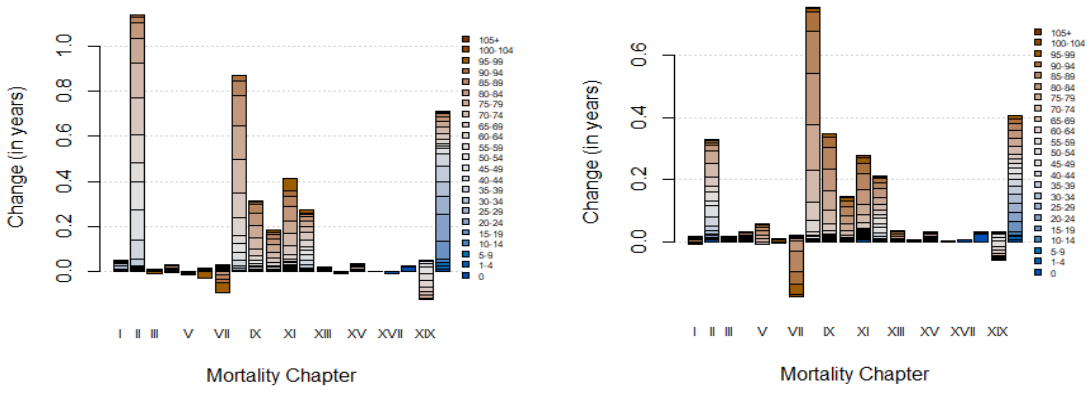

Figure 3.1.3. Contributions to changes in Life Expectancy at birth in France per Cause of Death and Age between Years 1998 and 2012. Males vs. Females.
Sources: Human Mortality Database, Cause of Death Mortality Database and MAC

3.2 Life Expectancy at Birth in Czech Republic

In the case of Czech Republic, life expectancy at birth increased 8.93 years for males and 7.99 for females between 1970 and 2012, going from 66.04 years and 72.99 years for males and females, respectively to 74.97 and 80.98 years. The causes of these variations, like in the case of France, seem to vary in time as mortality evolves per age and cause of death.

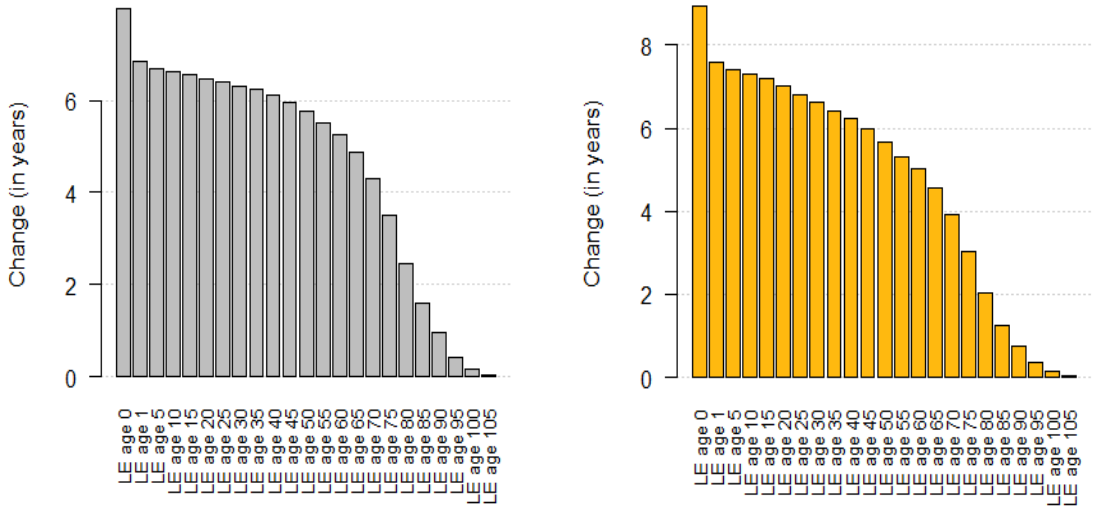

Figure 3.2. Changes in life expectancy (LE) for all age groups from 1970 to 2012. Czech Republic. Females vs Males.
Sources: Human Mortality Database and MAC

3.2.1 Period 1970-1984

The change in life expectancy at birth in Czech Republic from 1970 and 1984 was very similar for both genders and reached 1.3 years in the case of males and 1.51 for females. Around a year of the change is estimated to have been generated by mortality changes in age groups younger than 65, which causes age groups over 65 to contribute in a much less significant manner during these years.

Mortality improvements in respiratory diseases are estimated to be among the main drivers of the increase for Czech Republic during this period for both genders, generating an estimated gain in life expectancy at birth of half a year for males and 0.43 years for females. Another main cause of death contributing to the enhancement of the indicator is also shared by both genders: mortality changes originating in Mortality Chapter XVII, Conditions of the Perinatal Period, which increased life expectancy in 0.36 and 0.33 years for males and females, respectively, according to estimations. All this variation is attributable to age 0. Improvements related to deaths caused by accidents, homicides, suicides, poisonings and the like (as defined in Mortality Chapter XX)

contributed also in a great manner. This chapter is estimated to have generated 0.63 extra years of life expectancy at birth in the case of males (being the main cause explaining the increase in this case) and 0.19 extra years for females. Some chapters, however, are estimated to cause losses in life expectancy at birth for both genders during this time interval. Among them one finds Malignant Neoplasms and Deaths related to Other Circulatory Diseases (Mortality Chapter X), estimated to have contributed to a loss in life expectancy of 0.16 and 0.1 years for males.

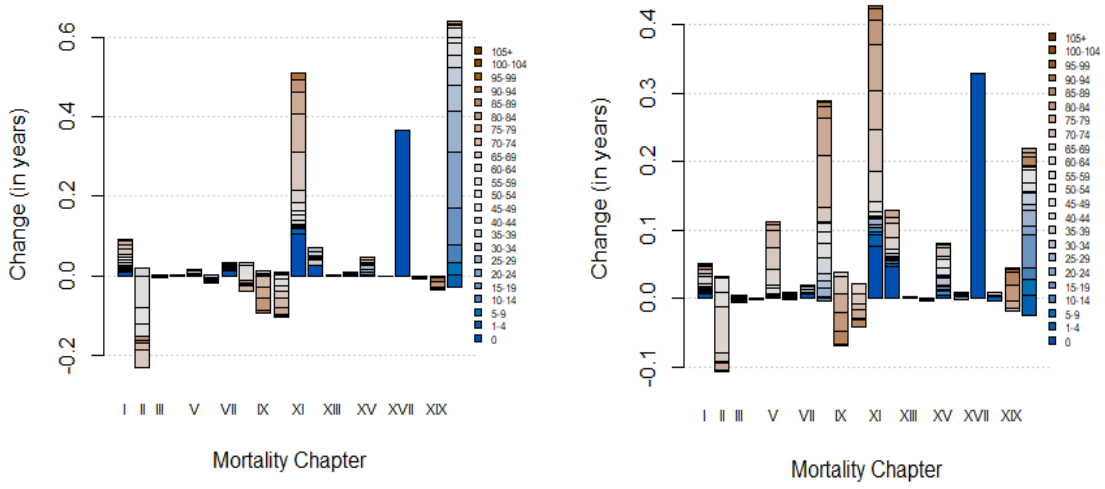

Figure 3.2.1. Contributions to changes in Life Expectancy at birth in Czech Republic per Cause of Death and Age between Years 1970 and 1984. Males vs. Females.
Sources: Human Mortality Database, Cause of Death Mortality Database and MAC

3.2.2 Period 1984-1998

Mortality improvements were much more significant during this fourteen-year period, which lead to a life expectancy increase of 3.71 years for males and 3.49 years for females. Again, mortality improvements for newborns are estimated to be the main driver in these changes, generating an estimated attributable life expectancy at birth of 0.72 years for males and 0.55 years for females. Despite this fact, age groups younger than 65 became, in relative terms, less "important" when compared to the previous period. Nevertheless, they continued to be the main driver in the change and their absolute contributions increased, generating 2.42 and 1.69 extra years in life expectancy at birth for men and women, respectively. This means that the contributions of changes in ages 65 and older represented only 35% of the variation in the masculine case but amount to 51% in the feminine.

When analyzing the changes per mortality chapter, the estimated main contributors seem to be different from the ones in the previous period. In the case of males, by far, mortality improvements in causes of death included in Mortality Chapter VIII, Heart Diseases, are the most relevant: they are estimated to have contributed with 1.10 years of extra life expectancy. These

improvements are registered mostly in ages from 45 to 74 years old. The influence of these groups is estimated to explain 0.83 years of the overall gains in this mortality chapter, showing that death rates associated to these causes improved greatly for adults mostly. Improvements in Cerebrovascular Diseases also seem to be central in the increase in life expectancy during this period. Their effect for men amounts to a gain of 0.67 years in the indicator. Respiratory diseases are also a major contributor in this case, generating 0.38 extra years of life expectancy at birth for males.

In the case of women, mortality improvements in Cerebrovascular Diseases are considered to be the main driver of the improvement in the indicator with an estimated effect of 0.89 extra years in life expectancy at birth. It's worth noting that 0.69 years out of total improvement come from mortality changes registered at ages over 65. Heart Disease comes second and generated an estimated 0.80 extra years. Conditions of the perinatal period also played a central role and caused an estimated increased in the indicator of over a quarter of a year.

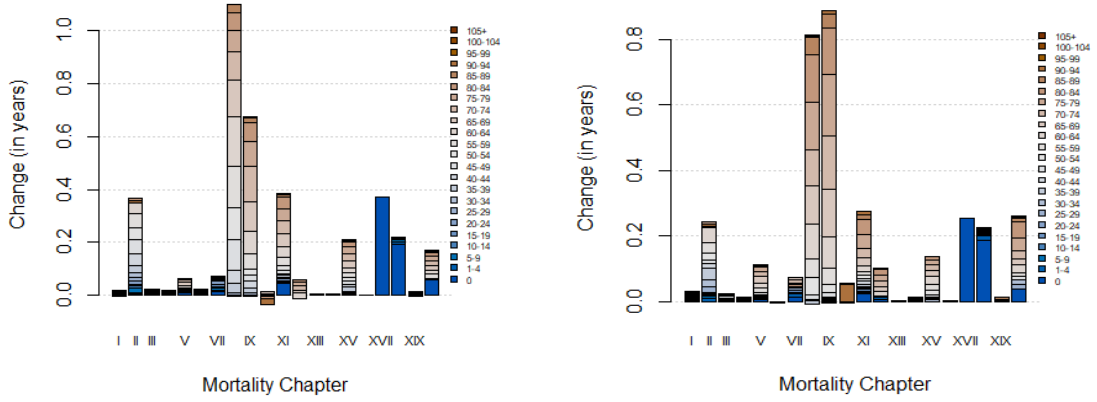

Figure 3.2.2. Contributions to changes in Life Expectancy at birth in Czech Republic per Cause of Death and Age between Years 1984 and 1998. Males vs. Females.
Sources: Human Mortality Database, Cause of Death Mortality Database and MAC

3.2.3 Period 1998-2012

From 1998 to 2012 life expectancy at birth in Czech Republic took another big leap (in fact the biggest in the entire period for males). The increase in life expectancy at birth during this time was 3.92 years for males and 2.99 years for females. Despite having registered a lower improvement in mortality at birth, the contributions of age groups younger than 65 continue to be the most relevant in the case of males, representing a total gain of 2.23 years out of the overall change (or around 57%). In the case of females, the changes attributable to these age groups have lost importance in overall terms and amounted to less than 36% (over one year) of the total variation. This evidence shows that women were already experiencing major mortality improvements in senior ages while men were still experiencing major changes in younger age

groups. In general terms, Czech Republic men seem to be slowly shifting to a pattern that should be more aligned with that of women in the years to come, but this shift seems to be happening at a much slower pace than with French men.

The effects registered per cause of death show subtle differences based on gender. Males increased their life expectancy at birth mostly due to improvements in mortality related to Malignant Neoplasms (generating 1.14 extra years out of which 64% is caused by age groups younger than 65). Heart Diseases also contributed greatly (0.88 extra years) whereas Cerebrovascular Diseases came third in importance (0.68 extra years).

For females, the main chapter contributing to changes is Cerebrovascular Diseases (0.92 additional years). Following closely, one finds Mortality Chapter X, Other Circulatory Diseases (0.88 years). Malignant Neoplasms close the group of the three major contributors, generating an estimated increase in life expectancy at birth of 0.66 years. Together these three Mortality Chapters explain 69% of the overall improvement in the indicator for males and 81% for females. In Table A.2 in the annex the detailed results are presented.

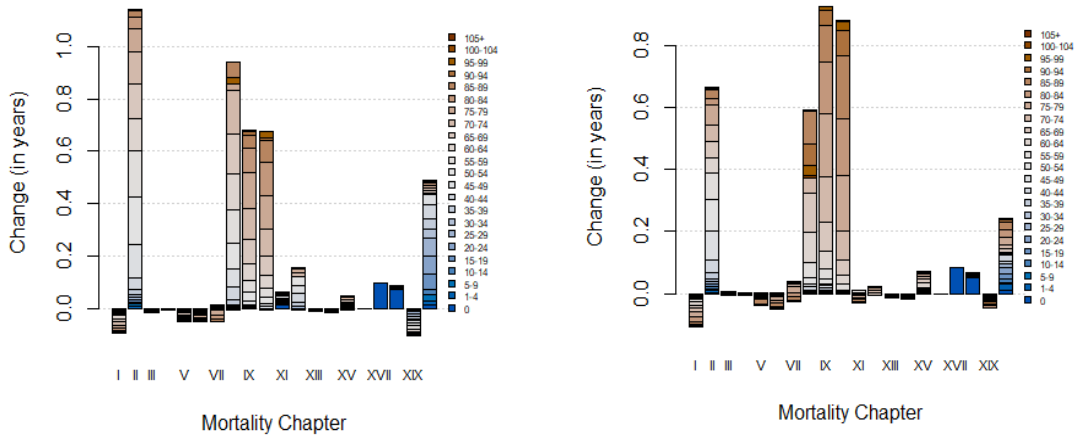

Figure 3.2.3. Contributions to changes in Life Expectancy at birth in Czech Republic per Cause of Death and Age between Years 1998 and 2012. Males vs. Females.
Sources: Human Mortality Database, Cause of Death Mortality Database and MAC

3.3 Life Expectancy at Birth in the United States of America

The United States saw their life expectancy at birth grow from 67.02 years for males and 74.65 for females in 1970 to 76.56 years and 81.34 years in 2012, respectively. One remarkable aspect about these changes is that, out of the three countries being studied, U.S. was the country to decrease the most the gender gap during this time period - aspect that will be analyzed more in depth in the following chapter. For now, just like in the case of France and Czech Republic, the focus will be placed on the sources of changes in life expectancy at birth.

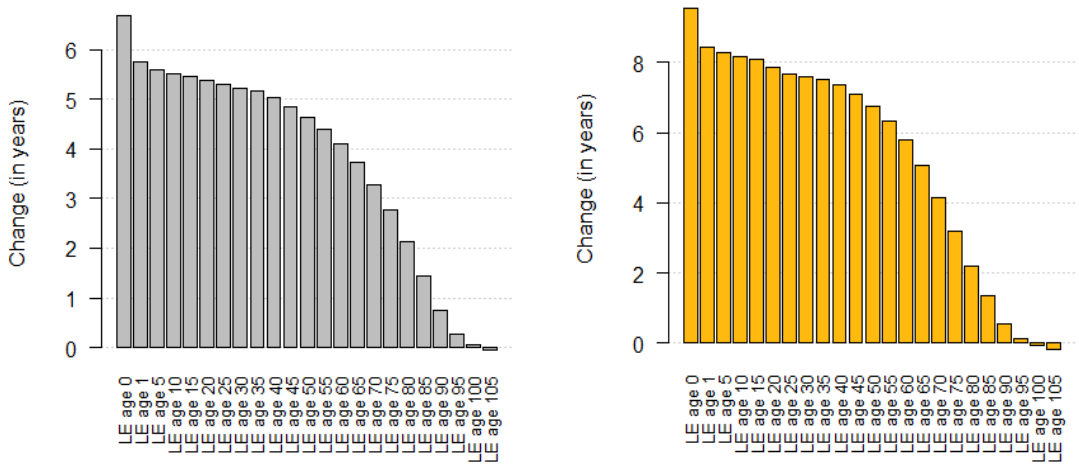

Figure 3.3. Changes in life expectancy (LE) for all age groups from 1970 to 2012. United States. Females vs Males.
Sources: Human Mortality Database and MAC.

3.3.1 Period 1970-1984

Life expectancy at birth in the United States experienced a great improvement from 1970 to 1984. The indicator for males increased 4.1 years and 3.52 years for females. By far, the most relevant change in mortality, attributed to a single age group, was the one registered at age 0, which is responsible for an estimated increase in life expectancy at birth of 0.8 and 0.66 years for males and females, respectively. Mortality changes at the age groups younger than 65 are responsible for most of the improvement in the indicator for this period in both genders, representing a total increase of 3.11 and 2.11 extra years of life expectancy at birth for US men and women. In the case of senior ages, the evolution was much less expressive during this period and amounted to an improvement in the indicator of 0.98 and 1.4 years, respectively.

A big part of the positive experience in life expectancy at birth in the United States during this period is estimated to have come from the country's success in fighting Heart Diseases, generating a reduction in deaths high enough to increase life expectancy at birth by 1.47 and 1.25 years for males and females. In the particular case of US women, the mortality reductions in Cerebrovascular Diseases and in Conditions of Perinatal Period contributed to increase life expectancy at birth by 0.75 and 0.43 years, respectively. For males, a very relevant improvement comes from a reduction of deaths related to accidents, homicides, suicides, poisonings and the like, which generated an additional 0.74 years of expected life at birth. Changes in mortality in conditions associated to Perinatal period also became a major contributor in the masculine case. The estimated decomposition of the changes in life expectancy per Mortality Chapter, for all chapters, is presented below.

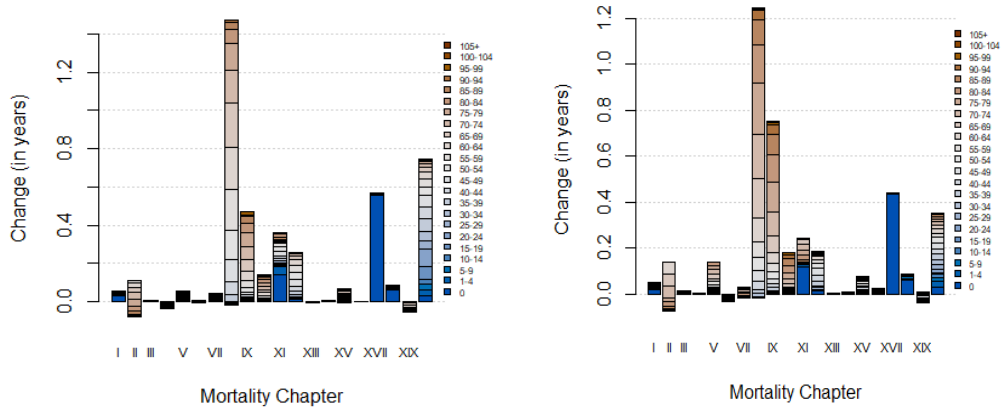

Figure 3.3.1 Contributions to changes in Life Expectancy at birth in USA per Cause of Death and Age between Years 1970 and 1984. Males vs. Females.
Sources: Human Mortality Database, Cause of Death Mortality Database and MAC

3.3.2 Period 1984-1998

This period was characterized by more modest increases in life expectancy at birth for the United States (2.69 year increase for males and 1.26 extra years for females). Out of the overall 2.69 additional years estimated for males, 1.66 years are attributable to mortality improvements registered for ages below 65. For females, these age groups represented 0.84 additional years of life expectancy at birth, out of the total 1.26 years. Because of this, during this time period, most improvements in life expectancy at birth are estimated to be generated by these "younger" age groups, representing in both genders over 60% of the overall change.

In general terms, the major improvement in life expectancy at birth, related to a mortality chapter, was gained in men due to a reduction of deaths caused by Heart Diseases (generating an increase of around 1.5 years). For females, the attributable effect of Mortality Chapter VIII is also the most relevant (one year in this period). Another relevant gain in the indicator is estimated to have happened in the case of men due to a reduction in the death rates associated to Mortality Chapter XX.

It is worth noting that Mortality Chapter XI, Respiratory Diseases, was responsible for a decrease in life expectancy at birth for females in the United States from 1984 to 1998, generating a reduction in the indicator of around a quarter of a year. This phenomenon explains a part of the advantage in favor of males registered during this period, which - together with the stronger improvement in mortality related to heart disease registered for males - explains about 0.75 years of the additional life expectancy gained by US men during this period, when compared to women.

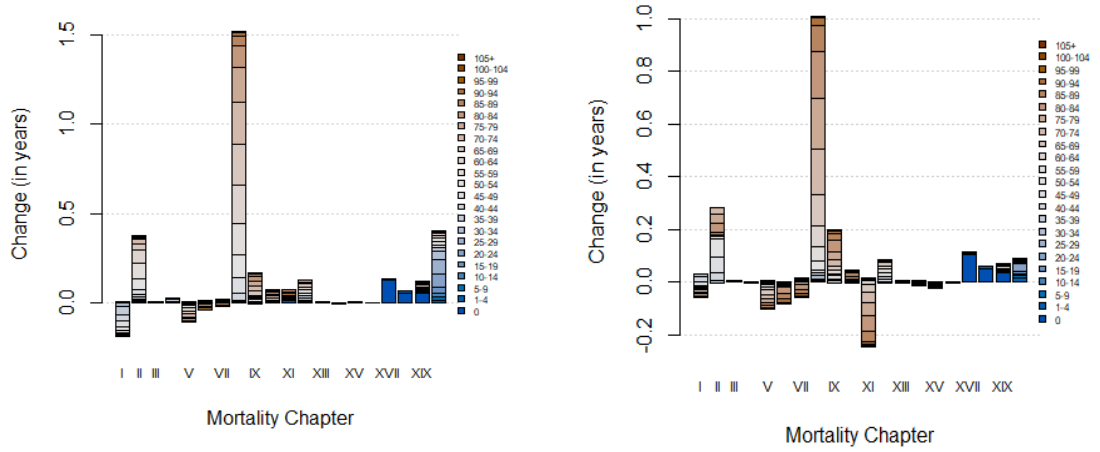

Figure 3.3.2. Contributions to changes in Life Expectancy at birth in USA per Cause of Death and Age between Years 1984 and 1998. Males vs. Females.
Sources: Human Mortality Database, Cause of Death Mortality Database and MAC

3.3.3 Period 1998-2012

In this term, increases in life expectancy at birth reached 2.75 and 1.90 years for males and females. These variations are much closer to those registered in the 1970-1984 time interval. However, during these years, USA seems to have entered a new stage in their life expectancy dynamics: one in which life expectancy at birth is driven by mortality improvements in senior ages, as treatments and prevention focuses more on retirees and individuals of more advanced ages. Mortality improvements in senior age groups are estimated to have contributed with 1.78 years of additional life expectancy for males and 1.32 years for females. This represents 65% and 69% of the overall change and shows a total shift in the pattern found previously. The fight against Heart Diseases and Malignant Neoplasms seems to be the main drivers of the increase in life expectancy at birth during this new phase. These two mortality chapters are, for both genders, the two main sources of gains. In the case of Heart Diseases, they are estimated to have increased life expectancy at birth by 1.25 years for US females and 1.36 in the case of males. In the case of Mortality Chapter II, Malignant Neoplasms, the effect is very similar for both genders, generating a gain estimated in 0.74 extra years of life for females (and 0.77 years for males).

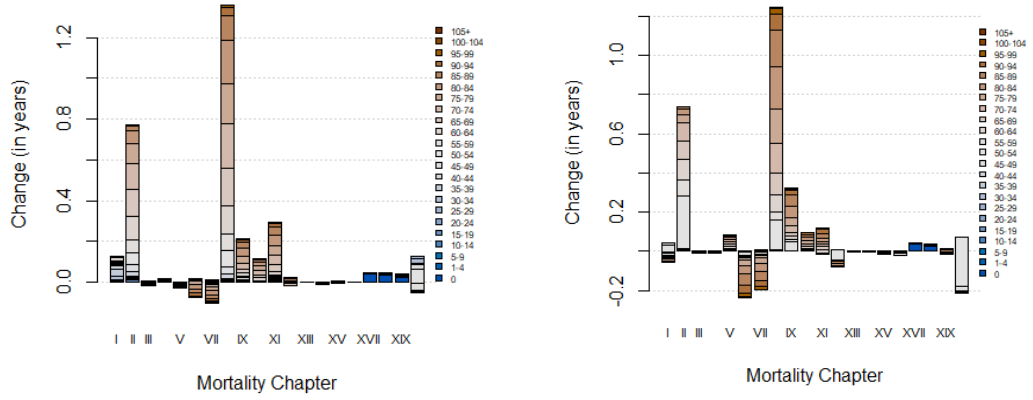

Figure 3.3.3. Contributions to changes in Life Expectancy at birth in USA per Cause of Death and Age between Years 1998 and 2012. Males vs. Females.
Sources: Human Mortality Database, Cause of Death Mortality Database and MAC

The detailed numbers of the decomposition of changes in life expectancy at birth in the USA are presented in the Table A.3 of the annex.

3.4 Some remarks

Judging by the findings in France, Czech Republic and United States, it seems that the evolution and increases in life expectancy at birth follows a tendency: improving mortality at birth is clearly an essential first step to enhance life expectancy in any country. Once this is achieved, countries move to improve survival at younger ages (say ages younger than 65) so that mortality is reduced for these age groups. Finally, they have just one way to continue to a more "advanced stage": once they reach a "high enough" life expectancy, improvements start to come from extending the life of seniors and reducing the effects of the diseases that affect them the most. It seems that women are the first segment of the population to reach this final stage in a country, but males are keeping up, seeing in general terms higher improvements in life expectancy at birth. France and United States seemed to be in this stage already for both genders by 2012. In the case of Czech Republic, women had reached this level while men still saw most increases in life expectancy at birth due to mortality changes in ages younger than 65.

Focusing only on four mortality chapters, one could explain at least 60% of the variations in life expectancy in the three countries. No matter the geography or gender, it seems that increasing effectiveness to reduce mortality related to Heart Diseases, Malignant Neoplasms, Cerebrovascular Diseases and External Causes have become the key to maintain increasing levels of life expectancy at birth from 1970 to 2012. In the case of French males, the influence of the reduction in mortality rates due to Diseases of the Digestive System has also played a major role in this time interval, gaining an estimated 0.89 years during the period. In the case of Czech

Republic, mortality chapter X has also become a very significant source of increases in life expectancy for females (0.90 years).

On one hand, from the results of this section, it is relevant to point out that USA was the country to decrease the most the gender gap in life expectancy at birth, reducing the difference in the indicator between males and females in 2.86 years from 1970 to 2012. On the other, Czech Republic decreased the gender gap the least out of the three country and registered a change of less than a year. This phenomena will be analyzed more in depth in the following chapter.

Chapter IV – Age Groups, Mortality Chapters and the Gender Gap

It is very well known that women have a higher life expectancy at almost any age when compared to men. The main objective of this chapter is to analyze those differences for the countries of interest and quantify the impact of the different age groups and mortality chapters in the generation of this gap. Doing so should allow actuaries to understand better the origin of the difference between genders and predict more accurately its future development.

Results in this section were obtained using equation (2.4) - where "experience 2" was that of females and "experience 1" that of males for the case of the decomposition of gender gap per age group, and equation (2.8) was used for the case of the decomposition of gender gap per cause of death.

4.1 The Gender Gap in France

In the case of France, the Human Mortality Database has information available since 1816. From it, it can be seen that the gender gap back in the 1800s was much less significant (around 2 years) in a context of very low life expectancy at birth (39.08 years for French males and 41.12 years for French females in 1816). By 1858, the gap was only 0.68 years according to the information available. From 1970 to 2012, the gender gap experienced many ups and downs, with levels ranging from 6.35 years to over 8 years.

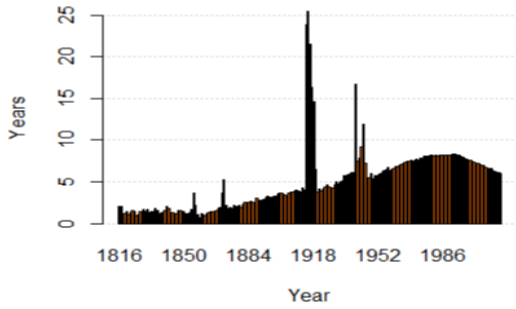

Figure 4.1.1: Historical Evolution of the Gender Gap in France
Source: Human Mortality Database and MAC.

4.1.1 Explaining the Gender Gap based on Mortality Chapters

In the time interval studied, Malignant Neoplasms were gaining relevance in the generation of the gender gap in France. This mortality chapter went from creating a gap of 1.43 years in life expectancy at birth in 1970 to 2.02 years in 2012. Its effect is highly concentrated in age groups over 50 years old. Mortality Chapter XX, External Causes, also belongs to the group of main generators of the gender gap, but its attributable effect shows a clearly decreasing tendency

(having decreased its effect from 1.63 years of gender gap in 1970 to 0.98 in 2012) and a much "younger component" than in the other major contributors. Finally, Heart Diseases also play a central role in this indicator, with an overall effect that went from 1.21 years of difference in life expectancy at birth between men and women to 0.99 years. The estimated contributions to the gender gap per mortality chapter can be found in Table A.4 of the Annex.

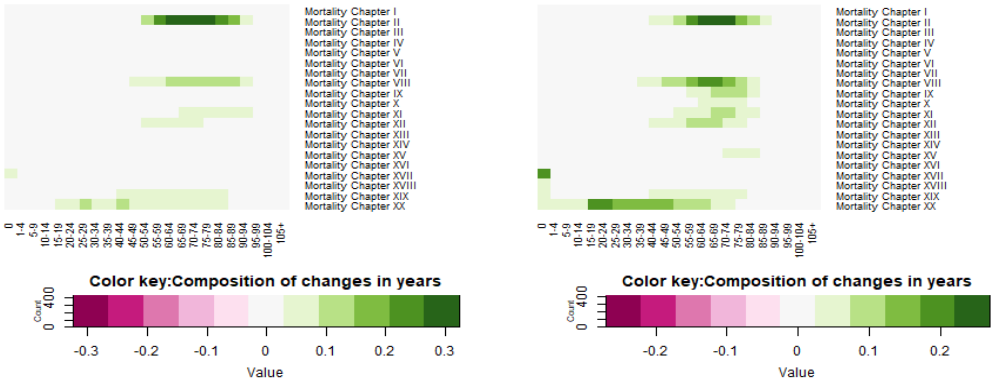

Figure 4.1.2: Attributable Contributions to Gender Gap in Life Expectancy at Birth in France, per age group and Mortality Chapter. 1970 vs. 2012
Source: Human Mortality Database, Cause of Death Database, and MAC.

Figure 4.1.2 shows the estimated decomposition of the gender gap considering not only age groups but also the mortality chapters involved. The magnitude of the contribution of an age group to the gender gap generated by a mortality chapter can be assessed by using the color key: the more intense the shade of green, the greater the contribution to an increase in the gender gap. In the case of the shades of pink, they indicate a contribution to a reduction in it.

4.1.2 Effects of Age Groups in the Gender Gap

In France, the gender gap is generated mostly due to differences in mortality at more advanced ages- trend that gets stronger as years progress. While the gender gap generated due to mortality differences at ages over 60 years old represented 50.5% of the total in 1970, by 2012 these age groups had generated an estimated 65.9% of the difference in life expectancy at birth between males and females. In the case of the attributions estimated to age 0, they have vanished in this period and went from representing 0.34 years of gender gap in 1970 to 0.06 years in 2012, which seems to highlight the fact that, more recently, male babies in France do not seem to be in a particular disadvantage in terms of survival when compared to female newborns. This was not necessarily the case in 1970.

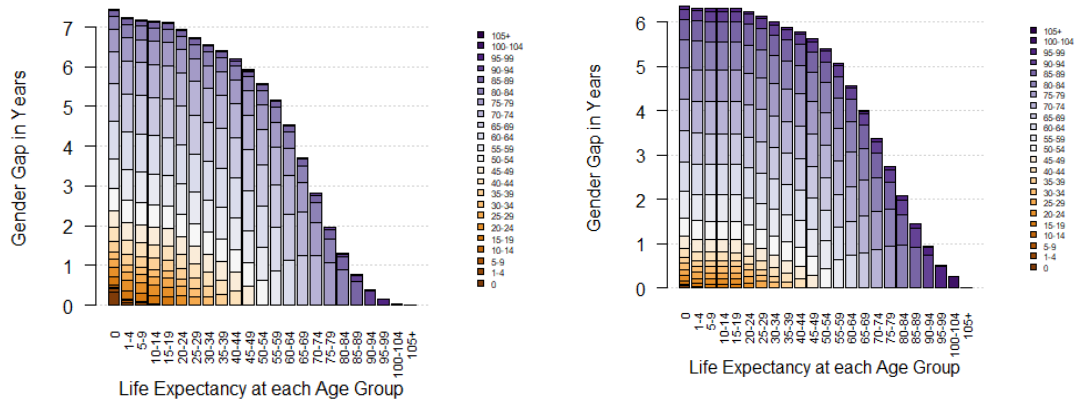

Figure 4.1.3: Attributable Contributions to Gender Gap in Life Expectancy at Different Ages in France, per age group. 1970 vs. 2012
Source: Human Mortality Database and MAC.

Figure 4.1.3 puts in evidence how the gender gap decreases gradually as individuals get older. It also shows how the gender gap has changed in overall terms from 1970 (when it reached 7.44 years) to 2012 (with a level of 6.35 years). The highly predominant shades of blue show how the gender gap in life expectancy at birth is mostly originated at advanced ages (notice how the color key of the contributing age groups is shown on the right of the charts for better understanding). It's also clear that younger ages are becoming less relevant when explaining the phenomena - as it can be interpreted from the less prominent shades of orange in the second chart.

4.2 The gender Gap in Czech Republic

The Human Mortality Database has information available from 1950 to 2017 for the Czech Republic. The minimum gender gap registered in the entire period was 4.79 years back in 1953, when life expectancy at birth was already above age 65 years for both genders. From 1970 to 2012, however, the indicator remained relatively stable. During this 42-year period, Czech Republic was not able to take the gender gap to levels below six years. While the difference between genders in life expectancy at birth was 6.95 years in 1970, by 2012 it was 6.01 years, which represents a decrease of only 0.94 years during the entire period. The levels of around six years in the indicator started in 1960 and, after that, they reached a maximum of 7.87 years in 1990.

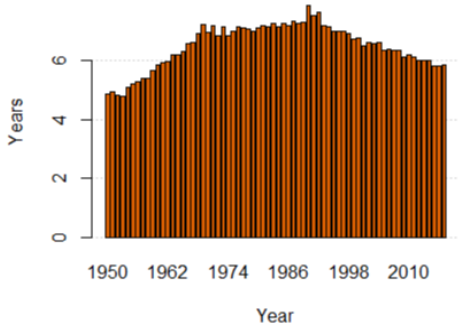

Figure 4.2.1: Historical Evolution of the Gender Gap in Life Expectancy at Birth in Czech Republic.
Source: Human Mortality Database and MAC.

4.2.1 Explaining the Gender Gap based on Mortality Chapters

Heart Diseases, Malignant Neoplasms, and External Causes generated most of the gender gap during the years of interest. In the case of Heart Diseases and Malignant Neoplasms, the gap is generated due to mortality differences between the genders at more advanced ages whereas for the case of Mortality Chapter XX the main differences between genders come from younger ages (see Figure 4.2.2). In the case of Mortality Chapter XX, a significant decrease is registered (going from 1.66 to 1.09 years). The attributable effect of Heart Diseases also shows a decreasing relevance, but not as large as in the case of Mortality Chapter XX (going from1.91 years in 1970 to 1.79 in 2012). Finally, in the case of Malignant Neoplasms, a small increase was registered in their estimated effect (1.26 years in 1970 *vs* 1.41 in 2012).

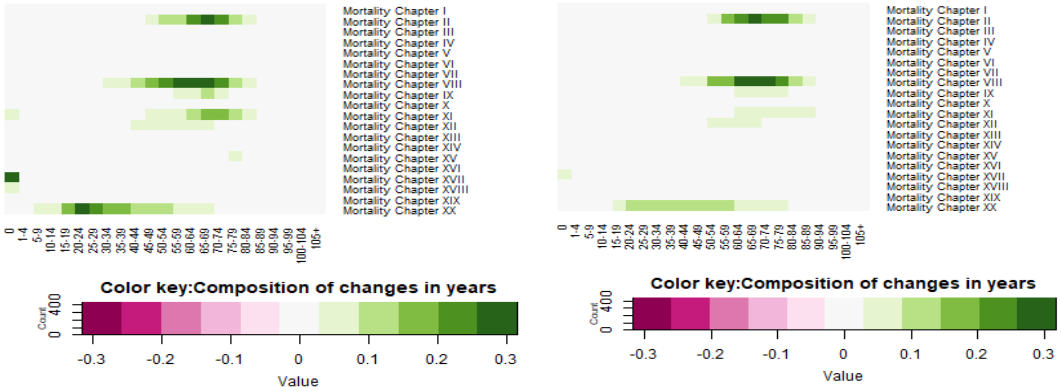

Figure 4.2.2: Attributable Contributions to Gender Gap in Life Expectancy at Birth in Czech Republic, per age group and Mortality Chapter. 1970 vs. 2012
Source: Human Mortality Database, Cause of Death Database, and MAC.

4.2.2 Effects of Age groups in the Gender Gap

From 1970 to 2012, the gender gap in life expectancy at birth in Czech Republic suffered a transition in terms of the age structure giving origin to it. The country went from having a gender

gap mostly explained by mortality differences at young ages in 1970 (when 54.4% of the indicator came from ages younger than 60) to a gender gap caused by mortality differences in seniors by 2012 (when 62.6% of the indicator is estimated to have come from ages over 60).

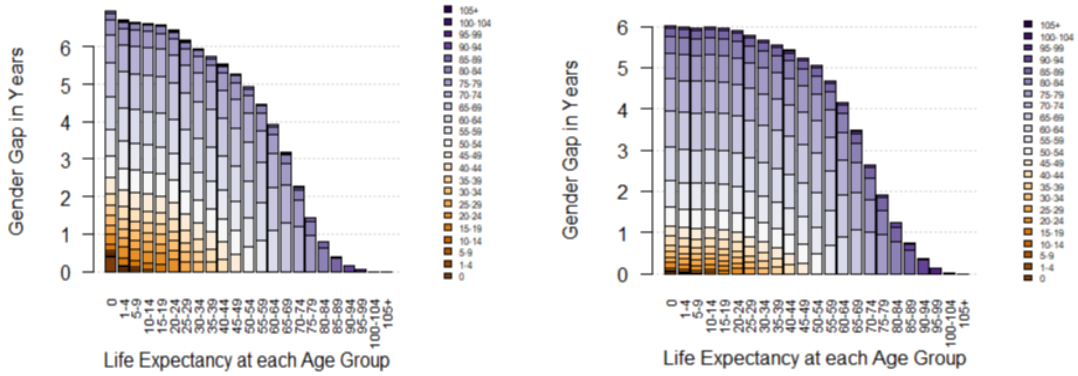

Figure 4.2.3: Attributable Contributions to Gender Gap in Life Expectancy at Different Ages in Czech Republic, per age group. 1970 vs. 2012.
Source: Human Mortality Database and MAC.

4.3 The gender Gap in United States of America

The gender gap in the United States of America has fluctuated greatly since 1933, first year with information available in the Human Mortality Database for this country. It reached a maximum value of 7.74 years in 1975 and a minimum of 3.61 years in 1933 (in a context of very low life expectancy at birth for both genders). In 1970, the gender gap in life expectancy at birth was 7.63 years, and by 2012 it had reached 4.77 years, which represents a reduction of 2.86 years, by far the highest reduction during the time interval analyzed in the three countries of interest.

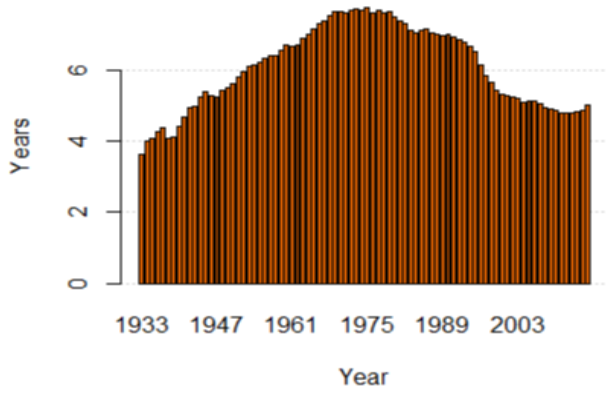

Figure 4.3.1: Historical Evolution of the Gender Gap in Life Expectancy at Birth in USA.
Source: Human Mortality Database and MAC.

4.3.1 Explaining the Gender Gap based on Mortality Chapters

In 1970, mortality chapters VIII, XX, and II were the main drivers of the gender gap in life expectancy at birth in USA. As in the case of Czech Republic and France, Heart Diseases were the major group of diseases contributing to this difference with 3.05 years, whereas External Causes came second with 1.97 years of gender gap and Malignant Neoplasms (Mortality Chapter II) came third with an estimated effect of 0.71 years. Reaching a very similar effect of that of Mortality Chapter II, one finds Respiratory Diseases, which were estimated to have contributed to the gap with 0.59 years.

As mentioned in Chapter II, estimations showed that a great deal of the reduction in the Gender Gap experienced from 1970 to 2012 in USA relates to the outstanding improvements men experienced in mortality due to Heart Diseases, which were much more prominent than the ones experienced by women. This phenomenon allowed men to increase their life expectancy more than women, which reduced the difference between genders. This is confirmed when performing an analysis of the gender gap: whereas Mortality Chapter VIII generated 3.05 years of gender gap in 1970, as mentioned before, its effect was decreased to 1.42 years by 2012. The estimated effect of respiratory diseases in the gender gap has also decreased greatly since it went from 0.58 years in 1970 to 0.25 years in 2012, being very close to the next major contributor, Mortality Chapter XII (Diseases of the Digestive System). The effect attributed to Mortality Chapter XX was also reduced and went from 1.97 years in 1970 to 1.44 in 2012. In the case of Malignant Neoplasms, its estimated effect increased to 0.80 years by 2012.

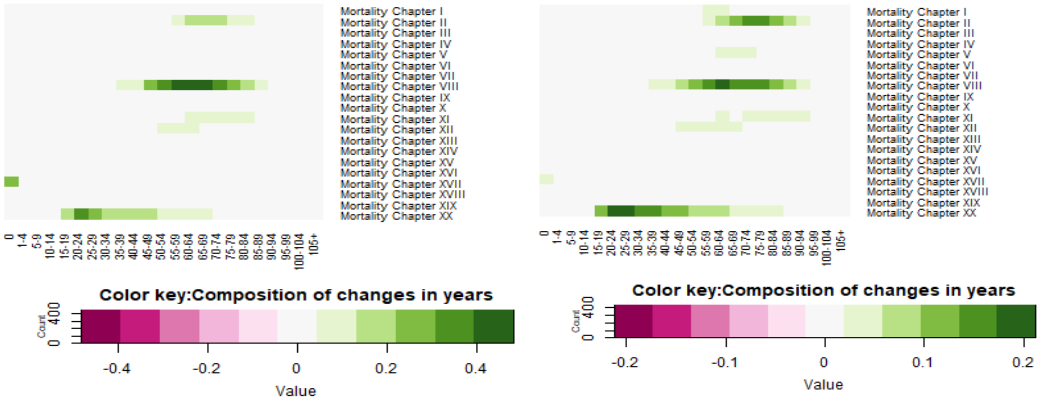

Figure 4.3.2: Attributable Contributions to Gender Gap in Life Expectancy at Birth in USA, per age group and Mortality Chapter. 1970 vs. 2012
Source: Human Mortality Database, Cause of Death Database, and MAC.

4.3.2 Effects of Age groups in the Gender Gap

In the case of the United States, it seems that the gender gap is a phenomenon that is more related to ages over 60, but this is not as evident as observed in the cases of Czech Republic and France.

The increasing influence of ages older than 60, very present in the other two countries, is not so visible here. Here the estimated contributions to the gender gap in life expectancy at birth coming from ages 60 and above represented 48.4% of the total in 1970, and it grew to reach 56.52% in 1984, but it remained almost constant by 1998 (56,9%), and slightly decreased to 54.73% in 2012. There still is a high concentration of effects in younger ages, mostly present in the accumulated effect of ages from 20 to 59 (which amount to around 1.92 years of gap).

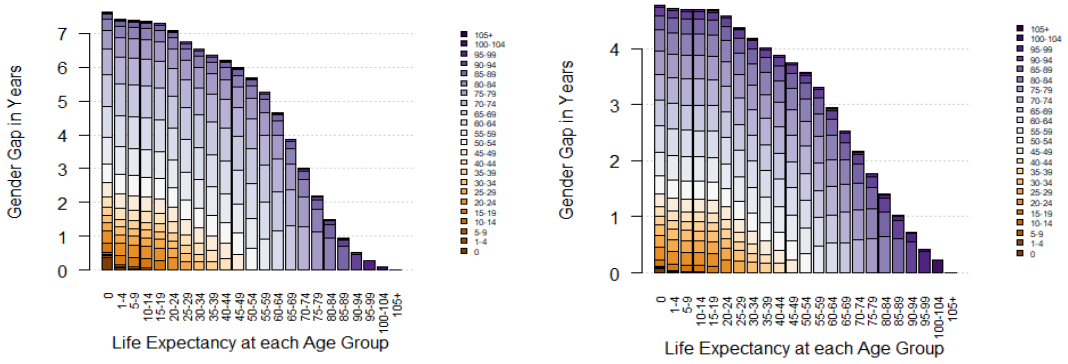

Figure 4.3.3: Attributable Contributions to Gender Gap in Life Expectancy at Different Ages in USA, per age group. 1970 vs. 2012
Source: Human Mortality Database and MAC.

4.4 Some remarks

The gender gap in life expectancy at birth has shown a tendency to decrease in all three countries when comparing its levels in 1970 with those of 2012. The magnitudes of the decreases differ significantly depending on the country, as it has been shown. However, all three countries have something in common: Heart Diseases, Malignant Neoplasms, and External Causes are among the main drivers when explaining the differences in life expectancy at birth between genders. Moreover, it seems that mortality differences at younger ages are no longer the most relevant factor when explaining the generation of the gender gap per contributing age group. Ages over 60 are gaining a more relevant role in the mortality differences between genders, and their importance seems to grow over time. This shows how women have more chances of survival, particularly when they have survived to advanced ages. By now, the gender gap originated due to mortality at birth seems to be nonsignificant. This is different from what was observed in 1970, when this component was among the highest contributors. Another factor becomes very evident: the effect on the gender gap of Mortality Chapter XX (accidents, suicides, homicides, poisonings, and the like) seems to be decreasing fast as shown in the analysis of the 42-year period. If this trend continues, the gender gap could see important reductions in the years to

come. This decrease could be more immediate since this mortality chapter is probably the only one not entirely responding to the development of medical treatments but to social factors.

Mortality Chapter XI, Respiratory Diseases, has also seen a remarkable decrease in its attributable effect on the gender gap in life expectancy at birth. Its highest remaining effect is registered in France (0.40 years estimated for 2012); its lowest, in USA (0.25 years), far from the experience registered in Czech Republic (0.38 years) .

Finally, in the previous chapter of this work it was mentioned that two phases seemed evident as societies move on to more "advanced" mortality patterns: firstly, an improvement of mortality at birth and at younger ages, and then an improvement of mortality at senior ages. This chapter puts in evidence what may be the third step in the cycle: developing enough medicine so that the mortality differences due to gender are reduced and eliminated. In this sense, at least in the case of Heart Diseases, the United States of America seems to be one step ahead.

The interested reader may find the detailed results of the estimated attributable effects of the different mortality chapters in the generation of the gender gap in Tables A4-A6 of the annex.

Chapter V - Age Groups, Mortality Chapters and Life Preparancy

It is now of interest to study more in depth the emerging concept of Life Preparancy. This chapter elaborates on the indicator and studies its evolution, emphasizing on the analysis of the decomposition of changes in Life Preparancy at age 60, at the 25th percentile. The detailed results are presented for this age in order to assess the variations of longevity experienced at a more advanced age, complementing in this manner the previous analysis presented using indicators at birth. Unless stated otherwise, in the next section, the concept of life preparancy at the 25th percentile for age 60 will be referred to as simply "life preparancy". Recalling again, this concept refers to the survival age of at least 75% of the lives in the population under study, given they had already attained age 60. More formally, the interest of this chapter is the analysis, for $z=0.25$, of the evolution of age y such that

$$y: \ Pr[T_0 > y | T_0 > 60] = 1-z$$

To compute life preparancy levels, the Mortality Analysis Calculator uses equation (2.3). For the decomposition of changes per age group equation (2.5) is used whereas equation (2.6) is used for the case of the decomposition per cause of death.

5.1 Life Preparancy in France at the 25th percentile

Life preparancy at the 25th percentile for age 60 in France is estimated to have been 69.34 years for males and 74.80 years for females in 1970. By 2012, the indicator had increased to 75.99 years for males and 81.94 for females, which represents an improvement of 6.65 and 7.14 years, respectively.

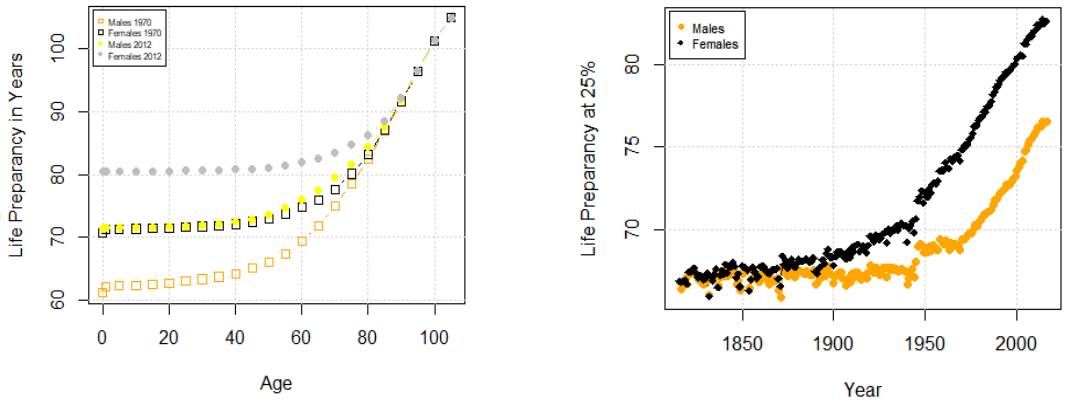

Figure 5.1: Life preparancy per age group and Historical Evolution of Life Preparancy for age 60 at the 25th percentile - France
Source: Human Mortality Database and MAC.

Using MAC and the information from the Human Mortality Database, in the case of France, it is possible to estimate historical life preparancy levels for years that go as early as 1816. Focusing on the indicator for age 60, one can see a series of ups and downs in the years from 1816 to the beginning of the XX century. After this, a much clearer increasing tendency starts appearing, in a more drastic manner for females than for males. This pattern becomes much more evident after the 50s for both genders.

Notice how Figure 5.1 puts in evidence how the improvements registered during the 42-year period studied have just been enough for men to reach the life preparancy levels that women already had in 1970.

5.1.1 Period 1970-1984

During the period that goes from 1970 to 1984, life preparancy increased 1.65 and 2.39 years for males and females (respectively), showing one more time women's biological mortality resilience. Even though the variations deferred significantly in magnitude between genders, the drivers seem to align. Cerebrovascular Diseases, Heart Diseases and deaths classified as Ill-Defined or Unknown (Mortality Chapter XIX) were the major drivers generating the increases for both genders. In the case of Cerebrovascular Diseases, they are estimated to have contributed to an increase in life preparancy at age 60 of 0.49 and 0.68 years for males and females respectively; Heart Diseases contributed with 0.35 and 0.51 years, and Mortality Chapter XIX with 0.33 and 0.48 years. It is important to point out that, in the case of males, a decrease of around 0.2 years in life preparancy was estimated because of the deterioration of mortality rates due to Malignant Neoplasms affecting negatively the experience of ages from 60 to 80 years old.

Figure 5.1.1: Decomposition of Changes in Life Preparancy at the 25th percentile for age 60 in France from 1970 to 1984. Males vs. Females.
Source: Human Mortality Database, Cause of Death Mortality Database, and MAC.

5.1.2 Period 1984-1998

The increases in the indicator continued and reached 1.97 and 2.73 years for men and women, respectively, during this period. Once again, the greatest increases in life preparancy are estimated to have been caused by improvements in mortality related to Heart Diseases (0.89 years for females and 0.58 years for males), Cerebrovascular Diseases (0.42 and 0.72 extra years for men and women), and Malignant Neoplasms (0.25 and 0.3 years for males and females). Moreover, Diseases of the Digestive System also contributed in an important way with estimated increases of 0.21 and 0.23 years for men and women.

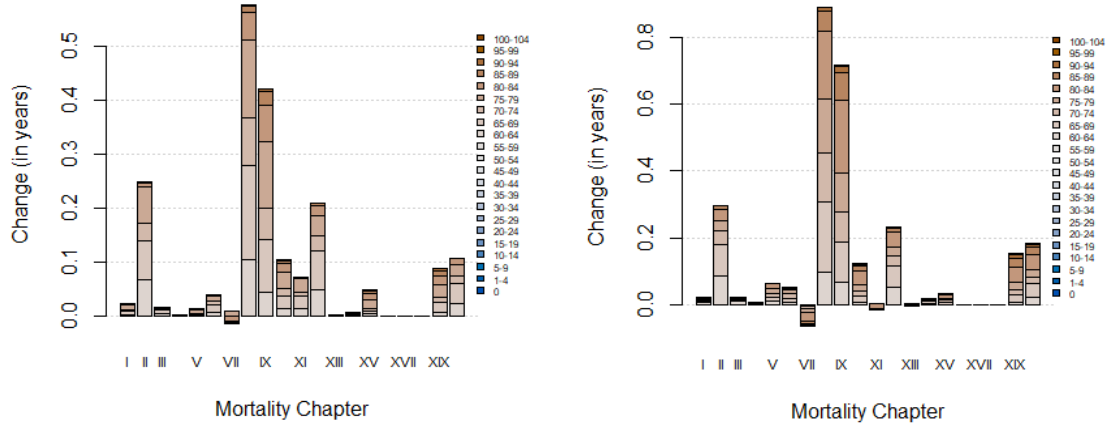

Figure 5.1.2: Contributions to Changes in Life Preparancy at Age 60 at the 25th percentile between Years 1984 and 1998. Males vs. Females. France.
Source: Human Mortality Database, Cause of Death Mortality Database, and MAC

5.1.3 Period 1998-2012

In this period, for the first time, life preparancy increases are much higher for males than females. On one hand, in the case of men, life preparancy went from a level of 72.96 years in 1998 to 75.99 in 2012, which translates into 3.03 extra years of life preparancy at age 60. On the other, for females, the indicator went from 79.92 years to 81.94 years, which corresponds to an increase of 2.02 years.

The main drivers in the gains in life preparancy for males are the improvement in mortality related to Malignant Neoplasms with an estimated effect of 0.95 years. In the case of females, Heart Diseases continued to be the main drivers of the increase, generating 0.82 extra years. This group of diseases also played a central role in the masculine case since it is the second most important mortality chapter affecting the indicator with an effect of 0.93 years - not very far from Mortality Chapter II. For females, the second main driver was Cerebrovascular Diseases. Finally, it is also relevant to point out at how the role of Respiratory Diseases, Mortality Chapter XI, gained importance in this term, being the third major cause of increases in life preparancy. The detailed results can be found in Figure 5.1.3.

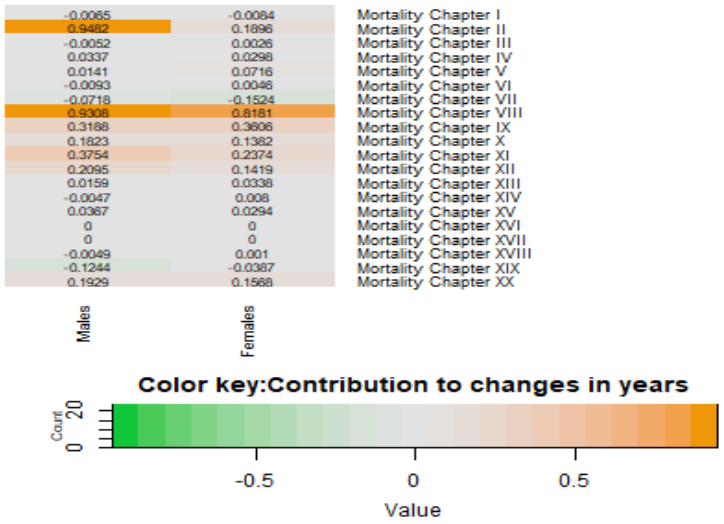

Figure 5.1.3: Attributable Changes in Life Preparancy at Age 60 in France between 1998 to 2012 at the 25th percentile.
Source: Human Mortality Database, Cause of Death Mortality Database, and MAC

5.2 Life Preparancy in Czech Republic at the 25th percentile

Using MAC and the information of the Human Mortality Database, the levels of life preparancy in Czech Republic can be estimated since 1950. In the case of males, the indicator stayed relatively constant at around age 68 until year 1990. In the case of females, life preparancy showed a slightly increasing tendency with ups and downs from 1950 to 1990. It is after the 90s that life preparancy at age 60 has shown a much clearer increasing pattern that has taken the indicator to age 72.36 for males and 78.25 for females in 2017.

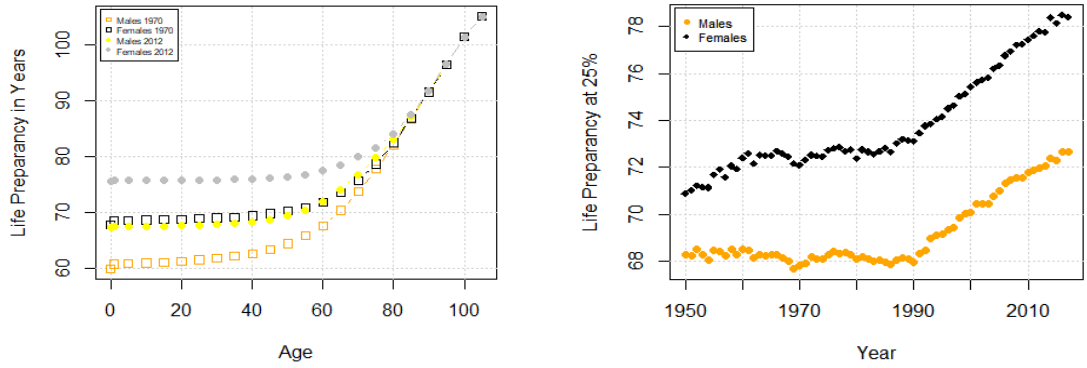

Figure 5.2: Life preparancy per age group and Historical Evolution of Life Preparancy for age 60 at the 25th percentile - Czech Republic.
Source: Human Mortality Database and MAC

More specifically, life preparancy at the 25th percentile for age 60 went from 67.69 and 71.92 years for males and females respectively, in 1970, to 71.87 and 77.45 years in 2012. This represents an additional 4.18 years of life preparancy for males and 5.53 years for females during

this term. The drivers of these variations vary in time and are presented in the following sections. It is also worth noting how, in Czech Republic, improvements have been just enough for males to reach the life preparancy levels that females had in 1970 (see Figure 5.2) as it happened in France as well.

5.2.1 Period 1970-1984

From 1970 to 1984, life preparancy in Czech Republic increased only 0.23 years for males and 0.53 years for females. In the case of males, in spite of a major increase in life preparancy due to the influence of Respiratory Diseases (0.57 years), the advancement in the indicator was minimum due to losses generated in other mortality chapters. In this sense, the second and third greatest effects respond to losses of life preparancy instead of gains, and they are caused by Other Circulatory Diseases (with an estimated effect of -0.196 years) and Heart Diseases (generating a loss of 0.194 years). In both cases, the major losses are associated to the contributions attributable to age group 60-64.

In the case of women, this time period was characterized by major increases in life preparancy due to mortality improvements in Malignant Neoplasms (0.62 years). Heart Diseases, opposite to what was observed for males, also generated a gain in the indicator (0.2 years). The third major effect is estimated to come from Mortality Chapter V (Endocrine, Nutritional and Metabolic Diseases) and corresponds to a decrease of 0.12 years. Following closely, one finds Respiratory Diseases and Diseases of the Digestive System generating losses not far from that of Mortality Chapter V (see Table A.13 in Annex for details). Again, the "most negative" attributable effects are linked to the experience of age group 60-64 whereas some adjacent age groups contribute with slightly positive effects that are not enough to outweigh the losses.

Figure 5.2.1: Decomposition of Changes in Life Preparancy for Age 60 in Czech Republic from 1970 to 1984 at the 25th Percentile. Males vs. Females.
Source: Human Mortality Database, Cause of Death Mortality Database, and MAC

5.2.2 Period 1984-1998

In this time period, life preparancy improved in a much more significant manner for both genders, registering increases of 1.93 years for males and 2.57 years for females, with most of the gains being explained by three different mortality chapters in the two genders. In the case of males, Heart Diseases contributed with an estimated increase of 0.71 years while Cerebrovascular Diseases come second with an attributable effect of over half a year (0.54). Lastly, Respiratory diseases generated an estimated increment of 0.24 additional years of life preparancy. Just these three Mortality Chapters alone explain 77.2% of the overall variation.

For females, the major drivers of change were Cerebrovascular Diseases, which have an attributable effect of 0.91 additional years of life preparancy. Heart Diseases come close generating an increase of 0.80 while mortality due to External Causes is estimated to have increased life preparancy in 0.19 years. Together these three groups of diseases explain around 73.92% of the overall change. It is also worth noting how Mortality Chapter XV, Diseases of the Genitourinary System, played an important role in the gains of life preparancy during these years for both genders, since mortality improvements in these diseases are estimated to have increased the indicator in around 0.12 years for both men and women during this term.

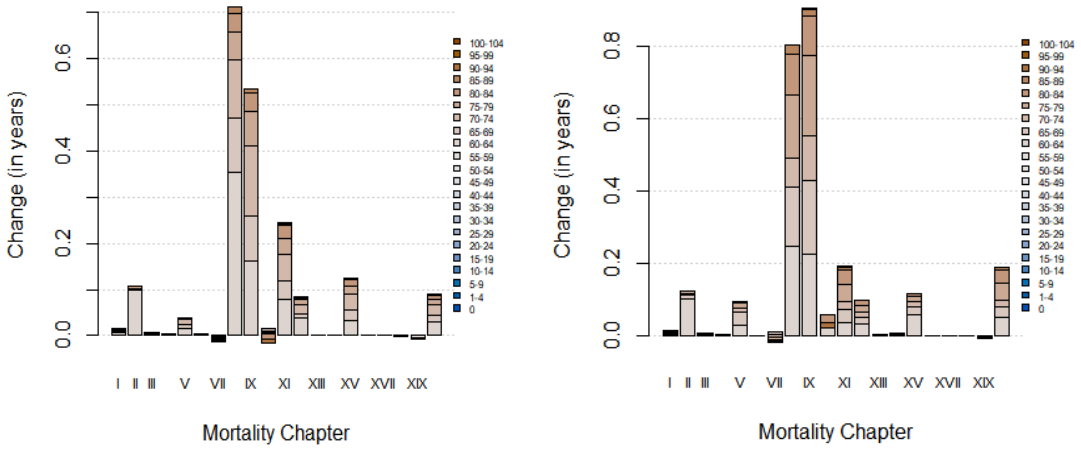

Figure 5.2.2: Contributions to Changes in Life Preparancy at age 60 at the 25th percentile from 1984 to 1998. Males vs. Females. Czech Republic
Source: Human Mortality Database, Cause of Death Mortality Database, and MAC

5.2.3 Period 1998-2012

Increases in life preparancy during these years registered levels of around two years for both genders (2.01 years for men and 2.43 years for women). In both cases, the improvements are estimated to come mostly from four different mortality chapters: Cerebrovascular Diseases, Heart Diseases, Other Circulatory Diseases, and Malignant Neoplasms. In any case, the total gains associated to these mortality chapters are greater than the overall change in life preparancy, since

the overall increment in the indicator is diminished by the effect of other mortality chapters that contributed to decreasing longevity like it is the case of Mental Disorders, Diseases of the Nervous System and Respiratory Diseases (see Figure 5.2.3 for details).

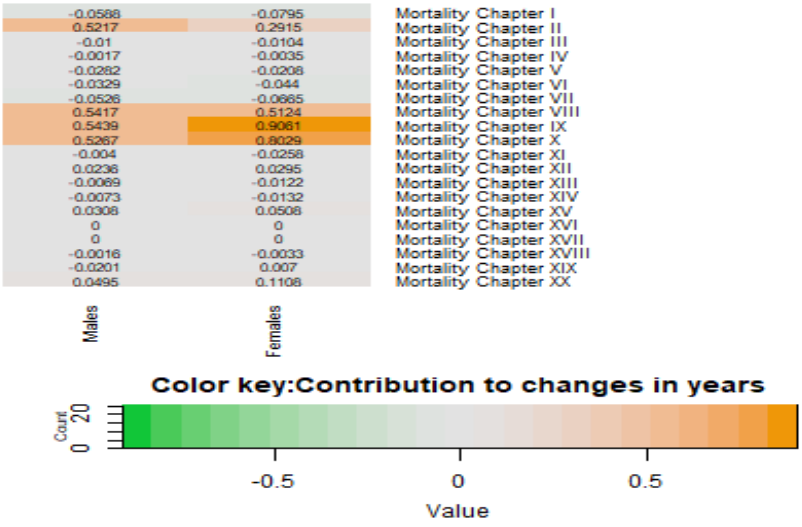

Figure 5.2.3: Attributable Changes in Life Preparancy at Age 60 in Czech Republic between 1998 to 2012 at the 25th percentile.
Source: Human Mortality Database, Cause of Death Mortality Database, and MAC

5.3 Life Preparancy in the United States at the 25th percentile

In the case of the United States, the Human Mortality Database has information available since 1933. For the most part, life preparancy shows a consistent increasing tendency. Nevertheless, as it can be seen in Figure 5.3, it seems that the indicator has deaccelerated in recent years. Moreover, just like in the case of France and Czech Republic, men have taken the 42-year period between 1970 to 2012 to reach the levels of life preparancy that women already had in 1970.

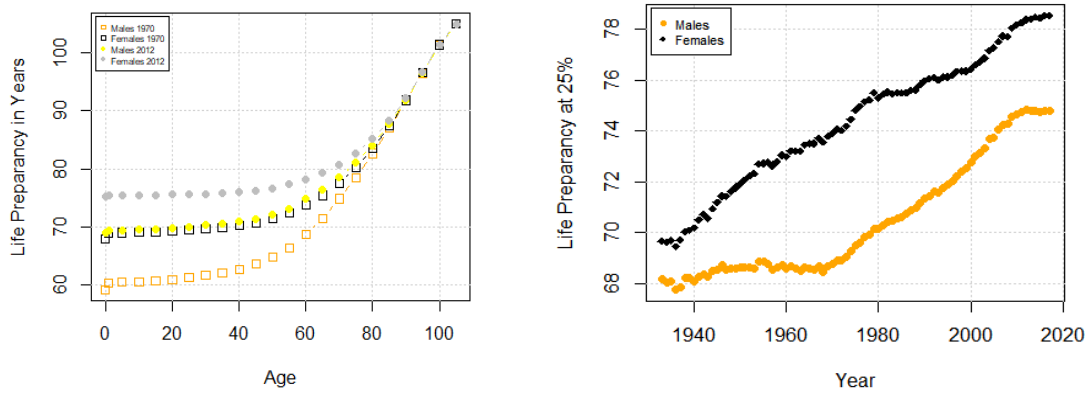

Figure 5.3: Life preparancy per age group and Historical Evolution of Life Preparancy for age 60 at the 25th percentile in United States.
Source: Human Mortality Database and MAC.

5.3.1 Period 1970-1984

From 1970 to 1984, the indicator increased 1.85 years for males and 1.70 for females. In the case of both genders, the greatest changes in life preparancy at age 60 are estimated to have originated due to mortality chapters VIII (with an increase of 1.17 and 1.13 years for men and women), IX (0.40 and 0.64 additional years for males and females), and II. In the case of Mortality Chapter II, Malignant Neoplasms, it contributed to decrease life preparancy levels. The estimated effect is a loss of 0.2 years in the indicator for males, and a slightly more prominent 0.28 years of reduction for US women. In the case of both genders, the reductions are explained by the mortality deterioration associated to Mortality Chapter II registered among all ages over 60, particularly from 60 to 85, with a more significant negative experience in the case of females.

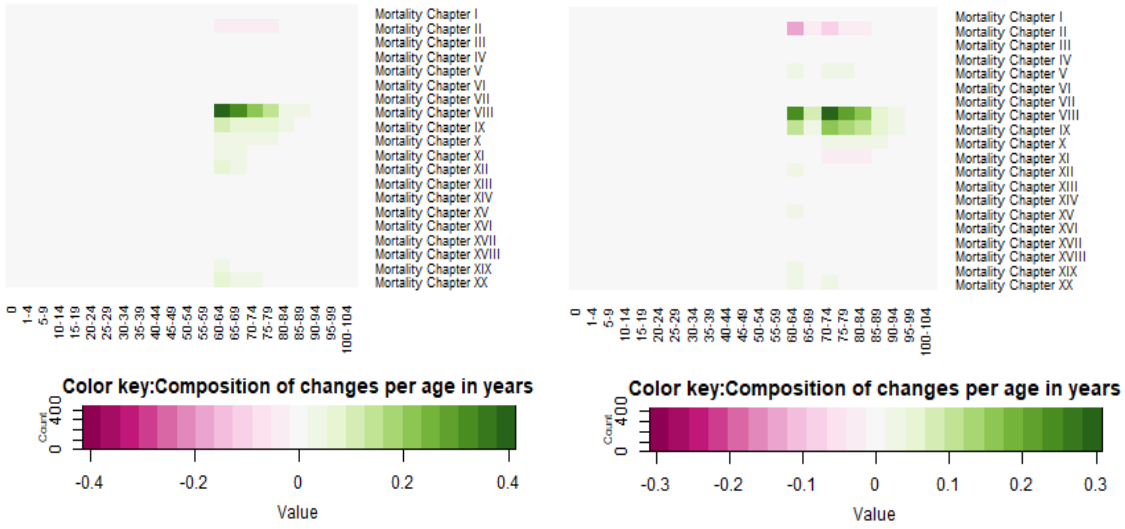

Figure 5.3.1: Decomposition of Changes in Life Preparancy for Age 60 in USA from 1970 to 1984 at the 25th Percentile. Males vs. Females.
Source: Human Mortality Database, Cause of Death Mortality Database, and MAC

5.3.2 Period 1984-1998

These years are characterized by a much more significant increase in life preparancy for males, when compared to females. Life preparancy at age 60 for US men increased 1.73 years while women's indicator did so by 0.76 years. Both genders experienced very significant increases attributed to the effect of Mortality Chapter VIII (generating an additional 1.3 years of life preparancy for males and 1.20 for females). Men also registered an increment due to Malignant Neoplasms and Cerebrovascular diseases estimated in 0.18 and 0.16 additional years, respectively. Women, on the contrary, experienced a deterioration in the indicator due to Mortality Chapter II estimated in 0.1 years. Nevertheless, the biggest negative effect affecting women's life preparancy comes from mortality due to Respiratory Diseases, generating a loss of about one third of a year. In the case of both genders, Endocrine, Nutritional and Metabolic

Diseases also generated a decrease in life preparancy estimated in around 0.1 years. Moreover, Mental Disorders generated a loss as well, which was much more prominent for women (0.09 years) than for men (0.04 years).

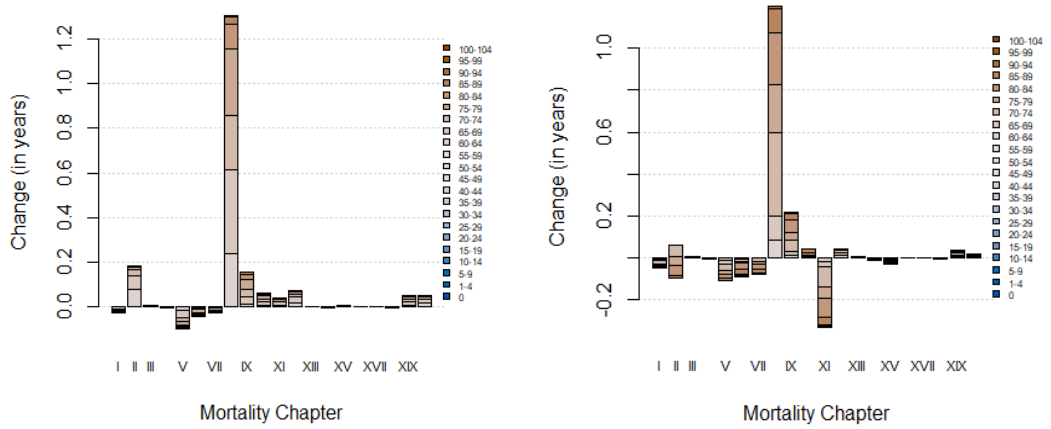

Figure 5.3.2: Contributions to Changes in Life Preparancy at age 60 and at the 25th percentile from 1984 to 1998. Males vs. Females. United States.
Source: Human Mortality Database, Cause of Death Mortality Database, and MAC

5.3.2 Period 1998-2012

Once again, life preparancy increased more for men than for women during this period, with 2.52 and 1.97 extra years, respectively. Mortality Chapter VIII is the major driver of the increments in the indicator for both genders whereas Mortality Chapter II also played a central role in the increment of life preparancy during these years. This 12-year period is also characterized by losses of life preparancy due to Mental and Behavioral Disorders, and Diseases of the Nervous System and Sense Organs. One more time, the negative effects are much greater for women than for men.

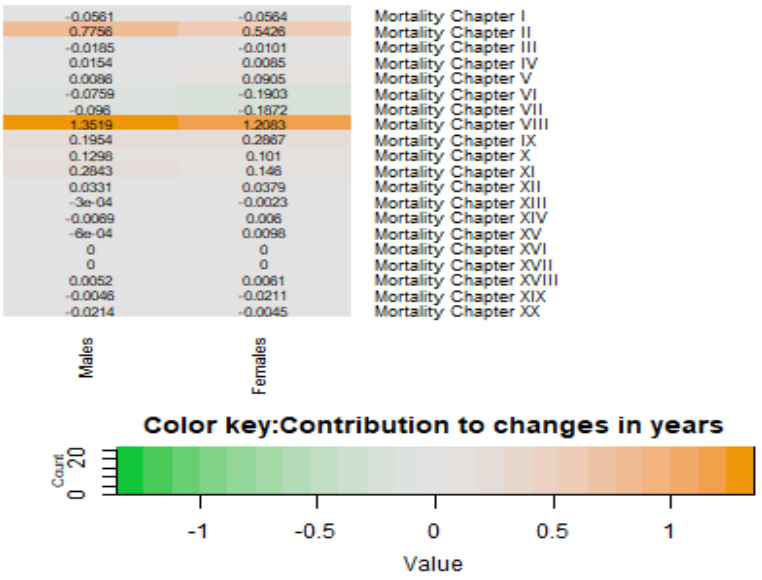

Figure 5.3.3: Attributable Changes in Life Preparancy at Age 60 between 1998 to 2012 at the 25th percentile. USA
Source: Human Mortality Database, Cause of Death Mortality Database, and MAC

5.4 Some Remarks

Just like in the case of life expectancy at birth, improvements in mortality related to Heart Diseases and Cerebrovascular conditions are without doubt the major contributors to life preparancy increases at age 60 during the term of interest. Since most of the overall gains in life expectancy at birth attributed to these chapters were registered in advanced ages, as mentioned in Chapter III, their effects linger and affect mortality indicators even at advanced ages. Improvements in other conditions, such as Malignant Neoplasms and Respiratory Diseases, have also contributed greatly to the extension of human life at a larger scale, but their effect differs from geography and gender. For instance, whereas mortality improvements in Malignant Neoplasms are estimated to have contributed greatly to extend life preparancy of males at age 60 in USA (0.76 extra years from 1970 to 2012), females have experienced a much lower impact due to these conditions (0.16 extra years). A similar case is the one of respiratory diseases in Czech Republic. When analyzing the effect of respiratory diseases between countries, the situation also diverges - improvements in these conditions contributed in a very significant way to the extended longevity registered in France for both genders while in USA the attributable improvements are much smaller for males. Moreover, in the case of females, it is estimated that this mortality chapter generated a slight decrease in life preparancy. Similarly, improvements in mortality related to Diseases of the Digestive System have a very marked role in the extended life preparancy in the case of France, but in the United States and Czech Republic their effect is not so relevant.

In addition, the evolution of conditions related to Mental Disorders and Diseases of the Nervous System (Mortality Chapters VI and VII) also changes based on geography. As a matter of fact, the United States of America is the only country out of the three that constantly reported decreases in life preparancy at age 60 due to these conditions for both genders. Because of this, it is by far the most affected country in this sense, having lost an estimated 0.27 years of life preparancy for males and 0.61 years in the case of females due to the deterioration of mortality in these conditions.

Chapter VI - Conclusions

The increase in life expectancy at birth in France, Czech Republic, and the United States was very relevant from 1970 to 2012, as shown in Chapter III. This comes as very good news in terms of social development, but it imposes financial challenges to Social Security Systems as well as public and private organizations.

Through this paper, it became clear that patterns in mortality and longevity have changed. Earlier in the time interval, changes in life expectancy had a much younger component – most of the gains would come from mortality improvements at younger ages, with a very strong component characterized by changes in mortality at birth. As time passes by and countries seem to evolve, the gains in life expectancy at birth due to mortality of newborns become less important, and the origin of the gains slowly shifts to a variation generated due to the mortality improvements associated to individuals of senior ages.

Clearly, males have gained more life expectancy at birth than women in these 42 years, with the most substantial case being the one of the United States. In general, except for France, males have experienced more relevant gains in life expectancy at birth due to Heart Diseases. Moreover, in all three countries, gains in the indicator due to Malignant Neoplasms, External Causes, Respiratory Diseases, and Diseases of the Digestive System are more relevant for males than for women. Among the major contributors to changes in life expectancy per mortality chapter, only Cerebrovascular Diseases seem to have a stronger female component, leaving evidence that men in these countries are advancing towards patterns that are more similar to those of women. This seems to be different from the past, when women were expected to experience more relevant gains in life expectancy. For example, in France and Czech Republic the increases in the indicator for males were much weaker than those of females from 1970 to 1984. Even in the United States, where men experienced a bigger increase when compared to women in the first period, the difference in gains between genders was less drastic. In this sense, this tendency could eventually end a mortality trait that has always been taken for granted: the gender gap.

In fact, the gender difference in life expectancy at birth has experienced relevant decreases in all three countries. From 1970 to 2012, it went from 7.44 to 6.35 years in France, from 6.95 to 6.01 years in Czech Republic, and from 7.63 to an outstanding 4.77 years in USA. As shown in Chapter IV, the gender gap in these countries is mostly originated due to Heart Diseases, External Causes and Malignant Neoplasms, which are mortality chapters that have shown a very positive experience for males - this contributes to the reduction of the difference in life expectancy at birth between genders.

Moreover, one aspect about the gender gap that seems to be changing is its composition by age group. In all three countries, the gap went from being generated by mortality differences in mostly very early ages (including a very strong discrepancy between genders in the chances of survival at birth) to being originated mostly by women's better chances of survival at senior ages, as the mortality differences between males and females become less relevant during childhood and early adulthood stages. As it was confirmed through the findings, most of the major contributions in the gender gap come from diseases that show older components, except for the case of External Causes (whose effect is originated at younger age groups).

In addition, as it is noted in Chapter II, the concept of life expectancy is a statistical measure of the average future years that a life is expected to live. In order to analyze longevity going beyond the concept of mean, life preparancy becomes a useful tool. As shown in Chapter V, life preparancy levels at age 60 for the 25th percentile have been characterized, just like in the case of life expectancy at birth, by a prominent tendency to increase. One difference with respect to life expectancy at birth obtained from the analysis presented is that, in two out of the three countries, life preparancy increases are still more relevant for females than males. As shown, the decomposition of changes in life preparancy levels at age 60 may differ with that of life expectancy at birth and the gender gap. For example, Mortality Chapter XX – Deaths due to External Causes – plays a very relevant role in the changes in life expectancy at birth and in the generation of the gender gap whereas its importance seems rather nonsignificant in the generation of changes in life preparancy levels at age 60.

In this context, after the findings presented throughout the work, it is possible to identify three stages in the evolution of human longevity: firstly, mortality improves through the contribution of the experience of younger ages -with a very important component coming from the first year of life. After countries have successfully passed this stage, they evolve to improve the mortality of individuals at much more advanced ages. Finally, they move on to a context in which gender becomes a less relevant factor in survival.

In general terms, one aspect seems to remain certain: the evolution of mortality appears to be the final result of human kind's resilience and determination to understand and fight the very complex processes and invisible forces that mold the boundaries of human existence - factors that, at a national and international level, remind us all about our own biological limits.

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Annex

Table A.1-Decomposition of changes in LE per mortality chapter-France

	1970-1984		1984-1998		1998-2012		1970-2012	
(In Years)	Males	Females	Males	Females	Males	Females	Males	Females
I- Infectious Diseases	0.1743	0.1324	0.0006	0.0191	0.0350	-0.0065	0.2099	0.1450
II-Malignant Neoplasm	-0.5536	0.1482	0.4669	0.3001	1.1369	0.3279	1.0502	0.7762
III-Other Neoplasm	0.0304	0.0342	0.0343	0.0271	-0.0101	0.0105	0.0546	0.0718
IV-Diseases of Blood	0.0029	-0.0119	0.0145	0.0178	0.0323	0.0307	0.0498	0.0366
V-Endocrine/Nutritional	0.0415	0.1053	0.0289	0.0547	-0.0028	0.0568	0.0676	0.2168
VI-Mental Disorders	0.0138	-0.0444	0.0537	0.0187	-0.0267	-0.0051	0.0407	-0.0308
VII-Nervous System	0.0866	0.1141	0.0001	-0.0585	-0.0942	-0.1755	-0.0075	-0.1199
VIII-Heart Disease	0.3524	0.5272	0.7238	0.7337	0.8708	0.7540	1.9471	2.0149
IX-Cerebrovascular Disease	0.5097	0.6421	0.4955	0.6651	0.3115	0.3491	1.3167	1.6563
X- Other Circulatory	0.0416	0.0805	0.1244	0.1169	0.1865	0.1447	0.3525	0.3420
XI-Respiratory Diseases	0.3136	0.3125	0.1050	-0.0080	0.4145	0.2777	0.8331	0.5822
XII-Disease of Digestive System	0.2464	0.1927	0.3726	0.2773	0.2722	0.2103	0.8912	0.6802
XIII-Diseases of the Skin	-0.0056	-0.0057	0.0019	0.0048	0.0218	0.0364	0.0181	0.0355
XIV-Diseases of the musculoskeletal system	0.0025	-0.0058	0.0073	0.0198	-0.0064	0.0068	0.0034	0.0207
XV-Diseases of the genitourinary system	0.1371	0.0985	0.0617	0.0396	0.0300	0.0311	0.2288	0.1692
XVI-Complications of pregnancy/childbirth	0.0000	0.0222	0.0000	0.0049	0.0000	0.0036	0.0000	0.0307
XVII-Conditions of Perinatal Period	0.4930	0.3957	0.0319	0.0220	-0.0087	0.0059	0.5161	0.4236
XVIII-Congenital malformations	0.1586	0.1380	0.0817	0.0760	0.0228	0.0273	0.2631	0.2413
XIX-Ill-defined or unknown	0.3800	0.5249	0.3295	0.3316	-0.1157	-0.0525	0.5938	0.8041
XX-External Causes	0.3449	0.1397	0.6456	0.3981	0.7104	0.4069	1.7008	0.9448
Total change	2.7700	3.5404	3.5800	3.0608	3.7800	2.4401	10.1300	9.0412

Source: Human Mortality Database, Cause of Death Database, Mortality Analysis Calculator

Table A.2 Decomposition of changes in LE per mortality chapter-Czech Republic

	1970-1984		1984-1998		1998-2012		1970-1984	
(In Years)	Males	Females	Males	Females	Males	Females	Males	Females
I- Infectious Diseases	0.0911	0.0505	0.0174	0.0308	-0.0882	-0.1046	0.0203	-0.0233
II-Malignant Neoplasm	-0.1623	-0.0941	0.3554	0.2376	1.1385	0.6627	1.3315	0.8063
III-Other Neoplasm	-0.0020	-0.0005	0.0215	0.0249	-0.0127	-0.0042	0.0068	0.0202
IV-Diseases of Blood	-0.0015	0.0019	0.0159	0.0152	-0.0025	-0.0061	0.0118	0.0110
V-Endocrine/Nutritional	0.0015	0.1112	0.0613	0.1117	-0.0420	-0.0372	0.0208	0.1857
VI-Mental Disorders	-0.0172	0.0094	0.0206	-0.0009	-0.0451	-0.0505	-0.0417	-0.0420
VII-Nervous System	0.0259	0.0206	0.0581	0.0458	-0.0463	-0.0252	0.0376	0.0412
VIII-Heart Disease	-0.0201	0.2883	1.0996	0.8077	0.8809	0.3788	1.9604	1.4747
IX-Cerebrovascular Disease	-0.0866	-0.0689	0.6744	0.8859	0.6777	0.9225	1.2656	1.7396
X- Other Circulatory	-0.1019	-0.0290	-0.0140	0.0565	0.6527	0.8768	0.5368	0.9043
XI-Respiratory Diseases	0.4918	0.4265	0.3788	0.2638	0.0529	-0.0300	0.9236	0.6603
XII-Disease of Digestive System	0.0491	0.1292	0.0583	0.1012	0.1566	0.0209	0.2639	0.2513
XIII-Diseases of the Skin	-0.0001	0.0030	0.0034	0.0029	-0.0093	-0.0140	-0.0060	-0.0081
XIV-Diseases of the musculoskeletal system	0.0062	0.0010	0.0020	0.0147	-0.0129	-0.0174	-0.0047	-0.0018
XV-Diseases of the genitourinary system	0.0458	0.0776	0.2048	0.1374	0.0506	0.0640	0.3012	0.2790
XVI-Complications of pregnancy/childbirth	0.0000	0.0095	0.0000	0.0043	0.0000	-0.0009	0.0000	0.0129
XVII-Conditions of Perinatal Period	0.3644	0.3278	0.3701	0.2552	0.0980	0.0837	0.8325	0.6667
XVIII-Congenital malformations	-0.0010	0.0102	0.2168	0.2254	0.0810	0.0509	0.2969	0.2865
XIX-Ill-defined or unknown	-0.0163	0.0440	-0.0022	0.0137	-0.0964	-0.0228	-0.1149	0.0349
XX-External Causes	0.6333	0.1918	0.1676	0.2564	0.4866	0.2423	1.2876	0.6905
Total change	1.3000	1.5100	3.7100	3.4900	3.9200	2.9900	8.9300	7.9900

Source: Human Mortality Database, Cause of Death Database, Mortality Analysis Calculator

Table A.3. Decomposition of changes in LE per mortality chapter-USA

	1970-1984		1984-1998		1998-2012		1970-2012	
(In Years)	Males	Females	Males	Females	Males	Females	Males	Females
I- Infectious Diseases	0.0319	0.0225	-0.1847	-0.0595	0.0819	-0.0583	-0.0709	-0.0953
II-Malignant Neoplasm	-0.0759	-0.0708	0.3567	0.1757	0.7711	0.7400	1.0519	0.8450
III-Other Neoplasm	0.0058	0.0109	0.0047	0.0052	-0.0154	-0.0115	-0.0050	0.0046
IV-Diseases of Blood	-0.0330	0.0007	0.0269	-0.0034	0.0190	0.0004	0.0129	-0.0023
V-Endocrine/Nutritional	0.0566	0.1378	-0.1100	-0.1036	-0.0141	0.0830	-0.0676	0.1173
VI-Mental Disorders	-0.0047	-0.0308	-0.0396	-0.0845	-0.0762	-0.2340	-0.1205	-0.3494
VII-Nervous System	0.0137	-0.0147	-0.0195	-0.0582	-0.1003	-0.1962	-0.1061	-0.2691
VIII-Heart Disease	1.4720	1.2454	1.5166	1.0075	1.3585	1.2445	4.3471	3.4974
IX-Cerebrovascular Disease	0.4717	0.7503	0.1709	0.1979	0.2149	0.3214	0.8575	1.2696
X- Other Circulatory	0.1397	0.1804	0.0731	0.0461	0.1188	0.0977	0.3316	0.3242
XI-Respiratory Diseases	0.3099	0.1306	0.0344	-0.2431	0.2973	0.1205	0.6417	0.0080
XII-Disease of Digestive System	0.2539	0.1788	0.1286	0.0820	0.0189	-0.0427	0.4014	0.2181
XIII-Diseases of the Skin	-0.0028	0.0006	0.0043	0.0068	-0.0002	-0.0037	0.0013	0.0037
XIV-Diseases of the musculoskeletal system	0.0042	0.0026	-0.0042	-0.0119	-0.0087	0.0044	-0.0087	-0.0050
XV-Diseases of the genitourinary system	0.0664	0.0625	0.0089	-0.0230	0.0040	-0.0007	0.0792	0.0387
XVI-Complications of pregnancy/childbirth	0.0000	0.0238	0.0000	-0.0026	0.0000	-0.0202	0.0000	0.0010
XVII-Conditions of Perinatal Period	0.5599	0.4336	0.1344	0.1131	0.0442	0.0414	0.7385	0.5882
XVIII-Congenital malformations	0.0870	0.0897	0.0666	0.0590	0.0474	0.0384	0.2010	0.1870
XIX-Ill-defined or unknown	-0.0008	0.0117	0.1229	0.0689	0.0318	-0.0127	0.1538	0.0679
XX-External Causes	0.7446	0.3543	0.3991	0.0880	-0.0428	-0.2116	1.1009	0.2307
Total change	4.1000	3.5199	2.6901	1.2602	2.7500	1.9001	9.5401	6.6802

Source: Human Mortality Database, Cause of Death Database, Mortality Analysis Calculator

Table A.4. Contribution to Gender Gap - France

(in Years)	1970	1984	1998	2012
I- Infectious Diseases	0.1350	0.0959	0.1230	0.1071
II-Malignant Neoplasm	1.4342	2.4053	2.6251	2.0249
III-Other Neoplasm	0.0440	0.0471	0.0409	0.0728
IV-Diseases of Blood	0.0141	0.0205	0.0261	0.0134
V-Endocrine/Nutritional	0.0195	0.0618	0.0833	0.1422
VI-Mental Disorders	0.1499	0.1594	0.1346	0.1656
VII-Nervous System	0.0993	0.1159	0.1100	0.1122
VIII-Heart Disease	1.2127	1.3979	1.2889	0.9875
IX-Cerebrovascular Disease	0.5086	0.3980	0.2605	0.1551
X- Other Circulatory	0.2024	0.2491	0.2164	0.1295
XI-Respiratory Diseases	0.5119	0.5230	0.5576	0.4042
XII-Digestive System	0.5979	0.5694	0.4167	0.3279
XIII-Diseases of Skin	-0.0046	0.0001	0.0007	0.0032
XIV-Musculoskeletal system	-0.0031	-0.0086	-0.0029	0.0086
XV-Genitourinary system	0.1685	0.0976	0.0684	0.0732
XVI-Pregnancy/childbirth	-0.0304	-0.0117	-0.0081	-0.0053
XVII-Perinatal Period	0.1723	0.0327	0.0220	0.0417
XVIII-Congenital malformations	0.0570	0.0245	0.0120	0.0145
XIX-Ill-defined or unknown	0.5253	0.4765	0.4151	0.5940
XX-External Causes	1.6254	1.5557	1.2995	0.9774
Total Gender Gap	7.4400	8.2100	7.6900	6.3498

Source: Human Mortality Database, Cause of Death Database, Mortality Analysis Calculator

Table A.5. Contribution to Gender Gap – Czech Republic

(in Years)	1970	1984	1998	2012
I- Infectious Diseases	0.0970	0.0196	0.0284	0.0734
II-Malignant Neoplasm	1.2672	1.5304	1.7958	1.4130
III-Other Neoplasm	0.0033	0.0036	0.0002	0.0175
IV-Diseases of Blood	0.0032	0.0067	0.0040	0.0037
V-Endocrine/Nutritional	-0.0535	0.0185	0.0424	0.0923
VI-Mental Disorders	0.0039	0.0346	0.0135	0.0448
VII-Nervous System	0.0585	0.0493	0.0455	0.1201
VIII-Heart Disease	1.9058	2.2853	1.9973	1.7945
IX-Cerebrovascular Disease	0.3899	0.4979	0.3713	0.2550
X- Other Circulatory	0.0864	0.2440	0.3974	0.1712
XI-Respiratory Diseases	0.8095	0.5125	0.3468	0.3766
XII-Digestive System	0.2961	0.3716	0.4337	0.3268
XIII-Diseases of Skin	-0.0020	0.0013	-0.0003	0.0010
XIV-Musculoskeletal system	-0.0021	-0.0106	-0.0022	-0.0011
XV-Genitourinary system	0.1522	0.1724	0.0504	0.0603
XVI-Pregnancy/childbirth	-0.0164	-0.0067	-0.0031	-0.0036
XVII-Perinatal Period	0.2611	0.1946	0.0560	0.0375
XVIII-Congenital malformations	0.0286	0.0384	0.0240	-0.0097
XIX-Ill-defined or unknown	-0.0005	0.0304	0.0509	0.1458
XX-External Causes	1.6617	1.1660	1.2880	1.0909
Total Gender Gap	6.95	7.16	6.94	6.01

Source: Human Mortality Database, Cause of Death Database, Mortality Analysis Calculator

Table A.6. Contribution to Gender Gap – USA

(in Years)	1970	1984	1998	2012
I- Infectious Diseases	0.0663	0.0798	0.1970	0.1262
II-Malignant Neoplasm	0.7109	1.0429	0.9708	0.8047
III-Other Neoplasm	0.0016	0.0089	0.0086	0.0250
IV-Diseases of Blood	0.0003	0.0449	0.0182	0.0018
V-Endocrine/Nutritional	-0.0140	0.0248	0.0809	0.1682
VI-Mental Disorders	0.0791	0.0778	0.0831	0.0294
VII-Nervous System	0.0704	0.0751	0.0789	0.0751
VIII-Heart Disease	3.0527	2.6981	1.8403	1.4206
IX-Cerebrovascular Disease	0.1741	0.1332	0.0845	0.0621
X- Other Circulatory	0.1639	0.1432	0.1036	0.0442
XI-Respiratory Diseases	0.5882	0.5517	0.4094	0.2481
XII-Digestive System	0.3430	0.2567	0.2170	0.2103
XIII-Diseases of Skin	-0.0049	0.0010	0.0008	-0.0021
XIV-Musculoskeletal system	-0.0245	-0.0300	-0.0332	-0.0235
XV-Genitourinary system	0.0636	0.0605	0.0444	0.0551
XVI-Pregnancy/childbirth	-0.0270	-0.0062	-0.0070	-0.0219
XVII-Perinatal Period	0.2516	0.0820	0.0506	0.0452
XVIII-Congenital malformations	0.0330	0.0275	0.0174	0.0115
XIX-Ill-defined or unknown	0.1271	0.1496	0.0813	0.0529
XX-External Causes	1.9744	1.6285	1.3732	1.4369
Total Gender Gap	7.6300	7.0499	5.6198	4.7697

Source: Human Mortality Database, Cause of Death Database, Mortality Analysis Calculator

Table A.7. Estimated Life Preparancy - France

25th Percentile	Males				Females			
Age	1970	1984	1998	2012	1970	1984	1998	2012
0	61.2464	63.3083	67.2889	71.3059	70.6734	74.5872	77.4447	80.4367
1-4	62.0973	63.7744	67.5193	71.4757	71.2181	74.9267	77.5976	80.5210
5-9	62.2437	63.8813	67.5686	71.5102	71.3113	75.0001	77.6257	80.5369
10-14	62.3396	63.9559	67.6024	71.5280	71.3655	75.0294	77.6481	80.5464
15-19	62.4281	64.0315	67.6411	71.5504	71.4100	75.0567	77.6726	80.5580
20-24	62.6832	64.2753	67.7918	71.6344	71.5022	75.1172	77.7217	80.5804
25-29	63.0028	64.6894	68.0426	71.7828	71.6067	75.1903	77.7934	80.6120
30-34	63.3203	65.0540	68.3009	71.9540	71.7235	75.2729	77.8710	80.6490
35-39	63.6949	65.3680	68.6037	72.1503	71.8773	75.3778	77.9738	80.6976
40-44	64.2452	65.7884	69.0323	72.4140	72.1059	75.5211	78.1353	80.7767
45-49	65.0545	66.4205	69.6939	72.8472	72.4557	75.7370	78.3781	80.9066
50-54	65.9820	67.4406	70.5165	73.5432	72.9748	76.0611	78.7279	81.1288
55-59	67.3627	69.0304	71.5485	74.6840	73.7652	76.5300	79.2335	81.4699
60-64	69.3438	70.9885	72.9611	75.9925	74.8006	77.1863	79.9209	81.9449
65-69	71.8548	73.2406	75.0033	77.5842	75.9260	78.1297	80.5482	82.5752
70-74	74.9769	75.9378	77.2441	79.6079	77.5651	79.5558	81.4478	83.4406
75-79	78.4857	79.0112	80.1980	81.6405	80.1162	81.2768	82.8761	84.7160
80-84	82.4721	82.7386	83.3039	84.3559	83.1990	83.8795	85.1571	86.1904
85-89	86.8982	87.0012	87.2470	87.6548	87.1889	87.4656	88.0040	88.5904
90-94	91.5730	91.6228	91.6989	91.8439	91.6744	91.8034	91.9893	92.2136
95-99	96.4040	96.4165	96.4440	96.4767	96.4327	96.4772	96.5380	96.6045
100-104	101.3273	101.3272	101.3315	101.3327	101.3259	101.3395	101.3538	101.3688
105+	105.0000	105.0000	105.0000	105.0000	105.0000	105.0000	105.0000	105.0000

Source: Human Mortality Database and Mortality Analysis Calculator

Table A.8. Estimated Life Preparancy – Czech Republic

25th Percentile	Males				Females			
Age	1970	1984	1998	2012	1970	1984	1998	2012
0	60.0106	60.3830	63.5861	67.3832	67.8189	68.9777	72.2565	75.6504
1-4	60.8165	60.9259	63.8345	67.4927	68.5071	69.4568	72.4106	75.7188
5-9	60.9384	60.9973	63.8875	67.5222	68.6105	69.5254	72.4448	75.7293
10-14	61.0178	61.0596	63.9319	67.5350	68.6662	69.5680	72.4663	75.7468
15-19	61.0981	61.1037	63.9780	67.5663	68.7219	69.6093	72.4949	75.7587
20-24	61.3060	61.2357	64.1257	67.6535	68.8265	69.6824	72.5454	75.7910
25-29	61.5974	61.4068	64.3289	67.7785	68.9256	69.7558	72.5985	75.8253
30-34	61.8870	61.6025	64.5581	67.9209	69.0459	69.8657	72.6480	75.8614
35-39	62.2542	61.8773	64.8122	68.1051	69.2100	70.0000	72.7141	75.9182
40-44	62.7126	62.3003	65.1507	68.3558	69.4605	70.1451	72.8456	76.0009
45-49	63.3847	62.9553	65.6716	68.7538	69.8275	70.3792	73.0751	76.1473
50-54	64.4774	64.0970	66.5090	69.3813	70.2969	70.7686	73.4543	76.3999
55-59	65.8597	65.7171	67.8745	70.3877	70.9425	71.4103	74.0587	76.7890
60-64	67.6895	67.9232	69.8516	71.8653	71.9189	72.4469	75.0182	77.4500
65-69	70.3967	70.8810	72.1264	74.0990	73.4982	74.1803	76.0367	78.4743
70-74	73.7619	74.0526	75.1519	76.7509	75.7517	76.2359	77.6575	80.0190
75-79	77.7317	77.8317	78.5292	79.8021	78.6633	78.9071	80.1927	81.6113
80-84	82.1040	82.0867	82.5630	83.1130	82.4854	82.5541	83.2690	84.0886
85-89	86.6910	86.6984	86.9350	87.1287	86.8265	86.8745	87.1415	87.4577
90-94	91.4630	91.4298	91.5415	91.6478	91.4974	91.5191	91.6512	91.7741
95-99	96.3529	96.3525	96.3953	96.4110	96.3612	96.3665	96.4012	96.4317
100-104	101.3125	101.3158	101.3119	101.3134	101.3000	101.3000	101.3093	101.3144
105+	105.0000	105.0000	105.0000	105.0000	105.0000	105.0000	105.0000	105.0000

Source: Human Mortality Database and Mortality Analysis Calculator

Table A.9. Estimated Life Preparancy - USA

25th Percentile	Males				Females			
Age	1970	1984	1998	2012	1970	1984	1998	2012
0	59.2109	63.5629	66.5954	69.0651	67.9782	71.2965	72.7879	75.2535
1-4	60.3204	64.1187	66.9310	69.4106	68.8599	71.6796	73.0687	75.4412
5-9	60.4622	64.2233	66.9922	69.4728	69.0030	71.7530	73.1198	75.4733
10-14	60.5568	64.2908	67.0323	69.5058	69.0847	71.7932	73.1504	75.4906
15-19	60.6537	64.3691	67.0856	69.5488	69.1543	71.8350	73.1846	75.5099
20-24	60.9520	64.6231	67.2844	69.7200	69.2993	71.9238	73.2667	75.5565
25-29	61.3640	64.9920	67.5638	70.0320	69.4733	72.0303	73.3590	75.6324
30-34	61.7342	65.2757	67.8238	70.2981	69.6778	72.1475	73.4675	75.7297
35-39	62.1509	65.5899	68.1325	70.5871	69.9509	72.2985	73.6226	75.8564
40-44	62.7151	65.9689	68.5495	70.9252	70.2675	72.5151	73.8539	76.0286
45-49	63.5689	66.5128	69.1522	71.3850	70.7178	72.8595	74.1925	76.2870
50-54	64.8628	67.3472	70.0052	72.0940	71.3968	73.4059	74.6771	76.6953
55-59	66.4312	68.6668	70.9044	73.1978	72.3652	74.2643	75.3171	77.3102
60-64	68.6845	70.5375	72.2671	74.7862	73.7301	75.4335	76.1985	78.1701
65-69	71.5134	72.7989	74.2911	76.4305	75.4532	76.8866	77.5512	79.3652
70-74	74.8578	75.6988	76.7560	78.5306	77.4737	78.9091	79.5064	80.8098
75-79	78.5448	79.1023	79.8939	81.0991	80.2573	81.3425	81.7065	82.6610
80-84	82.6577	82.9069	83.1796	84.1150	83.5025	84.2434	84.4653	85.2925
85-89	87.0508	87.1964	87.2625	87.7147	87.4438	87.8235	87.8970	88.2986
90-94	91.6902	91.7537	91.7398	91.8681	91.8525	92.0417	92.0186	92.1463
95-99	96.4901	96.5136	96.4791	96.5188	96.5556	96.6298	96.5947	96.6294
100-104	101.3763	101.3833	101.3528	101.3578	101.3929	101.4213	101.3949	101.3979
105+	105.0000	105.0000	105.0000	105.0000	105.0000	105.0000	105.0000	105.0000

Source: Human Mortality Database and Mortality Analysis Calculator

Table A.10. Estimated Decomposition of Changes in Life Preparancy for France- Males

(in Years)	1970-1984	1984-1998	1998-2012	1970-2012
I- Infectious Diseases	0.0460	0.0237	-0.0065	0.0632
II-Malignant Neoplasm	-0.1959	0.2472	0.9482	0.9995
III-Other Neoplasm	0.0030	0.0169	-0.0052	0.0146
IV-Diseases of Blood	-0.0085	0.0027	0.0337	0.0280
V-Endocrine/Nutritional	0.0445	0.0152	0.0141	0.0738
VI-Mental Disorders	-0.0006	0.0373	-0.0093	0.0273
VII-Nervous System	0.0441	-0.0124	-0.0718	-0.0402
VIII-Heart Disease	0.3523	0.5762	0.9308	1.8593
IX-Cerebrovascular Disease	0.4855	0.4208	0.3188	1.2251
X- Other Circulatory	0.0416	0.1054	0.1823	0.3293
XI-Respiratory Diseases	0.1871	0.0720	0.3754	0.6345
XII-Digestive System	0.1546	0.2107	0.2095	0.5748
XIII-Diseases of Skin	-0.0052	0.0032	0.0159	0.0139
XIV-Musculoskeletal system	-0.0043	0.0084	-0.0047	-0.0006
XV-Genitourinary system	0.1091	0.0489	0.0367	0.1946
XVI-Pregnancy/childbirth	0.0000	0.0000	0.0000	0.0000
XVII-Perinatal Period	0.0003	0.0000	0.0000	0.0003
XVIII-Congenital malformations	-0.0002	-0.0002	-0.0049	-0.0053
XIX-Ill-defined or unknown	0.3267	0.0882	-0.1244	0.2905
XX-External Causes	0.0648	0.1084	0.1929	0.3660
Total Change	1.6448	1.9726	3.0314	6.6488

Source: Human Mortality Database and Mortality Analysis Calculator

Table A.11. Estimated Decomposition of Changes in Life Preparancy for France- Females

(in Years)	1970-1984	1984-1998	1998-2012	1970-2012
I- Infectious Diseases	0.0080	0.0236	-0.0084	0.0232
II-Malignant Neoplasm	0.0864	0.2982	0.1896	0.5742
III-Other Neoplasm	0.0059	0.0183	0.0026	0.0268
IV-Diseases of Blood	-0.0092	0.0077	0.0298	0.0283
V-Endocrine/Nutritional	0.1067	0.0629	0.0716	0.2413
VI-Mental Disorders	-0.0459	0.0450	0.0046	0.0037
VII-Nervous System	0.0785	-0.0614	-0.1524	-0.1353
VIII-Heart Disease	0.5124	0.8874	0.8181	2.2179
IX-Cerebrovascular Disease	0.6790	0.7159	0.3606	1.7556
X- Other Circulatory	0.0749	0.1230	0.1382	0.3360
XI-Respiratory Diseases	0.2379	-0.0146	0.2374	0.4607
XII-Digestive System	0.0691	0.2331	0.1419	0.4442
XIII-Diseases of Skin	-0.0081	0.0042	0.0338	0.0299
XIV-Musculoskeletal system	-0.0098	0.0200	0.0080	0.0182
XV-Genitourinary system	0.0639	0.0355	0.0294	0.1288
XVI-Pregnancy/childbirth	0.0000	0.0000	0.0000	0.0000
XVII-Perinatal Period	0.0004	0.0000	0.0000	0.0004
XVIII-Congenital malformations	-0.0011	-0.0006	0.0010	-0.0007
XIX-Ill-defined or unknown	0.4842	0.1530	-0.0387	0.5985
XX-External Causes	0.0526	0.1835	0.1568	0.3929
Total Change	2.3857	2.7348	2.0240	7.1445

Source: Human Mortality Database and Mortality Analysis Calculator

Table A.12. Estimated Decomposition of Changes in Life Preparancy for Czech Republic- Males

(in Years)	1970-1984	1984-1998	1998-2012	1970-2012
I- Infectious Diseases	0.0792	0.0149	-0.0588	0.0353
II-Malignant Neoplasm	-0.0310	0.0999	0.5217	0.5906
III-Other Neoplasm	-0.0062	0.0060	-0.0100	-0.0102
IV-Diseases of Blood	-0.0085	0.0042	-0.0017	-0.0060
V-Endocrine/Nutritional	-0.0290	0.0391	-0.0282	-0.0181
VI-Mental Disorders	-0.0023	0.0031	-0.0329	-0.0322
VII-Nervous System	0.0145	-0.0121	-0.0526	-0.0502
VIII-Heart Disease	-0.1940	0.7111	0.5417	1.0588
IX-Cerebrovascular Disease	-0.0734	0.5354	0.5439	1.0059
X- Other Circulatory	-0.1956	-0.0084	0.5267	0.3227
XI-Respiratory Diseases	0.5733	0.2421	-0.0040	0.8114
XII-Digestive System	0.0065	0.0832	0.0236	0.1133
XIII-Diseases of Skin	0.0019	0.0021	-0.0069	-0.0029
XIV-Musculoskeletal system	0.0019	0.0011	-0.0073	-0.0043
XV-Genitourinary system	0.0355	0.1224	0.0308	0.1887
XVI-Pregnancy/childbirth	0.0000	0.0000	0.0000	0.0000
XVII-Perinatal Period	0.0000	0.0000	0.0000	0.0000
XVIII-Congenital malformations	0.0007	-0.0005	-0.0016	-0.0014
XIX-Ill-defined or unknown	0.0082	-0.0056	-0.0201	-0.0175
XX-External Causes	0.0523	0.0904	0.0495	0.1922
Total Change	0.2337	1.9284	2.0137	4.1758

Source: Human Mortality Database and Mortality Analysis Calculator

Table A.13. Estimated Decomposition of Changes in Life Preparancy for Czech Republic- Females

(in Years)	1970-1984	1984-1998	1998-2012	1970-2012
I- Infectious Diseases	-0.0751	0.0160	-0.0795	-0.1386
II-Malignant Neoplasm	0.6208	0.1160	0.2915	1.0284
III-Other Neoplasm	-0.0243	0.0055	-0.0104	-0.0292
IV-Diseases of Blood	0.0125	0.0053	-0.0035	0.0143
V-Endocrine/Nutritional	-0.1202	0.0951	-0.0208	-0.0459
VI-Mental Disorders	-0.0009	0.0004	-0.0440	-0.0445
VII-Nervous System	0.0502	-0.0157	-0.0665	-0.0320
VIII-Heart Disease	0.2003	0.8036	0.5124	1.5163
IX-Cerebrovascular Disease	-0.0488	0.9053	0.9061	1.7626
X- Other Circulatory	0.0703	0.0373	0.8029	0.9104
XI-Respiratory Diseases	-0.1136	0.1876	-0.0258	0.0483
XII-Digestive System	-0.1066	0.0986	0.0295	0.0215
XIII-Diseases of Skin	0.0108	0.0022	-0.0122	0.0007
XIV-Musculoskeletal system	0.0125	0.0074	-0.0132	0.0068
XV-Genitourinary system	0.0695	0.1175	0.0508	0.2379
XVI-Pregnancy/childbirth	0.0000	0.0000	0.0000	0.0000
XVII-Perinatal Period	0.0000	0.0000	0.0000	0.0000
XVIII-Congenital malformations	0.0005	0.0000	-0.0033	-0.0028
XIX-Ill-defined or unknown	0.0365	0.0000	0.0070	0.0435
XX-External Causes	-0.0666	0.1892	0.1108	0.2334
Total Change	0.5280	2.5712	2.4319	5.5311

Source: Human Mortality Database, Cause of Death Database, Mortality Analysis Calculator

Table A.14. Estimated Decomposition of Changes in Life Preparancy for United States- Males

(in Years)	1970-1984	1984-1998	1998-2012	1970-2012
I- Infectious Diseases	-0.0075	-0.0224	-0.0561	-0.0860
II-Malignant Neoplasm	-0.1943	0.1774	0.7756	0.7587
III-Other Neoplasm	-0.0038	0.0050	-0.0185	-0.0172
IV-Diseases of Blood	-0.0073	-0.0011	0.0154	0.0071
V-Endocrine/Nutritional	0.0366	-0.0945	0.0086	-0.0492
VI-Mental Disorders	-0.0090	-0.0402	-0.0759	-0.1251
VII-Nervous System	-0.0258	-0.0276	-0.0960	-0.1494
VIII-Heart Disease	1.1669	1.3023	1.3519	3.8211
IX-Cerebrovascular Disease	0.4005	0.1564	0.1954	0.7523
X- Other Circulatory	0.1141	0.0654	0.1298	0.3093
XI-Respiratory Diseases	0.0553	0.0224	0.2843	0.3619
XII-Digestive System	0.1018	0.0743	0.0331	0.2091
XIII-Diseases of Skin	-0.0031	0.0035	-0.0003	0.0002
XIV-Musculoskeletal system	0.0016	-0.0006	-0.0069	-0.0059
XV-Genitourinary system	0.0385	0.0088	-0.0006	0.0467
XVI-Pregnancy/childbirth	0.0000	0.0000	0.0000	0.0000
XVII-Perinatal Period	0.0000	0.0000	0.0000	0.0000
XVIII-Congenital malformations	-0.0012	-0.0024	0.0052	0.0016
XIX-Ill-defined or unknown	0.0409	0.0507	-0.0046	0.0870
XX-External Causes	0.1487	0.0522	-0.0214	0.1796
Total Change	1.8530	1.7296	2.5191	6.1017

Source: Human Mortality Database, Cause of Death Database, Mortality Analysis Calculator

Table A.15. Estimated Decomposition of Changes in Life Preparancy for United States- Females

(in Years)	1970-1984	1984-1998	1998-2012	1970-2012
I- Infectious Diseases	-0.0245	-0.0480	-0.0564	-0.1290
II-Malignant Neoplasm	-0.2833	-0.0965	0.5426	0.1629
III-Other Neoplasm	0.0004	0.0029	-0.0101	-0.0067
IV-Diseases of Blood	-0.0039	-0.0033	0.0085	0.0013
V-Endocrine/Nutritional	0.0995	-0.1094	0.0905	0.0806
VI-Mental Disorders	-0.0239	-0.0886	-0.1903	-0.3027
VII-Nervous System	-0.0446	-0.0801	-0.1872	-0.3120
VIII-Heart Disease	1.1254	1.1995	1.2083	3.5331
IX-Cerebrovascular Disease	0.6391	0.2181	0.2867	1.1440
X- Other Circulatory	0.1417	0.0450	0.1010	0.2877
XI-Respiratory Diseases	-0.1086	-0.3296	0.1460	-0.2921
XII-Digestive System	0.0505	0.0408	0.0379	0.1293
XIII-Diseases of Skin	-0.0047	0.0081	-0.0023	0.0010
XIV-Musculoskeletal system	-0.0045	-0.0098	0.0060	-0.0083
XV-Genitourinary system	0.0248	-0.0281	0.0098	0.0065
XVI-Pregnancy/childbirth	0.0000	0.0000	0.0000	0.0000
XVII-Perinatal Period	0.0000	0.0000	0.0000	0.0000
XVIII-Congenital malformations	0.0002	-0.0047	0.0061	0.0016
XIX-Ill-defined or unknown	0.0191	0.0370	-0.0211	0.0350
XX-External Causes	0.1007	0.0117	-0.0045	0.1079
Total Change	1.7035	0.7650	1.9716	4.4401

Source: Human Mortality Database, Cause of Death Database, Mortality Analysis Calculator