Quantification of the Economic Burden of Premature Mortality: The Case for the Three Least and Most Burdensome Countries within the European Union

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Abstract. *Premature mortality affects both developing and developed countries, having social and economic impacts. On the social side, premature mortality creates a shift in the population which affects the adequate functioning of systems like the pension funding. On the economic side, the income lost due premature mortality generate an impact both at household and macro level. The existing evidence, points towards a quantification of this burden as a function of the GDP, which lacks specificity to better understand the impact of this mortality or is leaning towards the purely epidemiological impact of mortality. a combination of using two methods to quantify economic burden, provides a different alternative to estimate the burden. the results show differences when using the value of statistical life method and the proposed modified production function. Having different methods to quantify economic burden of mortality provides another set of tools for researchers looking to quantify its impact and assess information to develop more specific public health interventions to address this.*

Keywords: premature mortality, economic burden, economic epidemiology, value of statistical life, production function.

Introduction

Parts of the changes experienced in the last century drove significant improvement in quality of life thanks to advancements in public infrastructure and education which in turn, drove improvement in the quality of life across many societies. As the concept of quality of life is rather ethereal, it can be better defined in terms of specific e indicators like life expectancy, which is a function of reduced morbidity and mortality. This can be explained in part to the specific improvements in access to sanitation services like potable water and sewer systems, better access to healthcare, immunization programs and better healthcare facilities, as well as enhanced access and quality to education. As a result of this, there has been a great reduction in the prevalence of communicable or infectious diseases and the mortality associated with it as recently as 1960, communicable diseases were the primary cause of mortality. By 1990, this changed as non-communicable diseases (NCD) also known as chronic diseases, started to shift the balance to become the most relevant cause of mortality. Unlike infectious or communicable programs like immunization and water potabilization; NCD's do not have a one way to be addressed, being extremely difficult to reduce the prevalence of these diseases.

Contrary to common believes, dengue, Ebola, HIV or SARS-COVID-19 are not the most prevalent causes of premature mortality as a measure of unfulfilled life expectancy (globally: nowadays, NCD are responsible for around 2/3 of all global deaths with over 16 million annually being premature deaths (James et al., 2018), which makes them, arguably, the most pressing matter to address with regards to public health. These group of diseases are driven by a plethora of risk factors that are often, related to societal changes with a strong behavioural component. Moreover, the NCD's are today the number one cause of mortality and account for about 80% of the total

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deaths in low and middle-income countries (Ndubuisi, 2021). Initially considered the diseases of affluent countries (Lloyd-Sherlock et.al., 2016; Ezzati et al., 2004), as they were closely related to sedentarism and access to food with limited or low nutritional value, which was often observed in developed economies, they expanded to be prevalent globally and specifically across the selected economies. NCD's are no longer the diseases of the wealthy countries but also to those who follow, as trends in overweight and obesity, high body mass index, high cholesterol and blood pressure, tobacco use, a primarily urban population, and the increased sedentary behaviours, in addition to the deleterious effect of highly processes food and high consumption of carbohydrates, have enabled these group of diseases to become prevalent globally, despite the country's GDP.

The scientific discipline best suited to assess the trends, impact and causality of mortality and is public health, more specifically epidemiology, which focus on the study of incidence, distribution, causality, and control of diseases. Due the incredibly impactful effect of infectious diseases, particularly through outbreaks (e.g., Bubonic, Cocoliztli, Spanish Flu, Smallpox, Typhus, Cholera, HIV, COVID-19), epidemiology has largely focused on infectious or communicable diseases, leading to the development of models -primary mathematical- to determine the R_0 (R-naught) of the disease or the specific number (on average) a single host would spread an infect other individuals. However, due the intrinsic nature of non-communicable diseases, these mathematical models were and remain unfit to address the upcoming wave of epidemics, as non-communicable diseases cannot be predicted based on current prevalence but based on specific health data from a given population (e.g., blood pressure, glycaemic index, BMI). In rather general terms, it is safe to state that 3 out 4 deaths can be attributable to non-communicable diseases (GBD, 2019).

Due the increased prevalence and the inherent cost of treatment of non-communicable diseases, which due their multi-factorial nature often requires long term medication and/or treatments, initial models were developed to address this new epidemiological profile from an economic perspective. This led to the development of health economics models which focuses largely on how a particular health intervention impacts the health care system based on cost and benefits. Unfortunately, health economics is limited to the reimbursement process which is not prevalent in all the health care system globally, let alone those within the OECD space. The economic burden of this new epidemiologic profile was leading to cost, expenses and financing issues due health care infrastructure use, pharmacological treatment and increased surgical procedures, posing questions related to how to address the need for better information. It wasn't until the early 1990's, that the blend between epidemiology and economy took its first steps, initially assessing the economic dimension of outbreak models, primarily due the HIV Epidemic. (McAdams, 2021). Moore recently, economic epidemiology took large strides assessing the most recent pandemic caused by SARS-COV-2.

The current challenges around the trends in premature mortality have a certain economic component: the healthier a population is, the more likely for them to produce (as form of employment), invest and spend. On the opposite side, the sicker a population is, the more they will spend in health care, and the less they will produce due early retirement caused by disability, intermittent employment due absenteeism, as well as the less likely they will be spending in housing, goods, education, savings and investment ([Oxford, 2016], [Ezzatti et al., 2005], [Pelinescu et al., 2015], [Abegunde et al., 2007]), This has a long-term impact as families with lower levels of education will carry on lower income to their offspring, as well as the lower level of investment and savings will carry over to posterior generations as well (Murphy et al., 2020).

The entanglement between economic development and well-being, provides an opportunity to further investigate several aspects of this entanglement, which for the purpose of this research will focus on providing ways to quantify the economic burden of premature mortality, one of which is new. More specifically, this research papers pursues to deliver a comparative analysis between the quantification methods and to provide an assessment of the causes driving premature mortality in the selected countries, using three causes of mortality: due all causes, due communicable diseases, and due non-communicable diseases. This allows to conduct a thorough analysis of the premature mortality, as well as provide specific results for further assessments of it.

Literature review

There is a wealth of literature available around the general trends in mortality, both on the epidemiologic and economic performance. However, there is limited information bridging both epidemiological trends and its economic impact (Kankeu et. al, 2013).

The economic burden of ill-health and mortality can be quantified by a plethora of indicators for both micro and macroeconomic level. The economic burden on the microeconomic level can be described as direct and indirect costs. Among the direct costs, cost of prevention, diagnosis, and treatment specifically in health care systems delivered through private providers under a non-universal coverage, where the individual has out-of-pocket expenses in addition to the monthly fees paid to cover a basic health care insurance. On the indirect cost side, loss of income due ill-health or death, is the most relevant, which has an impact not only on the individual but on the household, loss or reduced income due ill-health or mortality has a compounded impact on the entire household (Murphy et al., 2020). More importantly, the biggest toll of this economic burden is often carried by the households with lower incomes, with impacts covering three dimensions: consumption and savings, labour supply and productivity and education and human capital accumulation (Kankeu et. al, 2013). At household level, the economic burden has shifted from high income countries to upper- and middle-income countries and below (Ezzati et al., 2004).

At the macroeconomic level, on the productivity side, the burden of premature mortality is estimated to be €342.39 per capita in 2015 (Lyszczarz, 2019). The productivity impact mortality has, can be further expanded when human capital is considered as part of the analysis, as a significant driver of economic growth, particularly when additional factors as innovation and education level are considered, particularly when this human capital is lost due mortality (Pelinescu, 2015). Bleakey (Bleakey, 2010) affirm that "health itself is part of the human capital as an input to produce other forms of human capital".

Abegunde (Abegunde et al., 2006), contributed to the expansion of the assessment of burden to include additional impacts of the burden of disease, particularly for NCD on what he describes as the "poverty spiral". On the microeconomic drivers, reduced labour due mortality will impact the dependency ratio (of one household member income), reduced access to employment and increase consumption on health services and reduced expenses on investment and education. These drivers will in turn affect the life expectancy and its human capital, which may influence GDP and foreign investment.

From a macroeconomic level, estimates provided by Barro (Barro et al., 1996) point towards the impact life expectancy has on annual GDP growth, with a five-year increase having an impact of 0.3 to 0.5% higher annual GDP growth rate in the subsequent years. Despite all the available information about the burden of non-communicable diseases, up to 2011 it is estimated that only 1-2% of the health financing is dedicated to address this pandemic (Allen, 2017).

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One aspect that comes about when reviewing current literature, is related to the fact that most of the available literature focus on burden of disease as opposed to the burden of mortality. Albeit both are adequate indicators of ill-health, the burden of disease covers aspects related to the care of the individual once the disease has set, which includes medication and the impact these may have on the life of the individual and more importantly, on their ability to work. On the other hand, mortality has a much more radical approach as on one hand, there is a lack of future care of those of died, hence reducing the cost of maintaining the individual alive; yet there is a cumulative effect mortality have on the household and on the society. In other words, burden of disease quantification methods will deliver much larger numbers, when compared to burden of mortality. The largest impact mortality has is at household level, particularly in low-income households.

It is broadly accepted that the most significant shift in the epidemiological profile, occurred around 1990, when the global mortality due both communicable/infectious and NCD diseases was around 20 million a year. From that point onwards, the infectious diseases rates dropped significantly while NCD's increased. By 2010 and estimate of 28 millions of deaths were attributable to non-communicable diseases yet only 15 to communicable diseases (Murray et al., 1996). Estimations from Habib and Ndubiosi (Ndubuisi, 2021), predicted the mortality due non-communicable diseases to be responsible for 69% of the total mortality with on 17% due to communicable diseases. The global burden of disease study from 2017 (GBD, 2017), provide information about the decrease rates of mortality and premature mortality between 1990 and 2016 with a direct impact on the life expectancy as positive outcome of this reduction. As for the value of statistical life (VSL), the use of potential years of life lost together with wages is a common way to estimate the burden of premature mortality (White et al., 2022, Sweis, 2022)

Methodology

General aspects

This research spans quantitative analysis using time series data of mortality to quantify premature mortality for the top 3 and bottom 3 countries within the European Union. The datasets include crude mortality and annualized wages. This research pursues the quantification of premature mortality using two different models: 1) value of statistical life (VSL), 2) a proposed production function to quantify economic burden under different scenarios. A secondary objective is to document the trends around premature mortality on the selected countries. The research spans the period 1995-2019, which has been selected based on a two rationale. First, is related to the need to use standardized information. Albeit there is significant information around mortality since as far back as 1950, the period 1995-2019 contains standardized data from the World Health Organization International Classification of Diseases (ICD), specifically the ICD-10. The use of Standardized ICD-10 information allows to conduct adequate comparisons between countries. The second rationale is related to the absence of globally impactful public health events as although not free from pandemics (e.g. HIV in 1990's, SARS in 2002, H1N1 in 2009, MERS in 2013, Ebola in 2014), they did not generate a substantial impact in mortality attributable to communicable diseases, hence was a rather steady period from a mortality perspective. The period 2020-2022 would be interesting as certainly had tremendous impact in mortality due communicable diseases as part of the SARS-CoV-2 pandemic; was not included due the lack of available data from the selected economies. In general, mortality information is usually available up to 2 years after the year the mortality database was accessed.

Datasets and data management

The information utilized for this research, comes from two primary sources of data, namely OECD and WHO. The former, provides quantitative information about the member states wages and household savings indicators. The latter, provides globally available quantitative information related to mortality for three causes: all, communicable diseases and NCD. These datasets are providing as time series.

Mortality information is provided as 1) crude numbers (i.e., the actual deceased within a country at a given year). The information is provided for a subset of age groups in the ranges described on table 1. Only 16 age groups are considered adequate for the scope of the research. The age group selection criteria include groups including all age groups, and age groups between 0 and 69 years of age. The age groups eliminated include 1) the age group labelled as "unknown" (1), as without actual age, is not possible to calculate the PYLL's, and 2) the groups of age above 69 years of age (4). The age groups available and utilized are summarized on Table 1.

Table 1. Age groups information showing included and excluded age groups

Age group code	Status
Age_All	Used to consolidate information by year.
Age00	Included in the research
Age01_04	Included in the research
Age05_09	Included in the research
Age10_14	Included in the research
Age15_19	Included in the research
Age20_24	Included in the research
Age25_29	Included in the research
Age30_34	Included in the research
Age35_39	Included in the research
Age40_44	Included in the research
Age45_49	Included in the research
Age50_54	Included in the research
Age55_59	Included in the research
Age60_64	Included in the research
Age65_69	Included in the research
Age70_74	Excluded from the research – not adequate
Age75_79	Excluded from the research – not adequate
Age80_84	Excluded from the research – not adequate
Age>85	Excluded from the research – not adequate
Age_Unknown	Excluded from the research – not valid

Source: author's own research.

Potential years of life lost (PYLL), value of statistical life (VSL) and modified production function

PYLL are an estimate of burden of mortality as a function of the years of potential income lost (OECD, 2023), from a standard age of 15 up to an arbitrary age. On purely epidemiological studies, 75 is usually the threshold age, however different t age threshold are used based on the nature of the research. For the scope of this research, 69 years of age is the selected age limit (Table 2), based on the current average retirement age for OECD Countries inhabitants (64.2 for males and 63.7 for females), and the expectation to continue raising the retirement age towards 67 and above (OECD, 2021).

PYLL are utilized as input for calculating the value of statistical life (VSL). In the simplest terms, the VSL is the willingness of an individual to pay to reduce a given risk and is calculated collectively as opposed to individually.

PYLL are used in different forms including age specific, crude mortality specific and the summation of PYLL. These different forms, take a slightly different approach but are ultimately utilized to obtain the ultimate form which is the most relevant from a methodological point of view. To collaborate with the expansion of the understanding of PYLL and its potential use, a description of the three forms utilized is provide as follows.

$PYLL_{\alpha}$: as the maximum possible number for a given age group can have. (Formula 1).

Formula 1: maximum years of PYLL

$$PYLL\ a = 69 - \left[\frac{\Delta ag}{2}\right]$$

with $\{2 \leq PYLL_{\alpha} \leq 54\}$

Source: modified from Gardner et al., 1990.

Formula 2: PYLL for age group

$$PYLL\beta \text{ for (age group n)} = PYLL_{\alpha} * Cm_{1}$$

With n = 16 and Cm_1: Crude mortality for age group 1.

Source: modified from Gardner et al., 1990.

$PYLL_{\gamma}$: as the summation of $PYLL_{\beta}$ of all the age groups within the scope of the research (Formula 3). $PYLL_{\gamma}$ is individually calculated for the three causes of mortality.

Formula 3: annualized PYLL

$$PYYL\gamma = \sum_{1}^{16} PYLL\beta$$

Source: Gardner et al.

Table 2. Age groups information showing included and excluded age groups

Age group code	Lowest age group limit	Highest age group limit	Age group mean	PYLL(69)α for Age group
Age_All	NA	NA	NA	NA
Age00	0	0.99	0.495	54
Age01_04	1	4	2.5	54
Age05_09	5	9	7	54
Age10_14	10	14	12	54
Age15_19	15	19	17	52
Age20_24	20	24	22	47
Age25_29	25	29	27	42
Age30_34	30	34	32	37
Age35_39	35	39	37	32
Age40_44	40	44	42	27
Age45_49	45	49	47	22

Age group code	Lowest age group limit	Highest age group limit	Age group mean	PYLL(69)α for Age group
Age50_54	50	54	52	17
Age55_59	55	59	57	12
Age60_64	60	64	62	7
Age65_69	65	69	67	2

Source: author's own research.

The PYLL are used to quantify the burden of premature mortality using the value of statistical life method. The VSL is the product of the $PYLL_{\gamma}$ which is the total number of years of life lost for a given cause, including all the age groups. (Formula 4).

Formula 4: maximum years of PYLL

$$PYLL\ a = 69 - \left[\frac{\Delta ag}{2}\right] \text{ with } \{2 \leq PYLL_{\alpha} \leq 54\}$$

Source: modified from Gardner et al., 1990.

Formula 5: Value of statistical life

$$VSL = [PYLLa * Wa] \text{ With Wa: annual wages.}$$

Source: modified from Sweiss, 2022.

To estimate the burden of premature mortality, a modified production function is used. This function provides the result as cost of opportunity of using what would have been available resources, should an individual had not prematurely died. The Formula considers the annualized wages and the crude mortality (Formula 6).

Formula 6: production function.

$Pl = [(\mathrm{Wt} * \mathrm{Cr}) * \mathrm{Cmt}]$ With W_t: annual wages on year t, C_r: consumption as % of wage and Cm_t: cumulative mortality on year t.

Source: author's own research.

The total cost of opportunity is then calculated for the period between 1995 and 2019.

Results and discussions

The mortality continues to trend downward in the selected countries, with a steeper reduction in those countries with a larger mortality (Estonia, Latvia, Lithuania) and a less step reduction in countries who had already a reduced mortality. Another aspect to consider, is the fact that the most developed economies (Sweden, Netherlands, Italy), had rather low crude mortality due communicable diseases, which have remained low or reduced marginally. On the other side, mortality due non-communicable diseases are either steady or is showing increase over the last years covered by this research paper (Estonia, Lithuania, Netherlands, Italy, Sweden). This is in line with broader studies showing the remarkable upward trend for non-communicable diseases premature mortality. (Figure 1, 2, 3, 4, 5, 6).

From the quantification perspective, both the Value of statistical life and the adapted production function show similar results, with the latter showing slightly lower economic burden, as this is calculated based on income, which is not allocated to savings, hence used as purely disposable income. There is also a natural impact on the overall burden based on the size of the country population and its annual wages, for which Italy has the largest economic burden of premature mortality given both its relatively high annual wages and its much larger population compared to the other countries.

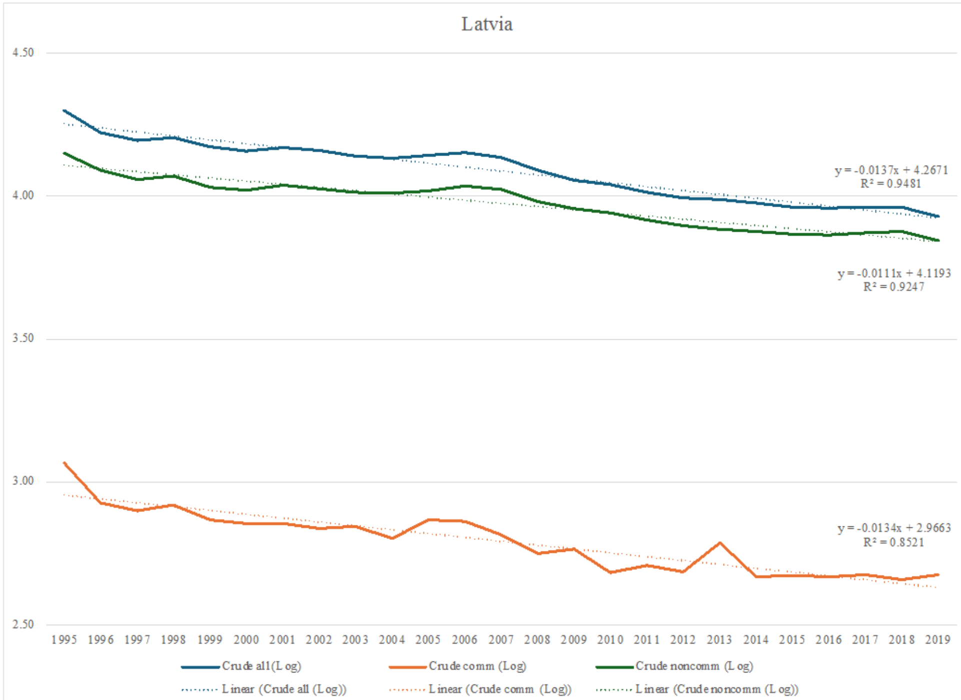

Figure 1. mortality trends for Latvia

Source: author's own research.

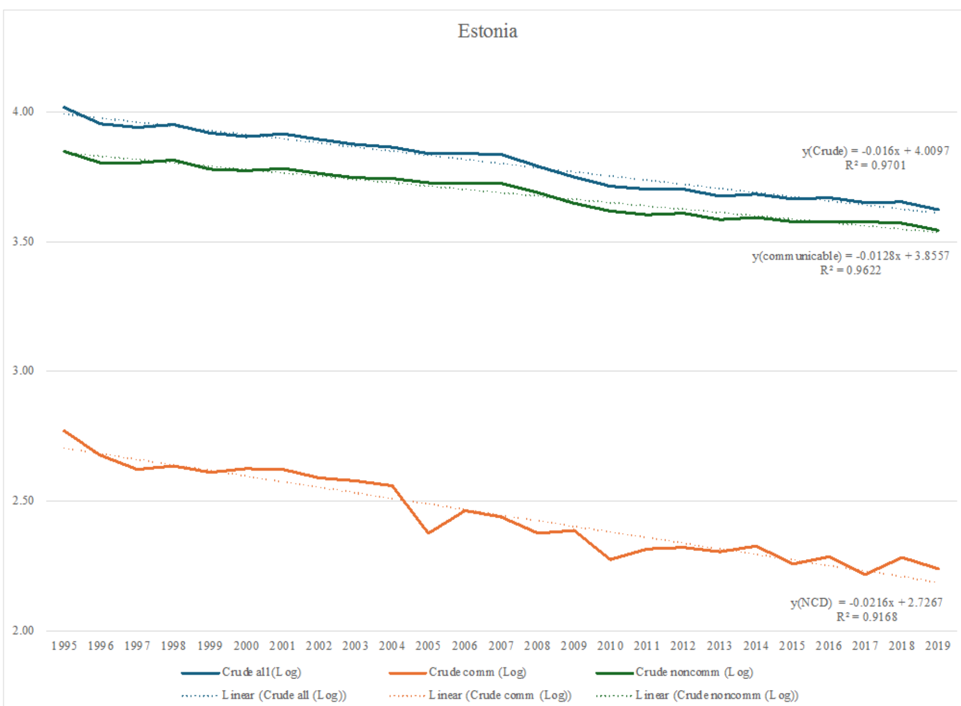

Figure 2. Mortality trends for Estonia

Source: author's own research.

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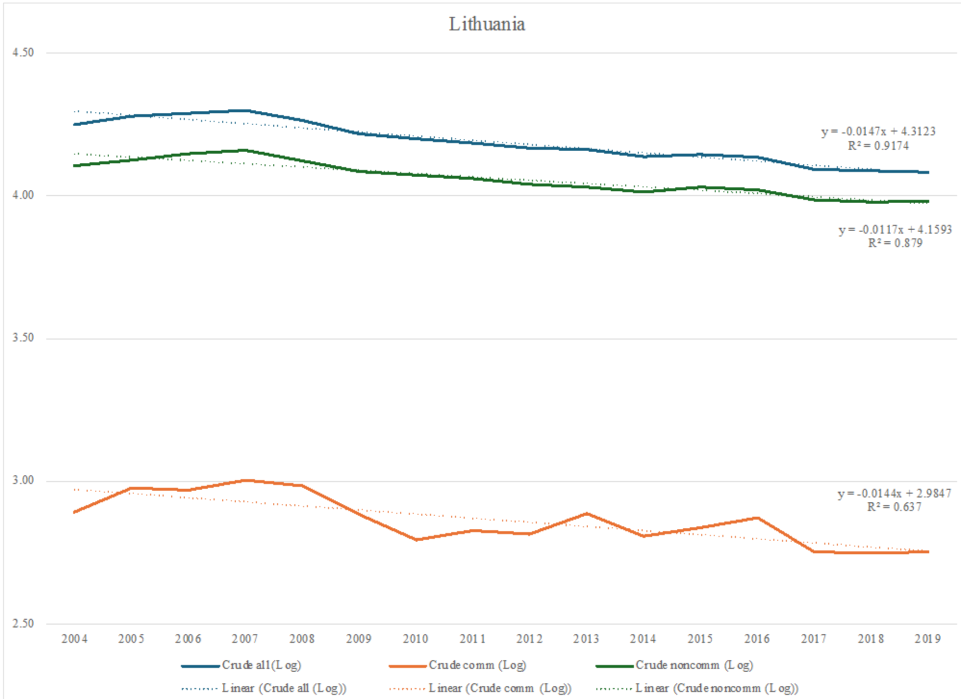

Figure 3. Mortality trends for Lithuania

Source: author's own research.

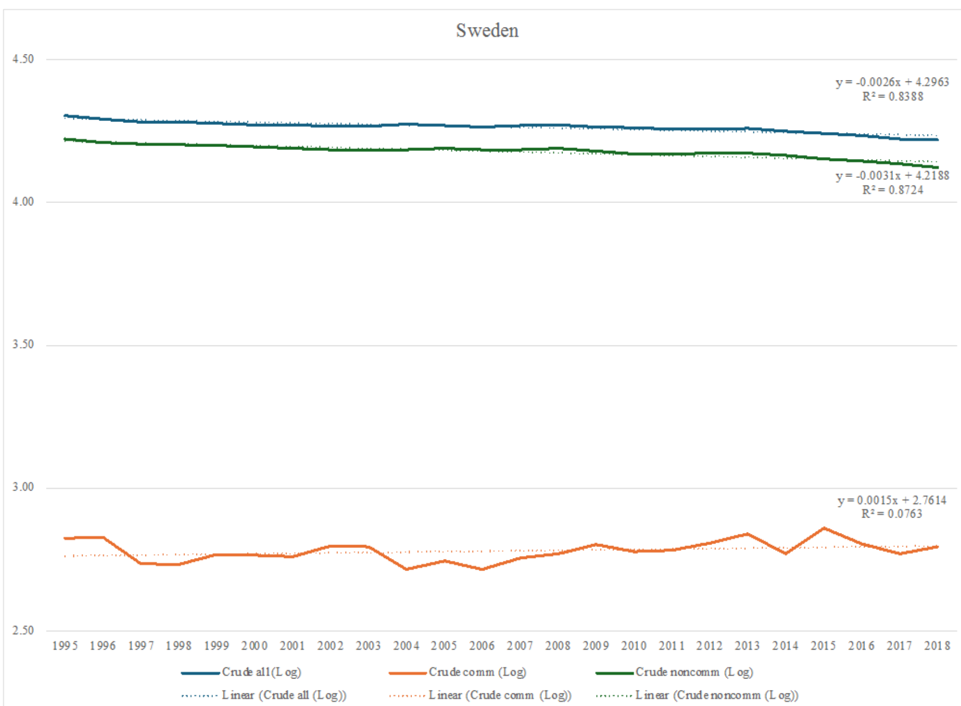

Figure 4. Mortality trends for Sweden

Source: author's own research.

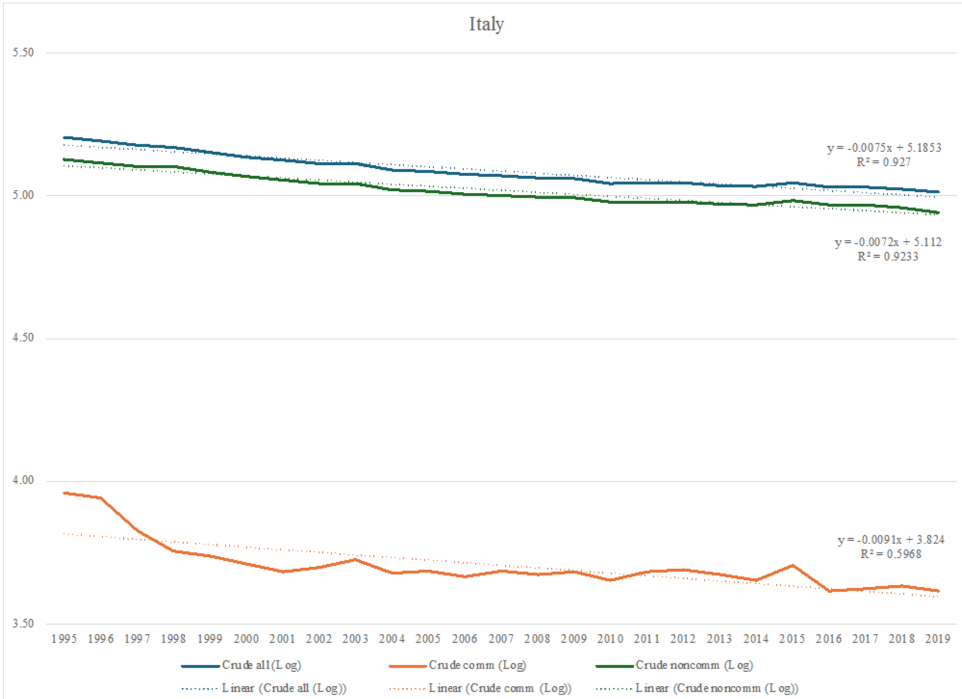

Figure 5. Mortality trends for Italy

Source: author's own research.

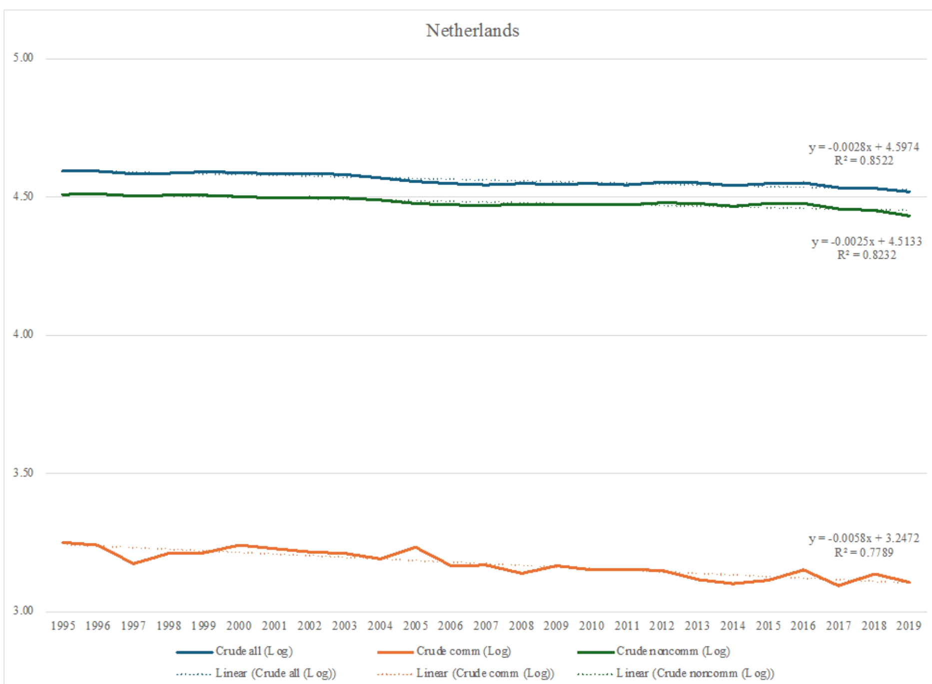

Figure 6. Mortality trends for Netherlands

Source: author's own research.

Table 3. Economic burden: VSL method

Country Code	VSL* All Causes (USD)	VSL* Communicable diseases (USD)	VSL* NCD **(USD)
1. Sweden	234,679,598,607	13,991,470,490	160,193,752,563
2. Italy	1,809,431,115,615	153,561,924,905	1,278,503,104,278
3. Netherlands	748,677,909,137	61,396,155,322	531,366,900,910
7. Lithuania	114,791,598,520	7,604,019,743	70,103,581,625
8. Estonia	45,052,382,275	3,315,735,123	28,558,138,315
9. Latvia	85,881,074,125	7,269,215,373	53,869,622,415

*VSL: Value of statistical life. **NCD: non-communicable diseases.

Source: author's own research.

Table 4. Economic Burden: production function method

Country Code	Adjusted burden All Causes (USD)	Adjusted burden - Communicable diseases (USD)	Adjusted burden NCD** (USD)
1. Sweden	217,589,736,680	12,947,919,347	148,628,101,798
2. Italy	1,669,441,473,988	140,452,261,813	1,181,755,340,105
3. Netherlands	696,564,601,854	57,157,966,365	494,407,696,580
7. Lithuania	116,483,915,157	7,720,720,690	71,162,361,181
8. Estonia	44,931,577,392	3,307,075,568	28,429,361,592
9. Latvia	93,740,451,985	7,958,436,462	58,491,572,034

**NCD: non-communicable diseases.

Source: author's own research.

Conclusion

The impact of premature mortality is substantial, and evidence shows it will remain increasing. There is a large economic toll which affects the available human capital and the ability of a country to fulfil its production needs. Particularly, the premature mortality due non-communicable diseases take the largest toll of the economic burden and, although this is part of heated debates about public health interventions, will most likely remain the same for the next 10 years, mostly due the complexity of health care interventions needed, the time to achieve a full implementation and the delay between intervention and results as populations' health profile. This research provides a dual way to quantify burden, which can be further used to assess mortality at age group and gender level, to better quantify the specific groups that are more significantly affected by premature mortality; it can further be expanded by including a larger groups of countries and by increasing the assessment of economic burden as a portion of the country GDP. The results from this research are aligned with the results from other authors (Abegunde et al., , Bleakey, James et al., Habib et al.), in both the mortality trends and the shift on the mortality profile, and the impact non-communicable diseases has on premature mortality. This paper does however provide a new approach utilizing a modified production function which utilizes wages and consumption rates to deliver a result. This approach allows a better understanding of the economic impact of premature mortality and helps deliver a different quantifier of its impact. Furthermore, due the complexity of the acknowledgement of the impact of premature mortality, the time to implement changes and the cost of reducing mortality, different indicators may allow policy makers to build better arguments with newer evidence.

This research is limited to 6 countries within the European Union, which makes it an intrinsic limitation due the limited number of countries assessed. Moreover, using wages and consumption as well as value of statistical life, provides valuable information yet information that may well be complimented and expanded by using further data including health care expenditure to assess the effectiveness of health care systems, gender-based employment rate to assess the impact due differences in employment and the retirement age to quantify the impact more accurately to a country-specific standardized retirement age. Ongoing research is pursuing to address these limitations and further expand this research.

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