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151 Slater Street, Suite 710

Ottawa, Ontario K1P 5H3

613-233-8891

csls@csls.ca

CENTRE FOR THE STUDY OF LIVING STANDARDS

Measuring the Appropriate Outcomes for Better Decision-Making: A Framework to Guide the Analysis of Health Policy

Matthew Calver

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Abstract

Many existing economic evaluations of health policy recognize multidimensional outcomes and the importance of equally distributing the benefits, but do not to incorporate all relevant outcomes into a single comprehensive metric for cost-benefit analysis. The Organization for Economic Co-operation and Development's (OECD's) inclusive growth framework offers a novel approach for improved evaluation of policies which can address these concerns by aggregating societal outcomes in terms of income, life expectancy, unemployment rates and inequality into a single measure of living standards. We discuss the inclusive growth framework in the context of health policy and how it can be utilized by business leaders and policymakers to make superior policy decisions. Using an inclusive growth index of living standards developed by the OECD, we decompose growth in living standards (as defined by the OECD) due to increased life expectancy in Canada between 2000 and 2011 by cause of death and estimate the equivalent value of these reductions in mortality in terms of billions of dollars of income. We discuss factors underlying these reductions in mortality and suggest how they have been linked to policy. This exercise illustrates one way in which the inclusive growth framework can be used to evaluate the impacts of health policy.

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Executive Summary

Introduction

There is increasing recognition that living standards include far more than just income. It encompasses a multitude of factors such as health, economic security, and equality. Taken together, these relatively tangible determinants of well-being dictate Canadian living standards.

Canadian public policy aims to maximize the living standards of Canadian citizens. This requires comprehensive evaluation of available policy options taking into account all their effects and how these combine to impact the standard of living. Only considering a subset of the relevant outcomes may lead to suboptimal decisions.

This report provides a brief overview of the standard approaches to economic evaluation of health policy. It suggests that, in many cases, these approaches fail to effectively capture the total impacts of policy on living standards. A recent approach to policy evaluation developed by the Organization for Economic Co-operation and Development (OECD) offers a means to improve upon existing policy evaluations in this regard.

A simple decomposition exercise is performed to demonstrate the potential of this approach to evaluate health policy benefits. In particular, we quantify the contributions of reductions in mortality from various diseases to the growth of an inclusive growth index of Canadian living standards since 2000. By linking these reductions in mortality to specific policies, health policy evaluators have a very simple approach to quantify the direct impact of these policies on aggregate well-being.

Traditional Approaches to Economic Evaluation of Health Policy

Most approaches to the economic evaluation of health policy have the same basic premise: calculate the benefits of the policy and compare to the costs. Costs tend to measured in dollars by all approaches, but there are many different approaches to assessing benefits.

Under several approaches to health policy evaluation, the benefits considered are very narrowly measured in terms of a specific health outcome (the prevalence rate of tuberculosis, for example). Sometimes, the desired outcome is so specific that the benefits do not vary at all –

minimizing costs is sufficient in these situations. Approaches which only consider specific health outcomes can be very effective, particularly when the scope of the policy objective is narrow.

For broader questions, health policy evaluations frequently need to be able to cope with both health and non-health outcomes which may be measured in very different units. For example, if a government is choosing how to allocate funding between health and education, then the effects on health outcomes and education outcomes must both be considered. For these sorts of decisions, it is necessary to aggregate across health and non-health outcomes. This poses a challenge, as it is not obvious how this aggregation should be performed.

One approach is to put an explicit dollar value on health (cost-benefit analysis). This option is often avoided because it can be controversial. Even when it is done, the approach used to value health is often quite arbitrary. The alternative is to consider all relevant consequences separately and not to attempt to aggregate them (cost-consequences analysis). This leaves the decision as to how to weight the various outcomes to the discretion of the decision maker – notice that this does not avoid the problem of aggregation, it simply obscures the weighting being used in making the final decision. Many health policy evaluations strike a balance between these approaches by aggregating all monetary benefits and supplementing this with a description of the health benefits.

This report argues that it is preferable to explicitly aggregate monetary and health outcomes into a single measure of the benefits. This way, the process through which evidence has been aggregated in arriving at the final decision is more transparent. However, transparency does not necessarily imply that the weighting is correct and it is unlikely that there will ever be a consensus on how this should be done. Nonetheless, for economic evaluation of health policy it seems reasonable that the chosen weighting should be based on standard economic theory and that it should be determined by the available data.

The Inclusive Growth Framework

The OECD has developed a new approach to measuring living standards which can be used to perform cost-benefit analysis of health policy. The inclusive growth method aggregates multidimensional outcomes (health, life expectancy, and the unemployment rate) into a single measure of well-being: an inclusive growth index of living standards. It is calculated by taking the average annual income of the population and adjusting this value based upon the unemployment rate and life expectancy in the society (the framework can accommodate other sources of well-being, but these are the ones the OECD has emphasized thus far). This adjusted measure of income is then scaled down to reflect the unequal distribution of these outcomes. The end result is a dollar figure which captures the standard of living.

It is important to understand how the conversion from life expectancy to dollars is performed. Inclusive growth relies upon fixed benchmark levels of life expectancy and the unemployment rate to make valid comparisons across multidimensional outcomes. For each multidimensional outcome under consideration, a second multidimensional outcome is identified which is equally desirable, but which contains the unemployment rate and life expectancy at their selected benchmark levels. These levels of income (combined with the benchmark unemployment rate and benchmark life expectancy) are equivalent to the original multidimensional outcomes which are to be evaluated, but they are readily comparable because they only vary along a single dimension (income).This measure is called "equivalent income" because it is a level of income (in conjunction with the benchmark life expectancy and unemployment rate) which is equivalent in terms of well-being to the actual combination of income, life expectancy, and unemployment rate being analyzed.

The level of equivalent income reflects an individual's willingness to exchange income for increased life expectancy and better employment prospects. While the choice of benchmark is arbitrary, the OECD suggests that the best outcomes are used as the benchmark so that equivalent income will always represent actual income reduced by the amount individuals would be willing to pay to achieve the highest observed life expectancy and no unemployment.

There are many ways to estimate what the willingness to pay will be. The OECD performs a simple statistical exercise (an ordinary least squares regression) which estimates the effects of life expectancy, the unemployment rate, and average income on average self-reported life satisfaction in a country. This statistical exercise provides a data-based approach to estimate the rate at which individuals are willing to trade life expectancy, unemployment risk, and average income. Using this approach, the OECD estimates that an additional year of life expectancy is worth approximately 5.3 per cent of annual income (all OECD figures cited in this report represent provisional results from ongoing research).

Life Expectancy and Canadian Living Standards

Based on the OECD's inclusive growth index of living standards, the Canadian standard of living improved by 3.52 per cent annually from 2000-2011. A substantial fraction of this growth, 41 per cent (1.45 percentage points), can be attributed to an increase in life expectancy at birth of 2.43 years from 79.23 years in 2000 to 81.66 years in 2011. For comparison, growth in income accounts for 61 per cent of the growth in living standards, slightly lower inequality accounted for 1 per cent of the growth, and a higher unemployment rate reduced growth in living standards by 4 per cent. Based on the estimate that one year of life expectancy is worth 5.3 per cent of income, the increase in life expectancy by 2.43 years was approximately equivalent to average annual income rising by $4,796 ($161 billion dollars of income nationally).

Growth in the Canadian Standard of Living by Source, 2000-2011

	Living Standards	Household Income	Life Expectancy	Unemployment Rate	Inequality
Contribution (percentage points)	3.52	2.15	1.45	-0.13	0.05
Contribution (per cent of total)	100.0	61.1	41.2	-3.7	1.4

Source: Author's calculations using provisional results from ongoing research provided by the OECD.

The primary exercise of this report is to decompose the growth in living standards due to increased life expectancy into growth in living standards due to reductions in mortality rates from specific causes of death. The decomposition of growth in life expectancy by cause of death is performed using a standard technique from the literature. This exercise provides a very detailed understanding of where two-fifths of recent growth in Canadian living standards has occurred. Using the OECD's estimates, it also allows us to put a dollar value on these reductions in mortality.

Highlights of the most important reductions in mortality for living standards include:

i. Major cardiovascular disease was linked to 58.3 per cent of the increase in life expectancy and 23.9 per cent of growth in livings standards with a national value of $93.5 billion of household income annually

ii. Cancer was linked to 24.4 per cent of the increase in life expectancy and 10.0 per cent of growth in livings standards with a national value of $39.1 billion of household income annually

iii. Chronic lower respiratory disease was linked to 3.7 per cent of the increase in life expectancy and 1.5 per cent of growth in livings standards with a national value of $5.9 billion of household income annually

iv. Accidents were linked to 3.6 per cent of the increase in life expectancy and 1.5 per cent of growth in livings standards with a national value of $5.8 billion of household income annually

v. Diabetes was linked to 3.2 per cent of the increase in life expectancy and 1.3 per cent of growth in livings standards with a national value of $5.2 billion of household income annually

The appendix of this report contains a complete breakdown of growth in life expectancy attributable to reduced mortality from 113 causes of death.

Much of these reductions in mortality will have been the result of health policy. This decomposition provides an easy way to put a specific dollar value on reduced mortality from a specific policy. All that is required is that one has a reasonable estimate of the reduction in mortality attributable to the policy. We illustrate how estimating the benefits of policy could work with a simple example.

Ischaemic heart disease was responsible for an increase in life expectancy of 0.91 years, which corresponds to 15.4 per cent of the improvement in living standards and is equivalent to $1,797 of adjusted household income per capita ($60.1 billion nationally). Wijeysundera et al. (2010) estimate that 42.6 per cent of reductions in mortality from ischaemic heart disease in Ontario between 1994 and 2005 were the result of improvements in medical treatment. Assuming that medical treatment accounted for the same amount of reduced mortality from ischaemic heart disease in Canada from 2000 to 2011, it is straightforward to estimate that improvements in medical treatment of ischaemic heart disease were responsible for 6.6 per cent of growth in Canadian living standards worth $766 of income per capita ($25.6 billion nationally).

Conclusion

The OECD's inclusive growth framework provides a new tool to assist decision-makers with the economic evaluation of health policy. This approach provides a novel way to address the problem of weighting health and non-health outcomes when evaluating more complex health policies. While the willingness-to-pay approach is unlikely to be universally praised, we suggest that it at least provides a transparent approach rooted in basic economic theory and supported by the data. By converting all outcomes to their equivalent incomes under a common benchmark, this method allows for valid comparison of policy outcomes. Furthermore, it explicitly accounts for inequality.

There are some notable limitations to this method and it continues to be refined. While the general approach should be very natural to economists, it can be difficult to communicate to those with different backgrounds. There remain many different ways in which researchers could estimate the willingness-to-pay for health. The results are also subject to the choice of baseline, at least in theory. It remains to be seen how robust the results are in practice. Lastly, data limitations can be a problem. While the method is designed to account for inequality, this requires information on the distribution of health outcomes or employment prospects. As a result of limited data availability, the adjustment for inequality is currently limited to an adjustment for income inequality.

The inclusive growth approach is most obviously useful for government policymakers, international organizations, think tanks, and academics. It can be applied to a broad range of policy questions – the inclusive growth index described in this report can be applied effectively to any policy which only significantly impacts life expectancy, income, and unemployment rates.

Simple variants on the detailed decomposition of sources of reduced mortality in this report could allow for analysis of the impacts of specific policies on living standards. For example, a cost-benefit analysis of options to reduce mortality among the First Nations population from diabetes could be assessed using a similar approach to the one in this piece (assuming sufficient data on First Nations life expectancy and cause specific mortality rates could be collected and a way to estimate the impact of these policies on diabetes).

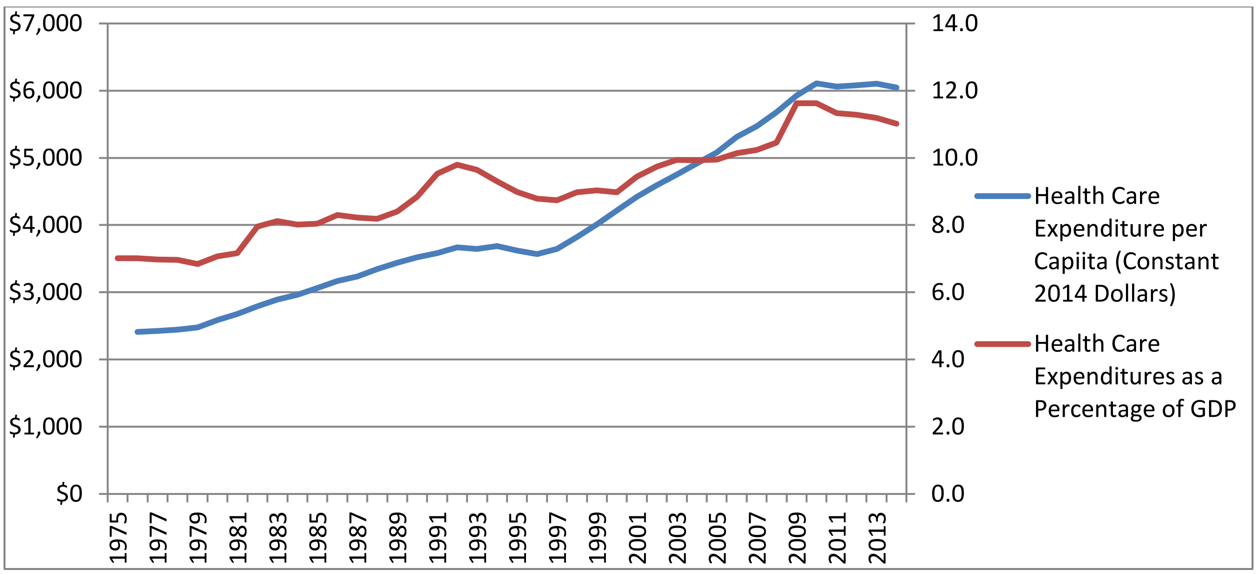
Businesses could also benefit from using the inclusive growth methodology. This may not be immediately obvious – if a firm's objective is to maximize profit (the standard assumption in economics), why would one want to evaluate policies based on a comprehensive measure of social well-being? One answer is that doing so can sometimes be profitable. A firm may gain from adopting health policies (health benefits, better working conditions, information sessions, etc.) which improve worker health if these policies serve as a form of non-wage compensation (lower turnover, attract better workers, or substitutes for wage compensation). Many firms engage in acts of corporate social responsibility which improve the firm's reputation. Inclusive growth could allow for more comprehensive evaluation of efforts to reduce environmental impact, improve worker health among suppliers, or support community health. Not only could this make spending on such policies more effective, it would also allow firms to communicate the impact more completely to the public. Inclusive growth could also be used by businesses to provide better evidence to policymakers when participating in public policy debates.

Measuring the Appropriate Outcomes for Better Decision-Making: A Framework to Guide the Analysis of Health Policy[1]

I. Introduction

In 2014, total health spending in Canada is projected to be $214.9 billion or $6,045 per person, according to a recent report on national health expenditure trends. Overall, health expenditure is expected to have represented about 11.0 per cent of Canada's gross domestic product in 2014 (Canadian Institute for Health Information, 2014).

Chart 1: Total Health Care Expenditure per, Canada, 1975-2014[2]



Source: The Canadian Institute for Health Information's National Health Expenditure Database (NHEX)

[1] This report was written by Matthew Calver under the supervision of Andrew Sharpe. The Centre for the Study of Living Standards (CSLS) thanks the Conference Board of Canada for financial support for this project and Thy Dinh, Louis Thériault, Brent Dowdall, and Maxim Armstrong of the Conference Board of Canada and Eugene Wen of the Workplace Safety and Insurance Board of Ontario for useful comments. The CSLS thanks the OECD for providing provisional data on their inclusive growth index and Fabrice Murtin of the OECD for informative comments on our application of the OECD's framework. The CSLS also thanks Bert Waslander for many insightful comments. Email: matthew.calver@csls.ca

[2] The current dollar figures published by the Canadian Institute for Health Information expenditures in this chart have been converted into 2014Canadian dollars using the consumer price index for all items in CANSIM Table 326-0021.

Ballooning costs and pressures stemming from an aging population make fiscal sustainability of the system while simultaneously maintaining a high level of care a central issue for all Canadians. Effective health policy must identify the most efficient means of achieving health and non-health outcomes and determine how much of society's scarce resources should be allocated towards health rather than towards other goals. Constructing such policy requires approaches to economic assessment which can fully quantify the costs and benefits of health related polices.

This report will go beyond the typical measures of economic performance to discuss the broader implications of health policy for improved living standards in Canada. To do this, we present a framework recently developed by the Organization for Economic Co-operation and Development (OECD) which provides a more inclusive approach to the economic assessment of policy. This "inclusive growth" approach is based upon a measure of living standards which extends beyond GDP to account for health outcomes, unemployment risk, and inequality. The framework provides a comprehensive way to evaluate the consequences of policy actions which can have impacts along these multiple dimensions.

Such an approach can overcome the limitations of many of the existing approaches to health policy evaluation which struggle to fully capture the value of improvements in health. In particular, existing evaluations are hesitant to attempt to put a dollar value on health outcomes. As a result, the effects of policies are frequently presented piecemeal, with separate discussions of the impact of the policy on health and on the dollar value of these improvements in health through reduced healthcare costs and increased production. If inequality is even considered, it often is discussed separately as well. Such analyses make decision making difficult, as policymakers must choose how to weight the various factors which are measured in different units while faced with mixed messages from various stakeholders who favour one weighting over another.

The inclusive growth framework provides a way to consolidate these various measures into a single measure of living standards. Such an approach could lead to better decisions regarding policy related to health. Similarly, it can provide a means to assess the allocation of funds across sectors with very different policy goals or lead to more comprehensive evaluations of policies which have health impacts but are primarily evaluated on other criteria.

To illustrate one potential application of this approach, this report decomposes growth in the OECD's inclusive growth measure of living standards attributable to increased life expectancy by cause of death. Such a decomposition allows for a clear identification of the contributions to growth in aggregate well-being made by reductions in mortality rates from specific causes. Furthermore, one can calculate the equivalent value of this improvement in terms of income. If one could identify the sources of the reductions in mortality for each specific cause of death, then one could estimate the total dollar value of these sources and any policies underlying them. We briefly discuss the likely major sources of improvement in mortality rates for some of the major causes of death, although quantifying the effects of specific policies is beyond the scope of this project.

This report is organized as follows. Following this introduction, the second section discusses several metrics and approaches which are commonly used in the economic evaluation of health policy and the strengths and weaknesses of these approaches. The third section describes the inclusive growth framework in non-technical terms and presents an international inclusive growth measure of living standards developed by the OECD. The fourth section provides background information on life expectancy in Canada and the many factors which determine life expectancy before showcasing the main results of our decomposition of growth in living standards due to increased life expectancy by cause of death. We follow this up with a discussion of likely sources of reduced mortality from major causes of death which would ultimately drive the growth in living standards. The conclusion recaps major points from this report, discusses the applicability of the inclusive growth method for health policy evaluation, and offers some suggestions for future research.[3]

[3] The major insights of this study have been condensed into the third briefing of a series released by the Canadian Alliance for Sustainable Health Care (CASHC) entitled *Health Care in Canada: An Economic Growth Engine*. This series aims to examine the relationship between health care in Canada and the broader economy.

II. Approaches to Economic Analysis of Health Policy

A. The Challenge

Policy evaluation is an important part of the process of sound decision making. Careful qualitative and quantitative analysis of the expected and realized effects of a policy can provide valuable insight into the best means to achieve policy goals and the most efficient way to allocate limited resources. Maintaining good health is a high priority for all Canadians, but limited health resources, an aging population, and increasing costs pose serious challenges. Decisions guided by effective evaluation contribute to the sustainability of Canada's health care system and the well-being of the population more generally.

Evaluating health policy can be a difficult task. In many cases health policy decisions are complex. There are frequently many viable policy options to choose from which can have many consequences, direct and indirect. For example, in evaluating multiple approaches to treating a disease, one could consider all the costs associated with each option (physician costs, medication costs, hospital costs, etc.), the effectiveness of each option, the time it takes for the treatment to succeed, any risks involved, any pain or side effects experienced as part of treatment, and the expected benefits of treatment. The benefits of treatment can extend beyond the reduced pain and suffering of the treated individual to include increased productivity at work (which may have a positive impact on the individual's wages, her coworkers' wages, the profits of her employer, and tax revenues), the value to the individual of extending her life, and the value of the individual's health to her family. Depending upon the nature of the health policy being evaluated, a wide variety of measures can be used to assess the policy.

The large number of potentially relevant factors to consider in evaluating any health policy can be problematic. As many of these factors are non-monetary, it can be very difficult to incorporate them into a cost-benefit analysis in a non-arbitrary way. In particular, the cost of an individual's pain or the intrinsic value of human life are notoriously difficult to put dollar values on. Moreover, health policy decisions often can impact a range of stakeholders who may wish to emphasize the costs and benefits relevant to themselves while putting little weight on factors which do not affect them directly. For example, compared to individuals, businesses may put more weight on lost productivity and output and less weight on the intrinsic value of better health when evaluating the effects of health policy.

The indistinct nature of the relevant weighting of health and non-health outcomes allows various researchers to produce methodologically sound studies which can lead to very different conclusions for health policy depending on which factors they choose to emphasize. Decision makers can be bombarded by conflicting analyses and recommendations from stakeholders with diverse interests.

In addition to difficulties in clearly identifying society's preferences over health policy outcomes, many decisions are made with a focus on how a policy will affect the average person without considering equitable distribution of the benefits of the policy. Data on population health inequality is often not readily available and so this aspect is often ignored in policy evaluation. Even when information on the distribution of outcomes is available, it is not clear how one should weight health outcomes of groups or individuals. For example, if a choice had to be made between a policy which could increase the life expectancy of all Canadians by one year or a different policy which could increase the life expectancy of half of Canadians by three years, it would likely be unclear which policy is socially preferable – the first policy would benefit more people , but the second policy would have a greater impact on life expectancy nationally.

Causality can also be a difficult problem in health policy evaluation. In some cases, causality can be very straightforward. For example, if there is a pharmaceutical which has been found to cure a disease with nearly 100 per cent effectiveness and no known side effects based on clinical trials, an analyst can be reasonably confident of what the health benefits of using this drug will be. Contrast this with an advertising campaign to reduce excessive consumption of alcohol. Teasing out the likely impact of such a campaign on alcohol consumption and any resulting effects on health, economic, and social outcomes can be very challenging.

This subsection begins with an overview of many of the types of measures which are frequently used to quantitatively analyze health policy. Next, we describe several general approaches to health policy evaluation used in the literature. The section concludes with an assessment of these approaches and their limitations in evaluating health policy.

B. Measures

Quantitative health policy evaluation relies upon choosing suitable metrics to measure the success of the policy. The appropriate choice of health measures to use depends upon what is being evaluated. We will very briefly review a large number of different types of health measures. This is not intended to be a comprehensive list. We broadly separate the discussion into two types of measures. The first is measures of health outcomes. These are measures which attempt to quantify health outcomes or health indicators of the population. The second broad class of measures which we discuss are measures of health system performance. These measures are focused more on evaluating specific aspects of the health care system itself rather than overall outcomes.[4]

Health Outcomes

i. Morbidity

Morbidity rates are a standard measure of the health of a population. Used generally, morbidity refers to a state being unhealthy. It can refer to the presence of any illness or it can be used to refer to the severity of illness. Within hospitals, the degree of morbidity of seriously ill patients is often quantified using one of several morbidity scoring systems. This information is sometimes used in making decisions regarding treatment and predicting the likelihood of death. Such individual level data at the hospital level are difficult to acquire for most researchers.

The term "morbidity rate" is also frequently used to discuss the rate of incidence or the prevalence of a specific disease. A prevalence rate is the proportion of a population that has a particular disease at a given time. In contrast, an incidence rate is the rate of new cases of a particular disease over a given period of time. Table 1 provides some estimated morbidity rates produced by Statistics Canada in 2013. For example, one sees that 6.6 per cent of the Canadian population aged 12 and above had been diagnosed with diabetes in 2013. Clearly this is a prevalence rate and not a rate of incidence of new cases.

Incidence rates of disease are likely more useful in evaluating the effectiveness of policies aimed at prevention rather than treatment. Prevalence rates are potentially useful in assessing the effectiveness of both prevention and treatment.

Table 1: Population Diagnosed with Selected Health Problems in Canada (per cent), 2013

Condition Diagnosed	Age	Per Cent of Population
Arthritis	15+	15.9
Diabetes	12+	6.6
Asthma	12+	7.9
High blood pressure	12+	17.7
Mood disorder	12+	7.6
Chronic obstructive pulmonary disease (COPD)	35+	4.3

Source: Statistics Canada, CANSIM Table 105-0501.

Information on population morbidity can also be useful in assessing how many people are affected by a specific ailment, which could be relevant for optimally targeting funding towards health investments with large fixed costs. If a fixed amount of funds is available to be spent

[4] The distinction between measures of health outcomes and measures of health system performance is made primarily to provide more structure to this subsection. There are many measures which could classified within either category, so this is not intended as a strict dichotomy.

researching the cure to a disease or taking preventative action to try to prevent disease in the first place, it may be prudent to target diseases which impact a lot of people, *ceteris paribus*.

Table 2 presents some additional morbidity rates for cancer, hospitalized heart attacks (myocardial infarction is a more technical term) and hospitalized strokes. Unlike the figures in Table 1, these rates represent the number of occurrences within the year[5] (incidence) rather than the total stock of individuals with the condition (prevalence). Notice that the figures in Table 2 are presented as age-standardized rates per population of 100,000. The rate is expressed per hundred thousand as opposed to per cent because less than 1 per cent of the population are impacted by each of these conditions annually. Expressing morbidity rates per 100,000 people is fairly common. The age standardization facilitates comparison across time. In this case, the incidence rates are standardized based upon the age distribution of the population in 1991. Age standardization is important to distinguish changes in morbidity rates from changes in the age structure of the population. For example, in the absence of age-standardization, if there was no change in the rate of new cancer cases at each age but the share of the population aged 65+ doubled, one would observe a higher rate of new cancer cases in the total population given the greater incidence rate of cancer among those aged 65+, even though individuals were no more likely to be diagnosed with cancer conditional upon age.

Table 2: Annual Incidence of Cancer, Heart Attack, and Stroke

Condition	Year	Age Standardized Rate (per 100,000)
New Cases of Cancer	2010	391.1*
Hospitalized Acute Myocardial Infarction Event	2012	207
Hospitalized Stroke Event	2012	118

*Standardization of rate of new cancer cases is based upon 1991 census population structure

Source: CANSIM Table 103-0553 (Cancer) and the Canadian Institute for Health Information's Health Indicators Interactive Tool

ii. Deaths

Many measures of health policy focus upon death. This is partly because death is straightforward to measure, but it is also often seen as the outcome which health policy is most focused on postponing. Statistics Canada collects and disseminates detailed information on every death in Canada in its Vital Statistics – Death Database. Information is provided on location, age, sex, and detailed cause of death.

[5] Per 100,000 people.

The raw counts of deaths are not as interesting as mortality rates and other related indicators derived from death counts. Mortality rates are similar to rates of incidence of disease, except that they report the number of individuals to die rather than just the number diagnosed. Mortality rates are used to calculate several other measures of population health.

Life expectancy is a measure of the average number of years a specific group of people can expect to live given a set of age-specific mortality rates. Usually, life expectancy is calculated based upon the prevailing mortality rates affecting the entire population in a given year rather than projections of future mortality rates. Consequently, life expectancy is not so much a prediction of how long individuals are likely to live as it is a measure of the overall level of health in society based upon mortality rates.

Mortality rates can also be used to estimate potential years of life lost. This is the extra number of years of life which we expect deceased individuals in a given population would have lived on average if they had not died.[6] Notice that potential years of life lost and life expectancy both give a much higher weight to the deaths of young people. Under both these measures, death at a young age reduces the expected total length of life much more than death at an advanced age. Thus, potential years of life lost is frequently used as a measure of premature mortality (early deaths).

Mortality rates can also be calculated for subsets of the population or grouped causes of interest. For example, some researchers explore differences in mortality rates along racial lines. Infant mortality rates provide an indicator of how many babies die compared to the number born. Enormous reductions in infant mortality were a major driver of increasing life expectancy in the twentieth century.

Table 3: Selected Mortality-Related Indicators

Indicator	2011
Life Expectancy at Birth (both sexes, years)	81.66
Infant Mortality Rate (per 1000 live births)	4.8
Premature mortality[*] (rate per 100,000)	285.5
Potentially avoidable mortality (rate per 100,000)	205.7
Mortality from preventable causes (rate per 100,000)	134.0
Mortality from treatable causes (rate per 100,000)	71.7
Potential Years of Life Lost from Potentially Avoidable Mortality (rate per 100,000)	3446.8

[*] Premature deaths in this table are defined as those of individuals below the age of 75. Potentially avoidable mortality in this table is a subset of premature mortality. Rates are not age-standardized.

Source: Canadian Human Mortality Database and CANSIM Tables 102-0507 and 102-4312.

[6] Potential years of life lost is frequently calculated by choosing an age limit (such as 70 years) and calculating the difference between the age limit and the age of death of an individual if the individual was below the age limit. For example, if a person died at age 65, then the potential years of life lost for that individual may be calculated as 70-65=5.

More nuanced measures of mortality can be used to assess the effectiveness of health policies geared towards treatment or prevention of disease. One can classify causes of death by whether or not they could have been avoided with some sort of intervention and calculate rates of mortality from potentially avoidable causes. A subset of these deaths is potentially avoidable through interventions aimed at preventing disease from occurring in the first case (primary prevention). A second subset could have been prevented through detection and treatment (secondary and tertiary prevention).

iii. Measures of Human Function

Mortality-related measures such as life expectancy and potential years of life lost are often criticized on the grounds that they treat all years of life equally while there is a significant difference between a year spent in good health and a year lying on one's deathbed.

A number of variations on life expectancy have been developed which attempt to address this measurement issue. These include measures of disability-adjusted life expectancy (DALE) and health adjusted life expectancy (HALE).[7] Such measures are usually constructed by reweighting each year of life by the quality of health an individual at that age would normally expect to have. A weight of one corresponds to perfect health, while years of imperfect health are discounted.

Similarly, the health-adjusted analogue of a potential year of life lost is a quality-adjusted life year. The quality-adjusted life year is a very common measure used in the health policy evaluation literature.

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[7] Conceptually, the differences between DALE and HALE are quite minor and the terms are often used interchangeably. Statistics Canada provides the following definitions of its measures of DALE and HALE:

DALE: "Disability-adjusted life expectancy (DALE) is a more comprehensive indicator than that of life expectancy because it introduces the concept of quality of life. DALE integrates data on mortality, long–term institutionalization and activity limitations in the population and represents a comprehensive index of population health status. Thus, the emphasis is not exclusively on the length of life, but also on the quality of life.

To calculate DALE, a set of weights (relative values) is assigned to four states of health. These states are, in order from greatest to least weight: no activity limitations, activity limitations in leisure activities or transportation, activity limitations at work, home and/or school and institutionalization in a health care facility in order to establish units of equal value. These units are summed to yield a type of quality-adjusted life expectancy."

HALE: "Health-adjusted life expectancy is a more comprehensive indicator than that of life expectancy because it introduces the concept of quality of life. Health-adjusted life expectancy is the number of years in full health that an individual can expect to live given the current morbidity and mortality conditions. Health-adjusted life expectancy uses the Health Utility Index (HUI) to weigh years lived in good health higher than years lived in poor health. Thus, health-adjusted life expectancy is not only a measure of quantity of life but also a measure of quality of life."

Statistics Canada, Health Indicators (82-221-X)

iv. Subjective Well-Being

Instead of looking at rates of death or disease, another way to assess an individual's health is to ask him about it. Statistics Canada collects subjective measures of health and well-being which are responses to survey questions asking about how an individual feels. Such questions can be very broad, such as "how satisfied are you with your life" or they can be more focused on specific aspects of one's life. Usually a range of responses are offered from very bad to very good in order to create a quantitative measure. Table 4 presents responses to several questions regarding subjective well-being. One sees that the majority of Canadians surveyed by Statistics Canada reported being in very good or excellent health and over 90 per cent claimed to be satisfied or very satisfied with their lives. However, 13.7 per cent of Canadians reported regularly experiencing moderate or severe pain or discomfort.

Table 4: Subjective Measures of Health and Well-Being, 2013

Indicators	Per Cent of Population
Perceived health, very good or excellent	59.4
Perceived mental health, very good or excellent	71.1
Life satisfaction, satisfied or very satisfied	91.7
Pain or discomfort by severity, moderate or severe	13.7
Sense of belonging to local community, somewhat strong or very strong	65.9

Source: Statistics Canada, CANSIM Table 105-0501. Population shares are for the population aged 12+.

While such measures can be informative, one does have to be cautious about subjective questions. There is no guarantee that individuals reported truthfully and, even if they did, people likely have different perceptions of what constitutes life satisfaction, good health, or discomfort.

v. Risk Factors

There are a number of health-related indicators which policymakers may be interested in which provide information about the extent to which the behaviour of the population is potentially contributing to poor health outcomes. Such risk factors include heavy drinking, tobacco use, weight (or body mass index, which takes height into consideration when assessing weight), diet, exercise, and use of safety equipment at work or in leisure activities. Table 5 presents the fraction of the Canadian population aged 12+ exhibiting health risk factors related to behaviour. These sorts of measures are very important for assessing the effectiveness of primary prevention strategies.

Table 5: Health Risk Factors of Canadian Population Aged 12+, 2013

Risk Factor	Per Cent of Population
Current smoker, daily or occasional	19.3
Exposure to second-hand smoke at home	4.5
Exposure to second-hand smoke in the past month, in vehicles and/or public places	16.0
5 or more drinks on one occasion, at least once a month in the past year (2012)	17.4
Fruit and vegetable consumption, 5 times or more per day	40.8
Physical activity during leisure-time, inactive	44.8
Body mass index, self-reported, adult (18 years and over), overweight or obese	53.6
Wears a helmet when riding a bicycle, always	41.5

Source: Statistics Canada, CANSIM Table 105-0501

vi. Non-Health Outcomes

The evaluation of health policy may involve consideration of non-health outcomes which are affected by health. Economic outcomes such as labour force participation (the share of the working age population employed or looking for work) and productivity (output per hour worked) in the workforce can be directly impacted by the health of the population. Individuals who are very sick are more likely to take time off work or go on permanent disability. Even if they come to work, unhealthy workers may not be as productive. Changes in output resulting from health policy impact individual incomes, profits, and the tax base.

Health policy can also affect several other non-health outcomes such as education, crime[8], leisure, and inequality.

Health System Performance

vii. Costs of Health Care Provision

One major measure related to health system performance is the amount of expenditure involved in providing health services and treating illness. Table 6 presents costs of specific illnesses in Canada as estimated by the most recent Economic Burden of Illness in Canada (EBIC) report released by the Public Health Agency of Canada (PHAC). The report estimates the total costs of illnesses and injuries in Canada in 2008 at $192.8 billion (2010 dollars). About $97 billion can be attributed to the direct and indirect costs of specific diseases (PHAC, 2014). Many

[8] A link to crime may not be obvious to the reader. One area of health policy closely related to crime is treatment of substance abuse. Prevention of substance abuse and rehabilitation may prevent some crimes in which drugs or alcohol are a factor or a motivation. Health policy can also create markets for criminal activity (e.g. regulation of drugs or regulation of organ trade).

of the direct costs of illness can be classified as expenditures on drugs ($29 billion), hospitals ($50 billion), and physicians ($24 billion).

Table 6: Costs of Illnesses in Canada, 2008, Millions (Constant 2010 Dollars)[9]

Illness	Drug Costs	Hospital Costs	Physician Costs	Mortality Costs*	Morbidity Costs	Total Costs
Cardiovascular Diseases	4,363	5,175	2,401	95	-	12,033
Neuropsychiatric Conditions	3,626	5,636	2,396	20	-	11,678
Factors Influencing Health & Contact with Health Services	715	5,660	2,628	0	-	9,003
Musculoskeletal Diseases	2,024	1,834	2,045	3	-	5,905
Digestive Diseases	1,464	2,899	1,259	25	-	5,647
Symptoms, Signs and Ill-Defined Conditions	1,310	2,177	1,885	8	-	5,379
Injuries of Undetermined Intent	265	3,467	1,463	6	-	5,201
Malignant Neoplasms	477	2,378	1,053	170	-	4,079
Genitourinary Diseases	685	1,531	1,661	4	-	3,880
Respiratory Diseases	1,222	1,857	646	12	-	3,737
Endocrine Disorders	1,765	432	600	6	-	2,803
Respiratory Infections	520	979	1,149	5	-	2,653
Maternal Conditions	60	1,412	809	0	-	2,280
Diabetes Mellitus	1,223	503	498	13	-	2,237
Sense Organ Diseases	289	531	1,357	0	-	2,178
Certain Infectious and Parasitic Diseases	711	889	520	13	-	2,134
Skin Diseases	695	419	851	0	-	1,965
Perinatal Conditions	10	948	43	0	-	1,001
Other Neoplasms	51	440	494	2	-	987
Congenital Anomalies	36	309	142	3	-	490
Oral Conditions	43	157	219	0	-	419
Nutritional Deficiencies	79	111	161	0	-	351
Unintentional Injuries	0	0	2	45	-	47
Intentional Injuries	0	0	1	36	-	36
Total Costs Attributable to Specific Causes	21,633	39,745	24,280	465	10,423	96,546
Unattributable Costs	6,876	10,411	0.0	0.0	6,318	23,605
Total Costs	28,510	50,156	24,281	464	16,741	120,151

* Mortality costs refer to the indirect costs of illness as a result of reduced economic output due to mortality. These are calculated using a "frictional approach" which estimates lost output over the period of time it takes to replace the deceased.

Source: Economic Burden of Illness in Canada Custom Report Generator produced by the Public Health Agency of Canada.

[9] Note that the values in this table do not sum to the totals described above. This is because this table only includes costs attributable to specific diseases and there are $72.7 billion in other direct costs which cannot be attributed to specific illnesses.

The cost of providing health care is a central part of sustainable health policy. Measuring the costs of providing a specific service is a first step to identifying ways in which the service can be provided more cost-effectively.

Measures of cost are also important for assessing the efficient allocation of resources towards different illnesses. For example, if one specific cause of illness accounts for a large share of health expenditure, developing new strategies or technologies to reduce the cost of treating that disease may be a higher priority than researching new approaches to a disease which only accounts for a small share of health expenditure.

viii. Patient Satisfaction

Asking individuals how pleased they are with the health care services they have received is a subjective approach to measuring health system performance. It can be useful for identifying areas in which health care service can be improved, as satisfying individual's health care needs is a primary goal.

Table 7: Per Cent of Patients Satisfied or Very Satisfied with Any Health Care Services Received, 2007

	Per Cent of Population
Canada	85.7
Newfoundland and Labrador	87.6
Prince Edward Island	87.6
Nova Scotia	89.6
New Brunswick	90.5
Quebec	88.8
Ontario	85.6
Manitoba	85.6
Saskatchewan	86.2
Alberta	81
British Columbia	82.4
Yukon	87.4
Northwest Territories	84.1
Nunavut	...

Source: Statistics Canada, CANSIM Table 105-4080. Figures are for the population aged 15+ who received health care services within the previous 12 months.

Table 7 shows the percentage of patients aged 15+ in 2007 who reported being satisfied or very satisfied with the health care services they received in the previous 12 month period. One sees that 85.7 per cent of Canadian patients were happy with their health care services. This was fairly consistent throughout the country, with positive responses ranging from a low of 81.0 per cent in Alberta to a high of 90.5 per cent in New Brunswick. However, examination of the survey microdata may reveal dissatisfaction among specific subsets of the population. Identifying the 14.3 per cent of individuals who are not satisfied[10] is important for understanding where there may be problems in the health care system.

ix. Accessibility

Access to health care services is essential to help prevent, identify, and treat many diseases. At least in theory, universal health care guarantees access to health services for all Canadians. However, providing greater access to health services is costly. Health policy must balance the costs and benefits of devoting resources to easing access to health care.

One simple measure of access to health care is the percentage of the population who have a regular medical doctor. This measure is relevant because a regular medical doctor can develop a better understanding of an individual's medical history through repeated interaction and may be useful in maintaining good health. CANSIM Table 105-0501 shows that 15.5 per cent of the population aged 12+ did not have a regular medical doctor in 2013. A related measure is whether or not an individual has seen a doctor in the last 12 months, but such a measure is more difficult to interpret because it reflects not just access but use of services.

Closely related to accessibility is the issue of timeliness. Timely access to health care services can lead to earlier identification and treatment of health problems, potentially reducing costs and improving health outcomes.

Wait times have received much attention in Canada in recent years. Long waits to receive care waste time (waiting in the emergency room), extend illness and suffering, and can lead to deterioration in an individual's condition. A recent report card by the Wait Time Alliance (2014) notes that 27 per cent of Canadians reported waiting more than four hours in hospital emergency departments compared to one per cent in the Netherlands and five per cent in the United Kingdom. Quantifying wait times and their impact is important for the allocation of health resources. A study prepared by the Centre for Spatial Economics (2008) estimated that wait times for hip and knee replacement surgery, magnetic resonance imaging (MRIs), coronary artery bypass graft (CABG) surgery, and cataract surgery cost the Canadian economy $14.8 billion in 2007.

x. Effectiveness

Besides being accessible and affordable, a good health care system must also be effective in preventing, detecting, and treating disease.

[10] One can also report being very dissatisfied, dissatisfied, or neither satisfied nor dissatisfied.

Morbidity rates, which we have discussed above, are the natural means to assess the success of prevention efforts.

The effectiveness of efforts to increase screening can be measured by quantifying the rate at which individuals are being screened or the rate of early detection. For example, one way to quantify the success of cancer screening methods is to look at the stage of the cancer at the time of first detection. If the percentage of new cases of cancer detected at an earlier stage increases, than this would suggest that screening has become more effective.

There are many ways one might measure the effectiveness of treatment, and the appropriate measure depends upon the nature of the ailment and what is being studied. If one is comparing multiple methods which could cure a disease, the rate of success of the treatment or the amount of time it takes for the treatment to succeed may be good measures of effectiveness.

For serious illnesses, survival rates may offer a measure of effectiveness of the health care system. We have already discussed rates of potentially avoidable mortality, which are a good measure of the effectiveness of a health care system at preventing death. Another useful way to assess the effectiveness of treatment is to consider what happens to a patient in the period following an initial emergency. In-hospital mortality rates following a heart attack or stroke over a period following admission to the hospital provide a measure of the effectiveness of treatment. Table 8 shows that the (risk adjusted) rate of in-hospital mortality over the thirty days following a heart attack was 7.0 per cent in Canada in 2011, while the comparable rate for strokes was 14.7 per cent.

Once an individual is deemed to have been treated, readmission rates offer a way to gauge the longer term effectiveness of the treatment and any efforts to prevent re-occurrence. Table 8 shows that the 30-day readmission rate for mental illness in Canada was 11.5 per cent in 2012 while the readmission rate for heart attacks was 4.1 per cent in 2009.

Table 8: Select Indicators of Effectiveness of Treatment in Canada

Indicator	Year	Risk Adjusted Rate (%)
30-Day Acute Myocardial Infarction In-Hospital Mortality	2011	7.0
30-Day Stroke In-Hospital Mortality	2011	14.7
30-Day Acute Myocardial Infarction Readmission	2009	4.1
30-Day Readmission for Mental Illness	2012	11.5

Source: Canadian Institute for Health Information's Health Indicators Interactive Tool

This concludes our overview of many of the quantitative measures which can be used in evaluating health policy. This is by no means intended as a comprehensive list or discussion of relevant measures, but rather is meant to convey the diversity of measurements available. This diversity reflects the breadth of options, challenges, and objectives which exist in health policy. The appropriate measures depend upon the nature of the health policy and what the researcher is trying to assess.

C. Approaches

Several different approaches to health policy evaluation are commonly employed in the literature. Most health policy evaluations amount to a comparison of the costs and benefits of one or more policies. The different approaches typically measure costs in a very similar way, estimating the total cost of a policy in terms of dollars. The estimation of benefits is where the methodologies diverge.[11]

i. Cost-consequences

A cost-consequences approach to health policy evaluation entails describing the various outcomes associated with a particular health policy and comparing these to the costs associated with the policy. The defining characteristic of this approach is that it lists a series of outcomes without attempting to quantitatively consolidate them into an overall metric of the effectiveness of the policy. For example, consider a decision to construct a new hospital in a rural community. Such an undertaking could have a wide range of benefits. A cost-consequences approach to evaluating whether or not to build the hospital would attempt to list all of the potential benefits such as reduced travel time for medical care, jobs created, additional hospital beds available, reduced mortality rates, economic benefits from improved health, numbers of medical procedures and tests, etc. All the major consequences of the policy would be enumerated in the evaluation, but they would be in many different units such as dollars, time, spaces, jobs, and rates. A cost-consequences evaluation does not attempt to convert all measures under consideration into a single unit. Any overall assessment of all the benefits is subjective and depends upon how one chooses to weight the list of consequences.

ii. Cost-effectiveness

Cost-effectiveness studies consider the cost per unit of some health outcome of interest such as years of life saved or number of persons treated. The notable feature of this sort of analysis is that it is restricted to only considering a very narrow set of outcomes which can be expressed in a common unit.

[11] The methodologies discussed in this section are well known in the economic analysis of health policy literature. Summaries of the methodologies which informed this section are available in reports by the Canadian Agency for Drugs and Technologies in Health (2006), Husereau et al. (2013), Huserau et al. (2014), and others.

This sort of approach would likely not be very useful for assessing a complex policy with a range of benefits such as construction of a hospital, but it can be applied effectively when comparing a number of options for achieving a specific goal. For example, if one wishes to determine the most cost-effective way to reduce the total number of people smoking or to treat a specific disease, then this sort of analysis can make sense. However, this approach is problematic if the different options under consideration can generate benefits along other dimensions as well. It also is usually not very useful for determining how to allocate resources across different objectives, unless the two objectives are measured in the same unit.

This has been a major form of economic evaluation of health policy. One review of a sample of 154 papers performing economic evaluations of health policy between 2000 and 2005 by Weatherly et al. (2009) classified 36 per cent of studies as cost-effective analyses, while 37 per cent were classified as cost-consequence analyses.[12]

iii. Cost-utility[13]

Cost-utility analysis is a special case of cost-effectiveness evaluation of health policy which uses a preference-based measure of health, but the approach is popular enough in the literature that it has received its own name. The usual measure used in cost-utility analysis is the quality-adjusted life year (QALY), although other preference-based measures of health such as disability-adjusted life years can also be used. In contrast, approaches which are labeled as cost-effectiveness analysis rely on more "natural" measures such as years of life which have not been adjusted to reflect preferences.

The advantage of cost-utility analysis over other types of cost-effectiveness analysis is that it can allow for comparisons across a wide range of health policies as it can be applied to any policy which increases the number of years lived or improves quality of life. Most health interventions aim to accomplish at least one of these two objectives, so cost-utility analysis can be used to make decisions regarding the allocation of resources across a wide variety of health-related uses. Non-preference-adjusted measures such as years of life gained can also be used for such comparisons, but these measures may overlook important differences between policies in

[12] Weatherly et al. (2009) constructed the sample of economic evaluations of health policy using the NHS Economic Evaluation Database. Eleven public health areas were specified: accidents, alcohol, ante-natal and post-natal visiting, drug use, HIV/AIDS, low birth weight, obesity and physical activity, sexually transmitted infections (STIs), smoking, teenage pregnancy and youth suicide prevention. Only "full" economic evaluations – those which consider at least two policy options and their costs and benefits – were included in the analysis. Additionally, studies related to screening and immunizations were excluded because there are standardized approaches for assessing policies in these areas.

[13] Weatherly et al. (2009) classified 27 per cent of the studies they examined from 2000 to 2005 as cost-utility analyses.

terms of quality of life and do not facilitate comparison between policies which improve longevity and policies which improve quality of life.

One challenge of cost-utility analysis is that costs remain in dollars while the benefits are measured in QALYs. If one has a fixed budget and wants to know how to best allocate funds across uses then this is not a substantial problem, as the funds be distributed to the uses which result in the most QALYs per dollar. If instead one must decide whether or not a given policy is worth pursuing, then one would need to decide how many dollars a QALY is worth. A review of efforts to determine the value of a QALY by Hirth et al. (2000) found that there was an extremely wide range of estimates.

iv. Cost-minimization

Cost minimization is another special case of the cost-effectiveness approach which occurs when the policies under consideration are deemed to have identically-valued outcomes. For example, the choice between two drugs which can immediately cure the same disease with no side effects which work 100 per cent of the time could be made using a cost minimization approach. If there is no difference in terms of the benefits, then choosing the appropriate policy amounts to choosing the option with the lowest cost. Cost minimization takes as given that the objective is worth achieving and attempts to determine the most efficient way to do so.

v. Cost-benefit

The last approach to economic evaluation of health policy which we consider is cost-benefit analysis.[14] The cost-benefit approach attempts to quantify all relevant benefits in terms of dollars which can then be directly compared to costs. This is the type of analysis which should be applied in assessing the overall economic impact of a policy on a society.

In theory, this is the most comprehensive and broadly applicable approach to economic evaluation of health policy, but in practice it has seen relatively little use. For example, Weatherly et al. (2009) found that only 3 per cent of the 154 studies between 2000 and 2005 they examined claimed to perform a cost-benefit analysis, but upon closer inspection these studies were deemed to be cost-consequence or cost-effectiveness analyses.

Why so few cost-benefit analyses? The difficulty in convincingly converting health outcomes into dollar terms is the main reason. We have noted that there remains considerable debate over how to value a quality-adjusted life year. The appropriate methodology to convert health outcomes into dollars is not obvious and decision makers are reluctant on moral grounds to make decisions based on such calculations. Many approaches to convert health outcomes to

[14] In the author's opinion, this is not a particularly useful name to distinguish the approach from most of those previously discussed (except for cost-minimization), but it is the terminology which the literature has adopted.

dollars are based upon willingness to pay. Given the link between willingness to pay and ability to pay (income), such approaches raise ethical concerns (Canadian Agency for Drugs and Technologies in Health, 2006).[15]

Reluctance to put a dollar figure on the inherent value of human health results in many attempts at cost-benefit economic analysis being incomplete. Sometimes, the direct benefits of improved health for individuals are largely ignored. At other times, they are only presented in terms of years of life gained or some other metric alongside a detailed calculation of other major benefits in terms of dollars which constitutes a partial or incomplete cost-benefit analysis.[16]

Such partial cost-benefit analyses characterize the general approach which has been adopted in a number of recent health policy evaluations by the Conference Board of Canada (Conference Board of Canada 2010, 2012a, 2012b, 2013b, 2013c, and 2014a). These studies typically include a series of estimates about the impact of an illness, behaviour, or health policy on Canadians and then estimate the impact on the Canadian economy. The economic analyses usually consider three broad sets of impacts.[17]

The first type of economic impact these studies consider are the direct costs incurred in preventing and treating illnesses in Canada. Such estimates can be made using data on direct expenditures on physicians, drugs, and hospitals which are attributable to specific diseases. Such data is available in the Economic Burden of Illness in Canada database. Avoiding these direct costs would represent savings to individuals, private health insurers, and government.[18]

The other two broad categories of impacts included in these analyses by the Conference Board of Canada involve indirect costs of disease which reduce GDP, negatively affecting wages of workers, profits of employers, and government tax revenue. The first of these indirect costs is lost labour productivity as a result of illness. These costs include absenteeism and presenteeism (working while sick) resulting from poor health.

The other major indirect cost is lost output as a result of mortality or long-term disability. This indirect cost is typically measured in one of two ways. The human capital approach estimates the total value of output which the individuals would have been expected to generate

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[15] One potential alternative to performing cost-benefit analysis using an approach grounded in willingness to pay is to adopt a capabilities-based approach along the lines of Sen (1985). A capabilities approach to measuring well-being focuses on what individuals are able to do (capabilities) rather than what they actually do (functionings). Lorgelly et al. (2010) discuss the potential use of a capabilities-based approach in health policy evaluation.

[16] Such assessments are technically cost-consequences analyses, although one can also think of them as partial or incomplete cost-benefit analyses in that they have made efforts to consolidate several sources of non-health economic benefits in dollar terms.

[17] The exact set of economic impacts considered obviously depends upon the specific subject of the study.

[18] One may also note that these total costs may overstate the burden of expenditures on treating illness on society generally. While these expenditures represent a significant diversion of resources away from other activities, there are some people who benefit from these expenditures as well –namely all the workers who make their living treating these diseases. Government expenditures in this area may also overstate costs to the extent that these expenditures are recouped through taxation.

had they remained able to work. The problem with the human capital approach is that, in many cases, there exists a large pool of potential workers who are unemployed or not in the labour force who could fill the vacant positions created by death and disability. The second approach, which has now been adopted in calculating the Economic Burden of Illness in Canada, is to only consider the cost of lost output over the period of time it normally takes a firm to replace a worker.

By combining these direct and indirect costs associated with disease (or changes in these costs associated with a policy), one can obtain an estimate of the total cost of an illness in terms of dollars (or the benefits of a policy).

Such estimates of the dollar impact of a disease or policy may be suitable for quantifying the effects of interest to most employers, as they include all the lost profits as a result of indirect costs. However, from the point of view of individuals and society as a whole, these dollar values underestimate the dollar value of disease because they do not include the intrinsic value of lost years of life or reduced health except to the degree that wages are lost as a result. A complete cost-benefit analysis would put a dollar value on these direct costs of illness to those afflicted.

The adequacy of such partial estimates of the benefits of health policy for the purposes of government policy making is questionable. If government is viewed as an entity which only cares about its own fiscal position (or that of its population), then calculating the impact on health expenditures and GDP may be sufficient. But if the goal of government is to maximize social welfare, then the exclusion of the intrinsic value of health is problematic.

Assessing all the consequences, direct and indirect, can be considerably more work than focusing on only the direct health impacts of a policy. Frequently the direct health benefits and subsequent economic and social benefits are treated as separate issues. For many decisions, focusing on the health benefits alone may be sufficient, but all relevant effects of a policy should be considered in making decisions.

D. Assessment of Common Approaches

The appropriate methodology for assessing the economic implications of health policy depends upon the policy being analyzed and the interests of those using the assessment. Generally, one should attempt to include all costs and benefits relevant to the policy under consideration. Ideally, these costs and benefits will all be expressed in the same units in order to facilitate transparent optimal decision making. This can be particularly important from the perspective of socially optimal decision making when the decision can impact multiple stakeholders along multiple dimensions.

As the costs of implementing health policy are typically expressed in terms of dollars, a natural way to perform an economic analysis is to convert health benefits into dollars as well.

The problem with adopting such a cost-benefit approach is that it requires assumptions as to the dollar value of health and longevity, which is a subjective matter about which opinions vary widely. However, in many cases, such a conversion may not be necessary in order to sufficiently evaluate the consequences of a policy.

A minimalist approach is reasonable for health policy evaluation – if there is no reason to make additional assumptions or calculations in order to reach a conclusion, one should not do it. Therefore, all the methods which we have discussed can be perfectly reasonable in the right context. The best approach depends on the breadth of goals and policy options under consideration. One can generally arrange the methods in order of widening scope of policy options and goals under consideration (Table 9).

Cost-minimization should only be applied in evaluating a narrow set of policy options which the researcher can convincingly argue will produce equally valuable benefits – this is easiest to do if the benefits are identical. In this case, the benefits do not require (further) quantitative analysis, so comparisons in terms of cost are all that matters. Such an analysis takes as given the goal which is to be achieved and then selects the least expensive way to achieve it.

Cost-effectiveness analysis allows for comparisons across a broader range of policy goals than cost minimization. Health outcomes per unit of cost are considered, which facilitates comparisons between policies with differing costs and effects on a common health outcome. The scope of policies which can be compared depends upon how specific the outcome of interest is. Cost-effectiveness analysis could be used to compare policies in terms of the number of years of life gained due to reductions in old-age mortality from cancer, but it could also be used to compare policies in terms of reducing mortality rates generally. Such analysis takes as given that resources should be devoted to improving a specific health outcome, but allows for comparison of various options which differ in terms of the total impact on the outcome.

Notice that cost-effectiveness is somewhat restrictive in that it cannot be applied to policies which impact health along multiple dimensions.

Table 9: Scope and Units of Approaches to Economic Analysis of Health Policy

Method	Relative Scope of Applicable Policies	Unit
Cost-Minimization Analysis	**Very Narrow** - Policies with equivalent effects, but potentially different costs	**Dollars** (costs only)
Cost-Effectiveness Analysis	**Narrow** - Policies aiming to impact a specific health outcome.	**Health outcome per dollar**
Cost-Utility Analysis	**Broad** - Policies aiming to raise the quantity or quality of life	**Preference adjusted health outcomes per dollar**
Cost-Consequences Analysis	**Very Broad** - Any policy which impacts health	**Multiple Units**
Cost-Benefit Analysis	**Very Broad** - Any policy which impacts health	**Dollars** (costs and benefits)

Cost-utility analysis is broader still in that it allows for economic comparison of policies which have different health outcomes facilitated by preference-adjusted measures of health. Virtually any health policy which impacts the quantity or quality of life can be readily compared using this approach. Unlike cost-effectiveness, this method can be applied to policies which impact health along several different dimensions. This method is useful for determining the allocation of funds to different health policies, but it cannot be used to determine the relative allocation of funds between health and other sectors.

These first three approaches can be useful if one is only interested in optimal allocation of resources towards a specific health goal. These approaches certainly can be valuable, especially in attempting to maximize efficiency within specific parts of the health care system or attempting to ensure some accountability in the use of health resources. Given a fixed budget allocated towards improving health, cost-utility analysis is likely sufficient to assess the optimal use of most of these funds. Similarly, if a fixed amount of resources are to be allocated towards reducing deaths due to heart attacks, cost-effectiveness would be sufficient to achieve this goal. However, these approaches are unable to optimize with regards to the total economic impacts of decisions. Furthermore, the optimal allocation of resources at the highest level of generality, where all possible options are on the table and the most social welfare is potentially at stake, requires estimates in terms of dollars.

Cost-consequences and cost-benefit analysis are necessary in order to make optimal policy decisions which have effects along health and non-health outcomes. Cost-consequences analysis suffers from the fact that it only lists various impacts of a policy and leaves it up to policymakers to weight these outcomes in order to make a decision. Cost-benefit analysis, which considers all costs and benefits in terms of dollars, is superior if health outcomes can be monetized in a credible way. If this cannot be done, then cost-consequences analysis may be a better approach because it is at least transparent as to what the various outcomes are. Given the lack of consensus regarding the correct way to calculate the intrinsic value of health in terms of dollars, incomplete cost-benefit analyses represent the state of the art for many health policy evaluations.

Given the diversity of stakeholders who have an interest in health policy, the inability to fully quantify the full economic benefit of many health policies presents a significant challenge to policymakers interested in maximizing social welfare. They must sift through a variety of studies which emphasize various aspects of health policy most relevant to particular stakeholders and attempt to decide the correct weighting to apply to various factors. This results in a decision making process which is highly subjective and may lack transparency. The lack of a unified approach to quantifying all the benefits impedes rational discussion and debate between those who are interested in different costs and outcomes of health policy.

Another major weakness of all the types of analysis commonly used is that, for the most part, they do not adequately address inequality in the benefits of health policy. Instead, they opt to focus on average health outcomes. This is partly due to limited availability of data and the difficulty in comparing the value of one individual's health to that of another. Several authors in the health policy evaluation literature have noted this shortcoming and have suggested that inequality should receive more attention, although how exactly inequality should be incorporated is subject to some debate (Cookson et al., 2009; Richardson, 2009; Shiell, 2009; Curtis, 2013).

Many existing studies have achieved considerable success in quantifying the impacts of health policy along a number of different economic dimensions, but very few are able to synthesize these impacts into an overall assessment appropriate for making socially optimal policy decisions. The inclusive growth framework, developed by the OECD, provides a new approach to policy evaluation which aims to overcome the shortcomings of existing approaches to cost-benefit analysis.

III. The Inclusive Growth Framework

This section of the report discusses a new approach to the measurement of well-being developed by the Organization for Economic Co-operation and Development (OECD) which we believe holds considerable promise as a tool in cost-benefit analysis of health policy. This inclusive growth approach involves the construction of a comprehensive measure of social welfare which incorporates non-income sources of well-being and takes into account the distribution of outcomes within society. Unlike most measures of aggregate well-being, the inclusive growth framework does not assign arbitrary weights to various outcomes, but endogenously generates weights using methods grounded in economic theory. This allows for a more comprehensive and credible evaluation of the dollar value of improvements in health outcomes.

We will briefly describe the inclusive growth framework, how it has been used by the OECD thus far to compare growth in living standards across countries, and how it can be used to address some of the challenges facing standard approaches to evaluating health policy.

This section is organized as follows. The first subsection presents an overview of what the inclusive growth framework is. The second subsection provides a non-technical description of the methodology underlying the inclusive growth index of living standards. The third subsection discusses the OECD`s inclusive growth index and how it compares to other measures of living standards. The fourth and final subsection highlights some of the strengths and weaknesses of the approach.

A. Overview

A team of researchers at the OECD has recently developed a novel approach to assessing economic policy as part of the Inclusive Growth project (Boarini et al., 2014b). This approach involves the construction of a measure of social welfare which has three key characteristics:

Multidimensionality – In addition to income, the approach acknowledges that non-monetary factors are relevant for well-being, such as health, education, the environment, and security. The inclusive growth framework combines monetary and non-monetary outcomes in a uni-dimensional measure of living standards.

Consideration of the Distribution of Outcomes – The approach recognizes that a proper assessment of aggregate living standards must go beyond average outcomes and includes an adjustment for inequality.

Policy Relevance – The approach is designed not just for purposes of comparison of well-being across countries and over time, but as a means for comprehensively assessing the consequences of policies on well-being.

These three attributes characterize the inclusive growth framework, but what does the approach actually entail?

It involves the construction of an inclusive growth measure of social welfare which can be used to compare expected outcomes under various alternative policy options. This process can be described in a few simple steps.

The first step in applying the approach is to identify all the relevant aspects of well-being for inclusion. The OECD has so far focused on a measure which incorporates three variables: real household net adjusted disposable income, the unemployment rate, and life expectancy (Boarini et al., 2014b),[19] but the methodology could be applied to other aspects of well-being.

Once the relevant dimensions of well-being have been identified, the second step is to combine them into a single measure of well-being. The measure chosen by the OECD is something they call "equivalent income", which is measured in dollars. Simply put, equivalent income is just actual income adjusted for the deviation of the non-monetary factors from some arbitrarily chosen baseline level. Essentially, the approach puts a negative dollar value on unemployment above a certain threshold and life expectancy below a certain threshold. The way in which the valuations of these non-monetary outcomes are assigned is a key part of the approach. We will discuss the calculation of equivalent income further in the next subsection.

The third step of the approach is to apply a penalty for inequality in the distribution of outcomes.

Once these three steps are completed, one possesses a measure which can be used to compare various societal outcomes in dollar terms. Such a measure can readily be utilized for policy analysis. To do so, one must have estimates of what the outcomes of various policy options would be. These outcomes (and the policies that lead to them) can then be compared by calculating the inclusive growth measure corresponding to each outcome.

[19] A related project, the OECD Better Life Index, incorporates 11 broad sources of well-being: housing, income, jobs, community, education, environment, civic engagement, health, life satisfaction, safety, and work-life balance. This project takes an index approach, but does not assign weights to these outcomes to create an overall measure of well-being. Instead, the project provides an interface which allows the user to apply a preferred set of weights at http://www.oecdbetterlifeindex.org/.

B. Equivalent Income

We will expand upon what equivalent income is and how it is calculated in a non-technical way in this section, but readers with a background in economics may prefer to read the technical appendix in lieu of this subsection, as it provides a more rigorous explanation.

The idea behind equivalent income is to reduce the comparison of two three-dimensional outcomes (in terms of income, life expectancy, and the employment rate), call them outcome A and outcome B, from three separate comparisons (income in A to income in B; unemployment rate in A to unemployment rate in B; and life expectancy in A to life expectancy in B) to just one comparison (equivalent income in A to equivalent income in B). To do this, one can identify two corresponding outcomes, call them A^* and B^*, which are of equal value to A and B but are identical along two of the three dimensions (unemployment rate and life expectancy). A^* and B^* can be readily compared along the remaining dimension (income).

We must choose a common level for the unemployment rate and life expectancy to facilitate the comparison. This common level is called the baseline. The choice of baseline is completely arbitrary, although Boarini et al. (2014b) suggest that it is natural to use a baseline unemployment rate of 0 per cent and the highest observed life expectancy in the set of multidimensional outcomes being compared.

For the comparison of outcomes to be legitimate, an individual must be equally well off under the respective adjusted outcomes (with baseline unemployment and life expectancy) as he or she was under the original outcomes which we seek to compare. As the baseline unemployment rate and life expectancy are chosen to always be superior to the observed outcomes, the individual must receive a lower level of income in the adjusted outcome to exactly offset the improvement in the unemployment rate and life expectancy over the original outcome. The level of income received in the adjusted outcome is such that the adjusted outcome has equivalent value to the original outcome. For this reason, this level of income is called "equivalent income".

Thus equivalent income is the amount of income, in combination with the baseline non-monetary outcomes, such that an individual would be equally well off when compared to the individual`s actual multidimensional outcome. Equivalent income is closely related to the economic concept of compensating variation.

A simple numerical example may help to clarify what equivalent income is (see Table 10). Suppose that we only care about two outcomes, income and life expectancy. For the purposes of this example, let us assume that one year of life expectancy is always worth $1,000 of annual income when it comes to assessing welfare.[20] Further, suppose that we want to compare living standards across two countries, call them “Canada” and “Japan”, between two years, say 2000 and 2010. Suppose that Canada has an average annual income of $50,000 and a life expectancy of 75 years in 2000 and an average annual income of $60,000 and a life expectancy of 80 years in 2010. Suppose that Japan has an average annual income of $45,000 and a life expectancy of 85 years in 2000 and an average annual income of $60,000 and a life expectancy of 90 years in 2010.

Table 10: Example of Equivalent Income Calculation Assuming a Linear Utility Function

Year	Income	Life Expectancy	Income Value of Life Expectancy	Welfare	Equivalent Income (Baseline of 90 Years Life Expectancy)	Increase in Equivalent Income	Increase Due to Income	Increase Due to Life Expectancy	Equivalent Income Under Alternative Baseline (75 Years)
	A	B	C	D=A+C	E = D-90,000				F
Canada									
2000	50,000	75	75,000	125,000	35,000	.	.	.	50,000
2010	60,000	80	80,000	140,000	50,000	15,000	10,000	5,000	65,000
Rate of Growth (per cent)	20.00	6.67	6.67	12.00	42.86	.	.	.	30.00
Japan									
2000	45,000	85	85,000	13,0000	40,000	.	.	.	55,000
2010	60,000	90	90,000	15,0000	60,000	20,000	15,000	5,000	75,000
Rate of Growth (per cent)	33.33	5.88	5.88	15.38	50.00	.	.	.	36.36

Source: Author's calculations.

To compare these four outcomes using an equivalent income approach, we first must set a baseline for non-material standards of living. We pick the best observed outcome, Japan’s 90 years of life expectancy in 2010, as the baseline.[21] This level of income is the equivalent income. Whichever country has the highest equivalent income will be deemed to have the highest standard of living.

First consider Canada. We see that in 2010 it has welfare of $60,000 of income plus $80,000 worth of life expectancy for a total welfare of $140,000. The equivalent income of Canada in 2010 is the amount of income such that Canada would have the same total welfare, worth $140,000, if its life expectancy were 90 years. This is easily calculated as $140,000 (total

[20] For simplicity, say 1 year life expectancy = $1,000 annual income = 1000 utils. This example uses an indirect utility function with the linear form $v_i(y_i, l_i) = y_i + 1000 * l_i$. The example refers to “welfare” in terms of dollars rather than utility in an attempt to be more accessible to readers who may be unfamiliar with the concept of utility.

[21] Except in the country with the baseline value in the baseline year

welfare) - $90,000 (value of life expectancy under the baseline) = $50,000 (value of income). Thus, the equivalent income of Canada in 2010 is $50,000.

Similarly, the total welfare in Japan in 2010 amounts to $60,000 + $90,000 = $150,000. The equivalent income of Japan in 2010 is the level of income such that welfare would remain $150,000 if life expectancy was the baseline value of 90 years. That is, $150,000 - $90,000 = $60,000. Notice that the equivalent income for the base country in the base year is exactly equal to its actual income. Comparing the equivalent incomes of the two countries, we find that Japan had the higher equivalent income and thus the higher standard of living in 2010, even though income was identical in both countries.

We could perform similar calculations in both countries in 2000 if we wanted to assess growth in welfare. For Canada, the equivalent income must produce total welfare of $125,000 ($50,000 + $75,000) if life expectancy were 90 years, so the equivalent income is $125,000 - $90,000 = $35,000.

For Japan in 2000, the equivalent income would produce total welfare of $130,000 ($45,000 + $85,000) if life expectancy were 90 years, so the equivalent income is $130,000 - $90,000 = $40,000.

As we have taken the highest life expectancy as the base, the equivalent income in every other country and time is equal to the actual income in the country at that time minus an adjustment for the value of the longevity lost compared to the baseline. While the equivalent income adjustment results in a negative adjustment for Canada in both 2000 and 2010, this adjustment becomes smaller as Canada's life expectancy rises towards the baseline. In this example, Canada's equivalent income rose by 43 per cent from $35,000 to $50,000. This growth can be decomposed into an additional $10,000 of income ($60,000 in 2010 compared to $50,000 in 2000) and $5,000 from life expectancy (a negative adjustment of $10,000 in 2010 compared to $15,000 in 2000).

The reader may be wondering what the point of calculating the equivalent income for every country under the baseline scenario is. After all, one could have compared $150,000 to $140,000 in the example above and reached a similar conclusion. In practice, economists do not measure individual well-being in terms of dollars – they measure it in terms of an abstract concept called utility. The mapping of health outcomes, income and unemployment rates onto utility is more complicated than the simple linear relationship used in the example, although we could still calculate welfare in terms of utility in principle. However, most people find it much easier to think in terms of dollars of income.[22] A valid comparison of welfare using income

[22] Additionally, the costs of various policy options are typically expressed in dollars, so this facilitates cost-benefit analysis.

requires that all non-income dimensions of welfare are held constant. For this reason, we need to convert each outcome in terms of income, life expectancy, and unemployment into an equivalent level of income under a common baseline level of life expectancy and unemployment.

Column F of Table 10 presents an alternative calculation of equivalent income if we used the worst observed life expectancy as the baseline instead of the best (75 years in Canada in 2000). One sees that the relative ordering outcomes is preserved under this alternative baseline, but the relative differences between countries and over time have been affected. For example, the growth in the Canadian living standard between 2000 and 2010 would be estimated at 43 per cent under a baseline of 90 years of life expectancy, but only 30 per cent under a baseline of 75 years of life expectancy. The impact of the choice of baseline in practice is not immediately clear.

Hopefully the reader has some understanding of what equivalent income means by this point. However, we still have the problem of determining how much income is required to compensate for a change in life expectancy or the unemployment rate. Unfortunately, this problem does not have a single simple solution.

One option is to ask individuals how much an additional year of life expectancy at birth is worth to them. In our opinion, this is a bad approach, as an individual likely does not know and responses do not have much meaning. I could tell you that I am willing to give up one billion dollars for an additional year of life, but it is impossible to verify if I would actually choose to do this. Studies such as Murphy et al. (2005) have found that individuals tend to overstate their own willingness-to-pay.

A better option is to look at behaviour. The literature on the value of a statistical life takes some creative approaches to this problem by looking at behaviour. The extent to which individuals are willing to trade money for life is suggested by wage premia earned for dangerous work or the extent to which individuals are collectively willing to insure against a loss of life.

Boarini et al. (2014b) utilize two approaches to estimate the trade-off between life, income, and unemployment. The first method, which they call the subjective approach, is to perform a simple multivariate regression on a measure of subjective well-being (essentially survey questions asking people how happy they are). The resulting coefficients from this regression provide sufficient information to calculate the amount of income which one would be willing to exchange for a given change to life expectancy and the unemployment rate. The results presented in the next subsection were generated using this approach, using a cross-country regression at the national level. [23]

[23] See technical appendix for details of the specific regression used by these researchers.

The second approach adopted by Boarini et al. (2014b), which they call objective, is to construct a utility function over lifetime consumption, calibrate it using reasonable parameter values from the literature, and calculate the amount of income which must be required for adjustments in life expectancy or the unemployment rate in this assumed utility function. Boarini et al. (2014a) conclude that their subjective and objective approaches produce similar estimates of the trade-offs between income, longevity, and the unemployment rate if a certain utility function[24] is chosen.

The adjustment for inequality is made using a Kolm-Atkinson inequality index.[25] The technical appendix provides additional information on this adjustment, but we will not elaborate on the calculation here except to mention that, in practice, detailed information on inequality of life expectancy and risks of unemployment is difficult to come by.

C. Index of Living Standards

The OECD has constructed an index of living standards using the inclusive growth methodology (OECD, 2014). This index offers a new measure of well-being at the national level which incorporates annual household real net adjusted disposable income per capita,[26] the unemployment rate, life expectancy, and income inequality. There are many other indices which include non-income components, but most rely on an arbitrary choice of weights while the equivalent income approach effectively weights the outcomes based upon willingness to pay. For this index, willingness to pay has been estimated by running a macro-level regression of

[24] Specifically, an Epstein-Zin-Weil utility function (see Epstein and Zin, 1989).

[25] The Kolm-Atkinson index is based on a concept of equally distributed equivalent income, which is “the level of income per head which if equally distributed [meaning everyone receives the same level of income] would give the same level of social welfare as the present distribution” (Atkinson, 1970). The index is defined as one minus the ratio of equally distributed equivalent income (that is, the level of income which, if equally distributed, would provide an equivalent amount of social welfare to the actual income distribution) to actual income. It lies between 0 and 1, with a higher value indicating greater inequality. The index has a very simple interpretation: a Kolm-Atkinson index of 0.225 means that society would only need 77.5 per cent of its existing national income to achieve the same level of social welfare if income were equally distributed. This measure is grounded in assumptions about the diminishing marginal value of money. If individuals have the same preferences, an additional dollar will be of less benefit for a rich person than for a poor one. As a result, redistribution of one dollar from a rich individual to a poorer one (more equality) would improve aggregate social welfare..

[26] An adjustment is made to household disposable income to reflect social transfers in kind received from the government (health, education, housing) and the income is net of depreciation of capital assets held by households. For brevity, we will refer to this as income or household income throughout the report, but the reader should understand that all figures represent household real net adjusted disposable income on a per capita basis. The OECD calculated these figures in terms of constant 2005 US PPP dollars, but we have converted all figures in this report (unless otherwise stated) to constant 2010 Canadian dollars based on the implicit PPP conversion factor (1.26 Candian dollars per US dollar) and price deflator (1.06 2010 Canadian dollars per 2005 Canadian dollars) for the OECD’s data on household disposable income available in the table *Regional Accounts: Regional Household Income* at stats.oecd.org.

subjective well-being on (log) income, life expectancy at birth, and the unemployment rate across a panel of countries.

Table 11: Comparison of Inclusive Growth and other Measures of Well-Being, 2011, Selected OECD Countries

	Measure of Well-Being			Country Ranking		
Country	Inclusive Growth Measure of Living Standards (2005 US PPP Dollars)	Index of Economic Well-Being	Real GDP per Capita (2005 US PPP Dollars)	Inclusive Growth Measure of Living Standards	Index of Economic Well-Being	Real GDP per Capita
Norway	21,822	0.80	46,791	1	1	1
Australia	18,855	0.53	37,359	2	10	3
Canada	**16,975**	**0.52**	**36,813**	**3**	**11**	**5**
Germany	16,759	0.64	34,628	4	4	7
Sweden	16,343	0.61	34,861	5	7	6
France	16,191	0.60	30,081	6	9	12
Netherlands	16,103	0.65	37,065	7	3	4
United States	15,657	0.48	44,376	8	13	2
Belgium	15,418	0.66	33,172	9	2	8
United Kingdom	14,487	0.62	32,887	10	6	9
Finland	13,910	0.63	32,057	11	5	11
Denmark	13,275	0.61	32,539	12	8	10
Italy	12,696	0.52	27,073	13	12	13
Spain	9,349	0.45	26,890	14	14	14

Source: Data on inclusive growth measure and real GDP per capita provided by the OECD. The inclusive growth data represents provisional results of ongoing research. The Index of Economic Well-Being includes indicators from four broad domains: consumption flows, stocks of wealth, economic equality, and economic security. It was developed by the Centre for the Study of Living Standards (Osberg and Sharpe, 2011).

Table 11 shows the equivalent incomes of 14 OECD countries in 2011[27] alongside the CSLS's index of economic well-being (IEWB)[28] (Osberg and Sharpe, 1998) and real GDP per capita. All inclusive growth estimates in this report reflect provisional results of ongoing

[27] The countries are chosen to match the 14 for which the CSLS has estimated the IEWB.
[28] The CSLS's IEWB is constructed from many sub-indicators which can be classified as consumption flows, wealth stocks, equality, and economic security. The version of the presented in this report assigns equally weights these factors.

research by the OECD. Norway, Australia, and Canada had the highest living standards of the countries in Table 11 based on the OECD's inclusive growth metric.

Table 12: Decomposition of Growth in the Inclusive Growth Measure of Living Standards, Annual Growth Rates, 2000-2011

Country	Living Standards (Per Cent)	Household Income (Percentage Points)	Life Expectancy (Percentage Points)	Unemployment Rate (Percentage Points)	Inequality (Percentage Points)
CHN	9.33	9.37	1.55	-0.05	-1.54
POL	7.16	2.64	2.31	1.96	0.25
CZE	4.92	2.62	1.78	0.51	0.00
FIN	4.66	2.58	1.77	0.41	-0.10
NOR	4.51	3.05	1.39	0.02	0.05
AUS	4.40	2.81	1.51	0.22	-0.14
NZL	4.27	2.49	1.60	-0.10	0.29
CAN	**3.52**	**2.15**	**1.45**	**-0.13**	**0.05**
FRA	3.09	1.24	1.83	0.20	-0.18
GBR	2.88	1.47	1.79	-0.50	0.13
SWE	2.88	2.36	1.25	-0.39	-0.35
BEL	2.82	0.77	1.68	-0.12	0.49
HUN	2.64	1.79	2.02	-1.42	0.26
DEU	2.53	0.87	1.51	0.37	-0.23
DNK	2.38	1.62	1.71	-0.70	-0.25
NLD	2.37	0.97	1.67	-0.27	0.01
AUT	2.22	0.83	1.57	-0.14	-0.04
ITA	1.66	-0.15	1.45	0.40	-0.04
ESP	1.51	0.99	2.27	-1.50	-0.26
PRT	0.82	0.38	2.22	-1.97	0.19
USA	0.75	1.38	1.16	-1.15	-0.63
Unweighted	3.40	2.01	1.69	-0.21	-0.10

Source: Author's calculations using provisional results from ongoing research provided by the OECD.

While the three measures of well-being in Table 11 are correlated,[29] there are some differences in the relative ranking of countries. France has the 6th highest inequality-adjusted equivalent income, but only the 12th highest real GDP per capita while the United States has the 8th highest equivalent income but the 2nd highest real GDP per capita. The differences between rankings under the IEWB and equivalent income are perhaps even greater. Australia and Canada rank high in terms of equivalent income (2nd and 3rd respectively), but low in the IEWB (10th and

[29] The Pearson correlation coefficient between equivalent income and the IEWB is 0.71. The Pearson correlation coefficient between equivalent income and real GDP is 0.80.

11th). The standard of living is very high in Finland according to the IEWB (5th) but is relatively low as measured by equivalent income (11th). All three measures indicate that Norway has the highest level of well-being.

Table 12 presents a decomposition[30] of growth in the inclusive growth measure of living standards for twenty OECD countries and China between 2000 and 2011 into growth of its four components: average household income, life expectancy, the unemployment rate, and inequality. Median[31] The Canadian living standard grew at a compound annual rate of 3.5 per cent over the period which was slightly above the average rate of growth of 3.4 per cent for all countries in the sample. Growth in the standard of living was strongest in China (9.3 per cent annually), Poland (7.2 per cent), and the Czech Republic (4.9 per cent). Living standards growth was lowest in Portugal (0.8 per cent) and the United States (0.8 per cent).

Comparison of countries with similar growth rates reveals that the sources of growth sometimes vary considerably across countries. For example, Great Britain and Sweden had identical growth rates in living standards of 2.88 per cent annually over the period. However, Great Britain's growth was largely the result of improvements in life expectancy (1.8 per cent) and income (1.5 per cent) while growth in income was much more important in Sweden (2.4 per cent) although increased life expectancy also made a substantial contribution (1.3 per cent). One can also see how differences in improvements of non-income factors can create significant differences in the overall growth of living standards even if income growth is similar. For example, Poland and the Czech Republic both experienced income growth of about 2.6 per cent annually, but much larger improvements in life expectancy, unemployment, and inequality resulted in 7.2 per cent growth in living standards in Poland compared to 4.9 per cent in the Czech Republic.

The decomposition allows one to see how countries compare not only in terms of growth in overall living standards but also in terms of growth as the result of improvements in specific components.

The average country experienced household income growth of 2.0 per cent. Italy, Portugal, and Belgium were notable for having especially slow income growth (-0.2 per cent, 0.4 per cent, and 0.8 per cent respectively) while adjusted household incomes expanded rapidly in China (9.4 per cent) and Norway (3.1 per cent).

Improvements as a result of changes in the compensating income for life expectancy relative to income were much more similar than improvements in income across countries. The average improvement in living standards attributable to life expectancy was 1.7 per cent, ranging from a high of 2.3 per cent in Poland to a low of 1.2 per cent in the United States.

[30] Note that this decomposition is additive.

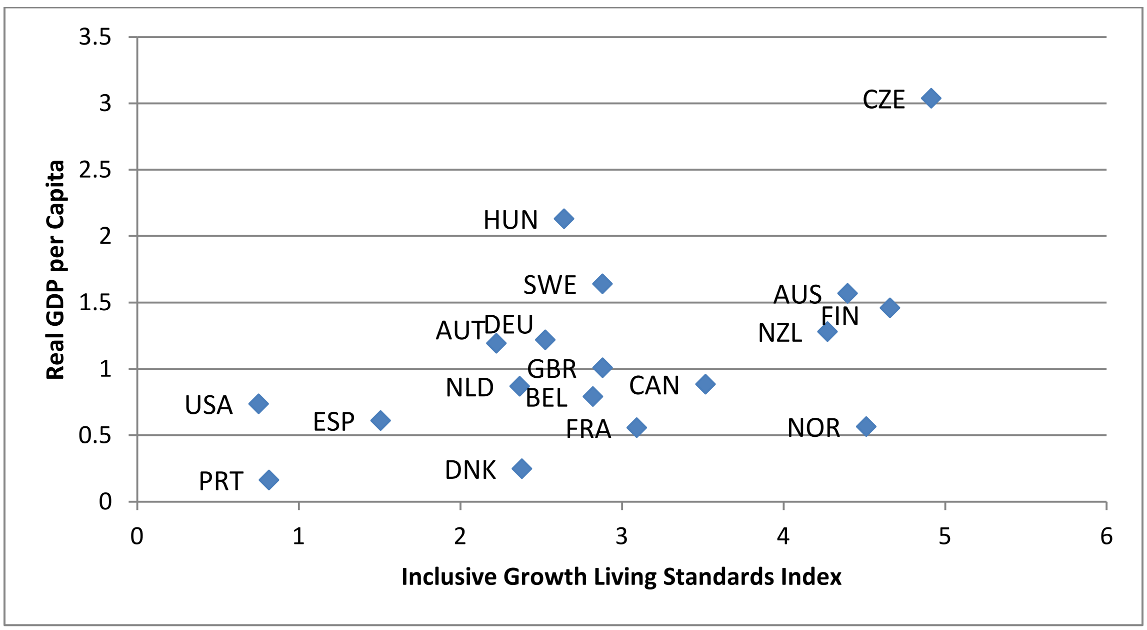
[31] The results we present are based upon an inequality adjustment which uses an inequality aversion such that the living standard is close to that of the median household. The OECD has also produced estimates with an adjustment for inequality reflecting the bottom decile and results for the average household (no inequality adjustment).

In most countries, rising unemployment rates following the global recession negatively contributed to the standard of living. The average impact of changes in the compensating income for the unemployment rate relative to income was -0.2 per cent annually. The biggest negative impacts of unemployment occurred in the countries that one might expect: Spain (-1.5 per cent), Portugal (-2.0 per cent), and the United States (-1.2 per cent).

Lastly, changes in inequality also varied across countries from 2000 to 2011, although in most cases this factor had a much smaller impact on the measure of living standards compared to others. The average effect of changes in inequality on growth in living standards was -0.1 percentage points. The largest improvements in inequality only contributed about 0.3 percentage points to growth in living standards in Hungary, New Zealand, and Poland. Rising inequality had a negative effect on growth in living standards of 0.4 percentage points in Sweden, 0.6 percentage points in the United States, and 1.5 percentage points in China.

Just like the levels of the inclusive growth measure of living standards, the growth rates are also correlated with those of GDP. Chart 2 illustrates how the growth rates of these two measures compare. The biggest difference is that growth rates in living standards tend to be higher than those of GDP.

Chart 2: Growth Rates of GDP per Capita and Inclusive Growth Index of Living Standards, 2000-2011, Select OECD Countries



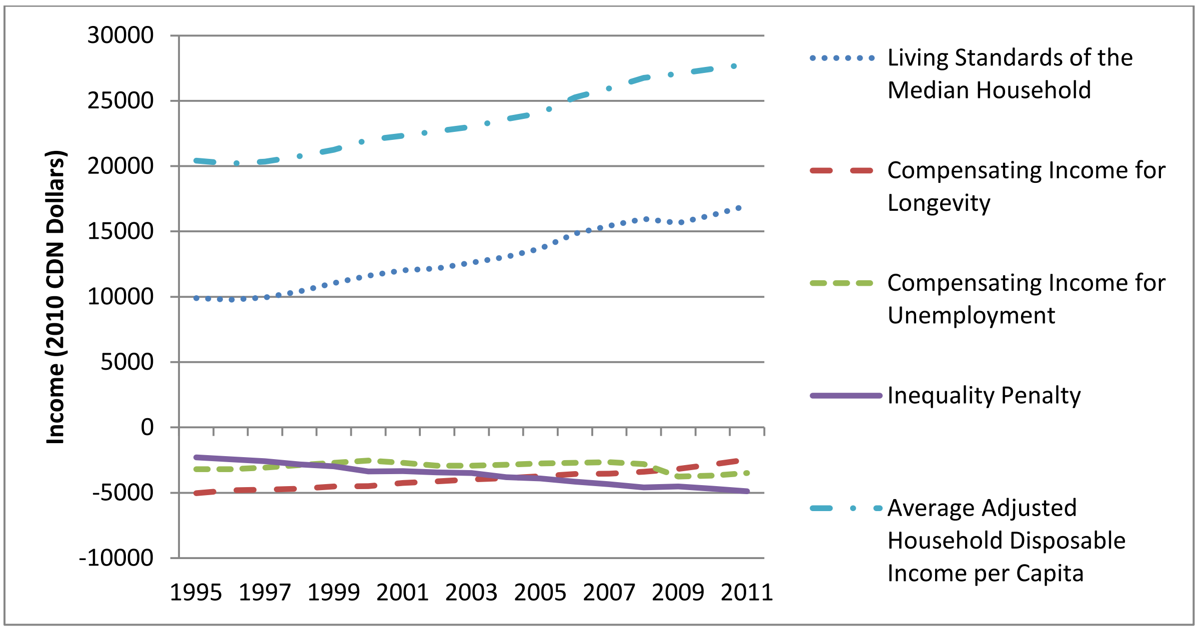
Source: Data on inclusive growth measure of living standards and real GDP per capita provided by the OECD. The inclusive growth data represents provisional results of ongoing research.

Within Canada, we will consider the sources of growth in living standards in more detail. Our focus will be on the 2000-2011 period as this is the period over which we will be analyzing the impact of specific improvements in life expectancy in the next section of this report.

Chart 3 shows a decomposition of equivalent income into income and the dollar value of the three adjustments in Canada between 1995 and 2012. This chart illustrates that, in absolute terms, most of the improvement was the result of rising incomes. However, the rate of growth in living standards far exceeded that of income because of improvement in the non-income components. The changes in the levels of compensating incomes can be somewhat informative, but what is more important for understanding growth in living standards is how the magnitudes of the penalties have changed relative to income. [32]

From 2000 to 2011, average household incomes in Canada rose at an annual rate of 2.1 per cent from $29,416 to $37,164. Over the same period, our measure of living standards (in terms of equivalent income) rose 3.5 per cent from $15,514 to $22,696. Income growth accounted for about 61 per cent of the total growth in living standards.

Chart 3: Standard of Living and Its Components, Canada, 1995-2011



Source: Data provided by the OECD. This data represents provisional results of ongoing research.

[32] Note that the contributions to the increase in living standards in Table 13 do not correspond to the decomposition in Table 12. For example, the inequality penalty increased by $2,017 even though reduced inequality can account for 0.05 percentage points of annual growth in living standards. This may strike the reader as inconsistent, but it is important to understand that the magnitude of the inequality penalty is relative to the level of equivalent income – the penalty increased as equivalent income rose from 2000 to 2011. If inequality had remained unchanged, the inequality penalty would have grown even more than it did. While Table 13 suggests an alternative decomposition in absolute terms of the change in living standards, the decomposition in Table 12 based on relative growth in the multiplicative components determining living standards is more informative.

Life expectancy increased by about 2.5 years[33] in Canada from 2000 to 2011. At the same time, the unemployment rate rose slightly from 6.89 per cent to 7.53 per cent. The reduction of total compensating income from these two non-material components relative to income resulted in growth in the living standard of 1.3 per cent annually. The total compensating income shrank from -31.9 per cent of income in 2000 to -21.4 per cent of income in 2011. This overall improvement can be decomposed into a reduction in the compensating income for the higher unemployment rate from -11.5 per cent of income to -12.6 per cent of income and an increase in the compensating income for the higher life expectancy from -20.4 per cent of income to -8.8 per cent of income. These improvements correspond to 1.5 percentage points of annual growth in the living standard due to increased longevity and -0.1 percentage points of annual growth in the living standard due to the elevated unemployment rate. As a share of total growth in the living standard, improvements in life expectancy can account for about 41 per cent of the growth while rising unemployment can account for about -4 per cent.

Table 13: Living Standards and Its Components, Canada, 2000 and 2011

	Levels (2010 CDN Dollars)		Absolute Change, (2010 Dollars)	Contribution to Change in Living Standards	Relative to Income (Per Cent)	
Year	2000	2011	2000-2011	2000-2011	2000	2011
Average Adjusted Household Disposable Income (per Capita)	**29,416**	**37,164**	**7,748**	**107.9**	**100.0**	**100.0**
Compensating Income for Longevity	-5,995	-3,275	2,720	37.9	-20.4	-8.8
Compensating Income for Unemployment	-3,395	-4,665	-1,270	-17.7	-11.5	-12.6
Equivalent Average Income	**20,026**	**29,224**	**9,198**	**128.1**	**68.1**	**78.6**
Inequality Penalty	-4,512	-6,529	-2,017	-28.1	-15.3	-17.6
Living Standards	**15,514**	**22,696**	**7,182**	**100.0**	**52.7**	**61.1**

Source: Data provided by the OECD. This data represents provisional results of ongoing research.

Lastly, the Kolm-Atkinson inequality index remained almost unchanged. It fell from about 0.225 to 0.223 in Canada from 2000 to 2011, resulting in 0.05 percentage points of annual

[33] Figure based upon the data used by the OECD. As years of life expectancy were only reported to one decimal place in the OECD's dataset, this is consistent with the improvement of 2.43 years from 79.23 years to 81.66 years reported by the Canadian Human Mortality Database which we use later in this report.

growth in the living standard as a result of slightly reduced inequality.[34] This source only accounts for about one per cent of growth in Canada's living standard.

D. Strengths and Weaknesses of the Approach

The major advantages of the inclusive growth framework are that it provides a systematic way to condense multidimensional policy outcomes into a single measure. Unlike most commonly used approaches, this is done without resorting to arbitrarily chosen weights. Instead, the weighting is dictated by a utility function which is, to some degree, determined from the data. The method also explicitly attempts to address concerns about inequality.

Such an approach can be a boon to the analysis of health policy in a number of ways. From the perspective of policymakers interested in maximizing social welfare, it provides a simple way to quantify the total impact of a policy which affects multiple outcomes of interest. Importantly, the weighting given to the various outcomes is chosen in a way which reflects the underlying preferences of all individuals in society. This represents a way to comprehensively incorporate the objectives of various stakeholders even if these objectives are measured in different units. Not only can this approach be used to improve cost-benefit analyses of health policy, it can also be used to quantitatively include health outcomes in economic analyses of traditionally non-health economic and social policies which may have an impact on health such as education.

The method also provides a means to identify the overall impact on living standards by including economic benefits of health policy which have traditionally been difficult to assess. Many analyses of health policy have focused on the direct impact of illness on government budgets and the lost output of firms because these are relatively easy to quantify. The inclusive growth framework offers a reasonable approach to incorporate the intrinsic value of life for individuals into policy evaluation.

While the inclusive growth approach offers new opportunities for more comprehensive analysis of health policy, it also has several limitations.

Currently, the inclusive growth index of living standards only incorporates income, unemployment risk, and life expectancy, but there are many other aspects of well-being which may be relevant for evaluating health policy such as housing, safety, and the environment. The framework can be further developed to incorporate additional health and non-health dimensions. An obvious improvement would be to adopt a more comprehensive health measure such as health-adjusted life expectancy.

[34] Note that, even though inequality fell over the period (at least according to this measure), the estimated inequality penalty grew considerably because of the increased value of material and non-material component. However, the magnitude relative to the total value of income and non-income components of well-being remained virtually unchanged so that this is consistent with very little change in inequality.

For some policy evaluations, the specific inclusive growth index outlined in this report may not be appropriate. Many health policies may not aim to directly affect life expectancy, but may target other health outcomes such as the incidence and duration of minor illnesses like the common cold. In principle, a similar approach could be used to evaluate health outcomes along other dimensions. In some cases where the policy only is expected to have an impact along a very specific dimension, extension of the analysis to multiple dimensions or conversion of health benefits into dollars may be more complicated than necessary. The researcher should always be careful to choose the best approach for a given research question.

The arbitrary choice of baseline (or benchmark) is another limitation of the equivalent income approach.[35] While the OECD's decision to use the best outcomes as a benchmark seems sensible, it is not clear that this would be a better choice than selecting the worst or average outcomes. Unfortunately, the resulting measures of well-being are not generally robust to the choice of baseline.[36] Although equivalent income preserves the relative order of individual preferences regardless of the choice of baseline, the relative order may change once the social welfare function (adjustment for inequality) is applied. This is problematic because the preferred policy option may depend upon the chosen baseline in some cases. Moreover, the comparison of benefits generated using the inclusive growth method to costs which are not included in the model can be problematic because the dollar value of the benefits will vary with the chosen baseline.

There are also concerns about how the value of an additional year of life expectancy or one additional percentage point of the unemployment rate is estimated. In particular, it is still not obvious what the correct approach is, and the results can vary considerably depending on the methodology employed (stated preferences, elicited preferences, "subjective" approach, or "objective" approach). Additionally, this approach does not fully avoid some of the moral concerns related to putting a dollar value on human life. In particular, the regression used by the OECD (Boarini et al., 2014a) to estimate the trade-off between the unemployment rate, income, and life expectancy implies that the value of a year of life rises with income for individuals facing an identical unemployment rate and life expectancy. The objective approach based on maximizing an individual's lifetime expected utility used in Boarini et al. (2014b) is subject to the same criticism. This is not necessarily to say that this implication is completely incorrect – if one is earning a higher income, one likely has a higher quality of life, so in some clear sense willingness to pay for life should be higher for these people – but the idea that society should value these individuals' lives more because they earn higher incomes is questionable. Fluerbaey and Gaulier (2009) argue that the aggregation of individual preferences using a social welfare function which adjusts for inequality can mitigate these concerns.

[35] All methodologies to aggregate the values of monetary and non-monetary components will need to rely on some arbitrary assumptions. However, the number of such assumptions would ideally be kept to a minimum.

[36] Note that a researcher could select a utility function or welfare adjustment to make the results robust to the choice of baseline. For example, the utility function underlying the OECD estimates in this report has a form such that the relative levels of equivalent income across countries and over time are robust to the chosen baseline.

One more difficulty is limited availability of data, particularly regarding inequality in health outcomes. The framework is designed with a very individual-centred approach in mind, but many of the OECD`s publications on this topic have had to rely on national-level estimates due to limited availability of individual level data from many countries. Individual data on income and employment are available in Canada, but estimates of inequality in life expectancy are not as readily available.

IV. Life Expectancy and Canadian Living Standards

We have seen how the inclusive growth framework allows for a comprehensive assessment of living standards by reducing multiple dimensions of well-being into a single measure, equivalent income. The previous section illustrated how this approach can be used to compare living standards across countries and over time. This section builds upon the index of living standards developed by the OECD to demonstrate one way in which the inclusive growth framework can be used to assess the effects of health policy. Focusing on the contribution of increased life expectancy to rising living standards in Canada over the 2000-2011 period, we will make progress towards understanding the sources of these improvements.

Ideally, we would like to identify specific policies which increased life expectancy, quantify the value of the resulting increases to living standards, estimate the impact of the policies on other dimensions of well-being, and assess the costs of the policies. In this way, we could quantitatively evaluate the overall economic consequences of the policies.

In practice, such an evaluation is difficult to do well. We focus our attention on a key part of this process: calculating the gains to life expectancy which have resulted from reductions in specific causes of death. Such a decomposition of the sources of increased life expectancy can be performed in a fairly precise way because data on mortality rates by cause of death are readily available and life expectancy is calculated using age-specific mortality rates.

Using the correspondence between life expectancy and living standards developed by the OECD's inclusive growth framework, we are able to quantify the improvements in living standards attributable to reductions in death from specific causes. In turn, reduced mortality from specific causes of death can be linked to specific sources such as improved medical treatment or lifestyle changes. To some extent, these sources of improvement can be connected with specific policies. This allows a means through which to estimate the impact of such policies on living standards through the channel of life expectancy.

This section is arranged into three subsections. The first subsection provides an overview of life expectancy in Canada, as this is our primary variable of interest. Once this background information on life expectancy is established, the focus shifts to understanding recent sources of increased life expectancy in Canada. The third subsection presents a decomposition of improvements in life expectancy and living standards by cause of death. The third subsection discusses the link between health policy and reductions in mortality resulting from the major causes of death, particularly cancer and cardiovascular disease, and how these sources of improvement contributed to rising living standards.

A. Life Expectancy in Canada

Generally, life expectancy can be defined as a measure of the average number of remaining years that an individual can expect to live. Life expectancy is calculated using age-specific mortality rates.

There are two broad approaches to calculating life expectancy. The **cohort approach** entails calculating the average remaining years of life of a given cohort of the population. For example, one could observe the age at which each individual born in the year 1880 in Canada died. The average age of death of all those born in 1880 is the life expectancy at birth of the 1880 cohort. The cohort approach is most commonly used for historical life expectancy calculations, but one could also forecast the future age-specific mortality rates to estimate the life expectancy of contemporary cohorts.

Most people likely think of this sort of forecasted average age of death of the cohort when they hear statistics on life expectancy at birth, but this is often not how life expectancy is calculated. Non-historical calculations of life expectancy frequently use a **period approach** which calculates the average remaining years of life of a cohort under the assumption that the cohort will face age-specific mortality rates of the entire population prevailing at a given point in time. This approach uses the current age-specific mortality rates observed for the entire population at a fixed point in time rather than the age-specific mortality rates of the cohort. This approach avoids forecasting future mortality rates, but it should be understood that the resulting life expectancy is not intended as a prediction of future life. Instead, life expectancy calculated in this way is a measure of the current health of the population. All life expectancies discussed in this report have been produced using a period approach.

Although life expectancy is often reported at birth, it can be calculated for a population at any age, as it refers to the remaining number of years of life expected from that age onward. Given suitably detailed information on mortality rates, life expectancy can be calculated for subpopulations based on geography, gender, or other characteristics. Note that life expectancy refers to the remaining number of years as opposed to the expected age at death (length of life).

Before proceeding, it is worth emphasizing what life expectancy calculated using a period approach is not. Life expectancy at age x is not a forecast of the number of years an individual of age x should expect to live. Life expectancy is not the same as average age of death observed in a population over a given period of time– the distinction between life expectancy at birth and the average age of death of the population is that life expectancy at birth is independent of the age distribution of the existing population.[37] Lastly, life expectancy is a different concept

[37] Note that, under a cohort approach, life expectancy at birth is the same as the average age of death of the cohort. Under a period approach, life expectancy at birth is the average age of death of the cohort if it has the same life age-

from maximum life span. Life expectancy refers to the average remaining years of life for a given group while life span refers to the length of life of an individual and maximum life span refers to an upper bound on an individual's length of life rather than an average.

We choose to focus on life expectancy for several reasons. First, it is a widely used measure of the overall health of a population which is correlated with many other measures of health.[38] Second, the fact that life expectancy can be calculated directly from mortality rates means that improvements in life expectancy can clearly be attributed to improvements in cause-specific mortality rates. Third, high quality data on mortality rates by age are readily available. Finally, it is convenient because this is the measure of population health which the OECD has used. If we chose a different measure of health, we would need to calculate its value in terms of equivalent income.

Canadian data on life expectancy originates from Statistics Canada's Vital Statistics Death Database, an administrative survey which collects demographic and medical information on all deaths in Canada. Statistics Canada publishes a variety of series related to deaths, including life expectancy and detailed breakdowns by cause of death,[39] age, gender, and location. Many of the numbers and calculations in this report draw upon the detailed life tables produced by the Canadian Human Mortality Database which is maintained by the Mortality and Longevity research team of the University of Montreal's Department of Demography. These tables are generated using Statistics Canada's data and the methodology used by the Human Mortality Database.

According to the Canadian Human Mortality Database, life expectancy at birth in Canada in 2011 was 81.66 years. As is well known, women tend to live slightly longer than men. Female life expectancy at birth was 83.69 years while male life expectancy at birth was 79.52 years (4.17 years less).

Internationally, Canadians enjoy a very high level of life expectancy. Chart 4 presents life expectancy at birth for the total population in 32 OECD countries in 2012. Canada has the 8th highest life expectancy on the list at 81.8 years. One sees that the highest life expectancies were in Japan (83.2 years), Switzerland (82.8 years), and Spain (82.5 years). Canada's life expectancy is comparable to that of most western European countries and is three years higher than that of the United States.

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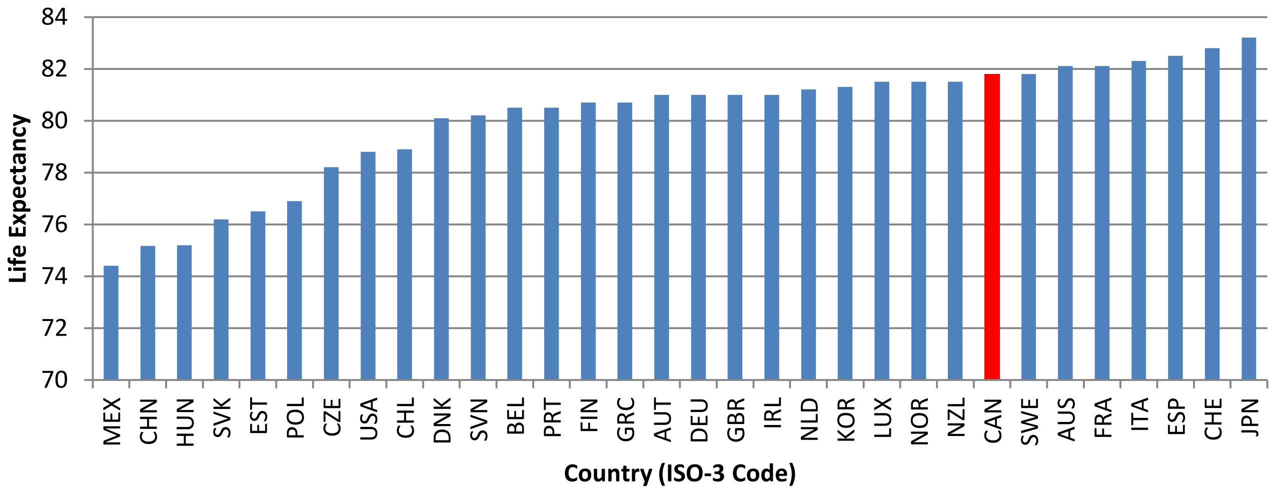
specific mortality rates of the population observed at that point in time. What we are emphasizing is that life expectancy is not the average age of death observed in the total population at a given time.

[38] While life expectancy may miss other important components of health (for example, if the population has higher rates of incidence of disease but low mortality rates), in practice those with higher life expectancy tend to perform better in other measures of health as well.

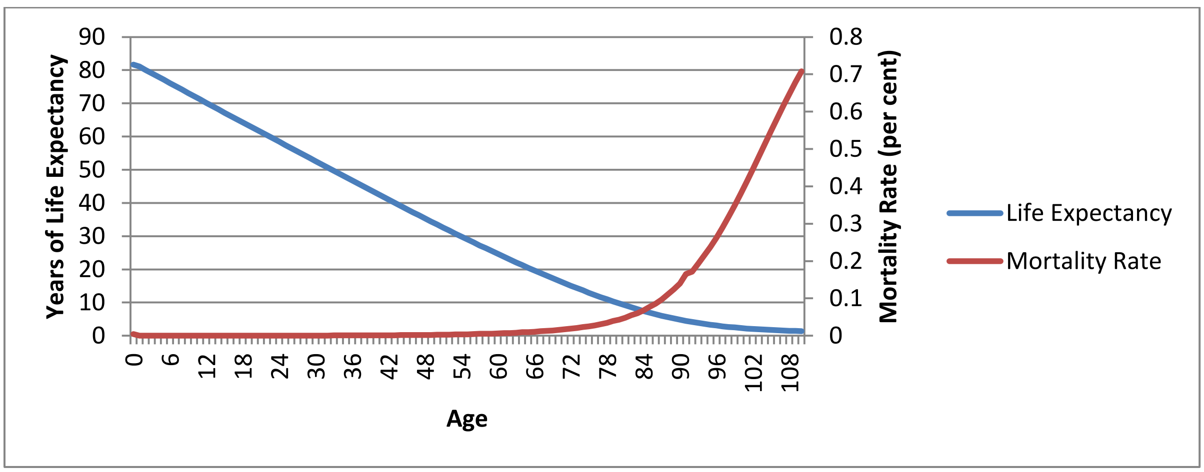
[39] Causes of death are classified using the World Health Organization's International Classification of Diseases

Chart 4: International Comparison of Life Expectancy, 2012



Source: Data provided by the Organization for Economic Cooperation and Development (OECD)

Chart 5: Life Expectancy and Mortality Rates by Age in Canada, 2011



Source: Life tables from the Canadian Human Mortality Database. Mortality rates have been smoothed.

Life expectancy gradually declines with age in Canada (Chart 5). From age one until the age of 54, life expectancy declines by over nine-tenths of a year for each year of age. This reflects the very low rates of death during these years. Towards the upper end of the age distribution, mortality rates become higher and the differences between ages in terms of life expectancy become much smaller. For example, in 2011, life expectancy at age 80 was 9.73

years, life expectancy at age 90 was 4.81 years, life expectancy at age 100 was 2.32 years, and life expectancy at age 110 (and above) was 1.41 years.[40]

Notice that the expected length of life always increases with age. Recall that life expectancy at birth in 2011 was 81.66 years. Life expectancy of 9.73 years at age 80 suggests that, conditional on surviving to age 80, the expected average lifespan is 89.73 years. The expected age at death rises with age because, conditional on survival to a given age, the probability of death prior to that age becomes zero.

Table 14: Life Expectancy by Province/Territory and Sex, 2009-2011 (three year period)

Region	At birth		At age 65	
	Males	Females	Males	Females
Canada	79.33	83.60	18.82	21.73
Newfoundland and Labrador	77.09	82.00	17.28	20.39
Prince Edward Island	78.15	82.90	17.95	20.96
Nova Scotia	78.05	82.64	17.92	20.83
New Brunswick	78.36	83.14	18.36	21.24
Quebec	79.43	83.55	18.60	21.56
Ontario	79.77	83.92	19.00	21.89
Manitoba	77.72	82.19	18.12	21.25
Saskatchewan	77.20	82.20	18.28	21.42
Alberta	79.06	83.45	18.81	21.83
British Columbia	80.25	84.40	19.65	22.32
Yukon	75.19	79.61	16.24	18.87
Northwest Territories	76.28	80.07	17.76	20.23
Nunavut	68.75	73.91	14.55	15.39

Source: Statistics Canada, Demography Division, Life Tables, Canada, Provinces and Territories (84-537-X)

There is considerable geographic variation in life expectancy at birth within Canada. Table 14 presents estimates of life expectancy by sex and province/territory produced by Statistics Canada based on mortality rates over the 2009-2011 period. Among the 10 provinces, life expectancies are fairly similar. For men, the highest life expectancy among the provinces was 80.25 years in British Columbia and the lowest was 77.09 in Newfoundland and Labrador. These were also the best and worst provinces in terms of female life expectancy at 82.00 and 84.40 years respectively. Life expectancy is noticeably lower in the territories. Male life expectancy at birth was only 76.28 years in the Northwest Territories (80.07 for women), 75.19

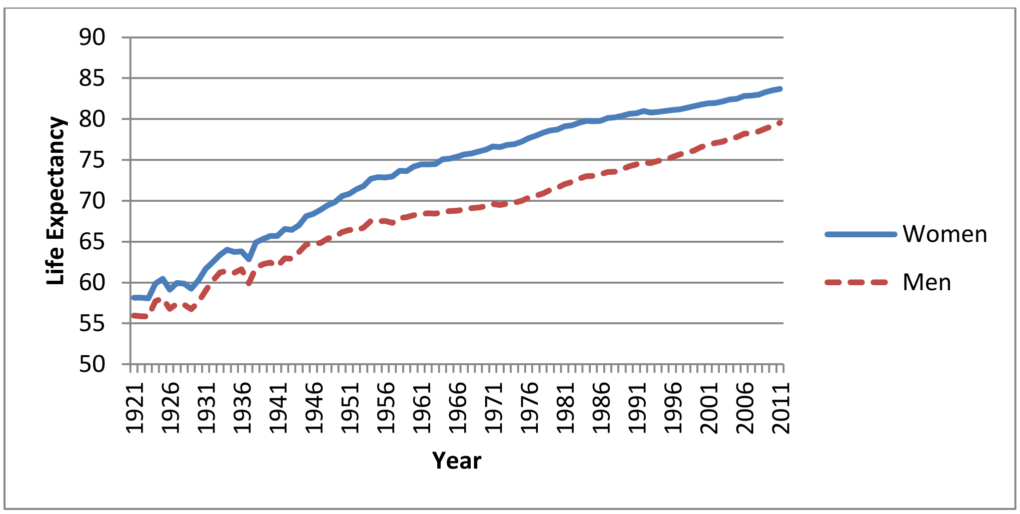
[40] Intuitively, when one is elderly and has a very high rate of mortality, being one year younger would not have a major impact on life expectancy. If the probability of death at age 100 is about 0.5, then reducing one's age from 101 to 100 would only raise life expectancy by half a year. In contrast, mortality rates are near zero for those aged 20, so a reduction in age from 21to 20 would result in a nearly one year increase in life expectancy.

years in the Yukon Territory (79.61 for women), and 68.75 years in Nunavut (73.91 for women) – more than 10 years below the national male life expectancy of 79.33 years (83.60 for women).

Of course, there is further variation in life expectancy within each province. Greenberg and Normandin (2011) document variations in life expectancy among health regions. They note that "[h]ealth regions with life expectancies lower than the Canadian average share similar characteristics. They tend to have higher levels of long-term unemployment, lower proportions of high school and university graduates, smaller immigrant populations, larger Aboriginal populations and rural/remote locations."[41]

Geographic variation in life expectancy should remind us of a key fact about life expectancy as it relates to the inclusive growth framework. Like most socio-economic outcomes, life expectancy is not equally distributed amongst the population. This inequality can arise for many reasons such as genetics, environmental factors, access to care, and differing behaviours.[42] The geographic differences above highlight regional inequalities, but there can also be large differences in terms of life expectancy across groups defined by non-geographic characteristics such as ethnicity or income.

Chart 6: Canadian Life Expectancy at Birth, 1921-2011



Source: Life tables from the Canadian Human Mortality Database

[41] In an appendix, we discuss several factors which are thought to be determinants of life expectancy such as diet, exercise, excessive drinking, smoking, income, education, environment, disasters, laws, culture, infrastructure spending, and health care. We use variation between health regions to illustrate the correlations between life expectancy and several of these factors.

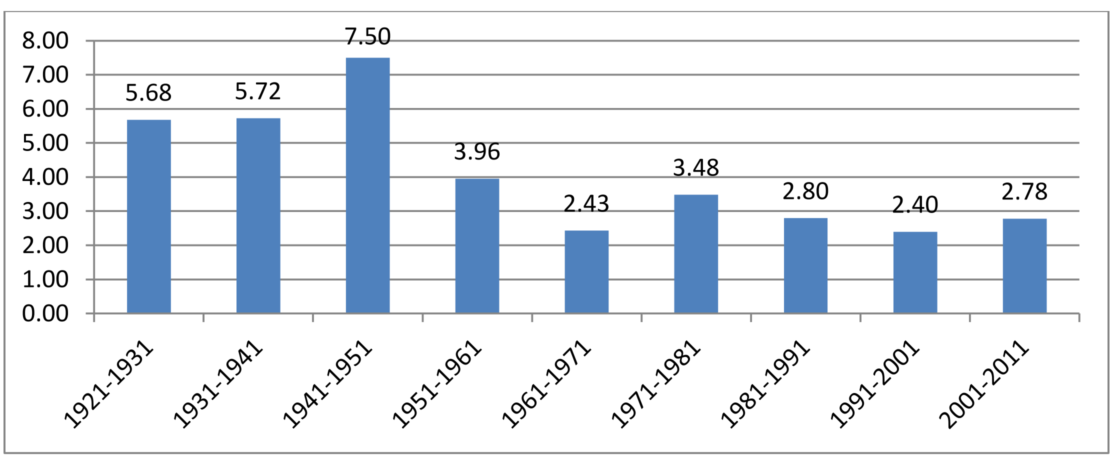
[42] Differences in behaviour which lead to unequal health outcomes may not be of concern to policymakers if they represent optimal decisions on the part of individuals as a result of differing preferences. Some of the inequality may be the result of unequal access to information, resources, or health care – these sources of inequality in life expectancy may be of great concern for policymakers.

Life expectancy has not always been so high in Canada. Chart 6 depicts how life expectancy at birth has increased by nearly 25 years from 1921 to 2011. Advances in health status and longevity were a major component of improved living standards in the 20th century. Decady and Greenwood (2014) provide a detailed analysis of how life expectancy changed over this period. They point out that the greatest gains to life expectancy occurred over the 1921-1951 subperiod. The biggest source of increased life expectancy was the reduction in infant mortality rates. Major medical advances such as immunization and the discovery of new medications such as penicillin also significantly reduced mortality rates from infectious diseases. These developments, which reduced mortality rates earlier in life, had a major impact on life expectancy.

Improvements at the upper end of the age distribution have had a much smaller impact historically. Decady and Greenwood (2014) note that "[o]ver the past 90 years, life expectancy has not greatly increased for those over 75 years of age."

The rate of improvement in life expectancy has been declining over time (Chart 7), although it has been fairly steady since about 1981. The slowdown in life expectancy growth since 1951 is partly due to the fact that many of the gains from reduced mortality rates earlier in life have already been realized. Infant mortality rates have fallen to about 0.48 per cent as of 2011 and mortality rates for the young are extremely low. For example, the mortality rate was about 0.05 per cent for the population aged 25-29 in 2011 (CANSIM Table 102-0504). Given these low mortality rates there, is little scope for large improvements. Eggleston and Fuchs (2012) note that most of the increases in life expectancy now arise later in life. However, it is difficult for reductions in mortality rates from specific causes to result in much of an overall increase in life expectancy because the probability of death due to other causes is high at an older age.

Chart 7: Life Expectancy, Ten Year Growth Rates (Per Cent), Canada, 1921-2011



Source: Author's calculations using life tables from the Canadian Human Mortality Database

Besides the general improvements in life expectancy, Chart 6 showcases how the gap between male and female life expectancy has changed over time. Interestingly, the gap was actually quite small in 1921. Women only were expected to live about 4.0 per cent longer than men. The gap began to expand in the 1930s. It was widest during the 1970s, when women had a life expectancy about 10 per cent greater than that of men. The gap has shrunk in recent decades and the difference was only about 5.2 per cent as of 2011. The reasons for this gap are not completely understood. While biological explanations seem plausible,[43] differing gender roles in society also may be at play.

Health Utilities Index

Health adjusted life expectancy can be calculated by rescaling the value of each year of life lived to reflect the average quality of life expected. Such a calculation requires a measure of quality of life such as the health utilities index.

The Health Utilities Index (HUI) was developed by researchers at McMaster University and Health Utilities Inc. It is based upon questionnaires designed to capture information about an individual's health status. The responses to these questionnaires are mapped into scores which measure functionality for a set of health attributes. In turn, these functional scores on the health attributes are mapped into a weighting factor using a utility function. The utility function represents community preferences and is based upon the stated preferences over various states of health.

There are several HUI classifications. The HUI3 classification classifies 8 health attributes into 5 or 6 levels of function. These states include vision, hearing, speech, ambulation (walking), dexterity, emotion, cognition and pain. The utility function converts a set of scores into an overall measure of overall health where 1.00 corresponds to perfect health and 0.00 corresponds to being dead. Scores can be negative, reflecting states which are considered worse than death. These scores of overall health are applied to each year of life to calculate HALE . For more information on the Health Utilities Index, see Horsman et al. (2003).

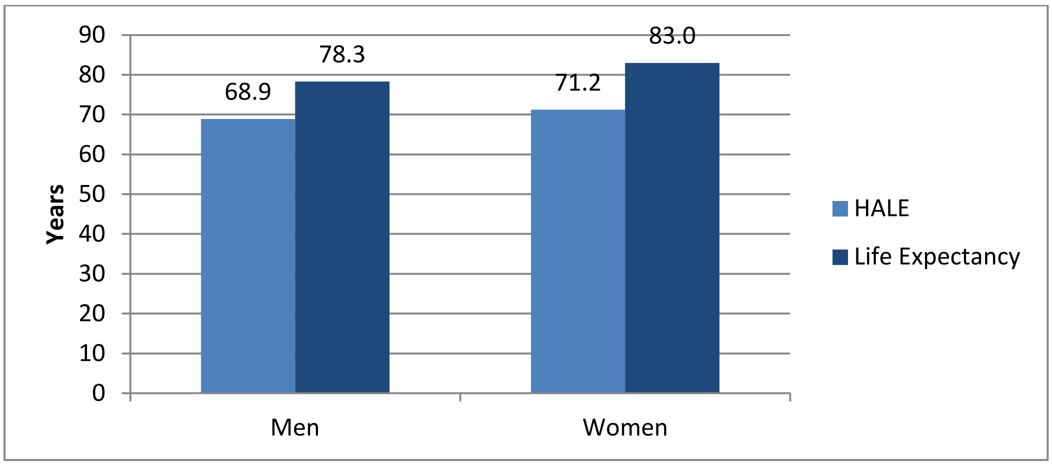
An obvious criticism of life expectancy as a measure of population health is that it does not account for the quality of each year of life lived. One may care whether a year of life gained is a year in good health or a year of pain and limited functionality. Variants on life expectancy have been developed which attempt to account for the quality of each year of life lived. Such measures include health-adjusted life expectancy (HALE) or disability adjusted life expectancy (DALE). Health-adjusted life expectancy can be calculated by rescaling the value of each year of life lived to reflect the average quality of life expected. Such a calculation requires a measure of

[43] It has been noted that there tend to be more men born than women. One explanation which has been suggested for this observation is that this is an evolutionary feature which arose because men face higher mortality rates (and thus lower life expectancies) than women.

quality of life such as the Health Utilities Index (HUI) or the Quality of Well-Being Scale (Public Health Agency of Canada, 2012).[44]

Health-adjusted life expectancy is lower than life expectancy, but by how much? Chart 8 shows traditional life expectancy and HALE for men and women in Canada based on mortality rates over the 2005-2007 period. One sees that health adjustment reduces male life expectancy by 9.4 years (12.0 per cent) and female life expectancy by 11.8 years (14.2 per cent). Years lived in imperfect health amount to a significant reduction in living standards. Women appear to live more years in poor health, but they still have a higher HALE than men.

Chart 8: Health Adjusted Life Expectancy vs. Life Expectancy, 2005/2007 (three year period)



Source: Statistics Canada, CANSIM Table 102-0122

The good news is that recent improvements in HALE have slightly outpaced those in life expectancy. Table 15 presents life expectancy and health-adjusted life expectancy calculated for the 2000-2002 and 2005-2007 periods. The rightmost column presents the increase from the first to second period. One sees that health-adjusted life expectancy increased more than unadjusted life expectancy between the two periods. This is encouraging, as it suggests that there has been an improvement in the overall quality of the years being lived. Notice that this does not necessarily mean that the additional years of life in the traditional measure of life expectancy represent healthy years. The improvement in health adjusted life expectancy could be driven entirely by improvements in health occurring during earlier years of life which were unrelated to mortality.[45]

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[44] There is currently no way to compare HALE internationally based on comparable data from national statistical systems. Consensus seems to be forming around a common set of questions to ask individuals, the BI/WG questions (developed by the UNECE's Budapest Initiative (BI) and the UN's Washington City Group (WG)) which build upon previous approaches such as the Health Utilities Index, but discussion is ongoing as to a standardized way to convert the responses to these questions to a summary measure between 0 and 1 (Wolfson, 2014).

[45] Note that the improvement in life expectancy is neither an upper bound nor a lower bound for the improvement in HALE. It would be a lower bound if one could assume that all increases in life expectancy represent expected years

Table 15: Improvements in HALE and Life Expectancy, 2000/2002 to 2005/2007

Sex	Characteristic	2000/2002	2005/2007	Increase (Years)
Men	Health-adjusted life expectancy	67.5	68.9	1.4
	Life expectancy	77.0	78.3	1.3
Women	Health-adjusted life expectancy	69.9	71.2	1.3
	Life expectancy	82.0	83.0	1.0

Source: Statistics Canada, CANSIM Table 102-0122

Now that we have a better understanding of some basic trends in Canadian life expectancy, we will move on to a discussion of the underlying factors.

B. Decomposing Increases in Life Expectancy by Cause of Death

In this subsection, we undertake the major exercise of this report which is a decomposition of improvements in Canadian living standards attributable to increased life expectancy by cause of death over the 2000-2011 period.

Our analysis utilizes life tables from the Canadian Human Mortality Database, age-specific mortality rates by 113 detailed causes of death from Statistics Canada`s Vital Statistics Deaths Database, and data on the contribution of life expectancy to the inclusive growth measure of living standards provided by the OECD.

We perform the decomposition of changes in life expectancy by cause of death using the Arriaga (1984) method which is prevalent in the life expectancy literature.[46] For robustness, we have also used an alternative methodology developed by Beltrán-Sánchez and Preston (2007), the results of which are presented in the appendix. The two decompositions result in similar estimates of the impacts of reduced mortality for the major causes of death. For details of the methodology employed, please consult the technical appendix at the end of this report.

of life in perfect health – we think that this is often the case, but it will almost certainly not be true for the entire improvement in life expectancy. The evidence reveals that it is not an upper bound because quality of health can improve without any increase in length unless everyone is in perfect health until the moment of death.

[46] The Arriaga method was originally developed to decompose gains in life expectancy by reductions in mortality within each age group (Arriaga, 1984). Within each age group, the improvement can be divided into a direct effect due to additional years lived within the age group, an indirect effect due to increased years of life at older ages, and an interaction between the two effects. This method has been extended in the literature to evaluate mortality by cause of death. Our calculation involves multiplying the contribution of each age group by the share of the mortality reduction within that age group attributable to each specific cause.

i. Major Causes of Death

Table 16 presents the broad causes of death associated with the greatest improvements in life expectancy in Canada between 2000 and 2011. The first column of the table shows the number of years of increased life expectancy attributable to reductions in mortality from each cause. The total increase over the period was 2.43 years. All factors which increased life expectancy by 0.01 years or more are included in the table.[47] The second column of the table shows the contribution of each cause as a percentage of the total.

The remaining columns examine how improvements in life expectancy attributable to reduced mortality from each cause translate into improvements in overall living standards based on the OECD's inclusive growth measure of living standards. Recall from the previous section that improvements in life expectancy contributed 1.45 percentage points to growth in living standards annually. We estimate the contribution of each specific cause of death by applying its share of growth in life expectancy to the total impact on living standards growth. For example, if a cause of death accounted for 10 per cent of growth in living standards over the period (0.243 years), then we would attribute 0.145 percentage points of growth in overall living standards to that cause of death (0.1 x 1.45).

Total growth in living standards in Canada over the period was 3.52 per cent. Life expectancy accounted for about 41.08 per cent of this growth each year. Column four shows the share of growth in Canadian living standards attributable to each specific cause of death. This is calculated by applying the share of the improvement in life expectancy (column 2) to the share of growth attributable to the total improvement in life expectancy.

The fifth and sixth columns approximate the value of these improvements in living standards in dollar terms based on provisional results from ongoing OECD research. Column 5 provides an estimate of the value of the increased life expectancy attributable to each cause of death in term of adjusted annual household income in per capita terms. The dollar valuations are constructed based upon the OECD's macro-level regression estimate (Boarini et al. 2014a, Table 3, column 3) that one year of life expectancy is subjectively valued at 5.3 per cent of household income.[48] We apply this estimate to the level of adjusted household income in 2011 ($37,164) to estimate that an additional year of life expectancy is worth about $1,969 of annual household income.[49] This valuation of a year of additional life expectancy is combined with the increases in life expectancy from column 1 to estimate the value of improvements from each cause of death.

[47] The complete decomposition for all causes of death is included in the appendix at the end of this report.
[48] The OECD has informed us that this was the estimate used to construct their measure of living standards which we are using in this report.
[49] If this figure strikes the reader as extremely low, note that this is income per year. Over a lifetime of 81.66 years (life expectancy at birth in Canada in 2011), this change in annual income would amount to about $160,800.

Table 16: Improvements in Life Expectancy and Living Standards, Major Sources of Improvement, Canada, 2000-2011

	(1)	(2)	(3)	(4)	(5)	(6)
Cause of Death	Contribution to Increased Life Expectancy at Birth (years)	Share of Increased Life Expectancy at Birth (per cent)	Contribution to Growth in Living Standards (percentage points)	Share of Growth in Living Standards (per cent)	Change in Equivalent Household Income per Capita[a] (2010 $CDN)	Total Value of Change in Terms of Equivalent Income (billions, 2010 $CDN)
Major cardiovascular diseases	1.42	58.25	0.84	23.93	2,793.28	93.51
Malignant neoplasms	0.59	24.36	0.35	10.01	1,168.40	39.11
Chronic lower respiratory diseases	0.09	3.67	0.05	1.51	175.93	5.88
Accidents (unintentional injuries)	0.09	3.61	0.05	1.48	173.07	5.79
Diabetes mellitus	0.08	3.22	0.05	1.32	154.35	5.16
Nephritis, nephrotic syndrome and nephrosis	0.05	1.89	0.03	0.78	90.69	3.04
Intentional self-harm (suicide)	0.04	1.81	0.03	0.74	86.64	2.90
Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	0.04	1.59	0.02	0.65	76.49	2.57
Alzheimer's disease	0.04	1.57	0.02	0.64	75.26	2.51
Influenza and pneumonia	0.04	1.52	0.02	0.62	72.84	2.43
Congenital malformations, deformations and chromosomal abnormalities	0.03	1.19	0.02	0.49	57.06	1.91
In situ neoplasms, benign neoplasms and neoplasms of uncertain or unknown behaviour	0.03	1.12	0.02	0.46	53.74	1.80
Other and unspecified infectious and parasitic diseases and their sequelae	0.02	1.00	0.01	0.41	48.01	1.60
Human immunodeficiency virus [HIV] disease	0.02	0.89	0.01	0.37	42.87	1.43
Peptic ulcer	0.01	0.24	0.00	0.10	11.46	0.39
Other disorders of circulatory system	0.01	0.21	0.00	0.09	10.07	0.33
All other causes	-0.17	-6.14	-0.07	-2.52	-294.51	-9.82
Total, all causes of death	2.43	100.00	1.45	41.08	4,795.65	160.54

[a] Values are in terms of household real net adjusted disposable income on a per capita basis where an adjustment is made to reflect social transfers in kind received from the government (health, education, housing) and are net of depreciation of capital assets held by households. One additional year of life expectancy is estimated to be worth $1,969 of household income per capita based upon provisional results of ongoing OECD research.

Source: Author’s calculations using data from Statistics Canada’s Vital Statistics Deaths Database and the Canadian Human Mortality Database. Decomposition performed using the Arriaga method. All causes of death at our highest level of disaggregation with an impact on life expectancy of 0.01 years or more (rounded) are included.

Thus, we estimate that the improvement in life expectancy of 2.43 years from 2000 to 2011 was worth about $4,796 of annual adjusted household income (per capita).[50]

Lastly, column six aggregates these valuations over the total population to estimate the total value of improvements in mortality from each cause of death to Canada in terms of increased adjusted household income earned annually. This is done by taking the values from column 5, which are expressed in per capita terms, and multiplying them by the population of Canada in 2011, which was estimated at 33,476,688 by the 2011 Census. We estimate the total value of reductions in mortality rates in Canada from 2000 to 2011 was about $161 billion of annual income.

Now that we have an understanding of what the figures in Table 16 represent, we can explore the impact of specific causes of death on life expectancy in Canada. One can see that the majority of improvements in life expectancy can be attributed to reductions in the rates of mortality from the two leading causes of death in Canada: cardiovascular disease and cancer (malignant neoplasms).

Reduced mortality rates[51] from cardiovascular disease boosted life expectancy by 1.42 years between 2000 and 2011, 58.3 per cent of the total increase in life expectancy. This factor alone can account for 0.84 percentage points (23.9 per cent) of annual growth in living standards over the period. In dollar terms, reduced mortality from cardiovascular disease over the 11 year period was worth an estimated $2,793 of annual household income per Canadian, or about $93.5 billion.

The other major source of improvement in life expectancy and living standards was reduced mortality rates from cancer, which accounted for an increase in life expectancy of 0.59 years (24.4 per cent of the total). These improvements in life expectancy translate into 0.35 percentage points of growth in living standards (10.0 per cent) and can be valued at $1,168 of annual household income per capita or $39.1 billion nationally.

The impacts of reduced mortality due to other causes of death were much smaller, but non-negligible. The third greatest increase in life expectancy was associated with chronic lower

[50] Note that we are approximating the value of 2.43 years of life expectancy based upon the percentage of income earned in 2011. One could just as reasonably measure it in terms of the income earned in 2000, which would result in a lower estimate of $3,788. Additionally, the inclusive growth methodology relies on a non-linear relationship between income and life expectancy such that this is only an approximate value – after giving up five percent of income for the first year of life, five per cent of income for the second year would be slightly less. One may also be confused if they notice that the change in the compensating variation for longevity in Table 13 between 2000 and 2011 was only $2,720 – while this figure may seem to represent a more reasonable approach in terms of the base year used for income, rising income raises the magnitude of the penalty in 2011, obscuring some of the value generated due to increased life expectancy. Adjusting this figure to reflect the fact that household income was about 25 per cent higher in 2011, one can estimate the change in the compensating variation at about $4,300.

[51] When we talk about reduced mortality rates, we really mean reduced age-specific mortality rates. While the overall number of people dying from a given disease may indeed have fallen, life expectancy will increase even if individuals still die from a disease at the same overall rate if these deaths occur later in life.

respiratory diseases such as bronchitis, emphysema,[52] and asthma which contributed 0.09 years (3.7 per cent) to the increase in life expectancy. This corresponds to 0.05 percentage points of growth in living standards (1.5 per cent) and was worth about $176 of annual income per capita ($5.9 billion nationally)

The fourth largest contributor was reduced mortality rates as a result of accidents which also contributed about 0.09 years (3.6 per cent) to the increase in life expectancy. This corresponds to 0.05 percentage points of growth in living standards (1.5 per cent) and was worth about $173 of annual income per capita ($5.8 billion nationally).

The fifth largest contributor was reduced mortality rates as a result of diabetes which increased life expectancy by about 0.08 years (3.2 per cent) to the increase in life expectancy. This corresponds to 0.05 percentage points of growth in living standards (1.3 per cent) and was worth about $154 of annual income per capita ($5.2 billion nationally).

These estimates of the contributions from specific causes to growth in living standards and the value of these improvements in can be useful for the analysis of health policy. By decomposing improvements in life expectancy into specific causes of death, one can narrow in on the factors which may have contributed to these improvements. As many policies or medical innovations are closely linked to a specific cause of death, such decompositions can assist in assessing the consequences of specific policies on well-being. Constructing dollar valuations of these improvements facilitates cost-benefit analysis. Of course, a limitation of this analysis is that it is all historical, but in principle policymakers could estimate the impact of future policies on life expectancy and use a similar approach to convert these impacts into growth in living standards or dollars.

Given the importance of understanding the specific sources of improved life expectancy for the evaluation of specific policies, we will consider the two major sources of improvement in much greater detail. Combined, cancer and major cardiovascular diseases accounted for 83 per cent of the growth in life expectancy from 2000 to 2011 and about one third of growth in Canadian living standards.

i. Major Cardiovascular Disease

Table 17 presents the same information as Table 16 for the subcomponents of major cardiovascular diseases. Broadly speaking, we are able to identify four major sources of the 1.42 year increase in life expectancy at birth associated with reductions in deaths from cardiovascular disease: heart disease, cerebrovascular disease, atherosclerosis, and aortic aneurysm and dissection.

[52] Emphysema and bronchitis are the main forms of chronic obstructive pulmonary disease.

Table 17: Improvements in Life Expectancy and Living Standards, Major Cardiovascular Disease, Canada, 2000-2011

Cause of Death	Contribution to Increased Life Expectancy at Birth (years)	Share of Increased Life Expectancy at Birth (per cent)	Contribution to Growth in Living Standards (percentage points)	Share of Growth in Living Standards (per cent)	Change in Equivalent Household Income per Capita[a] (2010 $CDN)	Total Value of Change in Terms of Equivalent Income (billions, 2010 $CDN)
Major cardiovascular diseases	1.42	58.25	0.84	23.93	2,793.28	93.51
Diseases of heart	1.05	43.09	0.62	17.70	2,066.34	69.18
Acute rheumatic fever and chronic rheumatic heart diseases	0.01	0.26	0.00	0.11	12.41	0.41
Hypertensive heart disease	0.00	-0.19	0.00	-0.08	-8.96	-0.29
Hypertensive heart and renal disease	0.00	0.07	0.00	0.03	3.18	0.11
Ischaemic heart diseases	0.91	37.46	0.54	15.39	1,796.55	60.14
Acute myocardial infarction	0.52	21.15	0.31	8.69	1,014.49	33.96
Other acute ischaemic heart diseases	0.00	-0.16	0.00	-0.07	-7.71	-0.25
Other forms of chronic ischaemic heart disease	0.40	16.45	0.24	6.76	788.77	26.41
Atherosclerotic cardiovascular disease, so described	0.00	0.01	0.00	0.00	0.70	0.03
All other forms of chronic ischaemic heart disease	0.40	16.44	0.24	6.75	788.51	26.39
Other heart diseases	0.13	5.49	0.08	2.26	263.45	8.82
Acute and subacute endocarditis	0.00	-0.15	0.00	-0.06	-7.02	-0.24
Diseases of pericardium and acute myocarditis	0.00	0.09	0.00	0.04	4.09	0.13
Heart failure	0.08	3.20	0.05	1.31	153.37	5.13
All other forms of heart disease	0.06	2.36	0.03	0.97	113.31	3.80
Essential hypertension and hypertensive renal disease	0.00	-0.11	0.00	-0.05	-5.43	-0.19
Cerebrovascular diseases	0.28	11.53	0.17	4.74	552.88	18.50
Atherosclerosis	0.03	1.27	0.02	0.52	60.83	2.03
Other diseases of circulatory system	0.06	2.42	0.03	0.99	116.17	3.89
Aortic aneurysm and dissection	0.05	1.94	0.03	0.80	92.80	3.10
Other diseases of arteries, arterioles and capillaries	0.01	0.48	0.01	0.20	22.97	0.76

[a] Values are in terms of household real net adjusted disposable income on a per capita basis where an adjustment is made to reflect social transfers in kind received from the government (health, education, housing) and are net of depreciation of capital assets held by households. One additional year of life expectancy is estimated to be worth $1,969 of household income per capita based upon provisional results of ongoing OECD research.

Source: Author's calculations using data from Statistics Canada's Vital Statistics Deaths Database and the Canadian Human Mortality Database. Decomposition performed using the Arriaga method.

By far the largest contributor is heart disease, which accounts for 1.05 years of the increase in life expectancy (17.7 per cent of growth in living standards). Within the category of heart disease, we can further narrow the specific sources of improvement to deaths from heart failure[53] (0.08 years) and ischaemic heart diseases (0.91 years). Ischaemic heart disease, sometimes called coronary artery disease, includes a range of conditions which prevent sufficient bloodflow to the heart, resulting in a shortage of oxygen and glucose to the cells (ischaemia) of the heart. The most well-known form of ischaemic heart disease is an acute myocardial infarction, more commonly referred to as a heart attack. Reduced mortality from heart attacks was the single greatest source of extended longevity, accounting for 0.52 years (21.2 per cent) and 8.7 per cent of the improvement in living standards. Improved mortality rates from heart attacks were worth an estimated $1,014 of annual income for Canadians. Chronic ischaemic heart diseases[54] were the other type of heart disease which was associated with significant extension of life expectancy (0.4 years).

The second greatest improvements from major cardiovascular disease were associated with reductions in mortality due to cerebrovascular disease. Cerebrovascualar diseases involve vessels which provide the brain with blood. Strokes fall within this category. Cerebrovascular disease explains 0.28 years of increased life expectancy (11. 5 per cent) and 4.7 per cent of growth in living standards. The estimated value of this extension to life expectancy is $553 of annual household income.

Atherosclerosis is a specific form of arteriosclerosis (the thickening and hardening of the arteries) in which plaque composed of cholesterol, fatty substances, cellular waste products, calcium, and fibrin builds up inside the arteries (American Heart Association, 2014). This can be dangerous if the plaque eventually leads to the blockage of blood flow. Reductions in mortality due to atherosclerosis raised Canadian life expectancy by 0.03 years (1.3 per cent) resulting in 0.5 per cent of the growth in living standards. The value of this improvement in terms of household income was $61.

The fourth type of cardiovascular disease which drove increased longevity was aortic aneurysm and dissection. The aorta is the largest artery in the body. It carries blood from the left ventricle of the heart down through the chest and abdomen before branching off into the two common iliac arteries which go to the legs. It plays a crucial role in distributing oxygen rich

[53] Heart failure occurs when the heart is unable to pump enough blood to meet the body's requirements.
[54] Chronic ischaemic heart diseases other than atherosclerotic cardiovascular disease, so described, under the ICD-10 classification system include atherosclerotic heart disease, old myocardial infarctions, aneurysm of the heart, coronary artery aneurysm and dissection, ischaemic cardiomyopathy, silent myocardial ischaemia, other forms of chronic ischaemic heart disease, and chronic ischaemic heart disease, unspecified. Our decomposition was not performed at this level of detail, but a quick study of the number of deaths by cause reported in CANSIM Table 102-0529 suggests that atherosclerotic heart disease was the major source of improvement. The total number of deaths attributable to chronic ischaemic heart disease fell from 21,615 in 2000 to 18,437 in 2011. The total number of deaths attributable to atherosclerotic heart disease over the same period fell from 15,528 to 13,084.

blood throughout the body. An aortic aneurysm is an expansion or bulge in the wall of the aorta. It can increase the risk of plaque build-up and blood clot formation. Additionally, an aortic aneurysm weakens the walls of the aorta where it occurs, which increases the risk of an aortic rupture which can lead to death due to internal bleeding. An aortic dissection is a tear in the inner wall of the aorta. Blood can flow through the tear causing the layers of the aortic wall to separate. This can cause death by reducing blood flow to the organs (ischaemia) or if it leads to an aortic rupture. Reduced mortality due to aortic aneurysms and dissections raised Canadian life expectancy by 0.05 years (1.9 per cent) and caused about 0.8 per cent of the improvement in Canadian living standards. The value in terms of income of these improvements was $93.

ii. Cancer

Besides cardiovascular disease, cancer had the greatest impact on life expectancy between 2000 and 2011. In 2011, cancer was the leading cause of death in Canada, responsible for 29.9 per cent of all deaths, followed by major cardiovascular diseases, accounting for 27.2 per cent of all deaths (see Appendix Table 4). Table 18 presents the contributions to life expectancy at birth and growth in living standards which can be attributed to changes in the mortality rates of specific cancers.

The sources of improved life expectancy from cancer are more widely distributed than those from cardiovascular disease which were largely concentrated in acute myocardial infarctions and chronic ischaemic heart diseases. The single most important group of cancers for increased longevity were malignant neoplasms of the trachea, bronchus, and lung. Reductions in mortality from these cancers raised life expectancy 0.14 years (5.8 per cent of total increase) and were responsible for 2.4 per cent of the growth in living standards. These improvements were worth $276 of income.

Reductions in mortality from breast cancer resulted in an increase in life expectancy of 0.07 years (3.0 per cent of the total increase) and 1.2 per cent of the growth in living standards. Reduced mortality from malignant neoplasms of the lymph and haematopoietic tissues,[55] particularly non-Hodgkin's lymphoma, resulted in a very similar improvement. The dollar values of the increased life expectancy associated with these two types of cancers were $145 and $140 respectively.

Prostate cancer was associated with the fourth largest increase in life expectancy (0.06 years or 2.3 per cent of the total increase. This resulted in 0.9 per cent of the total improvement in living standards. The value of this improvement was $109 of household income per person or $3.7 billion nationally.

[55] Cancers of the blood, bone marrow, and lymphatic system.

Table 18: Improvements in Life Expectancy and Living Standards, Cancer, Canada, 2000-2011

Cause of Death	Contribution to Increased Life Expectancy at Birth (years)	Share of Increased Life Expectancy at Birth (per cent)	Contribution to Growth in Living Standards (percentage points)	Share of Growth in Living Standards (per cent)	Change in Equivalent Household Income per Capita[a] (2010 $CDN)	Total Value of Change in Terms of Equivalent Income (billions, 2010 $CDN)
Malignant neoplasms	0.59	24.36	0.35	10.01	1,168.40	39.11
Malignant neoplasms of lip, oral cavity and pharynx	0.00	0.08	0.00	0.03	4.01	0.13
Malignant neoplasm of oesophagus	0.01	0.29	0.00	0.12	14.07	0.47
Malignant neoplasm of stomach	0.03	1.25	0.02	0.51	59.91	2.01
Malignant neoplasms of colon, rectum and anus	0.04	1.79	0.03	0.74	86.06	2.87
Malignant neoplasm of liver and intrahepatic bile ducts	-0.02	-0.93	-0.01	-0.38	-44.38	-1.48
Malignant neoplasm of pancreas	0.00	0.19	0.00	0.08	8.88	0.29
Malignant neoplasm of larynx	0.01	0.58	0.01	0.24	27.86	0.94
Malignant neoplasms of trachea, bronchus and lung	0.14	5.75	0.08	2.36	275.92	9.24
Malignant melanoma of skin	0.00	0.03	0.00	0.01	1.32	0.04
Malignant neoplasm of breast	0.07	3.03	0.04	1.24	145.17	4.85
Malignant neoplasm of cervix uteri	0.00	0.20	0.00	0.08	9.79	0.33
Malignant neoplasms of corpus uteri and uterus, part unspecified	0.00	-0.14	0.00	-0.06	-6.59	-0.23
Malignant neoplasm of ovary	0.01	0.32	0.00	0.13	15.30	0.51
Malignant neoplasm of prostate	0.06	2.27	0.03	0.93	109.02	3.65
Malignant neoplasms of kidney and renal pelvis	0.01	0.43	0.01	0.18	20.47	0.68
Malignant neoplasm of bladder	0.01	0.32	0.00	0.13	15.16	0.51
Malignant neoplasms of meninges, brain and other parts of central nervous system	0.01	0.22	0.00	0.09	10.56	0.35
Malignant neoplasms of lymphoid, haematopoietic and related tissue	0.07	2.91	0.04	1.20	139.59	4.67
Hodgkin's disease	0.00	0.09	0.00	0.04	4.24	0.15
Non-Hodgkin's lymphoma	0.05	1.88	0.03	0.77	90.26	3.02
Leukaemia	0.02	0.72	0.01	0.30	34.75	1.16
Multiple myeloma and immunoproliferative neoplasms	0.00	0.20	0.00	0.08	9.52	0.32
Other and unspecified malignant neoplasms of lymphoid, haematopoietic and related tissue	0.00	-0.02	0.00	-0.01	-0.86	-0.03
All other and unspecified malignant neoplasms	0.14	5.74	0.08	2.36	275.21	9.21
In situ neoplasms, benign neoplasms and neoplasms of uncertain or unknown behaviour	0.03	1.12	0.02	0.46	53.74	1.80

[a] Values are in terms of household real net adjusted disposable income on a per capita basis where an adjustment is made to reflect social transfers in kind received from the government (health, education, housing) and are net of depreciation of capital assets held by households. One additional year of life expectancy is estimated to be worth $1,969 of household income per capita based upon provisional results of ongoing OECD research.

Source: Author's calculations using data from Statistics Canada's Vital Statistics Deaths Database and the Canadian Human Mortality Database. Decomposition performed using the Arriaga method.

Several cancers of the digestive system, notably malignant neoplasms of the stomach and malignant neoplasms of the colon, rectum, and anus also had a significant impact. Combined, these cancers were associated with an improvement in life expectancy and living standards similar to that of breast cancer.

Malignant neoplasms of the liver and intrahepatic bile ducts also merit a mention as they were the only specific class of cancer which we found negatively affected life expectancy.[56] Increased mortality rates from these cancers decreased life expectancy by 0.02 years (-0.93 per cent of total increase). This resulted in a reduction in aggregate living standards growth of 0.4 per cent, a loss comparable to $44 of adjusted household income per capita.

iii. Improvements in Life Expectancy by Age

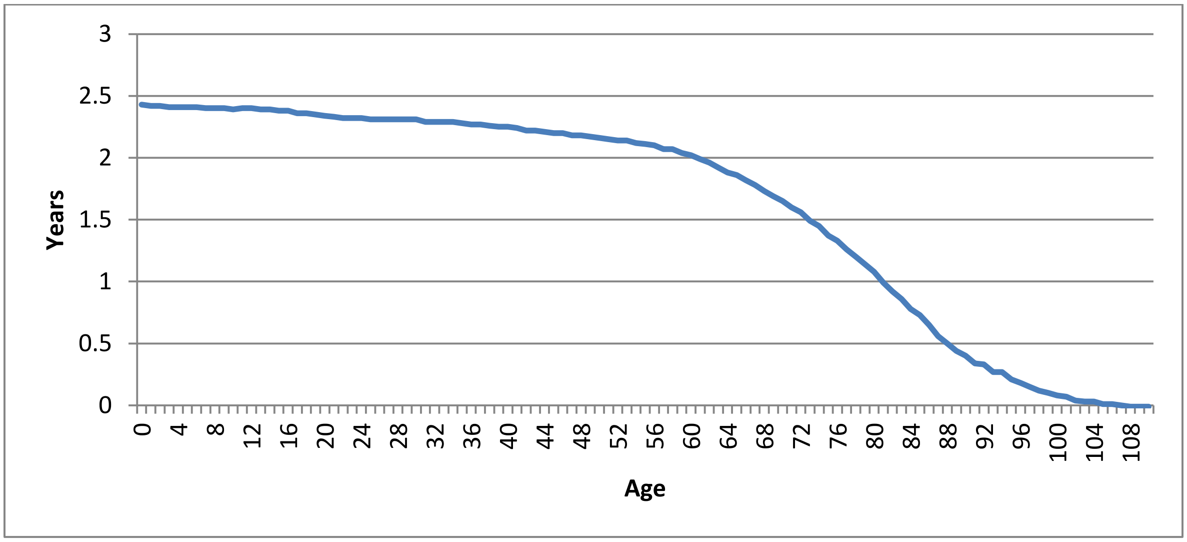
Although it is not our primary focus, in addition to decomposing improvements in life expectancy by cause of death we will also briefly discuss how improvements in life expectancy were spread over the age distribution. Chart 9 shows how life expectancy increased at each age between 0 and 110 based on the life expectancies reported in the Canadian Human Mortality Database. The magnitude of the increase in life expectancy generally declined with age. This is because an individual only benefits from improvements in life expectancy at or above his own age.[57]

One sees that the improvements are fairly similar, although gradually decreasing up to about age 60. Life expectancy at birth increased by 2.43 years while at age sixty the increase was 2.02 years. This suggests that the bulk of the improvement occurred above age 60. From age 60 onwards, the curve steepens significantly, indicating that the increase in life expectancy associated with each year was significantly larger than below age 60. At about 90, the slope of the curve flattens out again and the gains are quite small.

[56] Other and unspecified malignant neoplasms of lymphoid, haematopoietic and related tissue also had a small negative impact.

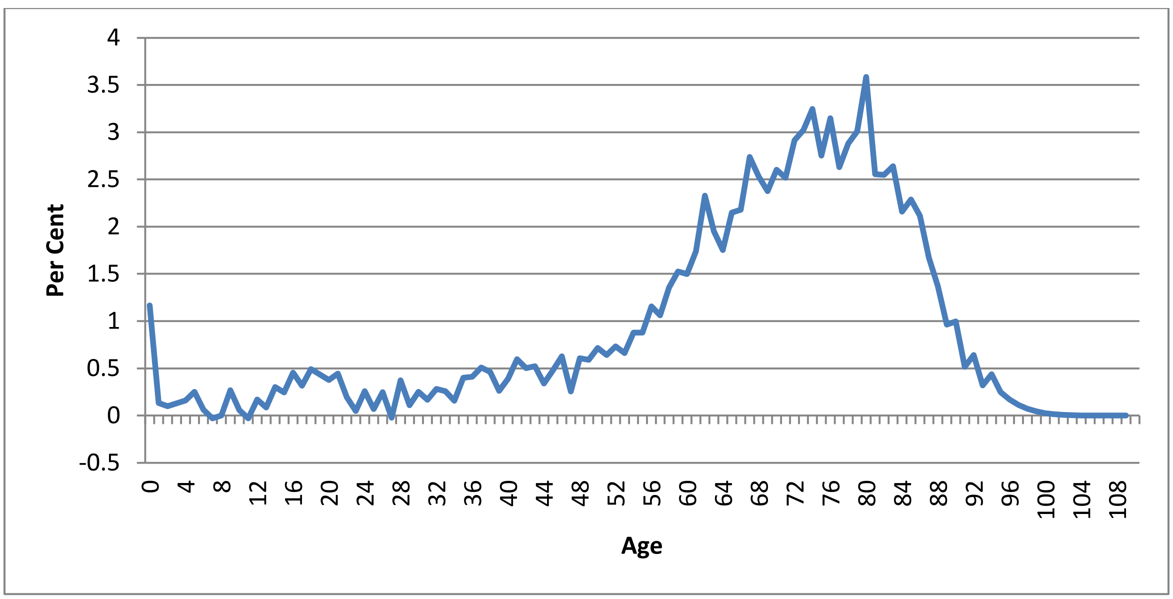
[57] Note that it is theoretically possible for increases in life expectancy to rise with age. For example, suppose that all of the improvement occurs past the age of 65 and that there is a high probability of death at birth. Life expectancy at birth would increase less than life expectancy at age 65 because those at age 0 are less likely to live to experience the increased life expectancy than those at 65.

Chart 9: Increased Life Expectancy by Age, 2000-2011



Source: Calculations using life tables from the Canadian Human Mortality Database

Chart 10: Contribution to Increased Life Expectancy at Birth by Age, 2000-2011



Source: Author's Arriaga decomposition using life tables from the Canadian Human Mortality Database

Our Arriaga decomposition breaks down the increase in life expectancy not only by cause of death but also by age. Chart 10 presents this decomposition by age. As we expected from looking at the improvements in life expectancy by age, most of the gains in life expectancy between 2000 and 2011 were concentrated in the later years of life, between the ages of 55 and 90. There was also a noticeable spike at age 0 of 0.03 years, suggesting that there have still been some improvements in infant mortality. There were very few gains in life expectancy due to reduced mortality in early childhood or among individuals in their twenties since rates of death at these ages are very low already. Improvements were in the realm of 0.01 years for those aged 16 through 21. From the age of about 25 until 55 there were gradually increasing reductions in mortality rates which raised life expectancy. The high concentration of improvements due to reduced mortality later in life should not be surprising given that the major sources of improvement, cardiovascular disease and cancer, are far more prevalent amongst the elderly.

Now that we have discussed the major sources of improvement in life expectancy in Canada between 2000 and 2011 and the impact of these improvements on living standards, we turn our attention towards identifying some of the underlying factors which were responsible for these improvements.

C. Health Policy, Life Expectancy, and Living Standards

A key part of policy analysis is the production of reasonable estimates of the likely effects of a given policy. The OECD (2014) emphasizes the importance of developing sophisticated models of the causal relationship between policy and multidimensional outcomes for the inclusive growth framework. This modelling aspect of the approach which links outcomes to policy is just as important as how multidimensional and unequal outcomes are measured.

Unfortunately, understanding the impact of a policy on the outcomes of interest can often be a very difficult task. As we have discussed, a multitude of factors are understood to have an impact on life expectancy. To estimate how a given policy impacts life expectancy, one needs to estimate the effects of the policy on determinants of life expectancy and how changes in these determinants of life expectancy impact life expectancy itself. The previous section has simplified this task somewhat by revealing how improvements in mortality due to specific diseases impacts living standards through the channel of life expectancy. However, policy evaluation using the inclusive growth framework would still require an understanding of how a given policy will reduce mortality rates from a given cause of death and an analysis of the non-health consequences of the policy.

Even if we are only focusing on the effects of a policy on a very specific cause of death, this can still be very challenging. The onset of illness can be the result of complex interaction between many factors. For example, often the cause of cancer is not well defined, although there are a large number of risk factors such as exposure to carcinogens and genetics which are known to increase one’s probability of developing the disease. Statistically, identifying the effects of various risk factors can be difficult due to limitations on data availability. Policies and risk factors, many of which are not readily observable to the researcher, also change over time. Factors related to lifestyle may have an impact over an extended period of time, which may require long term monitoring of individual behaviours and outcomes. Breakthroughs in genomics have provided new opportunities to understand the role of genetics, but the human genome is astoundingly complex.

Understanding survival conditional on having a disease can also be difficult. It can be relatively simple if one is considering treatment policies which have effects that are readily observable. When considering policies aimed at promoting “better health” or preventing disease, comorbidities can complicate analyses. It is not uncommon for individuals to have multiple health conditions which reduce their probability of survival. For example, whether or not one has diabetes can be a factor for heart disease. Understanding the impact of a policy aiming to reduce mortality from heart disease may require some understanding of the relationship between smoking or diabetes and heart disease as well.

In this subsection, we discuss major factors which are believed to have lead to the improvements in mortality (and life expectancy) from four of the most important causes of death identified in our analysis. This discussion relies heavily on the existing literature and provides only some indication of the sources of the improvement of living standards attributable to specific causes from 2000 to 2011. This discussion is meant to illustrate how the inclusive growth framework may be used in conjunction with an understanding of the sources of improvement to better inform policy. To be useful in practice, a researcher would need to develop a model of how a policy comprehensively impacts the outcomes of interest. Development of such a model is far beyond the scope of this report.

In very broad terms, one major health policy issue is the allocation of resources between prevention and treatment of disease. The relative merits of these two approaches are subject to considerable debate, but the issue is difficult to resolve because of the challenges in understanding the impacts of policy when many risk factors may be relevant. Different groups will benefit from these approaches, so it is natural that both have strong advocates. In the data, one might expect that it would be reasonably straightforward to distinguish between the impacts of prevention and treatment by considering how the rates of incidence and rates of survival (conditional on incidence) respectively impact mortality, but it is more complicated than this because preventative measures may affect the success of treatment and more effective treatments may affect incidence through changes in behaviour (moral hazard). Screening, which falls somewhere between treatment and prevention, can have a positive impact on survival rates while raising observed rates of incidence.

It is also important to note that there can be differences between improved mortality rates and improvements in life expectancy, depending on the individuals whose deaths are avoided. Age is one source of these differences, but the general health of the individuals is another. The link to age is straightforward. Avoiding a death at a young age will have a much greater impact on life expectancy than avoiding a death at age 80. The relationship to general health of individuals may be less clear. Suppose, for example, that one could prevent the death of a smoker at age 65 or a non-smoker at age 65. Assuming that these two individuals are identical in every respect besides smoking, preventing the death of the non-smoker would have a greater impact on life expectancy because the non-smoker will be expected to live longer on average.

If risk factors for a particular disease contribute to the probability of mortality from other diseases, avoiding a death through mitigating risk factors may have more impact on longevity than avoiding the death through treatment of that disease.

i. Sources of Reduced Mortality from Heart Disease

The debate on the sources of improvement in cardiovascular disease has been raging for over four decades. It is generally agreed that the massive reduction in deaths due to cardiovascular disease since about 1960 has been the result of more effective surgical techniques, the development and adoption of new pharmaceuticals, and reductions in major risk factors such as smoking. Disagreement arises as to the relative importance of these factors.

A wide variety of models have been developed to quantitatively evaluate the sources of improvement and predict the impacts of future policies (Unal et al., 2006). Approaches to understanding this improvement have ranged from simple back-of-the-envelope calculations to complex (and sometimes opaque) models. Researchers using many of these approaches have concluded that the contributions of prevention and treatment to reduced mortality from cardiovascular disease have been about equally important. For example, Cutler (2001) concludes that one third of improved mortality from cardiovascular disease can be explained by each of three sources: improved intensive acute treatment, non-acute pharmaceuticals, and behavioural changes such as diet and smoking.[58] While such results may be correct and would support the objectives of a variety of interests, they can make it difficult for policymakers to set priorities across a range of policies (Jones and Greene, 2012).[59]

We consider one specific study, Wijeysundera et al. (2010), which estimated the sources of reduced mortality due to ischaemic heart disease[60] in Ontario between 1994 and 2005. While the timeframe does not perfectly align with that which we are interested in (2000-2011), the analysis is only for a subset of the Canadian population, and the outcome measured is mortality rather than life expectancy, this study still likely provides us with a rough idea of the major drivers of improvement in life expectancy in Canada due to the single biggest source.

[58] Cutler's analysis used data from the Framingham heart study, an impressive research effort to gather information on the risk factors of cardiovascular disease which has tracked a group of individuals from Framingham, Massachusetts, their children, and their children's children since 1948.

[59] Even when such models do provide evidence supporting some policies over others, this will not necessarily lead to changes in policy. Academic researchers develop sophisticated methods and models which attempt to inform policymakers on such issues, but these techniques are often complicated and difficult to communicate. Orton et al. (2011) found policymakers in universal health care systems frequently accessed a range of research evidence to inform policy, but the impact of this evidence tended to be indirect, competing with other influences such as organisational, political and strategic factors; financial and resource constraints; personal experience; common sense; expert opinion; stakeholder and public pressure; and community attitudes.

[60] Referred to as coronary heart disease in the study, but the terms are synonymous.

Table 19: Estimated Sources of Reduced Mortality from Ischaemic Heart Disease and Impact on Living Standards, Canada

Cause of improvement in Mortality from Ischaemic Heart Disease	Mean Estimate (per cent)	Minimum Estimate (per cent)	Max Estimate (per cent)	Share of Living Standards Growth (per cent)	Change in Equivalent Household Income per Capita[a] (2010 $CDN)	Total Value of Change in Terms of Equivalent Income (billions, 2010 $CDN)
Improvements in Medical Treatment	**42.6**	**11.3**	**124.5**	**6.56**	**765.33**	**25.62**
Acute Myocardial Infarction (AMI)	8.3	-5.1	39.9	1.28	149.12	4.99
Acute Coronary Syndrome	2.0	0.7	2.4	0.31	35.93	1.20
2' Prev Post AMI	2.3	2.0	10.0	0.35	41.31	1.38
Chronic Angina and Coronary Heart Disease	17.2	7.0	35.4	2.65	309.00	10.35
Hospital Heart Failure	1.0	0.4	2.2	0.15	17.97	0.60
Community Heart Failure	9.9	6.1	31.1	1.52	177.87	5.95
Hypertension Treatment	0.7	-0.2	0.9	0.11	12.58	0.41
Hyperlipidemia Treatment	1.2	0.4	2.6	0.18	21.55	0.72
Select Forms of Treatment						
Statins	13.5	-0.5	48.8	2.08	242.54	8.12
Beta Blockers	12.7	6.9	38.4	1.95	228.16	7.63
ACE Inhibitors	3.6	-4.1	13.2	0.55	64.67	2.17
Risk Factors	**48.3**	**22.0**	**69.5**	**7.43**	**867.73**	**29.05**
Plasma Cholesterol (not including pharmaceutical impact)	22.8	9.8	32.6	3.51	409.61	13.72
Systolic Blood Pressure (not including pharmaceutical impact)	20.4	12.7	26.0	3.14	366.49	12.27
Smoking	9.5	7.6	11.4	1.46	170.67	5.71
Physical Inactivity	4.1	3.3	4.9	0.63	73.66	2.46
Diabetes	-6.2	-7.8	-4.1	-0.95	-111.39	-3.73
Body Mass Index	-2.3	-3.6	-1.3	-0.35	-41.31	-1.38
Total Explained	**90.9**	**33.3**	**194.0**	**13.99**	**1,633.06**	**54.67**

[a] Values are in terms of household real net adjusted disposable income on a per capita basis where an adjustment is made to reflect social transfers in kind received from the government (health, education, housing) and are net of depreciation of capital assets held by households. One additional year of life expectancy is estimated to be worth $1,969 of household income per capita based upon provisional results of ongoing OECD research.

Source: Estimates of reductions in mortality were generated by Wijeysundera et al. (2010) using the IMPACT model for Ontario over the period 1994-2005. Taking these estimates as approximations of the sources of improvement in life expectancy due to ischaemic heart disease in Canada from 2000 to 2011, we have applied them to our estimates of the impact of reduced ischaemic heart disease from Table 17 to estimate the impacts on living standards.

Additionally, the IMPACT model used in the study has been applied to evaluate sources of improvement in mortality in many countries and time periods with broadly similar findings.[61]

Table 19 summarizes the contributions to reduced mortality reported in Wijeysundera et al. (2010). Given considerable uncertainty regarding many of the parameters utilized in the model, a large sensitivity analysis was performed which applied estimated parameter values from the extreme ends of their estimated 95 per cent confidence intervals. The maximum and minimum effects of each estimate are reported to give the reader a sense of the uncertainty involved. The final three columns of the table are calculated using the mean estimate for each factor reported in Wijeysundera et al. (2010), assuming it corresponds to the share of improvement in life expectancy, and multiplying the share by the observed improvement in living standards attributable to ischaemic heart disease and the value of this improvement as reported in Table 17. Ischaemic heart disease was responsible for an increase in life expectancy of 0.91 years, which corresponds to 15.4 per cent of the improvement in living standards and is equivalent to $1,797 of adjusted household income per capita, or $60.1 billion nationally.

Wijeysundera et al. (2010) find that their model can explain 90.9 per cent of the reduction in mortality from coronary heart disease in Ontario from 1994 to 2005. This improvement is decomposed into two broad categories. The first is improvements in medical treatment, which can explain 42.6 per cent of the improvement. Improvements in medical treatment improvements include medical and surgical procedures and the use of pharmaceuticals to treat and manage disease. We estimate that the improvements from these sources correspond to about 6.6 per cent of growth in living standards between 2000 and 2011, worth about $765 of adjusted household income per capita annually.

The study provides a breakdown of the improvements into treatments for 8 conditions which we list in Table 19. The improvements within each condition are broken down into several more specific treatments in Wijeysundera et al. (2010), although we do not provide those details here. One sees that the condition for which treatments are estimated to have had the greatest impact is chronic angina and coronary heart disease, which accounts for 17.2 per cent of the total improvement in mortality (roughly 2.7 per cent of growth in living standards).

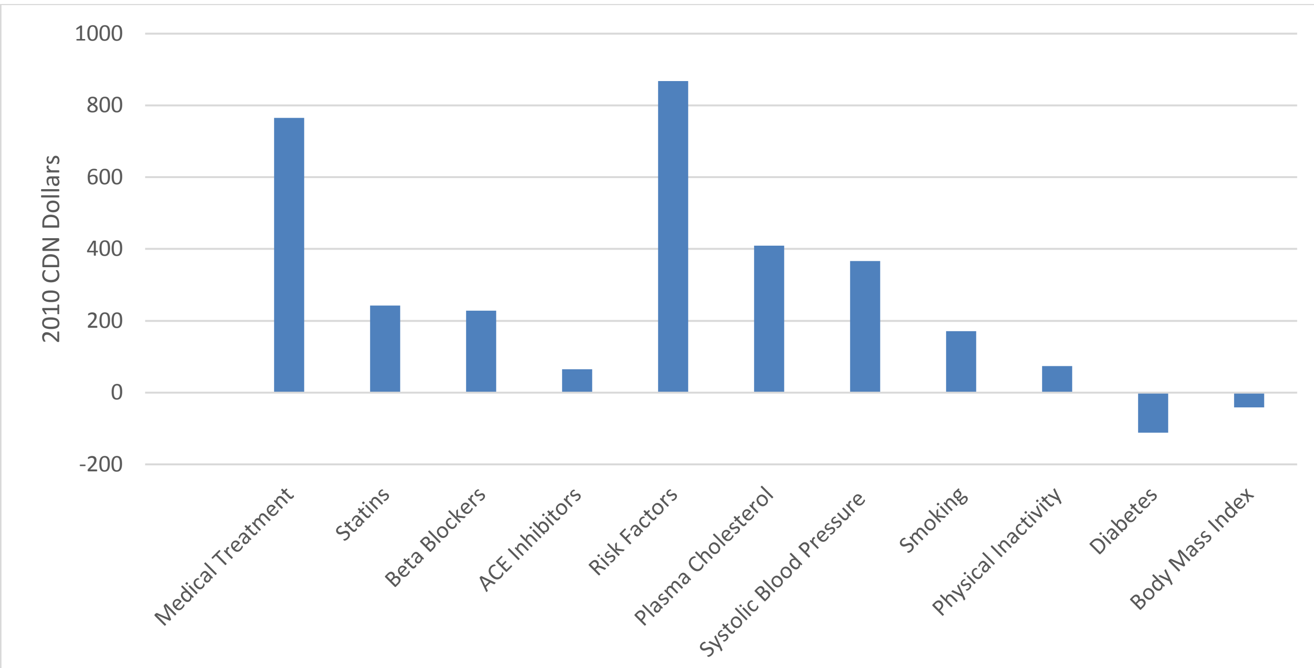
One key factor is the adoption and use of a number of pharmaceuticals to manage heart disease. These include drugs such as statins, which lower cholesterol levels, beta blockers, which block the effects of epinephrine to reduce heart rate and lower blood pressure, and angiotension converting enzyme (ACE) inhibitors, which relax blood vessel walls to lower blood pressure. Wijeysundera et al. (2010) presents data on the increased use of each drug in treating each of the

[61] The IMPACT model developed by epidemiologist Simon Capewell has been used to evaluate the sources of improved life expectancy in Scotland, the United States (Ford et al., 2007), England and Wales, Finland, Ireland, Sweden, Italy, Iceland, China, Spain, and Northern Ireland. In all cases, the contributions of treatment and prevention were almost even, with the exception of the Scandinavian countries such as Finland in which there were aggressive public campaigns aimed at reducing fat consumption and the results indicated that three quarters of the improvement were due to prevention (Jones and Greene, 2012).

relevant conditions and the estimated impact on mortality. For example, their data indicates that the uptake of statin use for treatment of acute myocardial infarctions rose from 9 per cent of patients in 1994 to 88 per cent in 2005, which they estimate prevented or postponed 320 deaths in 2005.

We have aggregated the estimates of the impacts of these pharmaceuticals across all conditions to generate the estimated impacts reported in Table 19. One can see that increased use of statins, beta blockers, and ACE inhibitors were estimated to account for 13.5 per cent, 12.7 per cent, and 3.6 per cent of the reduction in mortality from ischaemic heart disease respectively. These improvements can be roughly translated into 2.1 per cent, 2.0 per cent, and 0.6 per cent of improvements in living standards with total values to society of $8.1 billion, $7.6 billion, and $2.2 billion worth of annual adjusted household income.

Chart 11: Estimated Increases in Equivalent Household Income per Capita due to Reduced Mortality from Ischaemic Heart Disease, Select Sources, 2000-2011



Source: Estimates of reductions in mortality were generated by Wijeysundera et al. (2010) using the IMPACT model for Ontario over the period 1994-2005. Taking these estimates as approximations of the sources of improvement in life expectancy due to ischaemic heart disease in Canada from 2000 to 2011, we have applied them to our estimates of the impact of reduced ischaemic heart disease from Table 17 to estimate the impacts on living standards. Note that these monetisations are based upon provisional results of ongoing research by the OECD.

To evaluate policy, one would also like to have an idea of cost. A recent report on the use of pharmaceuticals by the Conference Board of Canada (2013c) indicates that total spending on

ACE inhibitors and statins in Ontario was $670.9 million in 2011.[62] Using figures from the most recent census, approximately 38 per cent of Canada's population lived in Ontario in 2011. Assuming costs and usage were the same in the other provinces, this would put total expenditures on these drugs at somewhere in the realm of $1.8 billion. This would suggest that statins and ACE inhibitors are easily worth the cost,[63] as the increased benefits of using these drugs were around $10.5 billion (2011 dollars) – and these benefits only include the improvements in life expectancy associated with increased use of these medications in 2005 over the level of use in 1994 while $1.8 billion was the total expenditure.

The other 48.3 per cent of reduced mortality from ischaemic heart disease explained by the model can be attributed to reductions in risk factors. Reduced risk of mortality from these sources is estimated to have been behind 7.4 per cent of growth in living standards from 2000 to 2011. The two major sources were reductions in plasma cholesterol (22.8 per cent of reduced mortality and 3.5 per cent of growth in living standards) and reductions in systolic blood pressure (20.4 per cent of reduced mortality and 3.1 per cent of growth in living standards). These improvements in blood pressure and cholesterol do not include the positive preventative impacts of the pharmaceuticals mentioned above (these effects were categorized under improvements in medical treatment), but were the result of lifestyle and dietary changes. Other notable factors included reduced smoking (9.5 per cent of reduced mortality and 1.5 per cent of growth in living standards), increased physical activity (4.1 per cent of reduced mortality and 0.6 per cent of growth in living standards), diabetes (-6.2 per cent of reduced mortality and -1.0 per cent of growth in living standards), and body mass index (-2.3 per cent of reduced mortality and -0.4 per cent of growth in living standards). Remember, these estimates of improvement only consider the impacts on mortality specifically due to ischaemic heart disease. These behavioural factors may have had positive impacts through other causes of death as well.

Before moving on to a few other diseases, the reader should note that the above estimates should be taken with caution. They are intended to illustrate how one could use the inclusive growth framework to link policies to improvements on living standards. However, besides the imperfect concordance between the timing and geography of our decomposition of improvements in living standards (Canada, 2000-2011) and the estimated determinants of reduced mortality from coronary heart disease in Wijeysundera et al. (2010) (Ontario,1994-2005), the reader may have noticed that many of the estimates were imprecise. In particular, depending upon the set of reasonable parameter values chosen,[64] the IMPACT model could explain between 33 per cent and 194 per cent of all deaths from ischaemic heart disease in Ontario over the period. The estimated impact of improved treatments ranged from 11 per cent to 125 per cent of reduced mortality while the estimated impact of improvements due to risk factors

[62] Based on data from IMS Brogan, which included the number of units and prescriptions dispensed by Ontario pharmacies and the prices of these pharmaceuticals.
[63] Ignoring research costs, at least.
[64] Reasonable defined as falling within the estimated 95 per cent confidence interval.

was more precise, ranging from 22 per cent to 70 per cent. Estimates of some specific factors, such as smoking or physical activity were much tighter.

In addition to the considerable amount of uncertainty surrounding the estimates, the reader should also note that there is an important distinction between estimating deaths prevented or postponed (reduced mortality) and estimating the impact on life expectancy. In mapping the results to our measures of living standards, we unrealistically assume that the contributions of specific sources to these two outcomes will perfectly correspond. In particular, deaths prevented by healthier lifestyles may be postponed longer than deaths which are avoided due to improved treatments. Indeed, Gouda et al. (2012) document and discuss how the relative contributions tend to shift from about half treatment and half risk factors to one-third treatment and two-thirds risk factors when the IMPACT model is used to estimate life-years gained rather than deaths avoided.

ii. Sources of Reduced Mortality from Major Cancers

Reduced mortality due to cancer was the second biggest source of increased life expectancy in Canada between 2000 and 2011. As we have seen, the gains from cancer were much less concentrated than was the case with cardiovascular disease, where the majority of the improvement was due to ischaemic heart disease. The specific sources of the gains varied from one type of cancer to another. Generally, the major sources of improvement are thought to be related to reductions in behavioural risk factors (particularly smoking), improved treatments, and enhanced screening efforts which resulted in discovery of the disease at an earlier stage where it was more amenable to treatment. We will not strive to quantify the impacts of specific sources in terms of improvements in living standards here, but we will briefly discuss the likely sources of improvement for a few of the cancers associated with increased life expectancy.

Malignant neoplasms of the trachea, bronchus, and lung were the single biggest component of increased life expectancy associated with cancer. It is generally agreed that reductions in smoking, which has been shown to cause these cancers, is the main driver of this improvement. Between 80 and 90 percent of cases of lung cancer are estimated to have been caused by tobacco use (Ruano-Ravina et al., 2003). The decline in smoking will in part have been driven by public advertising campaigns, requirements that cigarette packaging contain striking warnings of the severe health risk, and reduced exposure to second hand smoke as the result of both new laws regarding smoking in public places and the voluntary decisions of individuals and businesses. The incidence of lung cancer has been declining for men since the 1980s while the rate of incidence for women continued to climb although the pace of this increase slowed around the turn of the millennium. These differing patterns reflect the fact that men began smoking less in the 1960s while the female smoking rate did not begin to fall until the 1980s (Navaneelan and Janz, 2011). These patterns suggest that reductions in female smoking may have had a significant impact on the incidence of these cancers from 2000 to 2011.

There is also some suggestive evidence that methods of treatment for lung cancer may have improved. Coleman et al. (2011) noted that the five year survival rate from lung cancer rose from 15.9 per cent in the 2000-02 period to 18.4 per cent in the 2005-07 period.

Colorectal cancer was associated with an increase in life expectancy of about 0.04 years over the 2000 to 2011 period. Coleman et al. (2011) note that the five year survival rate for colorectal cancer has also been on the rise in Canada, increasing from 81.5 per cent in 2000-02 to 83.5 per cent in 2005-07. Much of the reduced mortality from colorectal cancer is likely the result of increased and enhanced screening efforts, which can help detect the cancer at an earlier stage when it can be more easily treated. Telford et al. (2010) performed a cost-effectiveness-model-based analysis of several colorectal cancer screening policies in Canada and found that a low-sensitivity guaiac fecal occult blood test performed annually, a fecal immunochemical test performed annually, and a colonoscopy performed every 10 years, reduced the incidence[65] of colorectal cancer by 44%, 65% and 81%, and mortality due to colorectal cancer by 55%, 74% and 83% over the lifetime of 100,000 individuals.

Improvements in breast cancer mortality explain 0.07 years of the increase in life expectancy between 2000 and 2011. Since the 1980s, improvements in treatment methods and the development of population-wide screening programs using mammograms have resulted in significant improvements in mortality due to breast cancer. Canada has had a population-wide screening program since 1988 (Youlden et al., 2012). However, it seems that the survival rate has likely not changed much from 2000 to 2011. Coleman et al. (2011) estimated that the five year survival rate in Canada remained virtually unchanged at about 86 per cent between the 2000-02 and 2005-07 periods.[66] One possible explanation for reduced breast cancer mortality is that incidence rates have fallen since about 2000 (Navaneelan and Janz, 2011). The reason for this is unclear, although some have suggested that it is because of decreased use of hormone replacement therapy after a study linking it to breast cancer was publicized (Gompel and Plu-Bureau, 2010).

The last type of cancer we will discuss is prostate cancer, which was associated with an increase of 0.06 years of life expectancy between 2000 and 2011. The major source of this improvement is somewhat controversial. One factor which has changed is the adoption of prostate specific antigen (PSA) screening which is intended to detect prostate cancer at an earlier stage where treatment is more likely to succeed. Unfortunately, the literature remains divided as to how effective PSA screening is at reducing mortality, and there are some concerns that it does more harm than good through false positives, risks associated with the test, and costly treatment of those who will die of other causes before their prostate cancer would ever become a serious health concern. Bouchardy et al. (2008) offer some suggestive evidence that PSA screening has had a positive effect, as they note that a number of countries experienced reduced mortality rates

[65] Through preventative treatment (e.g. removal of polyps during colonoscopies).
[66] Along similar lines, Younden et al. (2012) cite a five year survival rate of 88 per cent between 2004 and 2006 which is the same survival rate currently estimated by the Breast Cancer Society of Canada.

from prostate cancer upon adopting screening while many countries which did not adopt screening did not experience such improvements. However, the authors acknowledge that this is far from proof of causation. Improvements in treatment could be another explanation.

iii. Sources of Reduced Mortality from Chronic Respiratory Disease and Diabetes

We close out this section by briefly touching upon factors which likely contributed to a couple more major sources of increased life expectancy. Chronic lower respiratory diseases explain about 0.09 years of increased life expectancy (1.5 per cent of growth in living standards) from 2000 to 2011. As with lung cancer, the prime suspect for these improvements is reduced smoking. After rising for a couple of decades, the rate of incidence of chronic obstructive pulmonary disorder has declined in Canada in recent years (Rycroft et al. 2012). A similar trend has been observed in which mortality rates of men with chronic obstructive pulmonary disorder have decreased more than those of women (Gershon et al., 2015), which could be related to differences in the timing of reduced smoking between these two groups. Improvements in screening and treatment have also likely played some role in reducing mortality rates from this cause.

Diabetes was another significant source of increased longevity, associated with an additional 0.08 years (1.48 per cent of growth in living standards) from 2000 to 2011. A study by Lipscombe et al. (2009) provides some insight as to how mortality from diabetes fell by over thirty per cent between 1994/95 and 2005/06 in Ontario. They uncovered a disturbing trend regarding inequality of these improvements. The reduced mortality rates were far greater for those living in wealthy neighbourhoods than for those in poor neighbourhoods. They offer three potential explanations for this inequality. Increased intensity of care for diabetes was a major source of the improved survival. They suggest that rising out-of-pocket costs for the medication necessary for this increased level of care may have acted as a barrier for low-income individuals. A second channel through which the difference may have operated was increased screening among higher income individuals who are also more educated on average. As is the case with many other diseases, early detection and treatment may improve the probability of survival. Lastly, they suggest that part of the difference between these groups may have arisen because of a large number of South Asian immigrants to Ontario over the period who tended to have relatively low income and were more susceptible to diabetes and related cardiovascular complications.

V. Conclusion

This report concludes with a brief recap of its major points, a discussion of implications for policymaking, and some suggestions for future work for health policy evaluation using the OECD's inclusive growth framework.

A. Highlights

1. **There are limitations to the approaches commonly applied to health policy evaluation in Canada.**

We have seen that there are a diverse set of metrics and approaches used in the economic evaluation of health policy in Canada. The optimal methodology depends upon the nature of the policy being evaluated. Common approaches such as cost-utility analysis, cost-minimization, and cost-effectiveness can be sufficient for assessing the best way to achieve a specific health outcome given limited resources. However, these approaches may be inadequate for assessing health policies with multidimensional consequences, particularly if these policies impact non-health outcomes. Inability to incorporate non-health outcomes makes these approaches insufficient for determining the allocation of resources between health and non-health uses.

In principle, cost-benefit analysis can be used to quantify all outcomes in terms of dollars, but in practice difficulties in putting a dollar value on the value of human life result in many decisions being made based on cost-consequences analyses which present health and monetary outcomes separately and leave the task of weighting these outcomes to the policymaker. Similarly, most health policy analyses fail to consider inequality of health outcomes in a systematic way. If inequality of outcomes is considered, it is often presented separately from the cost benefit analysis.

2. The inclusive growth framework offers a multidimensional approach to policy evaluation which explicitly accounts for inequality.

The OECD has developed a methodology for the evaluation of policy which could overcome some of the limitations of traditional approaches. Multiple dimensions of individual well-being, including health, are converted into a single measure of living standards which is reported in dollars using a willingness-to-pay based approach closely linked to the standard economic concept of compensating variation. The willingness-to-pay for non-monetary outcomes can be estimated based on statistical analysis based on subjective measures of well-being or using an "objective" approach with an appropriately chosen utility function. An adjustment to this equivalent income measure of living standards is made to reflect inequalities in outcomes. This approach offers a transparent and consistent way to incorporate a broad set of outcomes and inequality into policy analysis.

3. **Extended longevity has been a major source of growth in living standards in Canada.**

Using data from the OECD's inclusive growth measure of living standards across countries and over time, we estimate that living standards in Canada increased by 3.52 per cent annually between 2000 and 2011. Using this same measure, we find that the 2.43 year increase in life expectancy from 79.23 years in 2000 to 81.66 years in 2011 accounts for approximately 1.45 percentage points of this growth (41 per cent). The rest of the growth in living standards can be attributed to adjusted household income (2.15 percentage points), the unemployment rate (-0.13 percentage points), and inequality (0.05 percentage points). Using the OECD's estimate that a year of increased life expectancy is worth about 5.3 per cent of adjusted household income, we estimate that the 2.43 years of increased life expectancy was worth $4,796 of adjusted household income (per capita annually), or $161 billion nationally.

4. **We can break down growth in life expectancy by cause of death to better understand the sources of growth in Canadian living standards.**

The primary exercise of this report was to decompose growth in living standards by cause of death in order to identify how reduced mortality from specific causes contributed to growth in living standards and estimate the dollar value of these improvements. The five leading causes of death linked to increased life expectancy and living standards in Canada were:

vi. Major cardiovascular disease was linked to 58.3 per cent of the increase in life expectancy and 23.9 per cent of growth in livings standards with a national value of $93.5 billion of household income annually

vii. Cancer was linked to 24.4 per cent of the increase in life expectancy and 10.0 per cent of growth in livings standards with a national value of $39.1 billion of household income annually

viii. Chronic lower respiratory disease was linked to 3.7 per cent of the increase in life expectancy and 1.5 per cent of growth in livings standards with a national value of $5.9 billion of household income annually

ix. Accidents were linked to 3.6 per cent of the increase in life expectancy and 1.5 per cent of growth in livings standards with a national value of $5.8 billion of household income annually

x. Diabetes was linked to 3.2 per cent of the increase in life expectancy and 1.3 per cent of growth in livings standards with a national value of $5.2 billion of household income annually

We further decomposed cardiovascular disease and cancer into more specific causes of death.

5. **In principle, one can link a specific policy to reductions in death from specific causes in order to estimate the effect of the policy on living standards.**

Using our decomposition of growth in living standards by cause of death, it is possible to estimate the impact of health policies on aggregate living standards. To do so, one would need to estimate the contributions of specific factors to reductions in age specific mortality rates from a specific cause and then estimate the impact of the policy of interest on these specific factors. Given the complicated interactions between many policies and factors in determining health outcomes, this can be a difficult task and we have not performed such an exercise. Instead, we provided an overview of the likely sources of improvement in several of the major causes of death associated with increased life expectancy which could be explored.

Using estimates of the factors contributing to decreased mortality from coronary heart disease in Ontario between 1994 and 2005 from Wijeysundera et al. (2010), we produced some crude estimates of the contributions of these improvements to overall living standards. For example, we estimated that improved medical treatments for coronary heart disease were the source of 6.6 per cent of the growth in Canadian living standards from 2000 to 2011 (equivalent to $25.6 billion worth of income) while reduced risk factors for death due to coronary heart disease could account for 7.4 per cent of the growth (equivalent to $29.1 billion worth of income).

B. Policy Implications

The inclusive growth framework offers a new approach to the evaluation of health policy which could be useful in the evaluation of policies in which other methods may be lacking – particularly policies with health and non-health outcomes, policies regarding the allocation of resources across health and non-health sectors, and policies where inequality of outcomes is a concern. The most commonly used evaluation methods are not well suited to comparing health and non-health outcomes to monetary costs. Attempts at cost-benefit analysis have been hindered by difficulties in putting a dollar value on human life.

The inclusive growth approach provides a way to incorporate both inequality and multidimensional outcomes into one measure of benefits which is expressed in dollars. The conversion of non-monetary outcomes into dollars is performed using a simple methodology grounded in economic theory. This is valuable because it provides a reasonable way to include the intrinsic value of human health alongside reduced health care costs, the value of lost productivity due to illness, and lost output as a result of mortality. The adjustment for inequality allows for a consideration of outcomes which puts more weight on those below the average. The approach is somewhat flexible and can be modified to include factors beyond those used in the index discussed in this report.

The inclusive growth approach should not be seen as a replacement for existing methods so much as a supplement. Each policy evaluation is unique and should be approached with the best possible methodology for the problem at hand. For example, if one is only interested in the best way to use a fixed budget to reduce mortality rates from a specific disease, a cost-effectiveness approach may be simpler than and just as effective as an inclusive growth approach. In cases where complex health policies with health and non-health outcomes are being considered, or where inequality is a major factor, the inclusive growth framework may offer a superior means of analysis.

Note that the inclusive growth framework does not rely upon a specific measure of health such as life expectancy. It is not limited to only policies which reduce mortality. Any policy which affects overall well-being could, in principle, be evaluated using an inclusive growth methodology provided that one is able to clearly link policies to relevant health and non-health outcomes and these outcomes to social welfare.

The inclusive growth approach can be used to extend policy analysis beyond traditional spheres. While we have focused on how the approach can be used to consider the impact of health policies along both health and non-health dimensions, the approach can also be applicable for more comprehensive evaluation of policies which are traditionally focused on economic outcomes but which may also have significant impacts on health. For example, the impact of education policy on health and the impact of education policy on labour market outcomes tend to be evaluated separately. Inclusive growth provides a means to simultaneously and comprehensively evaluate the impact of education policy on both health and labour market outcomes simultaneously. This sort of analysis requires sophisticated economic modeling and estimation of the interactions between health, education, and the labour market. The development of such models to inform policymaking is a critical aspect of the inclusive growth framework, but only received very limited attention in this report.[67]

Inclusive growth can be used by policymakers to compare outcomes across time and space, to evaluate the impacts of past events, and to estimate and compare the consequences of future policy options.

[67] Wolfson (2011) discusses the importance of clearly linking measures of aggregate outcomes (such as life expectancy or HALE) to policy levers familiar to politicians. He advocates micro-simulation as a modern tool which is well-suited to this task.

Given the focus of inclusive growth on maximizing social welfare, the approach is likely best suited for academics and government policymakers. Those in government currently face the difficult task of balancing a diverse range of interests when making policy decisions. Bombarded with an enormous quantity of research supporting different policy options, it can be extremely challenging for policymakers to make socially optimal decisions. Even if economic policy analysis cannot incorporate inequality, the intrinsic value of health, monetary outcomes, and costs into a common metric, decisions still need to be made but the relative weights to put on various factors are left to the subjective discretion of the policymaker. Adoption of a systematic approach which uses economic theory and statistical analysis to weight the various factors could make the decision making process more transparent and facilitate dialogue with competing interests whose outcomes of interest are measured in differing units.

Besides facilitating discussion, the inclusive growth approach offers a few additional benefits to individuals and businesses. Individual interests which may be underrepresented in the existing policymaking process would be more explicitly included in economic evaluation under the inclusive growth approach. The poor and marginalized, who may struggle to influence the decisions of policymakers, would receive increased consideration by the use of an approach which penalizes policy options which generate unequal outcomes. Instead of looking at average outcomes, the inclusive growth framework can be applied to consider what happens throughout the distribution. Additionally, many recent attempts to quantify the economic impacts of health policy exclude the intrinsic value of human life from the cost-benefit analysis – a factor which is of direct interest to most individuals.

At first blush, one may not think that this approach is well-suited for the business community. After all, we usually assume that businesses seek to maximize profits and put relatively little weight on equality or on the intrinsic value of human health to individuals. Nonetheless, businesses may still find the approach useful for conducting research for three reasons.

First, employer health programs can benefit the employer through increased productivity and output, but resulting improvements in health can also serve as a form of compensation to employees. Increased compensation through better health may benefit employers by attracting better workers, reducing turnover, or substituting for other forms of compensation (wages). Therefore, a multidimensional assessment of such programs which incorporates the intrinsic value of benefits to employees using an inclusive growth approach could benefit employers.

Second, many businesses undertake a variety of charitable activities to improve their reputations as socially responsible. Inclusive growth offers a more comprehensive means to quantify how such activities have a positive impact on society.

Third, business frequently engages with government in the formulation of public policy by providing valuable research and insights. As government is concerned with choosing socially optimal policies, policy evaluations provided by business may be more credible and influential if they utilize a methodology which fully captures multiple aspects of well-being.

C. Suggestions for Future Work

There are many ways in which the measure of inclusive growth discussed in this report could be extended and applied. There are three major shortcomings with the inclusive growth index of living standards we have considered. The first issue is that it only covers three aspects of well-being: income, employment, and longevity. This is not a major problem as the methodology can be easily adapted to incorporate other factors such as security, the environment, or education. The specific factors which should be included likely depend on the purpose for which the measure is being used.

The second issue is that the measure of health used in the index only focuses on length of life and excludes any considerations of quality. Switching from life expectancy to health adjusted life expectancy would be a very natural improvement, subject to availability of data. A decomposition of contributions to growth in living standards based upon health adjusted life expectancy may look quite different from the one presented in this report.

The third issue is related to inequality data. Due to limited availability of information on inequality in life expectancy and unemployment within many countries, the inclusive growth index in this report only adjusted for inequality in income. The OECD is currently undertaking efforts to extend inequality to additional dimensions and future research applying this framework should do so where possible.

The major work which remains to be performed with the inclusive growth framework is the application to policy analysis. In many cases, this will be a complicated task which will require the development of models linking policy to health and non-health outcomes. Creating sensible models and developing reasonable strategies to identify the causal impacts of specific policies on outcomes remains a major area for research.

This report has made a small contribution towards linking policy to living standards by decomposing increased life expectancy and its direct contribution to living standards by cause of death in Canada. However, there is a long way to go to link such a decomposition to specific policies. The work in this report could be greatly extended by developing estimates of the specific sources of reduced age-specific mortality rates for specific causes of death and the impact of specific policies on these specific sources of improvement. This would allow for a greater understanding of the direct impact of a policy on living standards through a specific channel.

Fully evaluating the impacts of a policy may be far more complicated. For example, to fully estimate the impact of anti-smoking policies in this way would be quite difficult. This is because smoking reduced mortality rates from many diseases, and the impact on each would need to be estimated. Decomposition by cause of death may be more useful for attempting to evaluate the impacts of policies which were relatively narrow in scope and only impacted a specific cause of death. Additionally, any effects of the policy on non-health outcomes would also need to be considered.

Future evaluations of the benefits of health policy using the inclusive growth approach will also need to develop estimates of the costs of policy and compare these to the benefits.

The decomposition approach adopted in this paper could also be applied to other countries or across regions in order to better understand why growth in living standards related to life expectancy has varied in differing policy environments.

The inclusive growth framework for policy evaluation is a developing approach which offers a multitude of opportunities for use in serious economic evaluations of health policy.

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Appendix A: Technical Appendix

This technical appendix briefly describes some of the methodology underlying the figures presented in this report. It consists of two broad parts.

The first part provides a more technical description of the inclusive growth framework. It begins with a simple mathematical formulation of equivalent income. Next, we discuss the "subjective" and "objective'' approaches to finding the shadow prices necessary to calculate equivalent income. Lastly, we describe the nature of the adjustment for inequality.

The second part provides details on our decompositions of increased life expectancy by cause of death.

A1. The Inclusive Growth Framework

i. The Equivalent Income Approach to Measuring Welfare

The inclusive growth framework combines multiple dimensions of wellbeing into one quantitative measure by calculating "equivalent income." Intuitively, this amounts to adjusting average income for deviations of non-income factors from some benchmark.

Consider a representative individual in country i who earns income y_i, faces an unemployment rate u_i, and has life expectancy l_i. Let the individual's preferences be represented by an indirect utility function $v_i(y, u, l)$. Suppose we choose baseline levels of unemployment and life expectancy which are denoted u^* and l^*. We define the equivalent income of the representative individual in country i as the level of income y_i^* such that:

$$v_i(y_i, u_i, l_i) = v_i(y_i^*, u^*, l^*)$$

The above expression indicates that the equivalent income is such that an individual is indifferent between maintaining his present and receiving the equivalent income, the benchmark unemployment rate, and the benchmark life expectancy. This is very closely linked to the concept of compensating variation which will be familiar to many economists. The compensating variation, δ_i, is the adjustment in income an individual would require to maintain indifference if an initial state of affairs changes. Equivalent income is thus:

$$y_i^* = y_i + \delta_i$$

The compensating variation δ_i represents the change in income which would offset a simultaneous change in life expectancy and the unemployment rate to the benchmark level. Note that the levels of equivalent income will depend upon the chosen benchmark. The OECD recommends using the best case scenario as a benchmark. Specifically, the benchmark unemployment rate is set at 0 per cent while the benchmark life expectancy is chosen as the highest life expectancy observed in the sample. Since the benchmark will always represent a better situation than that observed in reality, our compensating variation will always be negative – the equivalent income is lower than actual income, reflecting the loss in welfare from failing to achieve the benchmark unemployment rate and life expectancy.

Equivalent income provides a simple way to compare welfare across countries or over time under the assumption that the indirect utility function remains constant. Suppose that one set of outcomes (y_i^1, u_i^1, l_i^1) is preferable to another set of outcomes (y_i^2, u_i^2, l_i^2). Then the first set of outcomes will have a higher equivalent income:

$$v_i(y_i^{1*}, u_i^*, l_i^*) = v_i(y_i^1, u_i^1, l_i^1) > v_i(y_i^2, u_i^2, l_i^2) = v_i(y_i^{2*}, u_i^*, l_i^*) \rightarrow y_i^{1*} > y_i^{2*}$$

Appendix Chart 1 provides an illustration of what equivalent income means which should be easily accessible to anybody who has taken an introductory course in microeconomics. For simplicity, consider only two dimensions of welfare: income (the y-axis) and life expectancy (the x-axis). Suppose that we want to compare the welfare of two bundles of income and life expectancy, (y^1, l^1) (labeled as point A) and (y^2, l^2) (Point B). Further suppose that we want to make this comparison in terms of a single dimension, income (dollars).

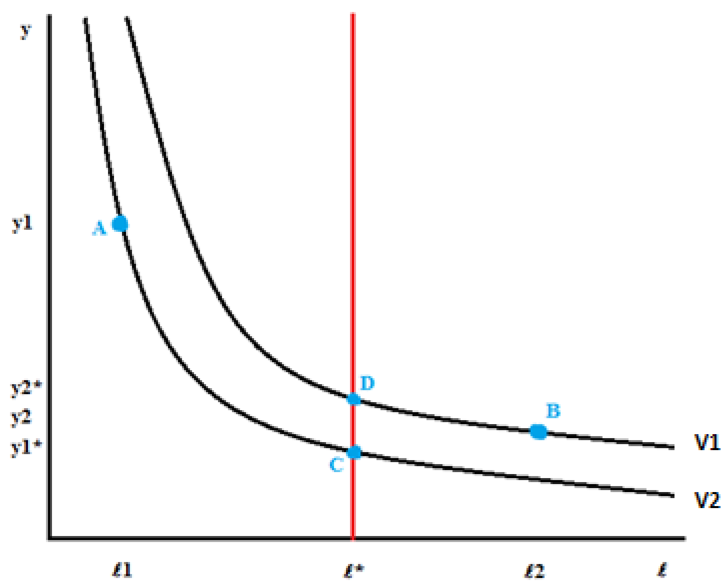
Under standard assumptions, we can draw indifference curves through points A and B. An indifference curve represents all the combinations of income and life expectancy such that an individual would receive an identical level of utility. Assuming monotonic preferences, having a bundle on an indifference curve further away from the origin is always preferable. Looking at our chart, we can thus see that point B is better than point A because it provides utility $v^2 > v^1$. Instead of comparing the utilities, we would prefer to compare dollar values.

To compare points A and B in terms of income, we first draw a line parallel to the income axis which represents all possible bundles which contain an arbitrary benchmark level of the non-income components, in this case l^*. Next, we identify points on this line which yield identical levels of utility to the points we want to compare. These points only differ in terms of income – they represent the equivalent income to the original points. The income of point C gives the equivalent income to point A while the income of point D represents the equivalent income of point B. In this way, we have reduced the multidimensional comparison of points A and B to a unidimensional comparison in terms of income.

A major drawback of this approach is that the results rely critically upon the chosen benchmark. If we chose a different benchmark, the ordinal ranking of the equivalent incomes would be preserved, but the measured size of the difference in welfare between points A and B could vary significantly. One can easily see this in Appendix Chart 1 by comparing the difference in equivalent incomes between A and B if we chose l^1 as the benchmark life expectancy to the difference in equivalent incomes between A and B if we had chosen l^2. While ordinality is preserved over an individual's preferences regardless of the choice of baseline, it is not guaranteed that this will remain the case after individual preferences have been aggregated using a social welfare function. Robustness of results to the choice of baseline is an important open empirical question.

In some contexts, there are debatably "natural" benchmarks. For comparing countries, the OECD recommendation to use the best outcomes seems reasonable, although worst or average outcomes are also obvious choices. If one was interesting in comparing a variety of policy options to a benchmark, the benchmark policy would serve as a baseline – in this case the "equivalent income" would closely correspond to the standard concept of equivalent variation, the amount one would be willing to pay to avoid a change.

Appendix Chart 1: Illustration of Equivalent Income



The choice of utility function will also have a major impact upon the estimated equivalent income. We now turn our attention to how the OECD's inclusive growth framework approaches this issue.

ii. The Subjective Approach

One major challenge is to estimate the rates at which individuals are willing to exchange income for other sources of utility – the "shadow prices". Given standard assumptions of diminishing marginal returns to consumption, these shadow prices are dependent upon the levels of income, life expectancy, and the unemployment rate.

Several approaches to estimating these shadow prices are available. We will focus this discussion on the approach which the OECD (2014) adopted in estimating the shadow prices used in this report. This was a "subjective" approach in that it was ultimately based upon survey responses regarding life satisfaction. Using life satisfaction as a proxy for utility, one can perform a simple linear regression to estimate the contributions of income and k non-income factors to utility. Ideally, such a regression exercise would be performed at the individual level, but data limitations make this empirically challenging. Consequently, the OECD estimates use coefficients from the following macro-level regression:

$$V_{i,t} = \alpha_i + \delta_t + \beta \ln \mathrm{y}_{\mathrm{i,t}} + \sum_k \gamma_k X_{i,t}^k + \varepsilon_{i,t}$$

Where the subscript i denotes the country, t denotes the time, y is income, X^k denotes the k^{th} non-income factor, and epsilon is an error term. The regression is estimated using data from the Gallup World Poll survey for 32 countries over the 2006-2010 period. The following table from Boarini et al. (2014b) presents the results of this macro-regression which underlie the estimates presented in this paper:

Appendix Table 1: Results of the OECD's Macro-Regression Exercise

	Actual series			Smoothed series		
	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable is average life satisfaction					
Log household disposable income	1.286***	1.286***	3.538***	1.290***	1.291***	2.465***
	(0.213)	(0.216)	(0.933)	(0.202)	(0.205)	(0.355)
Unemployment rate	-0.067***	-0.068***	-0.063***	-0.067***	-0.066***	-0.041***
	(0.014)	(0.015)	(0.012)	(0.014)	(0.015)	(0.008)
Lagged life expectancy	0.058***	0.058**	0.192**	0.059***	0.060***	0.200***
	(0.022)	(0.023)	(0.087)	(0.021)	(0.022)	(0.036)
Subjective price of one unemployment percentage point (% income)	**5.1**	**5.2**	**1.8**	**5.1**	**5.0**	**1.6**
Subjective price of one year of life expectancy (% income)	**4.4**	**4.4**	**5.3**	**4.5**	**4.5**	**7.8**
Time dummies	No	Yes	Yes	No	Yes	Yes
Country dummies	No	No	Yes	No	No	Yes
R^2	0.51	0.52	0.96	0.59	0.59	0.99
N	144	144	144	144	144	144

note : annual series smoothed with Hodrick-Prescott filter with smoothing parameter 50

Source: This is Table 3 from Boarini et al. (2014b). The estimates in column 3 are the ones underlying the numbers used in this report. These figures represent provisional results from an ongoing research agenda.

Once the coefficients $\hat{\beta}$ and $\hat{\gamma}_k$ for $k \in \{l, u\}$ have been estimated, it is straightforward to calculate equivalent income. To do so, one begins by using the definition of equivalent income to note that the difference between the observed life satisfaction and the equivalent income life satisfaction must be zero. This allows one to express the relationship between income, equivalent income, the non-income factors, and the benchmark levels of the non-income factors:

$$0 \equiv V_{i,t}^{*} - V_{i,t} = \hat{\beta}(lny_{i,t}^{*} - lny_{i,t}) + \sum_{k} \hat{\gamma}_k (X^{k,*} - X_{i,t}^{k})$$

where $X^{k,*}$ denotes the benchmark level of non-income factor k.

Rearranging for equivalent income:

$$y_{i,t}^{*} = y_{i,t} e^{-\sum_k \frac{\hat{\gamma}_k}{\hat{\beta}}(X^{k,*} - X_{i,t}^{k})}$$

The simple utility function used in this exercise has a very nice property: relative comparisons of equivalent income across space and time are invariant to the choice of baseline. This is easy to see from the above expression. If we take the ratio between any two equivalent incomes, one at time t in country i and the other at time s in country j, the ratio will always be:

$$\frac{y_{i,t}^{*}}{y_{j,s}^{*}} = \frac{y_{i,t}}{y_{j,s}} e^{\sum_k \left(\frac{\hat{\gamma}_k}{\hat{\beta}}\right)\left(X_{i,t}^{k} - X_{j,s}^{k}\right)}$$

Notice that this expression does not include the benchmark terms $X^{k,*}$.

iii. The Objective Approach

We will briefly mention a major alternative to the above procedure for estimating the shadow prices which has been explored by OECD researchers (Fleurbaey and Gaulier, 2009; Boarini et al., 2014a).

Instead of relying upon self reported life satisfaction, one can take a more model-based approach. Such an approach involves specifying a specific form of an individual's objective function and applying existing data to the model to estimate equivalent incomes. While the OECD sometimes refers to this as the "objective" approach, the specific modeling assumptions which drive the results are subjective to a significant degree. In extremely broad terms, the model considers individuals attempting to maximize their expected discounted utility. The objective function takes the form:

$$E\left(\sum_{t=0}^{L} B^t u(y_t)\right)$$

Where B represents is a discount factor, L is life expectancy, and u represents utility which is a function of income. One can expand upon this basic objective function to explicitly generate a relationship between expected wellbeing, life expectancy, annual income, and the unemployment rate. Such a model can be used to calculate equivalent income.

Boarini et al. (2014a) compares the shadow prices estimated using this model based approach to those from micro- and macro-level subjective approaches. They find that if certain conditions are satisfied, the results of the subjective and objective approaches are broadly consistent.

iv. Adjusting for Inequality

In addition to adjusting annual incomes downwards to reflect substandard performance in other areas relevant to well-being, the inclusive growth framework makes an additional adjustment for the inequality of outcomes. Atkinson (1970) suggests that the level of social welfare can be expressed as:

$$W(y_1^*, \dots, y_N^*) = \frac{1}{N}\left[\sum_i {y_i^*}^{1-\tau}\right]^{\frac{1}{1-\tau}}$$

where $i = 1, \dots, N$ subscripts the individual, y_i^* represents the outcome for individual i (in this case, as measured by equivalent income), and τ is a parameter which reflects society's aversion to inequality. Inequality aversion is increasing in τ, with $\tau = 0$ representing a perfectly utilitarian goal to maximize total utility regardless of how it is distributed, and $\tau \to \infty$ corresponding to a situation in which social welfare is determined by only the lowest income in society. It is possible to rewrite the above social welfare function as the average equivalent income multiplied by a penalty for inequality:

$$W(y_1^*, \dots, y_N^*) = \left(\frac{1}{N}\sum_i y_i^*\right)\left(1 - I(y_1^*, \dots, y_N^*, \tau)\right)$$

The expression $I(y_1^*, \dots, y_N^*, \tau)$ represents the Kolm-Atkinson index of inequality. The Kolm-Atkinson index is based on a concept of equally distributed equivalent income, which is "the level of income per head which if equally distributed would give the same level of social welfare as the present distribution" (Atkinson, 1970). The index is defined as one minus the ratio of equally distributed equivalent income to the mean of the actual income distribution.

Formally, the index can be expressed as:

$$I(y_1^*, \dots, y_N^*) = 1 - \frac{y_{EDE}^*}{\bar{y}^*}$$

where y^*_{EDE} is the equally distributed equivalent income and $\bar{y}^*$ is the average equivalent income. Given an individual utility function $U(y)$ and an income distribution with a probability density function $f(y)$, the equivally distributed equivalent income is the level of income y^*_{EDE} such that:

$$U(y^*_{EDE})\int_0^\infty f(y^*)d\,y^* = \int_0^\infty U(y^*)f(y^*)d\,y^*$$

The index lies between 0 and 1 and has a very simple interpretation: a Kolm-Atkinson index of 0.25 means that society would only need 75 per cent of its existing national income to achieve the same level of social welfare if income were equally distributed.

If we define $\bar{y}$ to be average income and $\bar{\mu}$ to be the monetized value of non-income components of living standards as a share of average income, then we can rewrite social welfare as:

$$W(y^*_1,\ldots,y^*_N) = \bar{y}(1+\bar{\mu})\big(1 - I(y^*_1,\ldots,y^*_N,\tau)\big)$$

Taking the first difference of logs of this expression, we can decompose improvements in living standards into improvements resulting from higher annual income, improvements from non-income components of living standards, and changes in inequality.

$$\Delta lnW(y^*_1,\ldots,y^*_N) = \Delta ln\bar{y} + \Delta ln(1+\bar{\mu}) + \Delta ln\big(1 - I(y^*_1,\ldots,y^*_N,\tau)\big)$$

As Δlnx is approximately equal to the growth rate of x,[68] this provides a simple way to decompose growth in living standards into growth in the subcomponents. The calculations we have made using the OECD data have been performed using the actual compound annual growth rates in the variables (rather than differences in logs). The relative contributions of the two compensating incomes for life expectancy and the unemployment rate are estimated based on the share of the change in each (relative to income) in the total change in $\bar{\mu}$.

Due to the limited availability of data on the distribution of unemployment and life expectancy, the OECD does not calculate inequality in living standards in the estimates of inclusive growth used in this report. The calculated inequality index only includes inequality in annual household income. We do not directly possess data on the Atkinson inequality index, so we have calculated inequality's contribution as a residual.

[68] Provided the growth rate is not too large.

A2. Life Expectancy and Related Calculations

i. Constructing Life Tables

Where possible, we have relied upon official estimates of mortality and life expectancy produced by statistics Canada or other credible sources. The life tables underlying our decompositions of improvements in life expectancy come from the Canadian Human Mortality Database. The methodology for calculating life tables described here is that used by the Human Mortality Database (Wilmoth et al., 2007).

Life tables describe several variables related to life expectancy for each year of life. We have utilized single year life tables which provide data for every year of life from age 0 to age 110+. In this section, we will use the variable x to denote age. A subscript of x means that the variable is for age x.

Life tables are derived from age specific mortality rates, M_x. Mortality rates are defined as the number of deaths at age x, D_x, divided by exposure (the number of individuals who could possibly die) at age x, E_x.

$$M_x = \frac{D_x}{E_x}$$

A smoothing procedure is applied to the age specific mortality rates to eliminate idiosyncratic shocks to mortality rates. Smoothing is particularly important at the upper end of the age distribution where the number of individuals living is relatively small. We take the smoothed mortality rates as given in the Canadian Human Mortality Database tables.

The smoothed mortality rates, m_x and the average number of years lived within the age interval $[x, x+1)$, a_x, are used to calculate the age specific probability of death:

$$q_x = \frac{m_x}{1 + (1 - a_x)m_x}$$

As the intervals are one year long, we generally assume $a_x = \frac{1}{2}$ for all ages x except for 110 and 0. For the open interval of those aged 110 and above, we assume $a_{110} = \frac{1}{m_{110}}$, and $q_{110} = 1$. The estimation of a_0 is a bit more involved, but we just adopt the value used in the Canadian Human Mortality Database Life tables (see Wilmoth et al. (2007) for details).

For each age, the probability of survival is calculated as:

$$p_x = 1 - q_x$$

Next, the age-specific survival probabilities are used to calculate the number of survivors at each age, l_x, based upon an initial number of $l_0 = 100{,}000$. The number of survivors can be calculated by taking the number of survivors in the previous interval and multiplying by the probability of surviving the interval, or equivalently:

$$l_x = l_0 \prod_{i=0}^{x-1} p_i$$

Similarly, the distribution of deaths by age can be calculated by applying the probability of death at each age to the number of survivors at that age:

$$d_x = l_x q_x$$

The number of survivors and the number of deaths at each age can then be used to calculate the number of person-years of life lived within each age interval $[x, x+n)$:

$$L_x = l_x - (1 - a_x)d_x$$

And $L_{110} = l_{110}a_{110}$.

Summing over the person-years of life from all remaining intervals, one can calculate the person-years remaining for individuals at age x as:

$$T_x = \sum_{i=x}^{110} L_x$$

Lastly, life expectancy of an individual at age x can be calculated as by dividing the remaining person-years for all individuals at age x by the number of individuals at age x:

$$e_x = \frac{T_x}{l_x}$$

ii. Decomposing Gains to Life Expectancy by Cause of Death

We have applied two different methods to decompose gains in life expectancy by age and cause of death. The first method is a classic Arriaga (1984) decomposition. Our second approach is a recently developed decomposition by Beltrán-Sánchez and Preston (2007). We find that the results are generally similar for both decompositions.

The decompositions are rooted in a common assumption which is that the age specific mortality rate (and thus also the number of deaths) attributable to a specific cause is equal to the smoothed age specific mortality rate from all causes of multiplied by the age-specific share of deaths attributable to that cause. That is:

$$m_x^i = r_x^i m_x$$

Where r_x^i is the share of deaths of those of age x attributable to that cause. This assumption may be less innocuous than it sounds for two reasons. Firstly, we are not smoothing the cause-specific mortality rates – we are assuming the share of each cause can be applied to the overall smoothed rates. This is probably not a major concern. Secondly, our data on cause of death is generally only available in five year intervals between the ages of 1 and 90.[69] We are assuming these cause-specific rates apply uniformly to all years in the interval. This is less accurate than we would like, but it is probably a reasonable approximation.

Now we will briefly describe the two decompositions.

Arriaga Decomposition

The Arriaga decomposition can be succinctly described as:

$$e_0^* - e_0 = \sum_{i=1}^{n} \int_0^{\infty} (\mu_x^{i*} - \mu_x^i) w_x dx$$

Where i denotes cause of death, a * indicates the more recent observation (e_0^* is life expectancy at birth in 2011 while e_0 is life expectancy at birth in 2000), μ_x^i is the force of mortality of cause i at age x, and the weights for each age are defined as $w_x = s_x^* e_x + s_x e_x^*$. In the expression for the weights, s_x denotes the probability of survival to age x.

The force of mortality is a major concept in actuarial science but will likely be unfamiliar to most readers. It is defined as the instantaneous rate of mortality at a given age on an annualized basis. Define F_x as the cumulative probability of death up to age x. Its derivative, $F_x^{'}$, is then the unconditional probability of dying at age x, while $1 - F_x$ is the probability of survival up to age x. We can express the force of mortality from all causes of death in several equivalent ways:

$$\mu_x = -\frac{s_x^{'}}{s_x} = \frac{F_x^{'}}{1 - F_x} = -\left[\frac{1}{l_x}\right]\left[\frac{dl_x}{dx}\right]$$

[69] And the intervals ages 0 to 1 and 90+.

As a result of our above assumption to generate the age-specific mortality rates by cause, the cause-specific force of mortality is also just the total force of mortality multiplied by the share of deaths r_x^i attributable to each cause of death at the relevant age.

A continuous expression is not very useful for implementing the decomposition. The integral is discretized in the natural way and we approximate the derivative based on the average of the rates of death observed in the intervals immediately preceding and following year x:[70]

$$\mu_x^i \approx \left[\frac{1}{l_x}\right]\left[\frac{d_x^i + d_{x-1}^i}{2}\right]$$

It is not surprising that this approximation of the above continuous expression of the Arriaga decomposition is slightly inaccurate. Our calculation results in a total increase in life expectancy which is about 0.015 years too high. In order to generate an Arriaga decomposition which yields a more precise total improvement in life expectancy, we use a discrete formulation of the Arriaga provided in the appendix of Auger et al. (2012):

$$e_0^* - e_0 = \sum_i \sum_x \left[\frac{l_x}{l_0} \times \left(\frac{L_x^*}{l_x^*} - \frac{L_x}{l_x}\right) + \frac{T_{x+n}^*}{l_{x+n}^*} \times \left(\frac{\frac{l_x l_{x+n}^*}{l_x^*} - l_{x+n}}{l_0}\right)\right] \times \left[\frac{\left(r_x^{i*} \times m_x^*\right) - \left(r_x^i \times m_x\right)}{m_x^* - m_x}\right]$$

Most of the notation in this expression has already been introduced. The notable addition is the inclusion of a term n in a few subscripts, which is the length of an age interval. In our case, n is equal to 1. The above expression appears quite complex, but each term is really just the product of an Arriaga age decomposition term for age x (the first term) and the share of the improvement in the mortality rate at age x attributable to cause i. The age decomposition term consists of a direct effect of the increased life expected within age interval x and an indirect effect as a result of more people surviving to experience improved mortality rates in future age intervals.

The results of this alternative calculation of the Arriaga decomposition are broadly consistent with those of our original calculation. We mention the original approximate calculations even though we did not use them as the consistency in terms of the relative sources of improvement builds confidence that there were no computational errors in our decomposition.

Beltrán-Sánchez and Preston Decomposition

Beltrán-Sánchez and Preston (2007) offer an alternative decomposition which they argue is slightly cleaner in terms of how it decomposes life expectancy by cause of death. In particular, they express concern that the weights in the Arriaga decomposition include life expectancies which are a function of all the factors which the decomposition attempts to isolate. They examine

[70] For the first and last ages (0 and 110+), we use the rate of deaths in the nearest interval as the approximation.

U.S. data and find that the choice of decomposition can have a notable impact on the estimated contribution attributed to each cause of death.

Note that one very simple way to express life expectancy at birth is:

$$e_0 = \int_0^{\infty} s_x \, dx$$

Discretized, this expression essentially just means that the expected length of life can be written as the sum of the probabilities of living each year.

The decomposition proposed by Beltrán-Sánchez and Preston is based off the assumption that the probabilities of death from each specific cause of death are independent – as a result the probability of survival from all causes can be written as the product of the probabilities of survival from each individual cause. Thus, using the above expression for life expectancy at birth, we can decompose the change in life expectancy at birth as:

$$e_0^* - e_0 = \int_0^{\infty} s_x^* \, dx - \int_0^{\infty} s_x \, dx = \int_0^{\infty} s_x^{1*} s_x^{2*} \ldots s_x^{n*} \, dx - \int_0^{\infty} s_x^{1} s_x^{2} \ldots s_x^{n} \, dx$$

The authors show that this expression can be manipulated so that it is just the sum of a series of improvements attributable to each cause of death plus a bunch of complicated interaction terms between the causes of death. It turns out that the complicated interaction terms tend to be very small so that a reasonable decomposition can be produced by focusing on the cause-specific terms.

$$e_0^* - e_0 = \sum_{i=1}^{n} \int_0^{\infty} (s_x^{i*} - s_x^{i}) \left(\frac{s_x^{-i*} + s_x^{-i}}{2} \right) dx - \ interaction\ terms$$

This expression shows that each cause of death raises life expectancy to the extent that it has a higher survival probability, but this is weighted by the average probability of survival attributable to all other causes of death. For implementation, this decomposition can be discretized by using the years of life lived in cause deleted life tables as follows:

$$e_0^* - e_0 = \sum_{i=1}^{n} \sum_{j=0}^{A} (L_j^{i*} - L_j^{i}) \left(\frac{L_j^{-i*} + L_j^{-i}}{2b} \right)$$

where b is the length of the age intervals used (b=1 in our case) and j denotes age. The cause deleted life table for cause i which generates L_j^{-i} is constructed using the methodology described above except that the probability of death is recalculated to only take into account deaths attributable to factors other than cause i. Similarly, we find L_j^i by constructing a new life table using age specific probabilities of death which do not include causes of death other than cause i. These calculations require that l_0 be set equal to 1 (or else the resulting years of life lived will need to be divided by 100,000).

Appendix B: Decompositions and Additional Tables and Charts

Appendix Table 2: Complete Arriaga Decomposition

Cause of Death	Contribution to Increased Life Expectancy at Birth (years)	Share of Increased Life Expectancy at Birth (per cent)	Contribution to Growth in Living Standards (percentage points)	Share of Growth in Living Standards (per cent)	Change in Equivalent Household Income per Capita[a] (2010 $CDN)	Total Value of Change in Terms of Equivalent Income (billions, 2010 $CDN)
Total, all causes of death	2.43	100.00	1.45	41.08	4,795.65	160.54
Salmonella infections	0.00	0.00	0.00	0.00	0.21	0.01
Shigellosis and amoebiasis	0.00	0.00	0.00	0.00	0.00	0.00
Certain other intestinal infections	-0.04	-1.62	-0.02	-0.67	-77.88	-2.61
Tuberculosis	0.00	0.06	0.00	0.02	2.85	0.09
Respiratory tuberculosis	0.00	0.05	0.00	0.02	2.62	0.09
Other tuberculosis	0.00	0.00	0.00	0.00	-0.07	0.00
Whooping cough	0.00	-0.01	0.00	0.00	-0.35	-0.01
Scarlet fever and erysipelas	0.00	0.00	0.00	0.00	0.08	0.00
Meningococcal infection	0.00	0.07	0.00	0.03	3.49	0.12
Sepsis	-0.02	-0.65	-0.01	-0.27	-31.13	-1.04
Syphilis	0.00	0.00	0.00	0.00	0.09	0.00
Acute poliomyelitis	0.00	0.00	0.00	0.00	0.00	0.00
Arthropod-borne viral encephalitis	0.00	0.00	0.00	0.00	0.00	0.00
Measles	0.00	0.00	0.00	0.00	-0.15	0.00
Viral hepatitis	-0.01	-0.61	-0.01	-0.25	-29.17	-0.98
Human immunodeficiency virus [HIV] disease	0.02	0.89	0.01	0.37	42.87	1.43
Malaria	0.00	0.00	0.00	0.00	0.00	0.00
Other and unspecified infectious and parasitic diseases and their sequelae	0.02	1.00	0.01	0.41	48.01	1.60
Malignant neoplasms	0.59	24.36	0.35	10.01	1,168.40	39.11
Malignant neoplasms of lip, oral cavity and pharynx	0.00	0.08	0.00	0.03	4.01	0.13
Malignant neoplasm of oesophagus	0.01	0.29	0.00	0.12	14.07	0.47
Malignant neoplasm of stomach	0.03	1.25	0.02	0.51	59.91	2.01
Malignant neoplasms of colon, rectum and anus	0.04	1.79	0.03	0.74	86.06	2.87
Malignant neoplasm of liver and intrahepatic bile ducts	-0.02	-0.93	-0.01	-0.38	-44.38	-1.48
Malignant neoplasm of pancreas	0.00	0.19	0.00	0.08	8.88	0.29
Malignant neoplasm of larynx	0.01	0.58	0.01	0.24	27.86	0.94
Malignant neoplasms of trachea, bronchus and lung	0.14	5.75	0.08	2.36	275.92	9.24
Malignant melanoma of skin	0.00	0.03	0.00	0.01	1.32	0.04
Malignant neoplasm of breast	0.07	3.03	0.04	1.24	145.17	4.85
Malignant neoplasm of cervix uteri	0.00	0.20	0.00	0.08	9.79	0.33
Malignant neoplasms of corpus uteri and uterus, part unspecified	0.00	-0.14	0.00	-0.06	-6.59	-0.23

Malignant neoplasm of ovary	0.01	0.32	0.00	0.13	15.30	0.51
Malignant neoplasm of prostate	0.06	2.27	0.03	0.93	109.02	3.65
Malignant neoplasms of kidney and renal pelvis	0.01	0.43	0.01	0.18	20.47	0.68
Malignant neoplasm of bladder	0.01	0.32	0.00	0.13	15.16	0.51
Malignant neoplasms of meninges, brain and other parts of central nervous system	0.01	0.22	0.00	0.09	10.56	0.35
Malignant neoplasms of lymphoid, haematopoietic and related tissue	0.07	2.91	0.04	1.20	139.59	4.67
Hodgkin's disease	0.00	0.09	0.00	0.04	4.24	0.15
Non-Hodgkin's lymphoma	0.05	1.88	0.03	0.77	90.26	3.02
Leukaemia	0.02	0.72	0.01	0.30	34.75	1.16
Multiple myeloma and immunoproliferative neoplasms	0.00	0.20	0.00	0.08	9.52	0.32
Other and unspecified malignant neoplasms of lymphoid, haematopoietic and related tissue	0.00	-0.02	0.00	-0.01	-0.86	-0.03
All other and unspecified malignant neoplasms	0.14	5.74	0.08	2.36	275.21	9.21
In situ neoplasms, benign neoplasms and neoplasms of uncertain or unknown behaviour	0.03	1.12	0.02	0.46	53.74	1.80
Anaemias	0.00	0.13	0.00	0.05	6.11	0.20
Diabetes mellitus	0.08	3.22	0.05	1.32	154.35	5.16
Nutritional deficiencies	0.00	0.07	0.00	0.03	3.41	0.12
Malnutrition	0.00	0.04	0.00	0.02	1.71	0.05
Other nutritional deficiencies	0.00	0.04	0.00	0.02	2.10	0.07
Meningitis	0.00	0.04	0.00	0.02	1.74	0.05
Parkinson's disease	0.00	0.15	0.00	0.06	7.07	0.24
Alzheimer's disease	0.04	1.57	0.02	0.64	75.26	2.51
Major cardiovascular diseases	1.42	58.25	0.84	23.93	2,793.28	93.51
Diseases of heart	1.05	43.09	0.62	17.70	2,066.34	69.18
Acute rheumatic fever and chronic rheumatic heart diseases	0.01	0.26	0.00	0.11	12.41	0.41
Hypertensive heart disease	0.00	-0.19	0.00	-0.08	-8.96	-0.29
Hypertensive heart and renal disease	0.00	0.07	0.00	0.03	3.18	0.11
Ischaemic heart diseases	0.91	37.46	0.54	15.39	1,796.55	60.14
Acute myocardial infarction	0.52	21.15	0.31	8.69	1,014.49	33.96
Other acute ischaemic heart diseases	0.00	-0.16	0.00	-0.07	-7.71	-0.25
Other forms of chronic ischaemic heart disease	0.40	16.45	0.24	6.76	788.77	26.41
Atherosclerotic cardiovascular disease, so described	0.00	0.01	0.00	0.00	0.70	0.03
All other forms of chronic ischaemic heart disease	0.40	16.44	0.24	6.75	788.51	26.39
Other heart diseases	0.13	5.49	0.08	2.26	263.45	8.82
Acute and subacute endocarditis	0.00	-0.15	0.00	-0.06	-7.02	-0.24
Diseases of pericardium and acute myocarditis	0.00	0.09	0.00	0.04	4.09	0.13
Heart failure	0.08	3.20	0.05	1.31	153.37	5.13
All other forms of heart disease	0.06	2.36	0.03	0.97	113.31	3.80
Essential hypertension and hypertensive renal disease	0.00	-0.11	0.00	-0.05	-5.43	-0.19
Cerebrovascular diseases	0.28	11.53	0.17	4.74	552.88	18.50
Atherosclerosis	0.03	1.27	0.02	0.52	60.83	2.03
Other diseases of circulatory system	0.06	2.42	0.03	0.99	116.17	3.89

Aortic aneurysm and dissection	0.05	1.94	0.03	0.80	92.80	3.10
Other diseases of arteries, arterioles and capillaries	0.01	0.48	0.01	0.20	22.97	0.76
Other disorders of circulatory system	0.01	0.21	0.00	0.09	10.07	0.33
Influenza and pneumonia	0.04	1.52	0.02	0.62	72.84	2.43
Influenza	0.01	0.32	0.00	0.13	15.18	0.51
Pneumonia	0.03	1.21	0.02	0.50	58.07	1.94
Other acute lower respiratory infections	0.00	0.13	0.00	0.05	6.24	0.21
Acute bronchitis and bronchiolitis	0.00	0.09	0.00	0.04	4.31	0.15
Unspecified acute lower respiratory infection	0.00	0.05	0.00	0.02	2.17	0.07
Chronic lower respiratory diseases	0.09	3.67	0.05	1.51	175.93	5.88
Bronchitis, chronic and unspecified	0.01	0.21	0.00	0.09	10.23	0.35
Emphysema	0.02	0.89	0.01	0.37	42.74	1.43
Asthma	0.01	0.30	0.00	0.12	14.48	0.48
Other chronic lower respiratory diseases	0.05	2.25	0.03	0.92	107.66	3.61
Pneumoconioses and chemical effects	0.00	-0.03	0.00	-0.01	-1.51	-0.05
Pneumonitis due to solids and liquids	-0.03	-1.08	-0.02	-0.44	-51.65	-1.72
Other diseases of respiratory system	0.00	-0.03	0.00	-0.01	-1.43	-0.05
Peptic ulcer	0.01	0.24	0.00	0.10	11.46	0.39
Diseases of appendix	0.00	0.03	0.00	0.01	1.52	0.05
Hernia	0.00	-0.09	0.00	-0.04	-4.20	-0.15
Chronic liver disease and cirrhosis	0.00	0.11	0.00	0.05	5.31	0.17
Alcoholic liver disease	-0.01	-0.25	0.00	-0.10	-12.17	-0.40
Other chronic liver disease and cirrhosis	0.01	0.35	0.01	0.14	16.89	0.56
Cholelithiasis and other disorders of gallbladder	0.00	0.09	0.00	0.04	4.52	0.15
Nephritis, nephrotic syndrome and nephrosis	0.05	1.89	0.03	0.78	90.69	3.04
Acute and rapidly progressive nephritic and nephrotic syndrome	0.00	-0.01	0.00	0.00	-0.47	-0.01
Chronic glomerulonephritis, nephritis and nephropathy not specified as acute or chronic, and renal sclerosis unspecified	0.00	0.01	0.00	0.00	0.55	0.01
Renal failure	0.05	1.88	0.03	0.77	90.24	3.02
Other disorders of kidney	0.00	-0.01	0.00	0.00	-0.31	-0.01
Infections of kidney	0.00	0.06	0.00	0.02	2.86	0.09
Hyperplasia of prostate	0.00	-0.03	0.00	-0.01	-1.58	-0.05
Inflammatory diseases of female pelvic organs	0.00	0.00	0.00	0.00	0.11	0.00
Pregnancy, childbirth and the puerperium	0.00	-0.02	0.00	-0.01	-1.16	-0.04
Pregnancy with abortive outcome	0.00	0.00	0.00	0.00	0.00	0.00
Other complications of pregnancy, childbirth and the puerperium	0.00	-0.02	0.00	-0.01	-1.16	-0.04
Certain conditions originating in the perinatal period	-0.02	-0.65	-0.01	-0.27	-31.03	-1.04
Congenital malformations, deformations and chromosomal abnormalities	0.03	1.19	0.02	0.49	57.06	1.91
Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	0.04	1.59	0.02	0.65	76.49	2.57
All other diseases (residual)	-0.04	-1.68	-0.02	-0.69	-80.44	-2.69
Accidents (unintentional injuries)	0.09	3.61	0.05	1.48	173.07	5.79
Transport accidents	0.12	4.85	0.07	1.99	232.82	7.79

Motor vehicle accidents	0.09	3.76	0.05	1.54	180.25	6.03
Other land transport accidents	0.03	1.07	0.02	0.44	51.26	1.71
Water, air and space, and other and unspecified transport accidents and their sequelae	0.00	0.03	0.00	0.01	1.32	0.04
Nontransport accidents	-0.03	-1.19	-0.02	-0.49	-57.09	-1.91
Falls	-0.05	-2.07	-0.03	-0.85	-99.31	-3.33
Accidental discharge of firearms	0.00	0.02	0.00	0.01	0.78	0.03
Accidental drowning and submersion	0.01	0.37	0.01	0.15	17.96	0.60
Accidental exposure to smoke, fire and flames	0.01	0.32	0.00	0.13	15.11	0.51
Accidental poisoning and exposure to noxious substances	-0.04	-1.76	-0.03	-0.72	-84.39	-2.82
Other and unspecified nontransport accidents and their sequelae	0.05	1.95	0.03	0.80	93.49	3.13
Intentional self-harm (suicide)	0.04	1.81	0.03	0.74	86.64	2.90
Intentional self-harm (suicide) by discharge of firearms	0.02	0.90	0.01	0.37	43.39	1.46
Intentional self-harm (suicide) by other and unspecified means and their sequelae	0.02	0.93	0.01	0.38	44.60	1.50
Assault (homicide)	0.00	-0.04	0.00	-0.02	-2.10	-0.07
Assault (homicide) by discharge of firearms	0.00	0.13	0.00	0.05	6.02	0.20
Assault (homicide) by other and unspecified means and their sequelae	0.00	-0.17	0.00	-0.07	-8.14	-0.27
Legal intervention	0.00	-0.05	0.00	-0.02	-2.57	-0.08
Events of undetermined intent	-0.02	-0.62	-0.01	-0.25	-29.88	-1.00
Discharge of firearms, undetermined intent	0.00	0.03	0.00	0.01	1.40	0.05
Other and unspecified events of undetermined intent and their sequelae	-0.02	-0.64	-0.01	-0.26	-30.90	-1.03
Operations of war and their sequelae	0.00	0.00	0.00	0.00	0.00	0.00
Complications of medical and surgical care	0.00	0.17	0.00	0.07	7.96	0.27

[a] Values are in terms of household real net adjusted disposable income on a per capita basis where an adjustment is made to reflect social transfers in kind received from the government (health, education, housing) and are net of depreciation of capital assets held by households. One additional year of life expectancy is estimated to be worth $1,969 of household income per capita based upon provisional results of ongoing OECD research.

Source: Author's calculations using data from Statistics Canada's Vital Statistics Deaths Database and the Canadian Human Mortality Database

Appendix Table 3: Complete Beltrán-Sánchez and Preston Decomposition

Cause of Death	Contribution to Increased Life Expectancy at Birth (years)	Share of Increased Life Expectancy at Birth (per cent)	Contribution to Growth in Living Standards (percentage points)	Share of Growth in Living Standards (per cent)	Change in Equivalent Household Income per Capita[a] (2010 $CDN)	Total Value of Change in Terms of Equivalent Income (billions, 2010 $CDN)
Total, all causes of death	2.43	100.00	1.45	41.08	4,795.73	160.55
Salmonella infections	0.00	0.00	0.00	0.00	0.19	0.00
Shigellosis and amoebiasis	0.00	0.00	0.00	0.00	0.00	0.00
Certain other intestinal infections	-0.04	-1.65	-0.02	-0.68	-79.29	-2.66
Tuberculosis	0.00	0.06	0.00	0.02	2.75	0.09
Respiratory tuberculosis	0.00	0.05	0.00	0.02	2.57	0.08
Other tuberculosis	0.00	0.00	0.00	0.00	-0.07	0.00
Whooping cough	0.00	-0.01	0.00	0.00	-0.35	-0.01
Scarlet fever and erysipelas	0.00	0.00	0.00	0.00	0.08	0.00
Meningococcal infection	0.00	0.07	0.00	0.03	3.41	0.12
Sepsis	-0.02	-0.69	-0.01	-0.28	-33.00	-1.11
Syphilis	0.00	0.00	0.00	0.00	0.08	0.00
Acute poliomyelitis	0.00	0.00	0.00	0.00	0.00	0.00
Arthropod-borne viral encephalitis	0.00	0.00	0.00	0.00	0.00	0.00
Measles	0.00	0.00	0.00	0.00	-0.15	0.00
Viral hepatitis	-0.01	-0.59	-0.01	-0.24	-28.25	-0.95
Human immunodeficiency virus [HIV] disease	0.02	0.87	0.01	0.36	41.74	1.40
Malaria	0.00	0.00	0.00	0.00	0.00	0.00
Other and unspecified infectious and parasitic diseases and their sequelae	0.02	0.97	0.01	0.40	46.72	1.56
Malignant neoplasms	0.57	23.42	0.34	9.62	1,123.23	37.60
Malignant neoplasms of lip, oral cavity and pharynx	0.00	0.08	0.00	0.03	3.62	0.12
Malignant neoplasm of oesophagus	0.01	0.28	0.00	0.12	13.26	0.44
Malignant neoplasm of stomach	0.03	1.22	0.02	0.50	58.37	1.95
Malignant neoplasms of colon, rectum and anus	0.04	1.70	0.02	0.70	81.30	2.73
Malignant neoplasm of liver and intrahepatic bile ducts	-0.02	-0.91	-0.01	-0.37	-43.72	-1.46
Malignant neoplasm of pancreas	0.00	0.16	0.00	0.07	7.62	0.25
Malignant neoplasm of larynx	0.01	0.56	0.01	0.23	26.95	0.90
Malignant neoplasms of trachea, bronchus and lung	0.13	5.44	0.08	2.23	261.11	8.74
Malignant melanoma of skin	0.00	0.02	0.00	0.01	1.00	0.04
Malignant neoplasm of breast	0.07	2.94	0.04	1.21	140.86	4.72
Malignant neoplasm of cervix uteri	0.00	0.20	0.00	0.08	9.56	0.32
Malignant neoplasms of corpus uteri and uterus, part unspecified	0.00	-0.13	0.00	-0.05	-6.30	-0.21
Malignant neoplasm of ovary	0.01	0.31	0.00	0.13	14.64	0.49
Malignant neoplasm of prostate	0.05	2.21	0.03	0.91	105.84	3.54

Malignant neoplasms of kidney and renal pelvis	0.01	0.41	0.01	0.17	19.80	0.67
Malignant neoplasm of bladder	0.01	0.29	0.00	0.12	14.04	0.47
Malignant neoplasms of meninges, brain and other parts of central nervous system	0.00	0.17	0.00	0.07	8.36	0.28
Malignant neoplasms of lymphoid, haematopoietic and related tissue	0.07	2.77	0.04	1.14	132.85	4.45
Hodgkin's disease	0.00	0.08	0.00	0.03	4.02	0.13
Non-Hodgkin's lymphoma	0.04	1.81	0.03	0.74	86.59	2.90
Leukaemia	0.02	0.67	0.01	0.28	32.33	1.08
Multiple myeloma and immunoproliferative neoplasms	0.00	0.18	0.00	0.07	8.69	0.29
Other and unspecified malignant neoplasms of lymphoid, haematopoietic and related tissue	0.00	-0.02	0.00	-0.01	-0.88	-0.03
All other and unspecified malignant neoplasms	0.13	5.53	0.08	2.27	265.01	8.88
In situ neoplasms, benign neoplasms and neoplasms of uncertain or unknown behaviour	0.03	1.08	0.02	0.44	51.84	1.74
Anaemias	0.00	0.12	0.00	0.05	5.68	0.19
Diabetes mellitus	0.08	3.13	0.05	1.29	150.15	5.03
Nutritional deficiencies	0.00	0.07	0.00	0.03	3.42	0.12
Malnutrition	0.00	0.04	0.00	0.02	1.75	0.05
Other nutritional deficiencies	0.00	0.04	0.00	0.02	2.06	0.07
Meningitis	0.00	0.04	0.00	0.02	1.68	0.05
Parkinson's disease	0.00	0.13	0.00	0.05	6.15	0.20
Alzheimer's disease	0.04	1.51	0.02	0.62	72.37	2.42
Major cardiovascular diseases	1.46	59.84	0.87	24.58	2,869.55	96.07
Diseases of heart	1.06	43.61	0.63	17.92	2,091.52	70.02
Acute rheumatic fever and chronic rheumatic heart diseases	0.01	0.25	0.00	0.10	11.98	0.40
Hypertensive heart disease	0.00	-0.18	0.00	-0.07	-8.64	-0.29
Hypertensive heart and renal disease	0.00	0.06	0.00	0.02	3.10	0.11
Ischaemic heart diseases	0.92	37.62	0.54	15.45	1,803.99	60.39
Acute myocardial infarction	0.51	20.89	0.30	8.58	1,002.01	33.55
Other acute ischaemic heart diseases	0.00	-0.18	0.00	-0.07	-8.62	-0.29
Other forms of chronic ischaemic heart disease	0.40	16.54	0.24	6.79	793.30	26.55
Atherosclerotic cardiovascular disease, so described	0.00	0.02	0.00	0.01	0.82	0.03
All other forms of chronic ischaemic heart disease	0.40	16.52	0.24	6.79	792.19	26.53
Other heart diseases	0.13	5.45	0.08	2.24	261.40	8.76
Acute and subacute endocarditis	0.00	-0.14	0.00	-0.06	-6.85	-0.23
Diseases of pericardium and acute myocarditis	0.00	0.08	0.00	0.03	3.85	0.13
Heart failure	0.08	3.25	0.05	1.34	155.92	5.21
All other forms of heart disease	0.05	2.24	0.03	0.92	107.26	3.60
Essential hypertension and hypertensive renal disease	0.00	-0.13	0.00	-0.05	-6.28	-0.21
Cerebrovascular diseases	0.28	11.60	0.17	4.77	556.11	18.61
Atherosclerosis	0.03	1.29	0.02	0.53	61.93	2.07
Other diseases of circulatory system	0.06	2.38	0.03	0.98	114.04	3.82
Aortic aneurysm and dissection	0.05	1.90	0.03	0.78	91.12	3.05
Other diseases of arteries, arterioles and capillaries	0.01	0.47	0.01	0.19	22.45	0.75

Other disorders of circulatory system	0.01	0.21	0.00	0.09	9.85	0.33
Influenza and pneumonia	0.04	1.54	0.02	0.63	74.00	2.47
Influenza	0.01	0.33	0.00	0.14	15.68	0.52
Pneumonia	0.03	1.22	0.02	0.50	58.50	1.95
Other acute lower respiratory infections	0.00	0.13	0.00	0.05	6.31	0.21
Acute bronchitis and bronchiolitis	0.00	0.09	0.00	0.04	4.28	0.15
Unspecified acute lower respiratory infection	0.00	0.05	0.00	0.02	2.25	0.08
Chronic lower respiratory diseases	0.09	3.55	0.05	1.46	170.48	5.71
Bronchitis, chronic and unspecified	0.01	0.21	0.00	0.09	10.26	0.35
Emphysema	0.02	0.87	0.01	0.36	41.77	1.40
Asthma	0.01	0.29	0.00	0.12	13.97	0.47
Other chronic lower respiratory diseases	0.05	2.15	0.03	0.88	103.29	3.46
Pneumoconioses and chemical effects	0.00	-0.03	0.00	-0.01	-1.55	-0.05
Pneumonitis due to solids and liquids	-0.03	-1.11	-0.02	-0.46	-53.31	-1.78
Other diseases of respiratory system	0.00	-0.06	0.00	-0.02	-2.71	-0.09
Peptic ulcer	0.01	0.24	0.00	0.10	11.59	0.39
Diseases of appendix	0.00	0.03	0.00	0.01	1.51	0.05
Hernia	0.00	-0.09	0.00	-0.04	-4.29	-0.15
Chronic liver disease and cirrhosis	0.00	0.10	0.00	0.04	4.56	0.15
Alcoholic liver disease	-0.01	-0.25	0.00	-0.10	-11.82	-0.40
Other chronic liver disease and cirrhosis	0.01	0.33	0.00	0.14	16.02	0.53
Cholelithiasis and other disorders of gallbladder	0.00	0.09	0.00	0.04	4.37	0.15
Nephritis, nephrotic syndrome and nephrosis	0.04	1.83	0.03	0.75	87.82	2.94
Acute and rapidly progressive nephritic and nephrotic syndrome	0.00	-0.01	0.00	0.00	-0.47	-0.01
Chronic glomerulonephritis, nephritis and nephropathy not specified as acute or chronic, and renal sclerosis unspecified	0.00	0.01	0.00	0.00	0.51	0.01
Renal failure	0.04	1.82	0.03	0.75	87.40	2.93
Other disorders of kidney	0.00	-0.01	0.00	0.00	-0.31	-0.01
Infections of kidney	0.00	0.06	0.00	0.02	2.77	0.09
Hyperplasia of prostate	0.00	-0.04	0.00	-0.02	-1.68	-0.05
Inflammatory diseases of female pelvic organs	0.00	0.00	0.00	0.00	0.11	0.00
Pregnancy, childbirth and the puerperium	0.00	-0.02	0.00	-0.01	-1.14	-0.04
Pregnancy with abortive outcome	0.00	0.00	0.00	0.00	0.00	0.00
Other complications of pregnancy, childbirth and the puerperium	0.00	-0.02	0.00	-0.01	-1.14	-0.04
Certain conditions originating in the perinatal period	-0.02	-0.65	-0.01	-0.27	-31.14	-1.04
Congenital malformations, deformations and chromosomal abnormalities	0.03	1.14	0.02	0.47	54.63	1.83
Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	0.04	1.55	0.02	0.64	74.26	2.49
All other diseases (residual)	-0.06	-2.38	-0.03	-0.98	-114.29	-3.82
Accidents (unintentional injuries)	0.08	3.40	0.05	1.40	163.10	5.46
Transport accidents	0.11	4.69	0.07	1.93	225.14	7.54
Motor vehicle accidents	0.09	3.62	0.05	1.49	173.39	5.80
Other land transport accidents	0.03	1.03	0.01	0.42	49.51	1.66
Water, air and space, and other and unspecified transport	0.00	0.02	0.00	0.01	0.99	0.03

accidents and their sequelae						
Nontransport accidents	-0.03	-1.27	-0.02	-0.52	-60.98	-2.05
Falls	-0.05	-2.16	-0.03	-0.89	-103.74	-3.48
Accidental discharge of firearms	0.00	0.01	0.00	0.00	0.66	0.03
Accidental drowning and submersion	0.01	0.34	0.00	0.14	16.37	0.55
Accidental exposure to smoke, fire and flames	0.01	0.31	0.00	0.13	14.73	0.49
Accidental poisoning and exposure to noxious substances	-0.04	-1.71	-0.02	-0.70	-81.79	-2.74
Other and unspecified nontransport accidents and their sequelae	0.05	1.93	0.03	0.79	92.71	3.10
Intentional self-harm (suicide)	0.04	1.74	0.03	0.71	83.47	2.79
Intentional self-harm (suicide) by discharge of firearms	0.02	0.88	0.01	0.36	41.97	1.40
Intentional self-harm (suicide) by other and unspecified means and their sequelae	0.02	0.88	0.01	0.36	42.14	1.42
Assault (homicide)	0.00	-0.05	0.00	-0.02	-2.53	-0.08
Assault (homicide) by discharge of firearms	0.00	0.12	0.00	0.05	5.70	0.19
Assault (homicide) by other and unspecified means and their sequelae	0.00	-0.18	0.00	-0.07	-8.42	-0.28
Legal intervention	0.00	-0.05	0.00	-0.02	-2.46	-0.08
Events of undetermined intent	-0.01	-0.61	-0.01	-0.25	-29.23	-0.98
Discharge of firearms, undetermined intent	0.00	0.02	0.00	0.01	1.18	0.04
Other and unspecified events of undetermined intent and their sequelae	-0.02	-0.63	-0.01	-0.26	-30.15	-1.02
Operations of war and their sequelae	0.00	0.00	0.00	0.00	0.00	0.00
Complications of medical and surgical care	0.00	0.16	0.00	0.07	7.88	0.27

[a] Values are in terms of household real net adjusted disposable income on a per capita basis where an adjustment is made to reflect social transfers in kind received from the government (health, education, housing) and are net of depreciation of capital assets held by households. One additional year of life expectancy is estimated to be worth $1,969 of household income per capita based upon provisional results of ongoing OECD research.

Source: Author's calculations using data from Statistics Canada's Vital Statistics Deaths Database and the Canadian Human Mortality Database

Appendix Table 4: Major Causes of Death, Select Characteristics, Canada, 2000 and 2001

Cause of Death	Average Age at Death		Age-Standardized Mortality Rate[a] (per 100,000)		Deaths		Share of All Deaths (per cent)	
	2000	2011	2000	2011	2000	2011	2000	2011
Total, all causes of death	74.0	75.8	615.5	489.0	218,062	242,074	100.00	100.00
Major cardiovascular diseases	79.0	80.2	209.1	125.1	76,046	65,839	34.87	27.20
Malignant neoplasms	71.1	72.8	180.4	154.1	62,672	72,476	28.74	29.94
Accidents (unintentional injuries)	57.1	65.2	25.8	24.2	8,589	10,716	3.94	4.43
Chronic lower respiratory diseases	79.1	80.3	27.2	22.1	9,813	11,184	4.50	4.62
Diabetes mellitus	76.0	77.1	18.9	14.5	6,714	7,194	3.08	2.97
Influenza and pneumonia	83.0	83.1	13.2	10.4	4,966	5,767	2.28	2.38
Nephritis, nephrotic syndrome and nephrosis	79.7	82.7	8.6	6.1	3,136	3,294	1.44	1.36
Intentional self-harm (suicide)	43.1	46.4	11.4	10.1	3,606	3,728	1.65	1.54
Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	64.8	69.5	8.0	6.4	2,737	3,017	1.26	1.25
Alzheimer's disease	85.1	86.9	13.2	10.8	5,007	6,356	2.30	2.63
All other diseases (residual)	76.6	80.3	50.9	55.6	18,404	29,583	8.44	12.22
Congenital malformations, deformations and chromosomal abnormalities	23.0	26.6	3.4	2.8	920	893	0.42	0.37
In situ neoplasms, benign neoplasms and neoplasms of uncertain or unknown behaviour	74.2	78.2	4.1	2.8	1,439	1,432	0.66	0.59
Other and unspecified infectious and parasitic diseases and their sequelae	68.5	74.7	2.1	1.1	745	526	0.34	0.22

[a] Standardized to reflect the age structure from the 1991 Canadian Census

Source: Author's calculations using data from the Canadian Human Mortality Database and Statistics Canada's Vital Statistics Death Database

Appendix Table 5: Cancer, Select Characteristics, Canada, 2000 and 2001

Cause of Death	Average Age at Death		Age-Standardized Mortality Rate (per 100,000)[a]		Deaths		Share of All Deaths (per cent)	
	2000	2011	2000	2011	2000	2011	2000	2011
Total, all causes of death	74.0	75.8	615.5	489.0	218,062	242,074	100.00	100.00
Malignant neoplasms	71.1	72.8	180.4	154.1	62,672	72,476	28.74	29.94
Malignant neoplasms of lip, oral cavity and pharynx	68.2	69.9	2.6	2.5	901	1,186	0.41	0.49
Malignant neoplasm of oesophagus	70.2	71.0	4.0	3.7	1,392	1,741	0.64	0.72
Malignant neoplasm of stomach	72.5	72.6	5.7	4.0	1,988	1,919	0.91	0.79
Malignant neoplasms of colon, rectum and anus	73.1	74.5	19.0	17.0	6,643	8,180	3.05	3.38
Malignant neoplasm of liver and intrahepatic bile ducts	70.4	71.3	3.7	4.9	1,291	2,273	0.59	0.94
Malignant neoplasm of pancreas	72.4	73.0	8.9	8.7	3,092	4,082	1.42	1.69
Malignant neoplasm of larynx	70.5	71.7	1.5	0.8	506	373	0.23	0.15
Malignant neoplasms of trachea, bronchus and lung	70.2	72.1	47.1	41.7	16,134	19,222	7.40	7.94
Malignant melanoma of skin	65.0	68.3	2.1	2.1	709	962	0.33	0.40
Malignant neoplasm of breast	68.5	70.4	13.9	10.5	4,901	5,011	2.25	2.07
Malignant neoplasm of cervix uteri	61.0	60.6	1.2	0.9	398	397	0.18	0.16
Malignant neoplasms of corpus uteri and uterus, part unspecified	73.3	71.5	1.8	1.9	640	898	0.29	0.37
Malignant neoplasm of ovary	69.3	70.2	4.0	3.6	1,390	1,695	0.64	0.70
Malignant neoplasm of prostate	78.6	80.4	10.4	7.3	3,718	3,693	1.71	1.53
Malignant neoplasms of kidney and renal pelvis	69.9	71.8	3.6	3.2	1,259	1,504	0.58	0.62
Malignant neoplasm of bladder	76.5	78.0	4.3	3.9	1,519	1,942	0.70	0.80
Malignant neoplasms of meninges, brain and other parts of central nervous system	60.7	63.6	4.5	4.5	1,533	1,949	0.70	0.81
Malignant neoplasms of lymphoid, haematopoietic and related tissue	70.0	73.4	16.9	14.2	5,823	6,620	2.67	2.73
Hodgkin's disease	57.1	62.4	0.4	0.3	128	127	0.06	0.05
Non-Hodgkin's lymphoma	69.6	73.5	7.3	5.5	2,537	2,562	1.16	1.06
Leukaemia	69.1	72.8	5.9	5.4	2,048	2,505	0.94	1.03
Multiple myeloma and immunoproliferative neoplasms	74.0	75.0	3.2	3.0	1,105	1,404	0.51	0.58
Other and unspecified malignant neoplasms of lymphoid, haematopoietic and related tissue	70.7	79.2	0.0	0.0	5	22	0.00	0.01
All other and unspecified malignant neoplasms	72.3	74.4	25.3	18.4	8,835	8,829	4.05	3.65
In situ neoplasms, benign neoplasms and neoplasms of uncertain or unknown behaviour	74.2	78.2	4.1	2.8	1,439	1,432	0.66	0.59

[a] Standardized to reflect the age structure from the 1991 Canadian Census

Source: Author's calculations using data from the Canadian Human Mortality Database and Statistics Canada's Vital Statistics Death Database

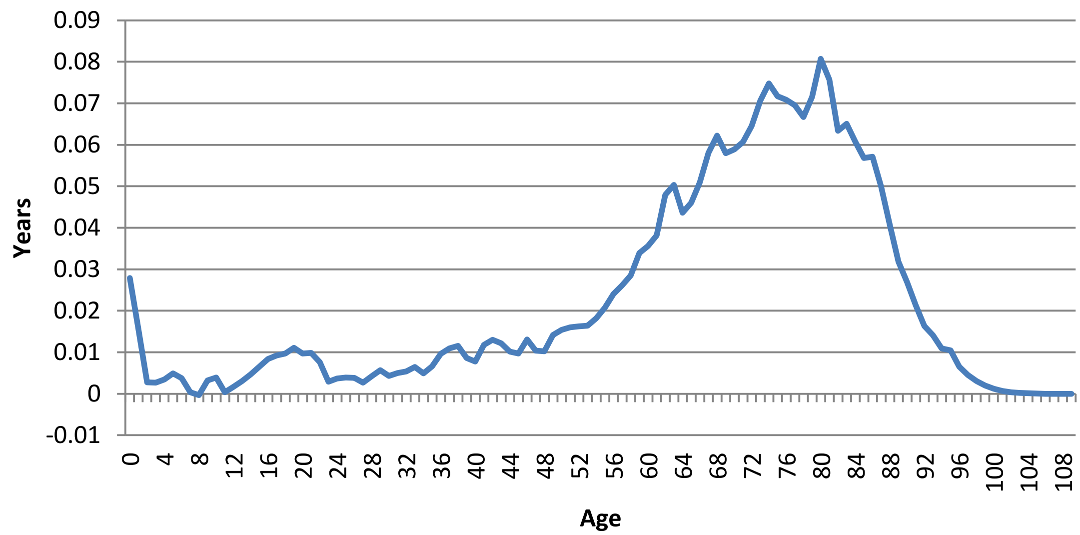
Appendix Table 6: Major Cardiovascular Diseases, Select Characteristics, Canada, 2000 and 2001

Cause of Death	Average Age at Death		Age-Standardized Mortality Rate (per 100,000)[a]		Deaths		Share of All Deaths (per cent)	
	2000	2011	2000	2011	2000	2011	2000	2011
Total, all causes of death	74.0	75.8	615.5	489.0	218,062	242,074	100.00	100.00
Major cardiovascular diseases	79.0	80.2	209.1	125.1	76,046	65,839	34.87	27.20
Diseases of heart	78.3	79.7	152.0	91.0	55,070	47,627	25.25	19.67
Acute rheumatic fever and chronic rheumatic heart diseases	75.7	77.6	1.2	0.9	426	441	0.20	0.18
Hypertensive heart disease	80.4	77.7	1.4	1.5	526	793	0.24	0.33
Hypertensive heart and renal disease	83.5	86.4	0.4	0.3	132	153	0.06	0.06
Ischaemic heart diseases	78.0	79.1	117.5	64.7	42,417	33,569	19.45	13.87
Acute myocardial infarction	76.7	78.6	55.7	27.2	19,944	13,938	9.15	5.76
Other acute ischaemic heart diseases	75.7	79.7	1.8	2.1	651	1,129	0.30	0.47
Other forms of chronic ischaemic heart disease	79.2	79.5	60.0	35.4	21,822	18,502	10.01	7.64
Atherosclerotic cardiovascular disease, so described	75.9	73.7	3.4	3.2	1,201	1,538	0.55	0.64
All other forms of chronic ischaemic heart disease	79.4	80.0	56.6	32.2	20,621	16,964	9.46	7.01
Other heart diseases	79.6	81.2	31.6	23.7	11,569	12,671	5.31	5.23
Acute and subacute endocarditis	64.6	64.3	0.2	0.3	56	133	0.03	0.05
Diseases of pericardium and acute myocarditis	58.7	62.8	0.3	0.2	83	89	0.04	0.04
Heart failure	84.2	85.1	12.9	7.6	4,835	4,323	2.22	1.79
All other forms of heart disease	76.6	79.6	18.3	15.5	6,595	8,126	3.02	3.36
Essential hypertension and hypertensive renal disease	82.5	83.5	2.8	2.9	1,034	1,615	0.47	0.67
Cerebrovascular diseases	80.9	81.9	42.2	24.8	15,576	13,283	7.14	5.49
Atherosclerosis	84.4	84.4	3.5	1.3	1,313	762	0.60	0.31
Other diseases of circulatory system	77.8	78.7	8.5	5.1	3,053	2,552	1.40	1.05
Aortic aneurysm and dissection	76.9	77.4	5.7	3.0	2,028	1,484	0.93	0.61
Other diseases of arteries, arterioles and capillaries	79.6	80.4	2.8	2.0	1,025	1,068	0.47	0.44
Other disorders of circulatory system	73.5	69.8	1.1	0.7	380	339	0.17	0.14

[a] Standardized to reflect the age structure from the 1991 Canadian Census

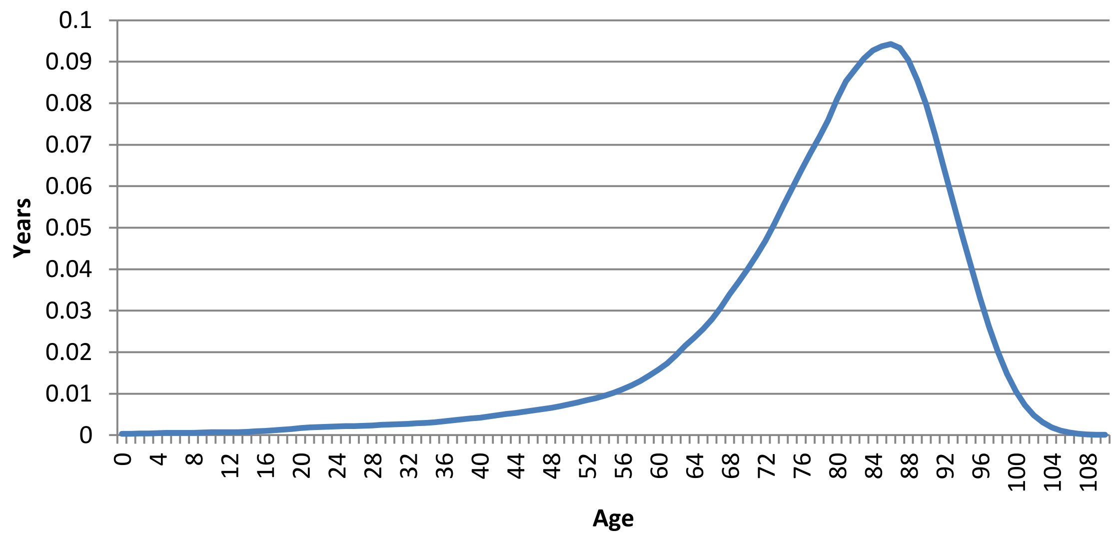
Source: Author's calculations using data from the Canadian Human Mortality Database and Statistics Canada's Vital Statistics Death Database

Appendix Chart 2: Contribution to Increased Life Expectancy by Age, 2000-2011, Arriaga Decomposition



Source: Calculations using life tables from the Canadian Human Mortality Database

Appendix Chart 3: Contribution to Increased Life Expectancy by Age, 2000-2011, Beltrán-Sánchez and Preston Decomposition



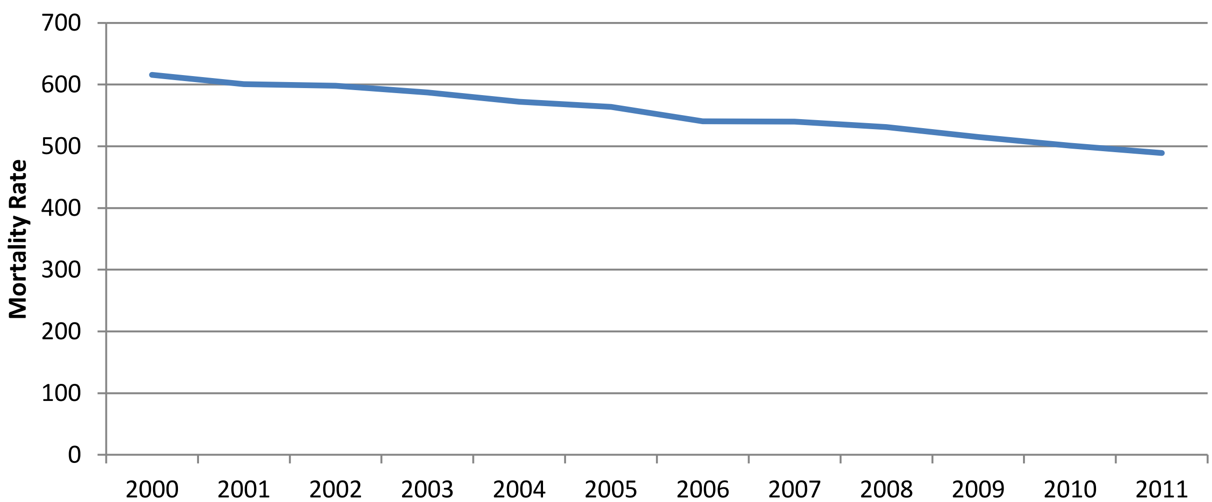
Source: Calculations using life tables from the Canadian Human Mortality Database

Appendix C: Determinants of Life Expectancy

A key component of formulating sound policy to improve Canadian life expectancy is understanding why life expectancy is what it is. This is simultaneously a very simple and a very difficult task depending on how detailed of explanation one requires.

It is fairly easy to explain differences in life expectancy across populations or over time in broad terms. As life expectancy is calculated directly from mortality rates, rising life expectancy can be explained entirely in terms of changes in mortality rates. Appendix Chart 4 presents age-standardized mortality rates in Canada from 2000 to 2011. One sees that they have steadily fallen from about 600 deaths per 100,000 people to below 500 deaths per 100,000 people.

Appendix Chart 4: Age-Standardized Mortality Rate (per 100,000), Canada, 2000-2011



Source: Statistics Canada, CANSIM Table 102-0552

Now, the total age-standardized mortality rate does not necessarily need to fall for life expectancy to improve. There could also be shifts in the timing of mortality (age-specific mortality rates) to later in the age distribution which have the same effect.[71] Similarly, it is

[71] For example, consider a population which has a uniform age distribution over ages 0, 1, 2. At age 2, mortality is 100 per cent. Suppose that mortality between the ages of 0 and 1 is 50 per cent and mortality between ages 1 and 2 is also 50 per cent. For ease of calculation, assume all deaths occur at the beginning of the year. The mortality rate of the population is $\left(\frac{1}{2}\times\frac{1}{3}\right)+\left(\frac{1}{2}\times\frac{1}{3}\right)+\left(1\times\frac{1}{3}\right)=\frac{2}{3}$ and life expectancy at birth is $\left(\frac{1}{2}\times 0\right)+\left(\frac{1}{4}\times 1\right)+\left(\frac{1}{4}\times 2\right)=\frac{3}{4}$. Let's compare this to a situation in which the age distribution of the population is identical, but the mortality in the first period falls to 25 per cent, but rises to 75 per cent in the second period. The overall mortality rate of the

theoretically possible for the age-standardized mortality rate to fall while life expectancy worsens. In our case, the decline in the overall age-standardized mortality rate coincides with declining mortality rates within all age categories over the 2000-2011 periods.

One can decompose the changes in mortality rates by age and cause of death using well-developed methods from actuarial science. Such an exercise is the focus of our next subsection. These sorts of decomposition allow for a very precise understanding of differences in life expectancy across groups or over time along specific dimensions, but these dimensions are not directly controlled by policymakers.

In most cases, the fundamental reasons underlying a death are less clear. It is easy to classify whether or not an individual dies of a stroke and to calculate the impact of reduced mortality rates from strokes on life expectancy. It can be far more difficult to attribute these improvements to socio-economic factors or health care policies. This is because the human body is an incredibly complex system and our understanding of many major diseases is limited.

This appendix provides an overview of some of the factors which are generally understood to impact the overall mortality (and life expectancy) of a population. We present this information as a series of short discussions supplemented by correlations or trends through time where appropriate. The reader is cautioned that such illustrations are suggestive but do not represent causal evidence of the impact of any specific factor on mortality. We invite the interested reader to consult studies which have investigated the determinants of mortality and life expectancy more rigorously than we do here such as Cutler et al. (2006), Soares (2007), Greenberg and Normandin (2011), Preston and Ho (2011).

We consider several general factors including lifestyle choices, education, income, the environment, laws and customs, disasters and outbreaks of disease, and health care. The reader will notice that most of these factors can be influenced by policy. Obviously, these broad factors are interlinked to various degrees which what makes identifying their specific impacts extremely challenging.

i. Lifestyle Choices

Excessive Consumption of Alcohol

Several lifestyle choices are known to be risk factors for serious health problems. While there may be some long term health benefits from low levels of alcohol consumption, excessive

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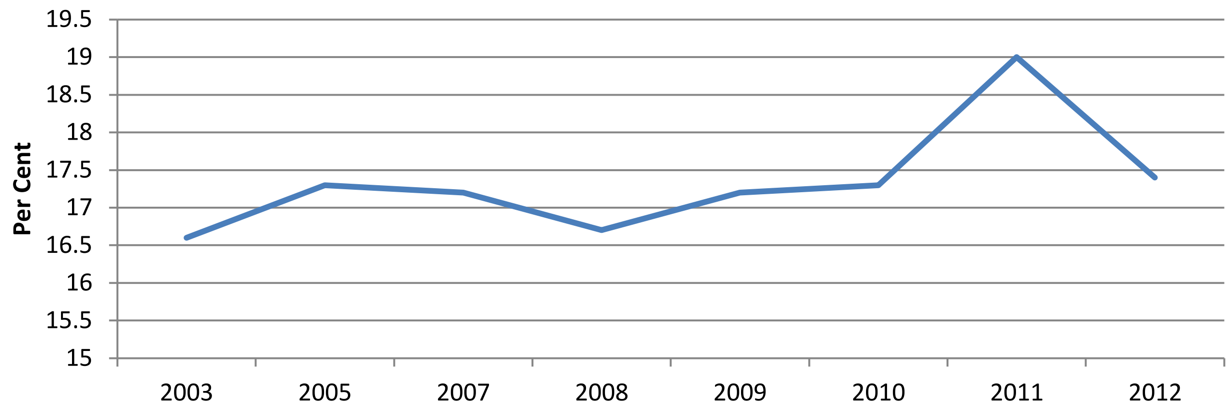
population is unchanged $\left(\frac{1}{4}\times\frac{1}{3}\right)+\left(\frac{3}{4}\times\frac{1}{3}\right)+\left(1\times\frac{1}{3}\right)=\frac{2}{3}$ but life expectancy rises to $\left(\frac{1}{4}\times 0\right)+\left(\frac{9}{16}\times 1\right)+\left(\frac{3}{16}\times 2\right)=\frac{15}{16}$.

alcohol consumption may be associated with liver disease, increased risk of heart disease, and memory loss, particularly in women (CDC, 2014). Heavy drinking is also known to raise the risk of cancer. Boffetta et al. (2006) estimate that 3.6 per cent of all cases of cancer worldwide in 2002 could be attributed to alcohol.

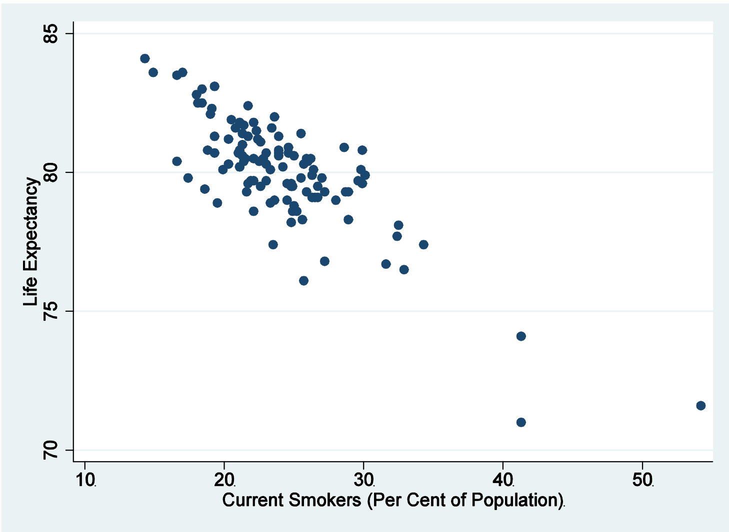
Appendix Chart 5: Canadians Aged 12+ Consuming 5 Drinks or More at Least Once per Month, 2003-2012, Per Cent



Source: Statistics Canada, CANSIM Table 102-0501.

Smoking

Appendix Chart 6: Smoking and Life Expectancy, Canadian Health Regions

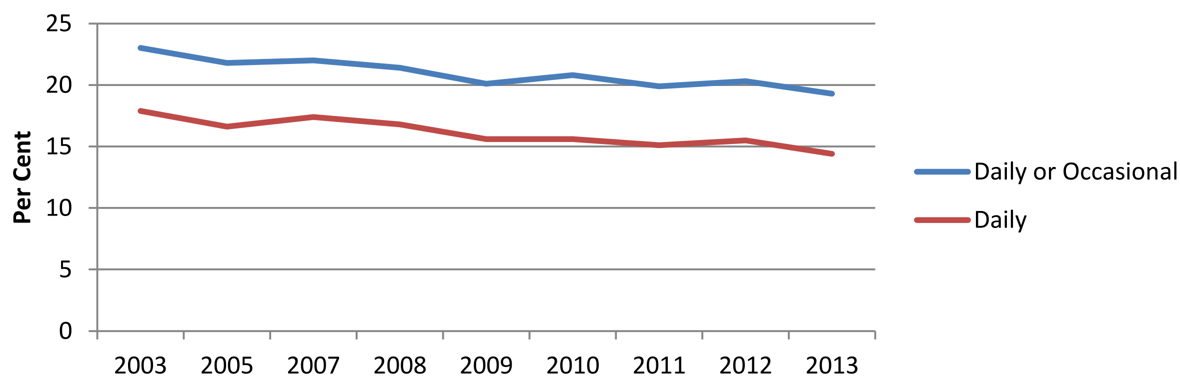


Source: Statistics Canada. Life expectancy at birth is calculated over the three year period 2007-2009 in CANSIM table 102-4307 and the per cent of the population 12+ who currently smoked in 2008 comes from CANSIM Table 102-0501.

Appendix Chart 5 shows the percentage of Canadians aged 12 and above who consumed five drinks or more on one occasion at least once each month from 2003-2012. The figure was quite stable over the course of the decade, hovering around 17 per cent.

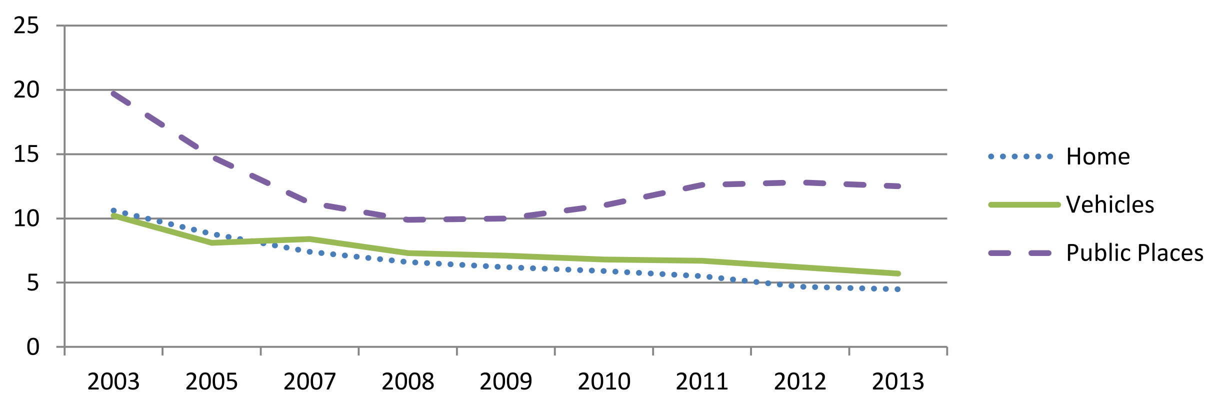
The negative health effects of smoking tobacco have been well established and are common knowledge in Canada. Smoking is known to lead to severe respiratory problems and significantly increases one's likelihood of developing lung cancer or cardiovascular disease. Smoking negatively impacts not only those who consume cigarettes, but also those around them who inhale the smoke second hand. Appendix Chart 6 shows the correlation between life expectancy in Canadian Health Regions and the share of the population who currently smoke. The negative correlation is clear.

Appendix Chart 7: Current Smokers, Canada, 2003-2013, Per Cent



Source: Statistics Canada, CANSIM Table 102-0501. Figures represent a percentage of the Canadian population aged 12+.

Appendix Chart 8: Exposure to Second Hand Smoke, Canada, 2003-2013, Per Cent



Source: Statistics Canada, CANSIM Table 102-0501. Figures represent a percentage of the Canadian population aged 12+.

Fortunately, widespread knowledge of the dangers of smoking has resulted in significant reductions in the prevalence of smoking. The government and Canadian businesses have invested in efforts to encourage smokers to quit.[72] Appendix Chart 7 shows that the decline has continued in recent years. The number of daily smokers has declined from 17.9 per cent of the population aged 12 and above in 2011 to 14.4 per cent of the population in 2013.

Appendix Chart 8 illustrates that there have also been significant reductions in smoking at home, in vehicles, and in public places since 2003. Reduced exposure to cigarette smoke will undoubtedly have a positive impact on the health of Canadians in the future.

Diet and Exercise

Decisions regarding diet and exercise can also have a major impact on an individual's health. Excessive girth is associated with type II diabetes, high blood pressure, and cardiovascular disease. It is widely recognized as a major cause of preventable mortality. Appendix Chart 9 shows the negative correlation between the share of the population 18+ which is obese and life expectancy in Canadian Health Regions.

Appendix Chart 9: Weight and Life Expectancy, Canadian Health Regions

Source: Statistics Canada. Life expectancy at birth is calculated over the three year period 2007-2009 in CANSIM table 102-4307 and the per cent of the population 18+ which is overweight or obese comes from CANSIM Table 102-0501.

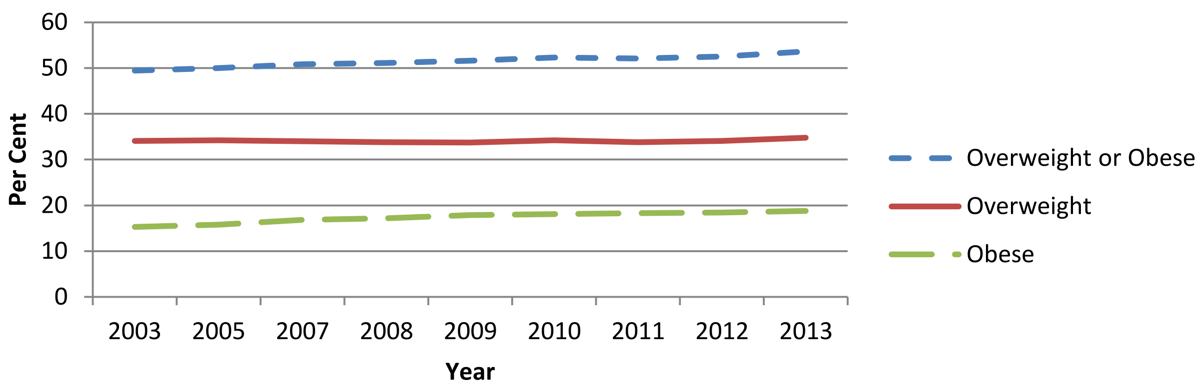
Unlike smoking, rates of obesity have not been on the decline in Canada (Appendix Chart 10). The share of the population 18+ which is overweight or obese has risen from 49.4 per cent

[72] The benefits of investing in smoking cessation programs can be substantial for Canadian firms as well as the workers themselves. The Conference Board of Canada (2013d) estimates that daily smokers cost employers an average of $4,256 per smoker in 2012.

in 2003 to 53.6 per cent in 2013. This is an issue which impacts the majority of the population. Olshansky et al. 2005 (2014) and Preston et al. (2014) estimate that rising obesity will have a negative impact on life expectancy in the United States in the future.[73] While weight is at least partly genetically determined, it is generally understood that diet and exercise are major determinants of an individual's weight.

There continues to be considerable debate over what an optimal diet should entail, but it is generally agreed that sufficient consumption of fruits and vegetables is important for good health. Appendix Chart 11 shows how the share of the population aged 12+ consuming fruits and vegetables five or more times per day has changed from 2003 to 2013. Slightly more than 40 per cent of the population claim to meet this dietary standard. Fruit and vegetable consumption appears to have declined somewhat from 2007 to 2013, although the importance of this specific measure of diet for health is not entirely clear.

Appendix Chart 10: Obese or Overweight Canadian Population, 2003-2013, Per Cent



Source: Statistics Canada, CANSIM Table 102-0501. Figures represent a percentage of the Canadian population aged 18+.

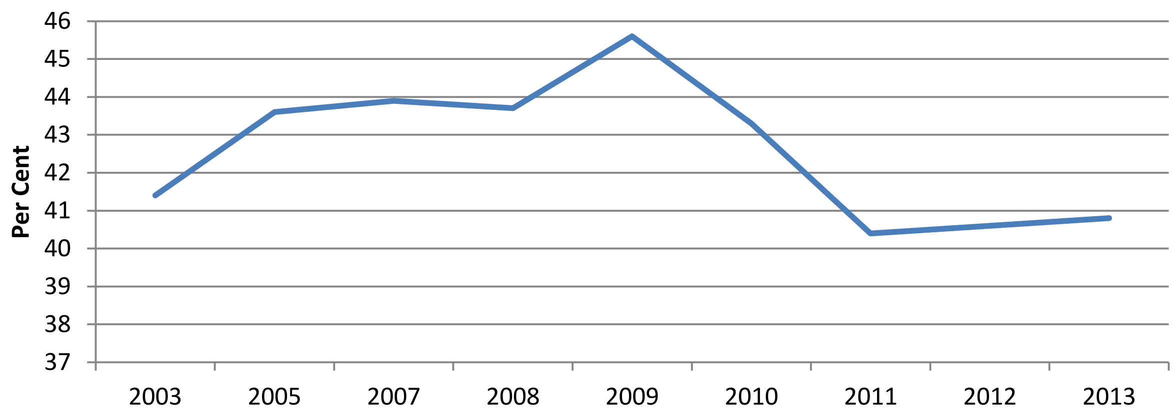
Finally, exercise is thought to be important for a healthy lifestyle, particularly through the channel of weight reduction. While it has long been understood that vigorous physical activity is important, recent research has also highlighted the dangers of sedentary behaviour throughout the day as a separate issue. The majority of Canadians spend most of their waking hours sitting. A recent study by the Conference Board of Canada (2014a) notes that analysis by Statistics Canada reveals that those who stand or walk during the day have a 30 per cent lower risk of mortality than people who usually sit all day.[74] Furthermore, this analysis estimates that reducing

[73] Preston et al. (2014) forecast that decreased life expectancy from rising obesity will offset much of the gains in life expectancy from reductions in smoking over the 2010-2040 period.

[74] Estimated by calculating life expectancy using two sets of age-specific mortality rates, one for the sedentary population and one for the non-sedentary population generated using Statistics Canada's Population Health Model (POHEM-PA).

sedentary behaviour could conceivably increase the number of health-adjusted life years lived by Canadians by 0.4 per cent in 2020 and by 1.2 per cent in 2040.

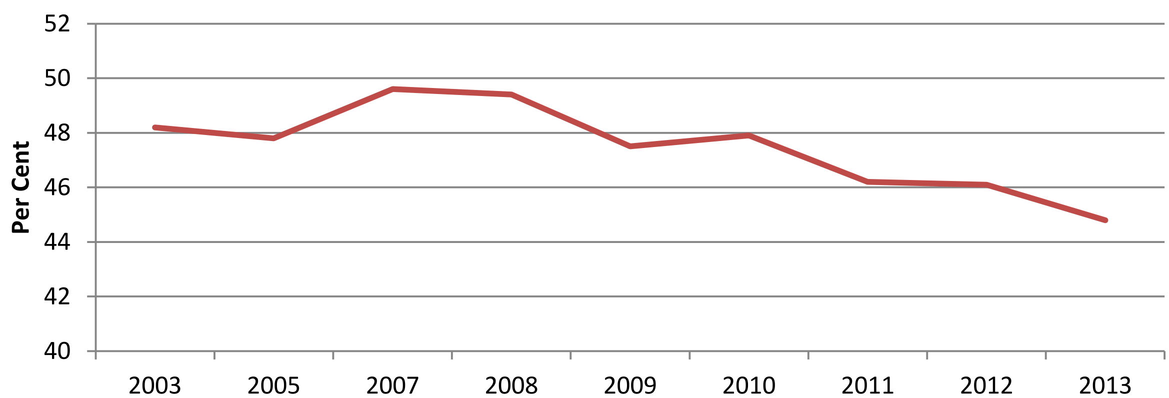
Appendix Chart 11: Canadian Population Consuming Fruits or Vegetables 5 or More Times per Day, 2003-2013, Per Cent



Source: Statistics Canada, CANSIM Table 102-0501. Figures represent a percentage of the Canadian population aged 12+.

Appendix Chart 12 depicts the percentage of the population which reports being physically inactive from 2003 to 2013. Physical inactivity has been on a decline from a peak of 49.6 per cent of the population in 2007 to a low of 44.8 per cent in 2013.

Appendix Chart 12: Physical Inactivity, Canada, 2003-2013, Per Cent



Source: Statistics Canada, CANSIM Table 102-0501. Figures represent a percentage of the Canadian population aged 12+.

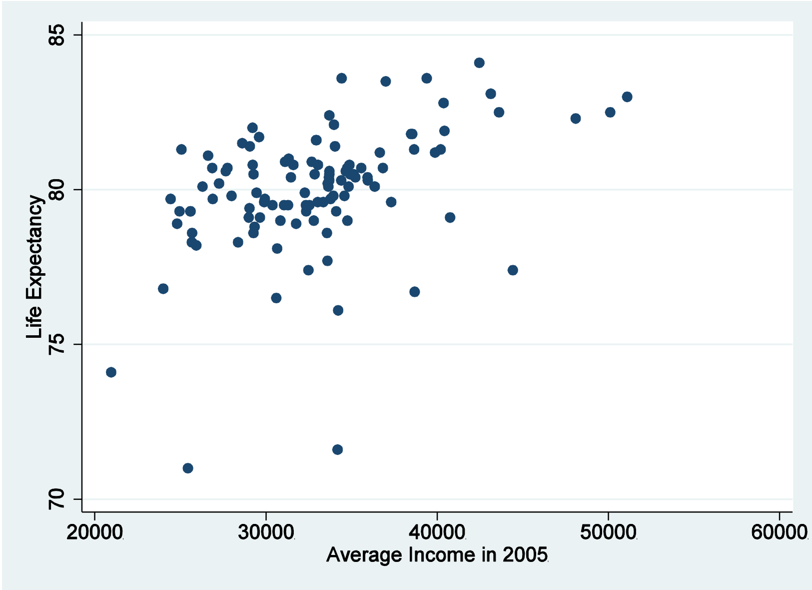
Most people will agree that heavy drinking, smoking, poor diet, and an inactive lifestyle pose significant health risks. Nonetheless, we observe many individuals choosing to continue these activities. From an individual's point of view, these decisions may very well be optimal given the individual's knowledge, incentives, and preferences, even if they come at the cost of an increased risk of poor health in the future. To the extent that individuals do not account for potential social costs of their actions, interventions to incentivize changes in behaviour may be justified. It is also possible that many individuals do not fully understand the health risks associated with their behaviour. To this end, the provision of credible and accessible research on the consequences of such behaviours remains a key component of empowering individuals to make well-informed choices.

ii. Income

Countries and subpopulations earning higher incomes tend to have longer life expectancies. A classic paper by Preston (1975) established this correlation at the national level across countries and over time and noted that the increase in life expectancy associated with an increase in real income per capita was much greater in poorer countries. At the national level, it is reasonable to think that this relationship reflects improvements in sanitation, nutrition, and health care as income rises. In wealthy countries where the most valuable health improving expenditures have already been made, rising incomes have less of an impact. Of course, these correlations at the national level may be spurious as income and life expectancy at the national level are correlated with many variables.

Those with greater incomes also tend to live longer within countries. Greenberg and Normandin (2011) find that life expectancy in Canada's highest income neighbourhoods exceeded that in the lowest income neighbourhoods. They find that life expectancy at birth for men in the 2005-2007 period was 75.6 years in the lowest income quintile neighbourhoods, 77.8 years in the second lowest income quintile, 78.7 years in the third lowest quintile, 79.1 years in the fourth lowest quintile, and 80.3 years in the highest income quintile. They find that the relationship between income and life expectancy exists for women as well, but the differences are smaller. In theory, universal healthcare should ensure that all Canadians have access to the same level of healthcare, but differences in health outcomes could arise in as a result of behavioural differences linked to income (drinking, smoking, diet, etc.), higher housing prices in neighbourhoods which offer health advantages (environment, safety, proximity to health care facilities), or greater health risks in low paying occupations. Much of the correlation may not be causal. For example, unhealthy individuals may not be as productive at work and could earn lower incomes on average as a result. Similarly, substance abuse problems could negatively impact health directly while also hindering an individual's labour market performance.

Appendix Chart 13: Income and Life Expectancy, Canadian Health Regions



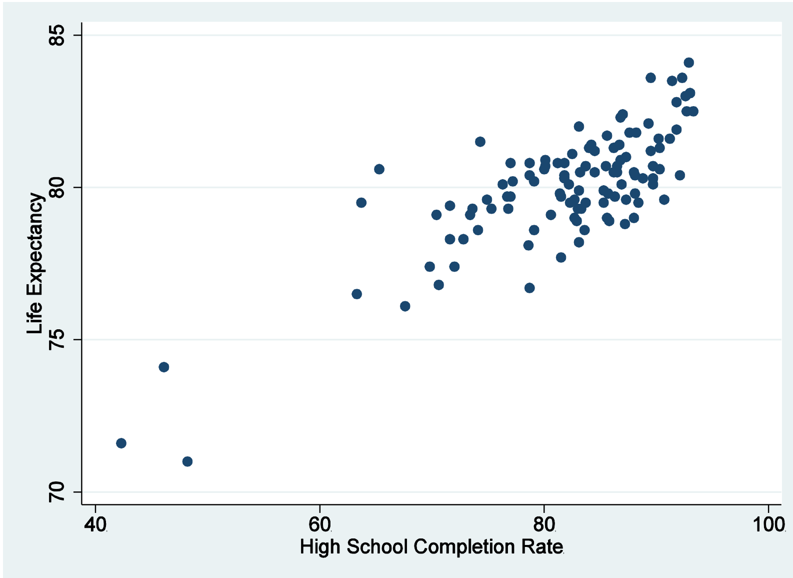
Source: Statistics Canada. Life expectancy at birth is calculated over the three year period 2007-2009 in CANSIM table 102-4307 and average income of the population 15+ comes from the 2006 Census and is available in CANSIM table 109-0300

iii. Education

One major factor which is correlated with both income and longevity is education. The positive correlation between the share of the population aged 25-29 which has completed high school and life expectancy depicted in Appendix Chart 14 is striking. In theory, high school completion provides individuals with basic skills and knowledge which can assist them in making better health choices. Of course, the close links between income, education, and the life style choices described above make it very difficult to tell how much improved educational attainment actually improves life expectancy compared to how other factors related to health improve one's chance of high school completion. Reverse causality is also potentially a factor, as the expected value of a higher level of educational attainment rises if one expects to live longer.[75]

[75] Indeed, recent studies have found evidence of changes in life expectancy impacting education decisions. For example, Oster et al. (2013) find that those with a mutation which causes Huntington disease (and thus have an exogenously shortened life expectancy) complete less education than those who are at equal risk ex ante but do not have the mutation.

Appendix Chart 14: High School Completion Rate of Population Aged 25-29 and Life Expectancy, Canadian Health Regions



Source: Statistics Canada. Life expectancy at birth is calculated over the three year period 2007-2009 in CANSIM table 102-4307 and high school completion rates of the population aged 25-29 comes from the 2006 Census and is available in CANSIM table 109-0300

iv. Environmental Factors

The environment in which one lives can have a significant effect on health. This is perhaps most evident in the large improvements in human longevity associated with the adoption of sanitation infrastructure in the nineteenth and early twentieth centuries.

Air and water pollution are potentially serious health issues. Exposure to high concentrations of substances such as lead or mercury can have a negative impact on health.

A large body of recent work has explored the link between particulate matter in the air and mortality from cardio-respiratory disease. The evidence suggests that air pollution has a significant impact on longevity. Chen et al. (2013) apply a quasi-experimental approach to estimate the negative impact of prolonged exposure to air pollution on life expectancy in China. They exploit the Huai River policy which provided free coal for heating to those living north of the Huai River but not to those living south of the river. They find that total suspended particulate concentrations are 55 per cent higher on average north of the river and that life expectancy is 5.5 years lower due to increased mortality from cardio-respiratory illness. Some studies have found that reduced pollution in American counties and metropolitan areas since the 1970s has had a notable impact on life expectancy (Pope et al., 2009; Correia et al., 2013). Correia et al. (2013) estimate that a reduction of fine particulate matter in a US county between

2000 and 2007 of ten micrograms per cubic meter was associated with an increase in life expectancy of 0.35 years.

There are also claims that increasing green space within urban areas can have a small positive effect on life expectancy, although the exact mechanism through which this operates is not entirely clear.

Another environmental factor which can impact life expectancy is climate. Extreme conditions in terms of precipitation or temperature can increase mortality rates. The impact of climate on life expectancy in developed countries is likely quite limited today, although it may have been an important factor in the past. Barreca et al. (2013) document a strong relationship between high temperatures and mortality rates in the United States in the early twentieth century. They find a massive decline in this relationship over the course of the century, which they attribute to the adoption of residential air conditioning.

v. Disasters and Disease Outbreaks

Major events which kill a lot of people clearly can have an impact on mortality rates. Natural disasters, wars, or outbreaks of disease can have a major direct impact on life expectancy, but in many cases the impact may only be temporary if the disaster only impacts mortality rates over a very short period of time. For example, if 5 per cent of the population dies in a war, that will significantly raise mortality rates in the year that the war occurs and will consequently have a negative impact on life expectancy within that year, but if mortality rates return to their pre-war levels in the next year, there will not be a long term impact on life expectancy.

However, major disasters may have persistent effects on the health of the population. If health related-infrastructure was damaged as a result of the disaster, people lost their homes, or individuals sustained serious injuries which impact their health in the future, then one-time disasters could have extended negative impacts on longevity.

vi. Laws / Cultural Norms

We have seen that several types of behaviour are related to human longevity. Rules and norms which constrain individual actions can impact life expectancy by altering behaviour. A classic example is the adoption of laws requiring the use of seatbelts which greatly improved survival rates from vehicular accidents. Regulatory requirements on restaurants, anti-pollution legislation, taxation of unhealthy behaviours, and requirements to post health relevant information on packaging are other examples of how a society’s legal framework can impact health.

Cultural differences can also matter. For example, Auger et al. (2012) document a French-English linguistic life expectancy gap in Quebec. Life expectancy at birth in the 2002-2006 period was 2.3 years higher for Anglophone men and 1.4 years higher for Anglophone women. The authors perform a decomposition of the gap by age and cause of death and found that tobacco related causes of death could explain most of the gap which is likely the result of higher smoking rates among Francophones.

vii. Infrastructure

Investments in infrastructure can have positive impacts on life expectancy. Historically, the construction of municipal sewer systems played a significant role in improving sanitary conditions and reducing the spread of disease. Investments in safer transportation infrastructure, such as the twinning of highways which eliminates the need to pass in the same lane as oncoming traffic, can reduce accidents and save lives.

viii. Access to and Quality of Healthcare

Timely access to high quality health care can be vital to prevent fatalities. Differences in the availability of health services can explain some variation in life expectancy. For example, there is widening gap in life expectancy between urban and rural populations in the United States Singh and Siahpush (2014). One reason for this gap is those living in rural areas often need to travel significant distances to get to the nearest hospital, and often the health facilities in rural areas are not as well-equipped to deal with uncommon medical problems.[76] Geographic proximity is important, but a sufficient number of qualified medical staff and medical equipment also need to be available to treat illness in a timely manner. Timely identification and treatment are important to reducing mortality rates.

The quality of health care received can also have a major impact on mortality. Advances in scientific knowledge and the development of more sophisticated medical technologies played a central role in the extension of life expectancy over the twentieth century. New medications provide simple cures to diseases which were once fatal. Modern surgical techniques and pharmaceuticals have significantly reduced the rate of death from heart attacks and strokes. Crémieux et al. (2005) find evidence of a link between spending on pharmaceuticals in Canada and increases in life expectancy for the population above retirement age.[77]

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[76] Of course, other socio-economic differences between the rural and urban populations will also have an effect.
[77] Although Guindon and Contoyannis (2012) challenge the robustness of this result.

ix. Limits to Longevity?

One fundamental issue is the extent to which future improvements in life expectancy are possible. A report by Canada's Office of the Chief Actuary (2014) projected future mortality trends. It reached the disappointing conclusion that, although living past age 90 will become much more likely than it has been in the past, it is unlikely that Canadian life expectancy will exceed 100 in the near future. If mortality rates continued to fall at the same pace as they have for the last 15 years, men could attain a life expectancy at birth of 100 years by 2094 and women could achieve the same life expectancy by 2121. However, the study is not optimistic that these rates of improvement can be maintained.

A major challenge to maintaining growth in life expectancy is that many of the "easy" improvements, such as greatly reducing infant mortality rates, have already been made. Most recent increases in longevity have been the result of lower mortality rates at the upper end of the age distribution. While progress has certainly been made, major extensions of life of reasonable quality at older ages are difficult because of aging itself. It is conceivable that there may be an upper bound on human longevity even if major causes of death such as cancer can be eliminated. If this is the case, than reducing mortality rates from one cause of death will only have a limited impact – people who are "too old" will likely just die of something else within a few years.

The difficulty in extending life expectancy by reducing mortality rates at advanced ages has been highlighted by what is known as the Taeuber Paradox (Keyfitz, 1977), which is the finding that even if a mortality due to a major cause of death, such as cancer, was completely eliminated, life expectancy would only increase by a few years because most of the older individuals who did not die from cancer would just die from another cause. Indeed, there are estimates of the potential years of life expectancy which could be gained by eliminating the major causes of death, and they are often disappointingly low. For the United States in 2008,Wang et al. (2013) estimate that the complete elimination of heart disease would have raised life expectancy by 2.13 year, elimination of cancer would have raised it 2.83 years, elimination of Alzheimer's disease would have raised it 0.13 years, elimination of kidney disease 0.16 years, and elimination of HIV/AIDS 0.08 years.

Motivated by the likely limited potential to extend life by eliminating specific diseases at old age, there have recently been some notable pushes for research aiming to tackle the more fundamental issue of aging itself. Google has recently made headlines by opening a research company, Calico (California Life Company), which is devoted to investigating technologies to mitigate age related diseases and to combat aging itself. Calico has partnered with AbbVie Pharmaceuticals to invest up to $1.5 billion (US dollars) in a new research centre. While technologies which attempt to counteract the negative effects of aging on health may one day provide the means for significant extensions to human longevity, at present the aging process is not well understood and such technologies remain in the realm of science-fiction.

Appendix Table 7: OLS Regression of Life Expectancy on Relevant Characteristics of the Population, Canadian Health Regions, 2008

	Life Expectancy
Per Cent Drinking	-0.0525**
(5 drinks in one day at least once each month over last year)	(0.0187)
Per Cent Overweight or Obese	-0.0366
	(0.0229)
Per Cent Smoking	-0.0767**
(daily or occasional)	(0.0281)
Per Cent Consuming Enough Fruits and Vegetables	0.0398*
(5 times or more per day)	(0.0173)
Per Cent With a Regular Doctor	0.0194
	(0.0124)
Per Cent with High Blood Pressure	-0.0384
	(0.0380)
Per Cent Active	-0.0671***
(Moderately Active or Active)	(0.0139)
Per Cent with a Sense of Belonging to Community	-0.0177
	(0.0154)
Per Cent Female	0.0243
	(0.181)
Average Income	0.0000475
	(0.0000268)
High School Completion Rate	0.0812**
(of population aged 25-29)	(0.0252)
Long-term Unemployment Rate	-0.0593
	(0.0442)
Per Cent Living in Rural Areas	0.0313**
	(0.0113)
Per Cent Living in Large Centre	0.0106
(100,000+ people)	
Per Cent Living in Medium Size Centre	0.00439
(30,000 – 99,999 people)	(0.00798)
Constant	76.35***
	(8.777)
N	103
adj. R^2	0.847

Heteroskedasticity robust standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Data at the Health Region level come from CANSIM Tables 102-4307 (Life Expectancy), 109-5335 (male and female populations), 105-0501 (health characteristics and correlates), and 109-0300 (demographic characteristics of health region from Census. The reader should be aware of a couple potential sources of error. First, some of the demographic variables come from the 2006 Census while other variables used data from 2008. We expect most of the variables to be highly persistent over time, so this is likely not a significant problem. Second, there are some small differences in some health region boundaries between the different tables as some use 2011 boundaries while others use 2013 boundaries. Health regions which could not be clearly matched across all sources have been dropped, most notably most of the health regions in British Columbia.