An Analysis of the Relationship between Healthcare Spending And Health Outcomes: A Data Analytics Perspective Using The Theory of Production Functions

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Abstract

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This research investigates the relationship between per capita spending on healthcare and population health outcomes at the provincial level in Canada using data from 1980 to 2010. The health outcomes examined include life expectancy at birth and at age 65, number of infant deaths, and potential years of life lost from treatable causes, all of which are separated by gender. Using analytics methods as an application of the theory of growth accounting, the study evaluates the performance of the provincial health care systems in terms of their ability to efficiently produce longevity. The study also specifies the categories of healthcare spending which are most influential in determining the efficient production of longevity and measures the contribution of healthcare spending to the determination of infant mortality and deaths from treatable causes. The methods employed include Data Envelopment Analysis, Decision Tree Induction, and Multivariate Adaptive Regression Splines. The results of the analysis point to the fact that Canada's provinces operate inefficiently in their production of health outcomes and confirm the importance of healthcare spending to determining health outcomes in Canada.

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1. Introduction

Improving healthcare delivery while containing costs is a major issue in many developed countries (Chatal, André, Joumard, & Nicq, 2008; Nam, Kongsrud, Joumard, & Price, 2004; Nicq, Joumard, & André, 2010; Or, 2000, 2001; Worthington, 2004). Since the creation of its universal healthcare program, Canada has managed the goal of providing universal coverage to citizens as costs have continued to rise over time. The Canadian Institute for Health Information reports that, as a percentage of gross domestic product, health spending has grown from 5.4% in 1960 to more than 10% in 2015 (that is $4,569 per person in 2015 dollars) (CIHI, 2015a; Inglehart, 2000). The policy changes which have structured the Canadian health system paint the picture of the importance of health spending and costs in the country.

The narrative of Canada's public healthcare system can be segmented into three acts: the program's founding, the implementation of the Canada Health Act within the era of incremental funding cuts, and the modern era of incremental, progressive reform. The foundation of Canada's healthcare system occurred in 1957 with the federal legislation of hospital care and related diagnostic services with medical insurance being added in 1968 (Inglehart, 2000). By 1971 all provinces and territories were participating in the program in which they received federal cash transfers for agreeing to provide universal coverage (Inglehart, 2000; Naylor, 1999).

In the late 1970s a combination of price inflation, caps on fee increases, and growth in the supply of physicians in urban markets combined to reduce doctors' real income. Some doctors responded to these conditions by charging patients beyond the government negotiated fee schedule. The Canadian Health Act was implemented in 1984 in major part to prohibit supplemental fees through a stipulation in which federal transfers would be reduced to provinces that allowed them, as well as to consolidate previous healthcare policy pieces (Inglehart, 2000; Naylor, 1999). Within two years all provinces abolished supplemental/non-negotiated medical fees, creating the economic characteristics which define the healthcare system to this day; monopsonistic (single-buyer) publicly financed health insurance with private model fee-for-service care provision (Hutchison, Levesque, Strumpf, & Coyle, 2011; Naylor, 1999).

While the era of financial austerity can be defined separately from that of the establishment of the Canada Health Act, in policy terms they began concurrently. The change in federal contributions to healthcare financing began in 1977 with a shift in the 50/50 cost sharing scheme between the federal and provincial governments. This left the provinces carrying a larger segment of health costs if those costs grew more rapidly than the size of the overall economy.

Though the budget cuts and financing rearrangements of the late 70s were an incremental step meant to regulate medical spending, reductions continued into the 80s that were intended to reverse the trend of ongoing government budget deficits. The economic recession of the early 90s also warranted continued reductions in spending at both the federal and provincial levels.

It is claimed that there were several negative effects of this era (Hutchison et al., 2011; Inglehart, 2000; Naylor, 1999). These include a reduced number of Canadian medical and nursing school enrolments, the conversion of many full-time nursing positions to part-time or on-call between 1993 and 1997, restricted purchasing of medical equipment, and a reduction in hospital beds due to the amalgamation and closing of facilities. These issues contributed to reduced public opinion concerning the quality of and satisfaction with the nation's healthcare system.

These conditions, combined with the emergence of a significant budget surplus at the end of the 90s set the correct political climate for progressive policy reform. In 2000 the First Ministers of Canada established an $800 million Primary Care Transition Fund for healthcare reform. An additional $16 billion federal investment was earmarked for primary healthcare, home care, and catastrophic drug coverage in the 2003 First Ministers Health Accord.

Since then, several policy initiatives have occurred in multiple jurisdictions across the country. These include:

"inter-professional primary healthcare teams, group practices and networks, patient enrollment with a primary care provider, financial incentives and blended-payment schemes, primary healthcare governance, expansion of the primary healthcare provider pool, implementation of electronic records, and quality improvement training and support."

(Hutchison et al., 2011, p. 264).

Based on this recount it would appear that, as a function of the public, single-payer model, economic policy has played a pivotal role in the narrative of Canada's healthcare system. Hutchison et al. (2011) argue that the recent provincial health reform efforts showing the most success have required high amounts of financial investment. Therefore the quantitative analysis of health funding allocation is important to deciding the optimal distribution of limited resources. In this thesis I offer a method for determining the efficiency of the healthcare spending in Canada’s provinces and also define the categories of healthcare spending which are most significant to determining the production of health outcomes in Canada.

1.1 The Scope of This Research

This research empirically analyzes health outcomes as a function of nine categories of per capita healthcare spending using thirty years of data from Canada’s ten provinces. All variables in the analysis are standardized and spending is specifically in 2015 dollars. The categories of healthcare spending are spending on hospital, institutions, physicians, other professionals, drugs, capital, public health, administration, and other spending.

The first phase of the analysis is separated into two parts. Part one models longevity (gender separated life expectancy at birth and life expectancy at age 65) as a function of the nine categories of health spending. This phase focuses on scale efficiency and resource allocation using data envelopment analysis and decision tree induction.

Phase two uses identical procedures to model infant mortality (gender separated number of infant deaths) and death from treatable causes (potential years of life lost due to deaths from treatable causes). Phase two focuses solely on resource allocation using multivariate adaptive regression splines. Overall, the results of the analysis provide evidence on which categories of healthcare spending are most influential in determining the observed levels of the separate measures of health outcomes.

1.2 Research Approach

This study is causal research using statistical techniques to examine longitudinal data and explore the relationships between separate categories of healthcare spending and different measures of population health. This is inductive research which makes inferences based on an examination of correlations between the observed values of independent and dependent variables. This inductive framework is approached by defining a production function in which each category of healthcare spending operates as a factor of production while the individual measures of health outcomes function as outputs. Multivariate regression analysis reveals relationships between spending and health outcomes, while a technical efficiency analysis provides a framework for comparing the performance of each of the provinces. The specific methods used in this process are multivariate adaptive regression splines (MARS), decision tree induction, and data envelopment analysis (DEA).

1.3 Research Goals

The goal of this research is to analyze the patterns of healthcare spending in Canada's provinces for two reasons. The first is to provide evidence as to which provinces have been most efficient in their allocation of funding. The second is to determine which categories of healthcare spending should be prioritized in improving specific health outcomes.

Based on this, the overarching research questions are

1. “How effectively have Canada’s provinces spent their healthcare funding?” and
2. “How should spending be prioritized in order to improve health outcomes?”

The results yielded from answering the first research question provide a framework that allows the second question to be interrogated as well.

1.4 Thesis Format

This thesis is formatted into seven chapters. Chapter Two is a literature review examining evidence-based decision making, data analytics, and the application of analytics techniques to the healthcare context. Chapter Three outlines the theoretical framework used to approach the research, the research methods used in the analysis and a description of the data being analysed. Chapters Five and Six contain the empirical analysis and the discussion of findings respectively. The thesis is then concluded in Chapter Seven with a discussion of the limitations and contributions of the research effort.

2. Literature Review

This literature review examines the study of the economic production of health outcomes through the application of growth accounting theory. These type of studies have a set of commonly used measures of performance which are applicable to healthcare systems. According to Worthington (2004), economists have developed three measures efficiency for use in the analysis of health system performance. Technical efficiency refers to the use of resources in the most productive manner. With regard to the healthcare context, technical efficiency is used to describe the relationship between healthcare resources (e.g. finances, staff, and equipment) and observable health outcomes. Allocative efficiency refers to the combination of specific proportions of resources that are used to achieve technical efficiency. At the hospital level, this could be explained as the mix of staff, equipment, and drugs used to efficiently treat patients. Productive efficiency is a measure of the combination of both technical and allocative efficiency. Productive efficiency is limited by the extent to which allocative and technical efficiency are maximized and therefore technical and allocative efficiency must be maximised to achieve maximum productive efficiency.

In terms of early applications of growth accounting theory to health production, Grossman (1972) provides a health production function for estimating health outcomes based on an individual's investment in their own health. In this model, investment in health is a function of medical care, time spent investing in health, and education. Grossman's (1972) claim is that the purpose of an individual investing in their health is to produce time spent in good health.

The literature examining the production of healthcare outcomes argues that the estimation of the performance of healthcare systems using technical methods is often undertaken, but is also not a simple task. Gravelle & Backhouse (1987) offer a macroeconomic approach to the study of health production. The authors dissect the production function approach used in studies of mortality rates using international data with the goal of demonstrating the difficulty of such analyses. Their findings confirm the validity of the approach but also emphasize that the estimation of the influences on mortality using production functions is not a simple task. The authors claim that at the international level, aggregated data may complicate analyses due to differences in data quality and missing data. This applies to data on health service provision and environmental variables. Regardless of the difficulty, there are several examples of studies which attempt to define the relationship between health spending and other inputs and health outcomes using production functions.

I proceed to first explain the relevant concepts within the theory of growth accounting and productivity. I then discuss examples of studies which apply growth accounting theory to study the production of health outcomes (internationally and within Canada). After this, I specify the health production function that will be used in this thesis.

2.1 Growth Accounting and Production Functions

The primary theoretical framework used in the study of health production is the economic theory of growth accounting as introduced by Robert Solow (1956). Applications of growth accounting are used to explain the relationship between factors of production (e.g. the classical inputs land, labor, and capital) and the productivity and growth (i.e. improvements in the creation of output) of economies. To elaborate, an economy is any system defined by the consumption of inputs and production of outputs within it. Growth accounting is concerned with the mathematical explanation of how the factors of production in an economy are used to modify that economy's productive abilities.

The basic model of growth accounting takes the form of the neoclassical production function which is defined mathematically as $Y=f(A,K,L)$. **Figure 1** depicts a graphical representation of the neoclassical production function. In this relation, output (Y) is a function of a combination of the inputs total factor productivity/technology (A), labour (L) and capital (K). Here, technology is used to broadly capture all processes (i.e. methods and techniques) and factors (i.e. knowledge, etc.) that influence the transformation of inputs to outputs. Broadly, capital can be understood as the wealth and physical resources that are consumed in the production of output, while labour can be understood as the physical work that is performed by persons during production.

The Cobb-Douglas production function is a form of the neoclassical production function that allows the equation to be applied to additional situations. (Cobb & Douglas, 1928). The Cobb-Douglas production function is defined as $Y= AL^{\alpha}K^{\beta}$. The terms α and β correspond with the level of elasticity (i.e. the sensitivity to change) of labour and capital respectively. The usefulness of the Cobb-Douglas function come from the inclusion of these measures of elasticity as they facilitate an analysis of returns to scale. In other words, the inclusion of α and β in the Cobb-Douglas function allows for an examination of how changes to inputs (labour and/or capital) affect an economy's output.

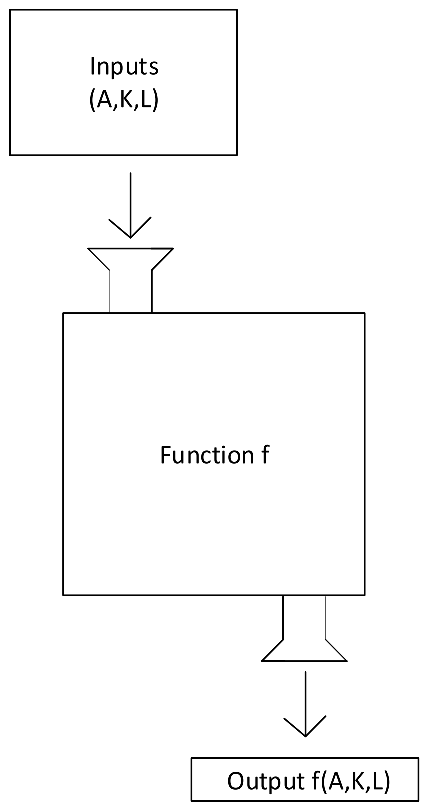

Figure 1: Diagram of the neoclassical production function

An economy's returns to scale may be decreasing, increasing or constant. In an economy operating at decreasing returns to scale (DRS), $\alpha + \beta < 1$. This means that an equivalent increase in both inputs will correspond with an increase in output that is smaller in magnitude than the increase in inputs 1 (e.g. a 10% increase in labour and capital generates a 5% increase in output). Likewise, in an economy operating at increasing returns to scale (IRS) $\alpha + \beta > 1$, and an equivalent increase in both inputs will correspond with an increase in output that is greater in magnitude than the increase inputs. An economy operates at constant returns to scale (CRS) when $\alpha + \beta = 1$ meaning that an increase in both inputs will correspond with a proportionate increase in output. The next section discusses the application of growth accounting theory to the study of the economic production of health outcomes.

2.2 The Study of Health Production

There is a significant body of literature which has explored the production of health outcomes and the factors which determine the efficiency and productivity of health systems. (Chatal et al., 2008; Hollingsworth, 2003, 2008; Hollingsworth, Dawson, & Manidakis, 1999; Worthington, 2004). At the macro level, cross-country analyses have been performed to examine the efficiency of health spending, and the monetary and contextual influencers on health outcomes (Chatal et al., 2008; Joumard & Häkkinen, 2007; Nicq et al., 2010). Comparative analyses have taken place in multiple instances examining different jurisdictional levels (both within and across nations) and utilizing both cross-sectional and longitudinal data to interrogate the determinants of health (Berger & Messer, 2002; Chatal et al., 2008; Nixon & Ulmann, 2006; Retzlaff-Roberts, Chang, & Rubin, 2004).

Elola, Daponte, & Navarro (1995) perform a comparative analysis relating different health system models (social security versus national health service) to health indicators (gender separated potential years of life lost, gender separated life expectancy, and infant mortality) in 17 countries in Western Europe. The results of their regression analysis indicate that, in both types of health systems, spending was inversely correlated with potential years of life lost for females and infant mortality rates. They also claim that spending was positively correlated with life expectancy. The authors conclude that increases in health spending as a percentage of GDP would decrease infant mortality rates more efficiently in countries with a national health service than in countries using social security systems.

Or (2000) develops a health production function to examine the differences in the health outcomes within 21 OECD member nations using data from between the years 1970 and 1992. In the regression analysis, health outcomes (i.e. potential years of life lost due to all causes except suicides) are modeled as a function of medical variables (total health expenditure per capita, share of public health spending, gross domestic product) and non-medical variables (i.e. work force composition, pollution, consumption of alcohol, tobacco, fat and sugar). The results indicate a positive relationship between health spending and health outcomes, and the significance of environmental factors in determining health outcomes in the countries examined.

Using a regression analysis, Berger & Messer (2002) model health outcomes (mortality rate per 1000 population) as a function of health spending, insurance coverage, health behaviors (alcohol consumption, consumption of fat, tobacco consumption), and other variables in 20 OECD member nations. Their results indicate that tobacco use, alcohol use, fat consumption, and female labor force participation are all significantly related to mortality rates. Interestingly the authors also conclude that higher income inequality leads to lower mortality rates, and that increases in public health spending also lead to increased mortality rates.

Retzlaff-Roberts et al. (2004) perform a comparative, technical efficiency analysis of the relationship between spending and the production of life expectancy and infant mortality in several OECD member nations. Using both input and output oriented models of data envelopment analysis, the authors attempted to determine which of the 27 countries included was performing at the highest level of technical efficiency. The analysis revealed that while some of the countries were outperforming others in the efficiency of healthcare spending and their ability to generate positive health outcomes, the nations which performed moderately in the production of health outcomes were still achieving technically efficiency in their spending.

Nixon & Ulmann (2006) use a log-linear production function to study health outcomes in 15 members of the European Union. The authors highlight the micro and macro level approaches to the production functions that are used in studying the relationship between health spending and contextual factors (e.g. diet, lifestyle, economic status), and health outcomes; electing to perform a macro-level analysis of 16 years of aggregated data. Their results confirm previous findings that since the 1980s increased healthcare spending has had a reduced impact on improving health outcomes in developed countries. In contrast, they also note that increased health spending has contributed to lowering infant mortality rates.

Joumard & Häkkinen (2007) define a theoretical framework for the evaluation of health production in OECD member nations. The authors also provide three approaches and to implementing this framework depending on the analysis being undertaken and the availability of data. The approaches are the aggregate/system level approach, the disease level approach and the subsector level approach (i.e. hospital, outpatient care, nursing homes etc.).

The authors argue that while the scope of each approach distinguishes them from one another, data availability is a primary limiting factor in these types of analyses. This leads to the claim that while the commonly used indicators of health status are not the best (i.e. life expectancy), they are used because they are more widely captured than more optimal indicators. **Figure 2** illustrates the theoretical model proposed by Joumard & Häkkinen (2007).

Chatal et al. (2008) develop a health production function to examine the monetary and contextual determinants of health status in the OECD area using both data envelopment analysis and panel data regression. The variables examined include contextual variables (tobacco consumption, alcohol consumption, diet, air pollution, education) and economic variables (health care resources per capita and gross domestic product per capita). In this work, it is acknowledged that the contribution of private spending to healthcare outcomes is both significant and extremely difficult to disentangle from public sector spending in these types of analyses. The results of the regression analysis reinforce logical assumptions on the correlations between smoking, alcohol consumption, diet, pollution, education and GDP with health outcomes. Additionally, the data envelopment analysis results reveal that increases in spending efficiency are likely to significantly contribute to increased life expectancy among OECD member nations. Nicq et al. (2010) present indicators for use in a cross-country health system level analysis based on the goals of raising population health status and improving equity in access. The authors adopt the theoretical model first proposed by Joumard & Häkkinen (2007). Using data envelopment analysis, the authors measure the efficiency of health care delivery across several OECD member nations in a production function that relates health inputs in terms of financial resources to health outcomes. The results of the study indicate that an increase in the absolute amount of spending would cause negligible changes in life expectancy without improvements in the efficiency of spending. I now move on to discussing these types of analysis as performed using data from the Canadian health system.

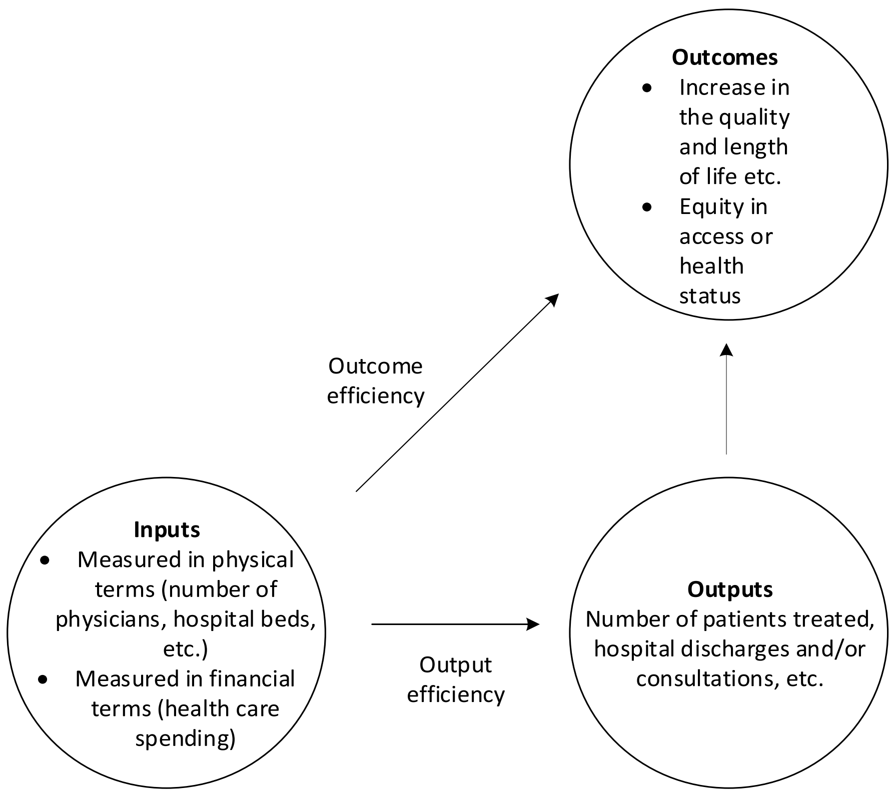

Figure 2: Framework of health efficiency measurement by Hakkinen & Joumard.

2.3 Canadian Context

Hanratty (1996) performs an analysis of the impact of national health insurance in Canada on infant health. The author uses panel data from 1960-1975 in regression models model outcomes as a function of the timing of the program's introduction across the country. The results link the implementation of national health insurance to improvements in the country's infant health measures.

At the provincial level, Crémieux, Ouellette, & Pilon, (1999) model gender-separated infant mortality and life expectancies as functions of spending, demographic, lifestyle, nutrition and province specific characteristics in a regression that uses pooled time-series cross-section data from 1978 to 1992. The results indicate that lower healthcare spending is correlated with increases infant mortality and decreases in life expectancy. The authors argue that their findings are strengthened by the homogeneity of their data. This claim is made in comparison to analyses performed using heterogeneous cross-country data which were unable to find strong correlations between health spending and health outcomes.

Bilodeau, Crémieux, Jaumard, Ouellette, & Vovor (2004) perform data envelopment analysis to measure the technical efficiency of hospitals in Québec. They specify a function that includes both discretionary and nondiscretionary inputs; meaning inputs that are within the control of the hospitals (discretionary) and those that are not (nondiscretionary). This is done to reduce bias created by missing variables. Their results indicate that there observed inefficiencies was attributable to differences in management and quality of care between hospitals.

Crémieux et al. (2005) use a regression model that focuses on the contributions of non-drug spending, pharmaceutical spending (public and private), and contextual variables (population density, poverty, per capita income, alcohol consumption, tobacco consumption, food and non-alcoholic beverage consumption). This analysis examines data from the years 1981 to 1988 in five regions of Canada (the Atlantic Provinces, Quebec, Ontario, the Prairies and British Columbia). The results indicate a strong relationship between increased public and private drug spending and improvements in infant mortality and life expectancy.

Day & Tousignant (2005) contribute a review of the academic literature which uses the production function method to examine the determinants of health status in Canada. The authors also discuss some of the problems that apply to performing this type of analysis at the cross-country level as discussed by Gravelle & Backhouse (1987). Of specific interest to this research are the problems of deciding on a measure (or measures) of health status, obtaining data on the inputs used to produce health, and the specification of the health production function's form. Day & Tousignant (2005) also argue that there are not many examinations of the Canadian healthcare system performed using the methods discussed above.

2.4 Summary of Literature Review

In this review of literature I introduced important concepts to the economic study of health outcomes. I first explain the theory of growth accounting and then identified several examples of papers that apply this theory to create production functions that explore the relationship between health spending and other relevant variables, and health outcomes. There are several examples of these papers in the international context which confirm that public and private spending on health care are important determinants of health outcomes. Canadian studies using more homogenous data have confirmed this relationship as well. Additionally, international studies have evaluated the effectiveness with which healthcare spending has contributed to health outcomes in terms of efficiency.

Based on these findings, this thesis will contribute an evaluation of the efficiency of health spending in Canada. Additionally, a gap in the literature appears to exist in terms of studies that identify how healthcare spending should be prioritized. That is there is a lack of research that directly discusses which components of overall healthcare spending are most important to determining health outcomes. In response, this thesis will examine the question of how healthcare spending should be prioritized.

3. Methods and Data

The study of health production relies on statistical techniques which apply growth accounting theory to examine the relationship between health spending and non-spending inputs, and the production of health outcomes. In this thesis, I focus on health spending and apply statistical techniques with two goals: to provide evidence as to which of Canada's provinces have been most efficient in their allocation of funding, and to determine which categories of healthcare spending should be prioritized in improving specific health outcomes. To achieve these goals I ask two research questions:

1. "How effectively have Canada's provinces spent their healthcare funding?" and
2. "How should spending be prioritized in order to improve health outcomes?"

These research questions are answered in two steps:

1. Specifying and applying a model for determining the efficiency of the healthcare spending in Canada's provinces;
2. Defining the categories of healthcare spending which are most significant to determining the production of health outcomes in Canada's provinces;

This chapter describes the techniques and dataset used to complete this analysis. Next I specify the health production function for use in this thesis.

3.1 Defining a Health Production Function

I now specify define a production function which relates healthcare spending to healthcare outcomes (Chatal et al., 2008; Or, 2000). This thesis uses a production function adapted from work performed by Chatal et al. (2008) to examine OECD member nations. Additionally, I adopt a modified definition of health outcomes provided by Joumard & Häkkinen (2007). In the original definition health outcomes are “changes in health status of the population which can be attributed to public spending on healthcare” (Joumard & Häkkinen, 2007, p. 5). For the purpose of this thesis I have included both private and public healthcare spending contributions in the analysis. This has been done to account for the non-negligible contribution of private healthcare expenditure in Canada (Chatal et al., 2008; CIHI, 2015b; Crémieux et al., 2005).

The health outcomes examined in this analysis are life expectancy at birth, life expectancy at age 65, Deaths from treatable causes, and infant mortality. Each outcome measure has been gender separated. This raises the total number of models examined to eight. All eight models consider nine inputs, each representing a separate category of healthcare spending. The function is specified as follows:

$$\begin{aligned} \mathrm{Y_{it}} = \ & \beta_0 + \beta_1 \cdot \mathrm{HOSP_{it}} + \beta_2 \cdot \mathrm{INST_{it}} + \beta_3 \cdot \mathrm{PHYS_{it}} + \beta_4 \cdot \mathrm{OPRO_{it}} + \beta_5 \cdot \mathrm{DRUG_{it}} + \beta_6 \cdot \mathrm{CAPT_{it}} \\ & + \beta_7 \cdot \mathrm{PUBH_{it}} + \beta_8 \cdot \mathrm{ADMN_{it}} + \beta_9 \cdot \mathrm{OTHR_{it}} + \varepsilon \end{aligned}$$

Where Y_{it} (output) is a measure of population health in province i, year t. In each model Y corresponds with either:

- Life expectancy at birth (LEB)

- Life expectancy at age 65 (LE65)
- Potential Years of Life Lost Due to Deaths from Treatable Causes (PYLLTC)
- Infant mortality measured in Number of Infant Deaths per year

The inputs are defined as per capita spending on hospitals (HOSP), other institutions (INST), physicians (PHYS), other professionals (OPRO), drugs (DRUG), health capital (CAPT), public health (PUBH), administration (ADMN), and other spending (OTHR). All spending values have been standardized to their value in 2015 dollars. This model allows for the decomposition of the relationship between health spending and the health outcomes specified above. This model does not control for non-spending contextual the variables that are often examined in studies which evaluate the health. A full description of the sources of data in this thesis will be given in a later point of this chapter. Moving on, I describe the techniques applied in this research.

3.2 Methods

The methods used in this study have been selected for their usefulness in applying the established growth accounting framework and their validity as applied data analytics techniques. These methods facilitate a quantitative, longitudinal examination, allowing for an explanation of how each category of health spending has influenced population health outcomes. The methods used in this study include Data Envelopment Analysis, decision trees, and multivariate adaptive regression splines. The next section discusses the details of DEA.

3.2.1 Data Envelopment Analysis

Data envelopment analysis (DEA) is a statistical method for evaluating the technical efficiency of a set of similar economies or production units. A DMU is conceptually equivalent to an economy or production unit that consumes input(s) to create output(s). When applying DEA to a set of DMUs, all of the DMUs are evaluated comparatively to reveal which are the most efficient. The method can be applied in a wide variety of contexts as demonstrated throughout the efficiency measurement literature, including the study of health systems and the production of health. This is because applying DEA does not require previous knowledge on the factors which affect production processes that the DMUs represent (Coelli & Coelli, 2005; Cooper, Seiford, & Zhu, 2010; Hollingsworth et al., 1999).

While methods of regression focus on creating a function which defines the central tendency (i.e. average behaviour) of observations, DEA is an extreme point method. This mean that it focuses on creating a spline (a linear mathematical function) that defines the most technically efficient production processes observed (Cooper et al., 2010).

It is important to understand that technical efficiency is a context specific interpretation of efficiency. When a DMU is determined to be technically efficient in a single application of DEA this is based on its performance relative to the other DMUs included in the analysis. A DMU that is technically efficient in one analysis will is not necessarily efficient in general. Also, the DMUs which are selected as technical efficient in an application of DEA are the units who cannot improve their performance beyond what they have already achieved. This is based on the criteria that a technically efficient DMU cannot increase its productive ability by modifying the consumption of any of its inputs or outputs without modifying the consumption any of its other inputs or outputs.

The basic mathematical model for DEA is based on an extension of the work of Farrell (1957) and is named the CCR model after its developers Charnes, Cooper and Rhodes (1978). Farrell was originally attempting to improve upon previous productivity measurement methods that were restrictive and ineffective at measuring the combination of multiple inputs into multiple outputs.

In DEA we assume that DMU_j consumes x_{ij} amounts of input i and produces y_{rj} amount of output r. We also assume $x_{ij} \geq 0$ and that $y_{rj} \geq 0$ and also assume that each DMU has at least one positive input value and at least one positive output value.

The CCR DEA model measures the relative efficiency of $DMU_j = DMU_o$ by using a ratio of all its observed inputs and outputs. The CCR model simplifies this by combining the multiple outputs and inputs of a DMU into one “virtual” output and one “virtual” input. This ratio of output to input provides a measure of efficiency which is a function of the multipliers u_r and v_i and is maximized. Mathematically this equation can be stated as follows:

$$\mathrm{Max}\ h_o(u, v) = \sum_{o} u_r y_{ro} / \sum_{o} v_i x_{io}$$

Where

- u_r corresponds with observed output,
- v_i corresponds with the observed input,

- y_{ro} represents the observed amount y of output r produced by DMU_o from the input amount x_{io}
- and x_{io} is the observed amount of input i consumed in order to produce y amount of output r by the DMU_o
- DMU_o is the DMU being evaluated

A full development of the CCR model replaces $u_r, v_i \geq 0$ with $\frac{u_r}{\sum_{i=1}^{m} v_i x_{io}}, \frac{v_r}{\sum_{i=1}^{m} v_i x_{io}} \geq \varepsilon > 0$ where ε is a non-Archimedean element smaller than any positive real number. This transformation guarantees a positive solution in the variables but also gives an infinite number of solutions. The Charnes and Cooper (1962) transformation, developed by the authors after which it is named, is used to select a single solution and changes the variables (u, v) to (μ, ν)

$$\max z = \sum_{r=1}^{s} \mu_r y_{ro}$$

subject to

$$\max z = \sum_{r=1}^{s} \mu_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0$$

$$\sum_{i=1}^{m} v_i y_{rj} = 1$$

$$\mu_r v_i \geq 0.$$

The Farrel model is the corresponding linear programming model and is defined as follows:

$$\theta^* = \min \theta$$

Subject to

$$\sum_{j=1}^{n} x_{ij}\,\lambda_j \;\leq\; \theta x_{io} \;\; i = 1,2,\dots,m;$$

$$\sum_{j=1}^{n} y_{rj}\,\lambda_j \;\leq\; \theta y_{ro} \;\; r = 1,2,\dots,s;$$

$$\lambda_j \;\geq 0 \qquad\qquad j = 1,2,\dots,n.$$

Where θ^* is the efficiency score for a particular DMU. This equation ignores non-zero slacks (left over inputs), meaning that any DMUs it deems to be efficient $(\theta^* = 1)$ are by definition weakly efficient. A strongly efficient DMU will have both an efficiency score equal to one and slacks equal to zero. In order to address the issue of non-zero slacks, the following linear programming model can be used.

$$\max \sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+$$

Subject to

$$\sum_{j=1}^{n} x_{ij}\,\lambda_j \;+\; s_i^- \;=\; \theta^* x_{io} \;\; i = 1,2,\dots,m;$$

$$\sum_{j=1}^{n} y_{rj}\,\lambda_j \;+\; s_r^+ \;=\; \theta^* y_{ro} \;\; r = 1,2,\dots,s;$$

$$\lambda_j, s_i^-, s_r^+ \geq 0 \forall i, j, r$$

Where s_i^- and s_r^+ are slack variables that do not affect θ^*. The next equation demonstrates the same principles above but using a ratio of input to outputs and is minimised. This is called an output orientation.

$$\text{Min} \frac{\sum_i v_i x_{io}}{\sum_r u_r y_{ro}}$$

Subject to

$$\frac{\sum_i v_i x_{ij}}{\sum_r u_r y_{rj}} \geq 1 \text{ for} j = 1, \ldots, n,$$

$$u_r, v_i \geq \varepsilon > 0$$

Applying the Charnes and Cooper transformation gives

$$\min \; q = \sum_{i=1}^{m} v_i x_{io}$$

Subject to

$$\sum_{i=1}^{m} v_i \, x_{ij} - \sum_{r=1}^{s} \mu_r y_{rj} \geq 0$$

$$\sum_{r=1}^{s} \mu_r y_{ro} = 1$$

$$\mu_r, v_i \geq \varepsilon \; \forall r, i$$

$$\max \varphi + \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$$

Subject to

$$\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = x_{io} \quad i = 1,2, \dots, m;$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = \varphi y_{ro} \quad r = 1,2, \dots, s;$$

$$\lambda_j \geq 0 \qquad\qquad j = 1,2, \dots, n.$$

Here φ^* represents the efficiency score of a DMU. Under this orientation, a DMU is only efficient when $\varphi^* = 1$ and $s_i^{-*} = s_r^{+*} = 0$ for all i and r and is only weakly efficient if $\varphi^* = 1$ and $s_i^{-*} \neq 0$ and/or $s_r^{+*} \neq 0$. The following linear programming problem uses an output orientation as part of a two-step problem involving the previous equation. In the first step φ^* is calculated while ignoring slacks. In the second step using the next equation, slacks are optimized by fixing φ^*.

$$\max \sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+$$

Subject to

$$\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = x_{io} \quad i = 1,2, \dots, m\,;$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = \varphi^* y_{ro} \; r = 1,2,\ldots,s;$$

$$\lambda_j \geq 0 \; j = 1,2,\ldots,n.$$

Table 1 summarizes the dual linear equations which correspond with the CCR model. By adding a constraint $\sum_{j=1}^{n} \lambda_j$ they become the BCC model which adds the variable μ_o and allows for the evaluation of returns to scale. Because of this the CCR model is known as the constant returns to scale (CRS) model and the BCC model is known as the variable returns to scale model (VRS).

Different constraints based on assumption of returns to scale can be applied in DEA. **Figure 3** illustrates a set of seven DMUs, each using one input (X) to produce one output (Y). The set of which DMUs which are considered to be performing efficiently depend on what constraint is applied. This means that different efficiency scores for a single DMU may be generated based on which constraint is applied. Under the assumption that all DMUs are operating at constant returns to scale (the CCR model), U2 would be the only DMU operating efficiently. Under the constraint of variable returns to scale (BCC model) the efficient DMUs would include U1, U2, U3, and U4. Under the assumption that all DMUs are operating at constant returns to scale (the CCR model), U2 would be the only DMU operating efficiently. Under the constraint of variable returns to scale (BCC model) the efficient DMUs would include U1, U2, U3, and U4.

Input-oriented CCR Model	
Envelopment model	**Multiplier Model**
$\min \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$ subject to $\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta x_{io} \quad i = 1,2,\dots,m$ $\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = y_{ro} \quad r = 1,2,\dots,s;$ $\lambda_j \geq 0 \quad j = 1,2,\dots,n.$	$\max z = \sum_{r=1}^{s} \mu_r y_{ro}$ subject to $\max z = \sum_{r=1}^{s} \mu_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0$ $\sum_{i=1}^{m} v_i y_{rj} = 1$ $\mu_r v_i \geq \varepsilon > 0$
Output-oriented CCR Model	
Envelopment model	**Multiplier model**
$\max \varphi + \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$ Subject to $\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = x_{io} \quad i = 1,2,\dots,m;$ $\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = \varphi y_{ro} \quad r = 1,2,\dots,s;$ $\lambda_j \geq 0 \quad j = 1,2,\dots,n.$	$\min\ q = \sum_{i=1}^{m} v_i x_{io}$ Subject to $\sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} \mu_r y_{rj} \geq 0$ $\sum_{r=1}^{s} \mu_r y_{ro} = 1$ $\mu_r, v_i \geq \varepsilon > 0$

Table 1: DEA CCR Model

As a technique within the application of DEA, efficiency scores generated by imposing different returns to scale constraints can be used to examine returns to scale in terms of efficiency (a concept called scale efficiency). Specifically, by comparing the efficiency scores generated for a single DMU under multiple constraints, one can determine whether the DMU is operating at IRS, DRS or most productive scale size. When a DMU is operating at its most productive scale size within this framework, it cannot improve its productivity by modifying any of its inputs of outputs.

This is because the two different models create different envelopment surfaces based on their constraints. The envelopment surface corresponds with the set of DMUs which are deemed efficient. In the CCR model this envelopment surface consists of a line from the origin and through U2 (the red line in **Figure 2**). In the BCC model the envelopment surface consists of U1, U2, U3 and U4 (the blue line in **Figure 2**).

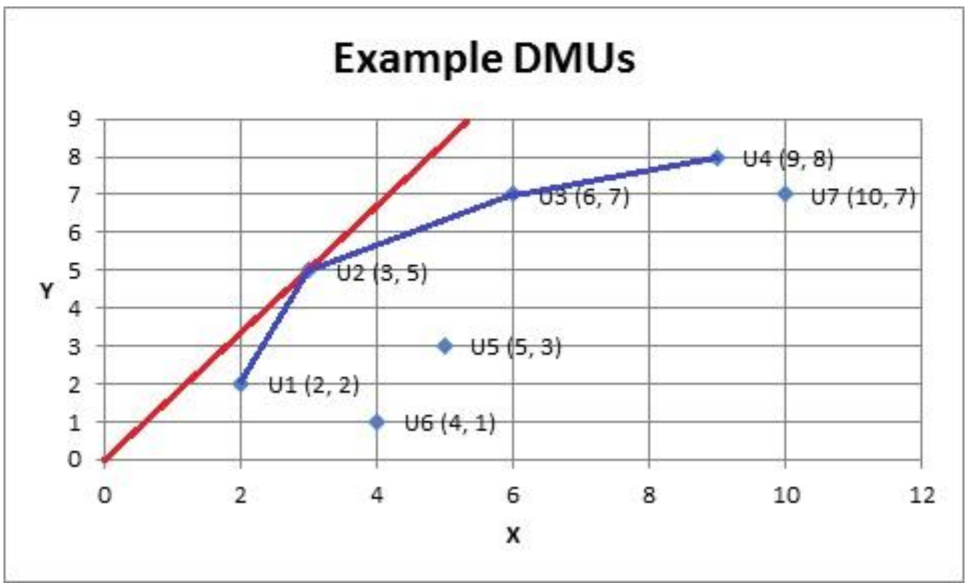

Figure 3: Graphic example of DMUs and envelopment surfaces

In addition to the constraints applied by the BCC and CCR models, the input and output orientations of DEA provide more criteria under which DMUs are evaluated. In the input orientation the goal is to minimize the use of inputs. Graphically this would represents a horizontal shift of DMUs towards the envelopment surface. Under the output orientation the goal is to augment output. This is graphically represented by the vertical movement of DMUs towards the envelopment surface. Ultimately, DMUs determined to be efficient in one orientation will also be efficient under the other orientation.

I will now provide a condensed summary of all of the above. First, DEA generates efficiency scores by comparing a set of decision making units (economies or production units) to each other based on their usage of resources. In the input orientation of DEA, efficient DMUs minimize their use of inputs while maintaining their output. In this orientation efficiency scores are calculated by calculating a ratio of all of a DMU's outputs to all of that DMU's inputs.

In the output orientation, the goal is to maximize output while holding input constant. In this orientation, efficiency scores are generated by calculating a ratio of a DMU's inputs to its outputs. In both orientations, an efficiency score of 1 or 100% indicates that a DMU is technically efficient. As DEA is a comparative method, it measures efficiency in a context specific sense. That is, a DMU which is deemed efficient in a DEA analysis is only efficient relative to the other DMUs included in that analysis.

As well, the type of efficiency that is measured when applying DEA is also determined by the constraint of returns to scale being imposed on the included DMUs (i.e. the DMUs may be assumed to be operating at constant returns to scale, variable returns etc.). Finally, in order for a DMU to be considered strongly efficient in DEA, it must have zero slacks, meaning it has no left over inputs. Otherwise, that DMU can only be considered weakly efficient. With these concepts established I now move on to an explanation of decision trees.

3.2.2 Decision Tree Induction

Decision trees (DT) are a category of predictive induction algorithms which take their name from their visual resemblance to an inverted tree. In simpler terms, decision trees are used to describe datasets in terms of a set of rules, visualized to resemble a flow chart. Additionally, while decision trees are based on a finite amount of observed data, a decision tree can be used to make predictions outside of these observations based the rules that it composes.

Decision trees are used in the prediction of both continuous and nominal variables (Breiman, 1998; Osei-Bryson, 2014a). **Figure 4** provides a visual example of a DT. The method is useful for partitioning datasets based on observed differences in the quantitative or qualitative characteristics of different parts of the dataset. When used for multiple regression, the method can also be used to provide information on the importance of its independent variables.

The first node in a decision tree is called the root node and contains all of the observations within the dataset being analysed. Each node stemming from this root node corresponds with a partition in the dataset that it analyzes. These are collectively referred to as decision nodes or leaf nodes. The terminology used to relate the leaf nodes within a decision tree is akin to that used to describe relationships in a family. A node which other nodes stem from is called a parent node, while the nodes which stem from a parent node are called child nodes. Likewise, child nodes which stem from the same parent are referred to as siblings.

Decision trees in which the splitting rules only allow for the creation of two child nodes are known as binary trees. Binary trees do not necessarily correspond with the best way to partition a dataset for visual interpretation, but they also do not necessarily detract from the strength or accuracy of a DT model.

A classification tree is a DT in which the target variable corresponds with nominal or categorical variables, while a regression tree is a DT in which the target variable is continuous. In a RT, each node corresponds with the mean value and standard deviation of the target variable. For both types of DT each leaf describes the logic of an “if-then” rule.

The conditions of the rule, which correspond with the value of independent variables, are denoted by the branches connecting the root of the DT to the given leaf. A DT algorithm is implemented by selecting a single target/dependent variable and multiple related predictor/independent variables.

The process of DT generation involves a Growth Phase and an optional Pruning Phase which use separate portions of the overall dataset. With large datasets the generation of a DT involves splitting the data into either two or three parts (Training and Validation or Training, Validation, and Test) to avoid over-fitting. For small datasets, cross-validation allows for the entire dataset to be used for both the Growth and Pruning Phases. These phases are both described in the next two sections.

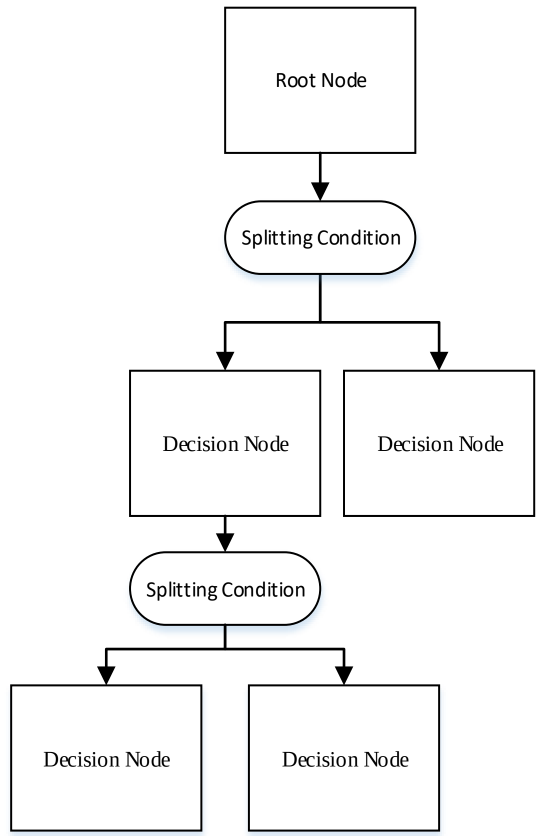

Figure 4: Visualization of a Decision Tree

Growth Phase

The Growth Phase involves generating a DT from the Training data in which each leaf node is associated with a single class, or where further division of a leaf would result in the number of observations in one or both child nodes being below a pre-specified threshold.

The Training data is continuously divided into smaller, more homogenous subsets targeting the dependent variable. The selected induction algorithm automatically decides how to divide the data by considering what variable to split, what the best split is, and when to stop splitting.

The part of the induction algorithm which determines both the independent variables to select for a given leaf, and the values of variables used to partition leafs into mutually exclusive subsets is called the splitting method. For classification trees, these include Chi, Gini, and various entropy-based methods while for regression trees, these include variance reduction and F-test.

There is no universally optimal splitting method for the best results from a dataset as datasets vary in sensitivity to different methods. Because of this it is important to explore the effects of different splitting methods in order to obtain the best DT.

Pruning Phase

The Pruning Phase generalizes the un-pruned DT that was generated in the Growth Phase to avoid over-fitting the final DT to the training data. In this phase, the un-pruned DT is evaluated against the Validation data subset. To do this, a sub-tree is created from the un-pruned DT from the Growth Phase with the lowest error rate in comparison to the Validation data, a tree that is not independent of the Training data or Validation data. Because of this, the sample distribution of observations in the Validation data must correspond with the population distribution of observations. The next section describes the Multivariate Adaptive Regression Splines technique.

3.2.3 Multivariate Adaptive Regression Splines

Multivariate Adaptive Regression Splines is a technique of inductive regression analysis used for examining the causal relationships between quantitative variables. The name of the technique indicates that it is a technique for multiple regression (regression using multiple independent variables) which adapts to the data being analysed. The technique allows the dataset that it analyses to determine the form of the function it generates by creating a piecewise function over the data's decision space (the observed values of independent variables in the dataset). The method is helpful for determining which of the independent variables in a multiple regression are most useful in explaining the variation in the dependent variable, for examining interactions between independent variables, and, in larger datasets, can make these observations in the presence of missing values (Friedman, 1991; Osei-Bryson, 2014b).

Regression Splines Model

The nature of a MARS regression equation is such that it is composed of multiple basis functions (BFs) smoothly connected at knots. Graphically, this appears as a piecewise polynomial functions with kinks where each basis function meets another. The behavior of a MARS function changes at each knot, and each knot is generated based on the data set being analyzed. **Figure 4** provides a graphic example of a MARS model. In MARS, the relationship between a single dependent variable X_t and independent variable Y_t takes the form:

$$Y_t = \sum_{k=1}^{M} a_k B_k(X_t) + \varepsilon_t$$

Where $B_k(X_t)$ is the kth basis function of X_t. Similar to linear regression, the coefficient of each basis function is estimated by minimizing the sum of square errors.

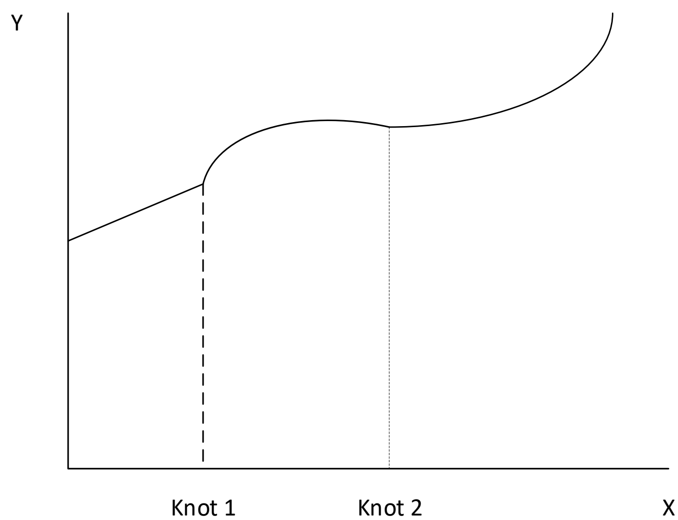

Figure 4: Graph of a MARS model

Basis Functions

A MARS model which does not allow for interactions between independent variables contains only simple/elementary basis functions while a model which allows for variable interactions contains complex basis functions.

A simple basis function consists of a single variable x and comes in the form of either $(x - t)_+$ or $(t - x)_+$ where t is the knot, $(x - t)_+ = (x - t)$ if x is greater than t, and is equal to zero otherwise; and $(t - x)_+ = (t - x)$ if x is less than t and is equal to zero otherwise (Osei-Bryson, 2014b). BF1 and BF2 in **Table 2** are examples of simple basis functions.

Simple Basis Functions	Complex Basis Function
BF1 = MAX(0, VAR_1 – 0.1) BF2 = MAX(0, 0.1 – VAR_1) BF1 is equal to (VAR_1 – 0.1) only if VAR_1 is greater than 0.1 and is otherwise equal to zero. BF2 is equal to (0.1 – VAR_1) only if 0.1 is greater than VAR_1 and is otherwise equal to zero.	BF3 = MAX(0, VAR_2 – 0.1) x BF2 = MAX(0, VAR_2 – 0.1) * MAX(0, 0.2 – VAR_1) BF3 is equal to the product of MAX(0,VAR_2-0.1) and BF2

Table 2: Explanation of Simple and Complex Basis Functions

A complex basis function takes the form $h_k(x)$ = Πijfij(x_{ij}) where x_1, …x_q are the independent variables and f_{ij} is a BF for the i_{th} independent variable x_i at jth knot. Complex basis functions are the product of at least two simple basis functions. A MARS model that includes complex basis functions demonstrates how independent variables may affect one another. BF3 in **Table 2** is an example of a complex basis function.

Model Generation and Final Model Selection

A MARS model is built in two steps, the Forward Stage and the Backward Stage. The Forward Stage begins with a constant to which BFs are added recursively until the model reaches a pre-specified limit. Each BF added in this stage corresponds with the variable-knot combination which most improves model performance given the BFs already within the model.

The Backward Stage takes the largest model created in the Forward Stage and removes the basis function in it which contributes the least to model performance. The removed basis function is selected based on a residual sum of squares criteria. The new model is then refitted and the process of basis function elimination is repeated again based on the same residual sum of squares criteria until all BFs have been eliminated. This results in a sequence of models which function as candidates for the selection of a final model.

In MARS, final model selection may be based on two different criteria. In cases where a subset of the data is used for training the model, the similarity in the mean squared error (MSE) of models in the test and training data subsets is used as selection criteria. Otherwise, generalized cross-validation (GCV) is used.

R-Squared Statistic

In a regression model, the R-Squared statistic, also known as the coefficient of determination, is a measure of the proportion of variance in the dependent variable that is predicted by the independent variable(s) used in the regression. The statistic is generated based on the value of the variables used to construct the regression model it describes. In simpler terms, the R-Squared is a measure of performance that describes how well a regression model is able to predict values of the dependent variable.

R-Squared scores range from zero to 1 with a higher score indicating better model performance. An R-Squared score can also be interpreted as a percentage. For a model with an R-squared of 0.713 explains 71.3% of the variance in the dependent variable.

Each of the MARS models generated in this analysis will have corresponding R-Squared statistics. These R-Squared values will be used to describe the models' performance and to discuss how well the spending categories that are included in the models as independent variables have been able to predict the health outcomes chosen for analysis. The next section describes the dataset examined in this analysis.

3.3 Description of Data

I will now proceed to describe the dataset used in this analysis. The data is derived from two sources. The use of funds categories which serve as the independent variables in the health production function are taken from the Canadian Institute for Health Information (CIHI) National Health Expenditure (NHEX) database. All of the population health indicators which serve as dependent variables were taken from the Canadian Socio-economic Information Management (CANSIM) System hosted by Statistics Canada (Stat Can).

Data availability restrictions limited the possibilities for panel analysis to the year 1979 at the earliest for all output variables. For estimates of life expectancy, the latest data is available to the year 2007. The latest data for both deaths from treatable causes and the included infant mortality measures are available up to the year 2011. Input variables were available from the year 1975 to 2013 with additional estimated values for the years 2014 and 2015.

Based on these restrictions, this analysis will include the three decades of data between 1980 and 2010 in the examination infant mortality and deaths from treatable causes, and will examine the years 1980 to 2007 for the measures of life expectancy.

3.3.1 Population Health Outcome Indicators

Below, the definitions of life expectancy, deaths from treatable causes, and infant mortality have been transcribed as they appear in the footnotes of the relevant tables within the CANSIM database. Life expectancy data was taken from CANSIM tables 1020025 and 1020512. Data on gender separated potential years of life lost from treatable causes was taken from CANSIM table 1024312. Data on the number of infant deaths was taken from table 1020030.

Life expectancy

Statistics Canada describes life expectancy as "the number of years a person would be expected to live, starting at birth (for life expectancy at birth) or at age 65 (for life expectancy at age 65) if the age- and sex-specific mortality rates for a given observation period (such as a calendar year) were held constant over the estimated life span." According to StatsCan, "life expectancy is calculated using annual mortality rates by Greville's method for abridged life tables, with five-year age groupings of population and mortality rates."

Deaths from treatable causes

In this analysis, the evaluation of preventable deaths will be completed by using the number of potential years of life lost from treatable causes. “Potential years of life lost (PYLL) is the number of years of potential life not lived when a person dies "prematurely", defined for this indicator as before age 75.”

Additionally, cause of death in this dataset is defined as the “underlying cause of death.” According to StatsCan “This is defined as (a) the disease or injury which initiated the train of events leading directly to death, or (b) the circumstances of the accident or violence which produced the fatal injury. The underlying cause is selected from the conditions listed on the medical certificate of cause of death.”

Infant mortality

According to StatsCan “Infant mortality corresponds to the death of a child less than one year of age.” This research utilizes data on the number of infant deaths. According to StatsCan “death refers to the permanent disappearance of all evidence of life at any time after a live birth has taken place. Stillbirths are excluded.”

3.3.2 Healthcare Use of Funds Categories

All descriptions for use of funds categories have been transcribed exactly as they appear in the CIHI’s NHEX Methodology Notes (CIHI, 2015b).

Hospitals – Institutions where patients are accommodated on the basis of medical need and are provided with continuing medical care and supporting diagnostic and therapeutic services. Hospitals are licensed or approved as hospitals by a provincial/territorial government, or are operated by the government of Canada, and include those providing acute care, extended and chronic care, rehabilitation and convalescent care, and psychiatric care, as well as nursing stations or outpost hospitals.

Other institutions – Include residential care types of facilities (for the chronically ill or disabled, who reside at the institution more or less permanently) and that are approved, funded or licensed by provincial or territorial departments of health and/or social services. Residential care facilities include homes for the aged (including nursing homes); facilities for persons with physical disabilities, developmental delays, psychiatric disabilities and alcohol and drug problems; and facilities for emotionally disturbed children. Facilities solely of a custodial or domiciliary nature and facilities for transients or delinquents are excluded.

Physicians – Expenditures include primarily professional fees paid by provincial/territorial medical care insurance plans to physicians in private practice. Fees for services rendered in hospitals are included when paid directly to physicians by the plans. Also included are other forms of professional income (salaries, sessional, capitation).

The physicians expenditure category does not include the remuneration of physicians on the payrolls of hospitals or public-sector health agencies; these are included in the appropriate category, for example, hospitals or other health spending. Physician expenditures generally represent amounts that flow through provincial/territorial medical care plans.

Provinces/territories differ in terms of what the medical care plans cover. CIHI has not attempted to make adjustments to physician expenditures to reflect these differences because only a few provinces, to date, can net out these differences from their data.

Drugs – At the aggregate level, include expenditures on prescribed drugs and non-prescribed products purchased in retail stores. Estimates represent the final costs to consumer including dispensing fees, markups and appropriate taxes.

The drugs category does not include drugs dispensed in hospitals and, generally, in other institutions. These are included with the category of hospitals or other institutions. The classification system is consistent with international standards developed by the Organization for Economic Co-operation and Development (OECD).

Capital – Includes expenditures on construction, machinery, equipment and some software of hospitals, clinics, first-aid stations and residential care facilities. It is based on full-cost or cash-basis accounting principles.

Public health – By governments and government agencies, includes expenditures for items such as food and drug safety, health inspections, health promotion activities, community mental health programs, public health nursing, measures to prevent the spread of communicable disease and occupational health to promote and enhance health and safety at the workplace in public-sector agencies.

Administration – Expenditures related to the cost the cost of providing health insurance programs by the government and private health insurance companies and all costs for the infrastructure to operate health departments. The administrative costs of operating hospitals, drug programs, long-term care programs and other non-insured health services are not included under the category of administration, but rather are included under the category of service, for example hospitals, other institutions and drugs

Other health spending – At the aggregate level includes expenditures on home care, medical transportation (ambulances), hearing aids, other appliances and prostheses, health research and miscellaneous healthcare. Some of the subcategories of the aggregate category are defined as follows:

Health research – Expenditures for research activities designed to further knowledge of the determinants of health, health status or methods of providing healthcare, or evaluation of healthcare delivery or of public health programs. The category does not include research carried out by hospitals or drug companies in the course of product development. These amounts would be included with either the hospitals or drugs category.

Other – Expenditures for items such as home care, medical transportation (ambulances) hearing aids, other appliances, training of health workers and voluntary health associations.

4. Empirical Analysis

4.1 Procedure

The research questions being asked in this thesis are “How effectively have Canada’s provinces spent their healthcare funding?” and “How should spending be prioritized in order to improve health outcomes?” I answer these questions using an empirical analysis of healthcare spending data and health outcomes which:

3. Specifies a model for determining the efficiency of the healthcare spending in Canada’s provinces;
4. Defines the categories of healthcare spending which are most significant to determining the production of health outcomes in Canada’s provinces.

In this section I outline the procedure used to answer these research questions, describe the dataset being examined, and summarize the output of the analysis. In this analysis effectiveness is measured by analyzing the efficiency with which Canada’s provinces have consumed healthcare spending to produce longevity. The specific focus is on scale efficiency analyzed across all 28 years of data, and in a year by year analysis.

In addition to analyzing scale efficiency, I will produce a ranking of categories of health care spending based on their importance in determining each province’s efficiency level. This ranking is provided by applying the decision tree induction method to the results of the data envelopment analysis. In other words, the first two steps of the analysis will evaluate how efficiently each province has been to produce longevity and will determine the categories of healthcare spending that are most significant in determining this efficiency.

In addition to the analysis of efficiency, an additional analysis of the influence of healthcare spending on deaths from treatable causes and infant mortality will be performed. I will first focuses on the categories of healthcare spending which determine the level of deaths from treatable causes in each province. This is done by applying the multivariate adaptive regression splines technique to model the relationship between healthcare spending and deaths from treatable causes. This same technique is used to model the relationship between infant mortality healthcare spending. Next I give a more detailed description of the entire analysis.

<u>DEA Scale Efficiency Analysis of Longevity</u>

Figure 5 illustrates the logic model of the procedure used in the analysis of longevity. In the analysis, estimates of life expectancy are used as outputs in a production function where each category of spending is treated as a separate input. The first step is to examine the efficient production of longevity over the entire 28 year dataset using the Efficiency Measurement System (EMS) DEA software.

In this step, each province in each year is treated as a separate decision making unit (DMU) or unit of production. Ten provinces in each of the 28 years of data total 280 DMUs. These DMUs are evaluated by comparison to one another to determine their relative efficiency in producing the included estimates of longevity. These estimates of longevity are female life expectancy at age 65 (FLE65), female life expectancy at birth (FLEB), male life expectancy at age 65 (MLE65), and male life expectancy at birth (MLEB).

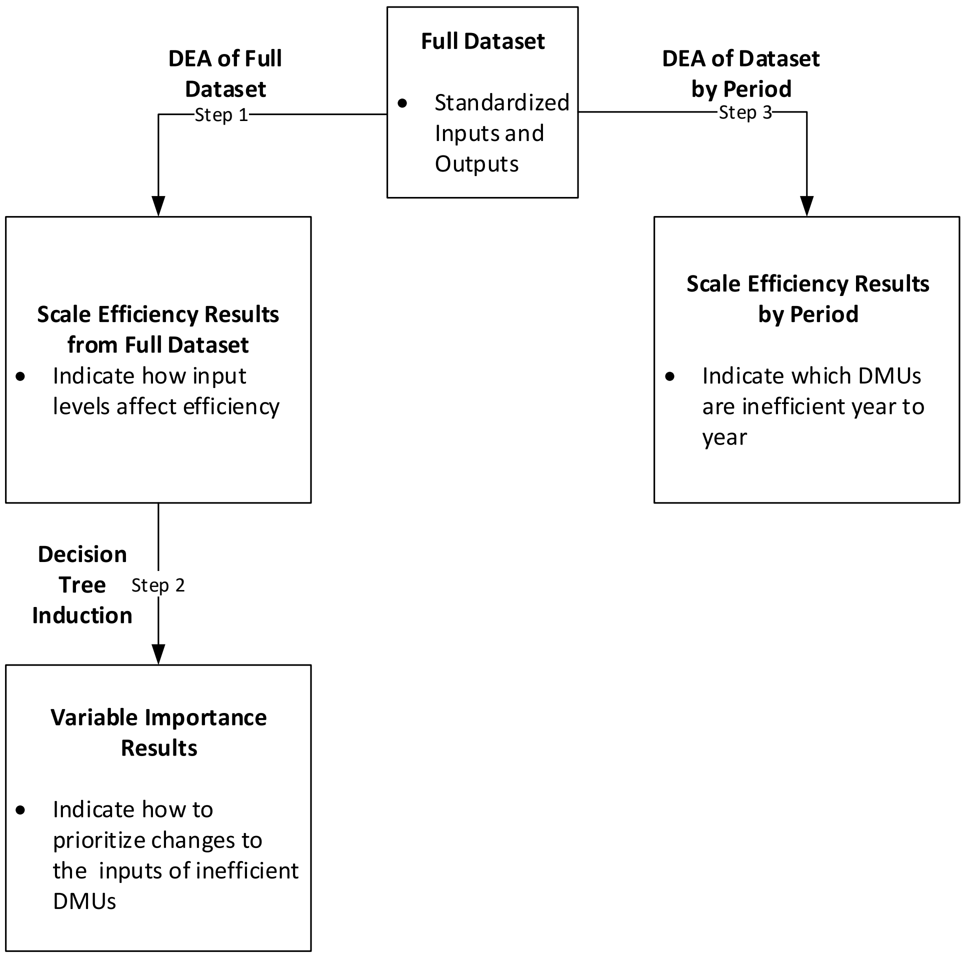

Figure 5: Logic Model of DEA Scale Efficiency Analysis

A total of three input-oriented DEA models are used in this analysis. Input orientation DEA models assume that each DMU is attempting to produce the most output with the least amount of input. These models are constant returns to scale (CRS), variable returns to scale (VRS), and non-increasing returns to scale (NIRS). Each of the three DEA models assumes different constraints regarding the efficiency of production for each DMU and may produce unique efficiency scores for the same DMU. Efficiency scores range in value from 0 to 100%. These assumptions correspond with the name of each model. The constant returns to scale model assumes that A DMU consumes one unit of input for each unit of output produced. The VRS model assumes that a DMU may produce greater or fewer than one unit of output for each unit of input consumed. The NIRS model indicates the point at which a DMU has maximized its consumption of inputs.

By comparing the efficiency scores from each DEA model we can determine the level of scale efficiency of each DMU. A DMU with a CRS efficiency score of 100% and a VRS efficiency score of 100% is operating at its most productive scale size. When a DMU has CRS efficiency score that is less than its VRS score but equal to its NIRS score, that DMU is operating at increasing returns to scale (IRS). When a DMU has a CRS score that is less than its VRS score and less than its NIRS score, that DMU is operating at decreasing returns to scale. The three possible levels of scale efficiency are most productive scale size (MPSS), decreasing returns to scale (DRS) and increasing returns to scale (IRS). A DMU operating at MPSS is operating efficiently. A DMU operating at increasing returns to scale consumes too few inputs to produce an efficient level of output. A DMU operating at DRS consumes inputs above the level of its production of output. This fulfills the goal of determining the performance of the provinces in terms of efficiency.

In the next step, the results of the scale efficiency analysis are inputted into the Salford Predictive Modeller (SPM) software to generate decision trees. These decision trees are generated by including the healthcare spending data as input and the scale efficiency results as output. The decision trees produced in this analysis are classification trees. These classification trees focus on defining the level of healthcare spending that corresponds with a province operating at its most productive scale size and rank the importance of each category of healthcare spending in determining whether or not a province is operating at its most productive scale size. These rankings fulfill the goal of defining t

In addition to the scale efficiency analysis in which the provinces were compared over 28 years, a second scale efficiency analysis was completed. In this analysis, the provinces' production of longevity was examined year by year. Each province was one of ten DMUs comparatively analyzed in each of the 28 years of data obtained for the measures of longevity. That is, 28 analyses were performed in which each of the 10 provinces were compared to each other using the same procedure described above. This allowed for an evaluation of the scale efficiency of each provinces year over year. As discussed, the next phase examined the influence of spending on infant mortality and deaths from treatable causes. These procedures will be discussed in the next section.

MARS Variable Importance Analysis of Longevity, Infant Mortality & Deaths from Treatable Causes

Identical procedures are used to examine infant mortality & deaths from treatable causes. Each province in each year was treated as a unique observation in the economic production of infant mortality and deaths from treatable causes. In these production functions the amount of spending in each category was used as one of nine independent variables. The SPM MARS software was used to determine the variable importance rankings for each of these production functions, and to determine the coefficients and knot points of the variables.

Applying MARS allows for interactions between variables which creates complex basis functions within a model. Two-way variable interactions were enabled for the MARS analyses in order to examine how each category of spending interacted with each other. The results of the MARS analysis also report on the performance of each of the models in terms of R-squared scores. An R-squared score corresponds with the accuracy of the model. In this case the R-squared scores provide information on the ability of per capita spending to predict infant mortality and PYLL. Moving on, the next section summarizes the descriptive statistics of the data set under analysis.

4.2 Descriptive Statistics

In this section I provide a simplified description of trends in Canada's provincial healthcare spending and health outcomes between 1980 and 2010. Given the richness of the dataset that is under analysis, it is beyond the scope of this thesis to fully explore all of the trends in healthcare spending and health outcomes. For our purposes I aim to explain the general trends that appear in the dataset. There are a full set of charts and summary statistics of per capita healthcare spending for each of Canada's provinces is included in **Appendix A**, and **Appendix B** contains charts and summary statistics for each of the health outcomes analyzed in this thesis. We proceed by examining common trends in spending across Canada. Afterwards I provide a description of trends in longevity, infant mortality, and deaths due to treatable causes.

Trends in Per Capita Provincial Healthcare Spending

This summary describes trends in per capita provincial healthcare spending. A full set of graphs and summary statistics describing healthcare spending data in each of Canada's provinces is available in **Appendix A**. Per capita spending has increased across all categories of healthcare spending in Canada's all provinces between 1980 and 2010. The size of each province's per-capita spending appears to correspond with the size of the province; larger provinces have higher levels of spending in comparison to smaller provinces.

It appears that the distribution of spending within each category moved in a similar manner from province to province. Capital spending is the only category that varies greatly in each province over the 31 years examined. For example in Newfoundland, spending on capital stayed below $50 per person until 1999 where it more than doubled to over $100 per person and doubled again in the next year, continuing in a parabolic pattern until 2010. This can be contrasted with spending in Ontario where there is a relatively gradual upward trend in Capital spending 1980 and 2010, or Manitoba where Capital spending has fluctuated and there are several peaks and valleys in capital spending patterns. From year to year, spending on hospitals appears to form the largest segment of total health spending within all provinces while spending on administration forms the smallest. Average spending on hospitals from 1980 and 2010 is more than double the amount of the next closest category in all provinces.

Spending on Administration likely forms the smallest segment of healthcare spending because it this category only includes spending on health insurance programs and health department infrastructure. The administrative costs of operating hospitals, drug programs, long-term care and non-insured services are not included. These summarize the common and noteworthy trends in health spending within the provinces. Next I discuss patterns within the health outcome data beginning with longevity.

Health Outcomes: *Longevity*

I will now summarize trends in gender separated measures of longevity. A full set of charts covering and summary statistics covering all of the health outcomes examined in this thesis is available in **Appendix B**. Data on female life expectancy at age 65 is available in **Table 3**. **Table 4** contains data on female life expectancy at birth**.** Data on male life expectancy at age 65 is available in **Table 5**. **Table 6** contains the data on male life expectancy at birth**.**

Year	NL	PEI	NS	NB	Qc	On	Mn	Sk	Ab	BC	Average
1980	18.0	18.5	18.0	18.5	18.5	18.8	19.1	19.9	19.4	20.0	**18.9**
1981	18.9	20.2	18.6	19.2	19.0	19.0	19.2	20.1	19.3	19.9	**19.3**
1982	18.4	20.9	18.8	19.3	18.8	18.9	19.2	19.6	19.4	19.7	**19.3**
1983	18.1	19.6	19.0	19.1	18.7	19.0	19.6	20.3	19.7	20.3	**19.3**
1984	18.5	19.1	18.7	19.2	19.0	19.3	19.8	20.3	20.0	20.0	**19.4**
1985	18.5	19.6	18.8	19.8	19.1	19.1	19.7	20.1	19.8	19.9	**19.4**
1986	18.3	19.5	18.9	19.3	18.9	19.1	19.6	20.2	19.6	20.2	**19.4**
1987	19.0	19.7	19.1	19.4	19.2	19.5	20.0	20.2	20.2	20.1	**19.6**
1988	18.5	19.9	19.2	19.7	19.3	19.4	19.8	20.6	19.8	20.0	**19.6**
1989	18.9	20.4	19.1	19.6	19.6	19.5	19.9	20.8	20.2	20.2	**19.8**
1990	18.4	19.3	19.2	19.9	19.8	19.8	20.0	20.5	20.4	20.2	**19.8**
1991	18.5	19.8	19.7	20.2	19.9	19.7	19.9	20.7	20.3	20.4	**19.9**
1992	18.9	19.9	19.5	19.7	19.8	19.8	20.2	21.1	20.4	20.3	**20.0**
1993	19.1	20.1	19.6	19.7	19.7	19.7	20.1	21.0	20.2	20.4	**20.0**
1994	19.1	19.8	19.6	19.9	19.8	19.8	20.0	20.8	20.3	20.4	**20.0**
1995	18.9	20.2	19.6	19.9	19.8	19.9	19.9	20.8	20.2	20.5	**20.0**
1996	18.8	19.9	19.4	19.8	19.9	19.9	19.9	20.7	20.4	20.5	**19.9**
1997	18.7	20.4	19.6	19.9	19.9	20.0	20.0	20.7	20.4	20.6	**20.0**
1998	18.8	19.9	19.7	20.0	20.2	20.1	20.2	20.6	20.6	20.8	**20.1**
1999	19.1	20.5	19.9	20.1	20.3	20.2	20.3	20.7	20.8	21.0	**20.3**
2000	19.2	20.1	19.8	20.2	20.5	20.4	20.4	20.8	20.9	21.1	**20.3**
2001	19.4	20.2	19.9	20.3	20.5	20.6	20.5	21.0	21.0	21.1	**20.5**
2002	19.4	20.0	20.1	20.3	20.7	20.8	20.5	21.0	21.0	21.1	**20.5**
2003	19.4	20.3	20.2	20.5	20.9	20.9	20.6	21.1	21.2	21.3	**20.6**
2004	19.4	20.5	20.4	20.7	21.1	21.2	20.7	21.2	21.4	21.5	**20.8**
2005	19.5	20.9	20.5	20.9	21.3	21.3	20.9	21.2	21.5	21.7	**21.0**
2006	19.4	21.0	20.7	20.9	21.5	21.6	21.1	21.2	21.6	21.8	**21.1**
2007	19.7	20.7	20.9	21.1	21.6	21.7	21.2	21.3	21.6	22.0	**21.2**
Average	**18.9**	**20.0**	**19.5**	**19.9**	**19.9**	**20.0**	**20.1**	**20.7**	**20.4**	**20.6**	

Table 3: Female Life Expectancy at Age 65 by Province, Annually – 1980 to 2007

Between 1980 and 2007, average female life expectancy at 65 has risen in Canada's provinces by 2.3 years from 18.9 to 21.2 years. Female life expectancy at birth rose by 3.8 years (78.9 years to 82.7 years). For male life expectancy at age 65, there has been an increase of 3.2 years (14.8 years to 18 years) while male life expectancy at birth has risen 6.1 years over the same timeframe (71.8 years to 77.9 years).

Year	NL	PEI	NS	NB	Qc	On	Mn	Sk	Ab	BC	Average
1980	78.1	79.7	78.1	78.6	78.5	78.9	78.8	79.9	78.9	79.9	**78.9**
1981	79.5	80.8	78.7	79.4	79.2	79.3	78.9	80.2	79.2	79.6	**79.5**
1982	78.9	81.2	78.9	79.5	79.2	79.4	79.1	79.6	79.7	79.9	**79.5**
1983	78.3	79.8	79.3	79.6	79.3	79.6	79.8	80.6	80.0	80.8	**79.7**
1984	78.8	80.2	79.2	80.0	79.7	79.9	80.3	80.8	80.3	80.5	**80.0**
1985	79.1	80.6	78.9	80.1	79.6	79.8	80.0	80.2	80.1	80.5	**79.9**
1986	79.1	80.1	79.6	80.0	79.6	80.0	79.8	80.6	79.9	80.8	**80.0**
1987	79.6	80.7	79.9	80.3	79.9	80.3	80.1	80.8	80.7	81.0	**80.3**
1988	79.2	81.2	79.6	80.7	80.1	80.3	80.4	81.1	80.5	80.8	**80.4**
1989	79.5	81.2	79.8	80.3	80.4	80.5	80.6	81.6	80.9	81.0	**80.6**
1990	79.3	80.5	79.9	80.7	80.7	80.9	80.5	81.2	81.2	81.1	**80.6**
1991	79.7	80.8	80.7	81.0	80.9	80.8	80.6	81.4	81.2	81.5	**80.9**
1992	79.8	80.8	80.4	80.7	81.0	81.0	80.9	81.8	81.1	81.5	**80.9**
1993	80.1	80.9	80.5	80.8	80.9	81.0	80.6	81.7	81.2	81.5	**80.9**
1994	80.2	81.1	80.6	81.0	81.0	81.1	80.6	81.5	81.3	81.6	**81.0**
1995	80.2	81.5	80.6	81.2	81.0	81.3	80.5	81.4	81.3	81.8	**81.1**
1996	80.0	81.0	80.5	81.1	81.1	81.4	80.7	81.4	81.5	81.9	**81.1**
1997	79.9	81.2	80.8	81.3	81.3	81.6	80.7	81.6	81.7	82.2	**81.2**
1998	80.1	80.8	81.1	81.5	81.6	81.7	80.8	81.5	81.8	82.4	**81.3**
1999	80.3	81.7	81.4	81.7	81.8	81.9	81.1	81.7	82.0	82.7	**81.6**
2000	80.6	81.7	81.4	81.9	82.0	82.1	81.2	81.8	82.1	82.8	**81.8**
2001	80.9	81.8	81.5	82.0	82.1	82.3	81.3	82.0	82.2	82.9	**81.9**
2002	81.1	81.5	81.6	82.1	82.3	82.5	81.3	82.0	82.3	82.9	**82.0**
2003	81.0	81.8	81.7	82.2	82.5	82.6	81.4	82.0	82.6	83.1	**82.1**
2004	80.9	82.1	82.0	82.4	82.8	83.0	81.6	82.1	82.8	83.3	**82.3**
2005	80.8	82.7	82.2	82.5	83.1	83.1	81.8	82.0	82.9	83.5	**82.5**
2006	80.9	82.9	82.3	82.7	83.3	83.4	82.0	82.1	83.0	83.6	**82.6**
2007	81.2	82.8	82.4	82.8	83.4	83.6	81.9	82.1	83.0	83.9	**82.7**
Average	**79.9**	**81.2**	**80.5**	**81.0**	**81.0**	**81.2**	**80.6**	**81.3**	**81.3**	**81.8**	

Table 4: Female Life Expectancy at Birth by Province, Annually – 1980 to 2007

For both genders, life expectancy at birth has increased by a larger margin than life expectancy at 65. To reiterate, the data suggests that in Canada's provinces longevity for newborns has increased by a larger margin than longevity for senior citizens.

Year	NL	PEI	NS	NB	Qc	On	Mn	Sk	Ab	BC	Average
1980	14.5	15.2	14.1	14.4	13.9	14.4	14.9	15.6	15.1	15.7	**14.8**
1981	14.8	14.8	14.2	14.7	14.2	14.5	14.7	16.0	15.1	15.8	**14.9**
1982	14.9	14.8	14.3	14.7	14.2	14.6	15.1	15.2	15.0	15.4	**14.8**
1983	14.9	16.1	14.2	14.6	14.2	14.6	14.9	15.8	15.6	15.9	**15.1**
1984	14.5	15.3	14.7	14.8	14.3	14.9	15.4	16.0	15.5	15.8	**15.1**
1985	14.5	14.5	14.3	14.7	14.2	14.8	15.2	15.7	15.5	15.9	**14.9**
1986	14.6	15.2	14.4	14.7	14.2	15.0	15.1	15.9	15.7	16.1	**15.1**
1987	14.5	14.5	14.8	15.1	14.4	15.2	15.4	16.5	15.9	16.1	**15.2**
1988	15.2	14.7	14.6	15.0	14.5	15.0	15.2	15.9	15.7	16.2	**15.2**
1989	14.7	15.2	14.6	15.2	14.7	15.4	15.7	16.1	15.9	16.4	**15.4**
1990	14.4	15.5	15.1	15.5	15.0	15.8	15.8	16.4	16.2	16.6	**15.6**
1991	15.0	14.3	15.3	15.5	15.1	15.8	16.0	16.4	16.2	16.6	**15.6**
1992	14.9	15.5	14.9	15.5	15.3	15.9	15.9	16.7	16.4	16.8	**15.8**
1993	14.8	15.4	15.0	15.5	15.3	15.9	15.9	16.7	16.4	16.8	**15.8**
1994	15.0	15.2	15.2	15.5	15.4	16.0	16.1	16.7	16.5	16.9	**15.9**
1995	14.9	15.4	15.4	15.7	15.5	16.1	16.2	16.7	16.7	17.0	**16.0**
1996	14.8	15.5	15.5	15.6	15.5	16.3	16.3	16.6	16.7	17.1	**16.0**
1997	14.9	16.0	15.7	15.7	15.6	16.4	16.2	16.5	16.8	17.2	**16.1**
1998	15.0	15.7	16.0	15.7	15.9	16.6	16.2	16.6	17.0	17.5	**16.2**
1999	15.2	16.0	16.3	16.1	16.3	16.9	16.4	16.8	17.2	17.6	**16.5**
2000	15.4	16.0	16.4	16.3	16.5	17.2	16.7	16.9	17.4	18.0	**16.7**
2001	15.6	16.4	16.5	16.4	16.8	17.4	16.8	17.0	17.6	18.1	**16.9**
2002	15.8	16.4	16.7	16.6	17.0	17.6	16.9	17.1	17.8	18.4	**17.0**
2003	15.8	16.9	16.8	16.8	17.3	17.8	17.0	17.4	17.9	18.5	**17.2**
2004	16.0	17.2	16.9	17.3	17.7	18.1	17.4	17.6	18.2	18.7	**17.5**
2005	16.2	17.5	17.1	17.5	18.0	18.3	17.5	17.8	18.3	18.9	**17.7**
2006	16.5	17.6	17.4	17.7	18.2	18.5	17.6	17.8	18.4	19.0	**17.9**
2007	16.6	17.6	17.5	17.7	18.3	18.7	17.7	17.9	18.5	19.2	**18.0**
Average	**15.1**	**15.7**	**15.5**	**15.7**	**15.6**	**16.2**	**16.1**	**16.6**	**16.6**	**17.1**	

Table 5: Male Life Expectancy at age 65 by Province, Annually – 1980 to 2007

An interesting geographical trend also persists across the longevity measures examined. Specifically it appears that Newfoundland trends towards having the shortest life expectancies while

British Columbia appears to have the longest. Also it appears that moving from the Maritime Provinces towards the Atlantic Provinces, life expectancy trends upward. Ontario stands out as the only province that deviates from this pattern as life expectancy in Ontario is similar to life expectancy in British Columbia. This pattern persists over the 28 years examined. Finally, when comparing genders it appears that females live longer than males across Canada's provinces.

Year	NL	PEI	NS	NB	Qc	On	Mn	Sk	Ab	BC	Average
1980	72.0	72.4	70.7	70.8	70.8	72.0	72.2	72.5	71.7	72.5	**71.8**
1981	72.3	72.9	70.9	71.3	71.3	72.5	71.7	72.8	72.3	73.0	**72.1**
1982	72.1	73.5	71.5	71.4	71.7	72.8	72.9	72.3	72.5	73.0	**72.4**
1983	72.2	72.4	71.3	72.3	71.8	73.1	72.5	73.5	73.6	73.8	**72.7**
1984	72.4	72.9	72.6	72.3	72.0	73.4	73.4	73.8	73.6	74.0	**73.0**
1985	72.4	72.7	72.1	72.8	72.1	73.5	72.9	73.6	73.5	74.1	**73.0**
1986	73.5	71.9	72.4	72.5	72.2	73.7	73.2	73.5	73.6	74.5	**73.1**
1987	72.7	73.8	72.8	73.0	72.3	74.1	73.6	74.4	74.1	74.5	**73.5**
1988	73.5	73.3	72.7	73.2	72.8	74.0	73.2	73.9	74.1	74.6	**73.5**
1989	73.3	73.0	72.9	73.7	72.9	74.4	74.0	74.7	74.6	74.7	**73.8**
1990	73.1	73.1	73.5	74.0	73.4	74.8	74.5	74.9	74.8	75.1	**74.1**
1991	73.9	72.5	73.9	74.4	73.7	75.0	74.6	75.0	75.0	75.4	**74.3**
1992	73.9	74.3	74.0	74.4	74.1	75.2	74.7	75.5	75.4	75.5	**74.7**
1993	73.9	74.2	74.4	74.4	74.1	75.3	74.7	75.1	75.5	75.7	**74.7**
1994	74.2	74.0	74.5	74.6	74.4	75.6	75.0	75.2	75.6	75.9	**74.9**
1995	74.4	74.6	74.8	74.8	74.6	75.9	75.2	75.3	76.0	76.2	**75.2**
1996	74.6	74.9	75.0	75.0	74.9	76.2	75.3	75.5	76.2	76.5	**75.4**
1997	74.7	75.6	75.3	75.0	75.1	76.5	75.3	75.5	76.4	76.9	**75.6**
1998	74.8	75.2	75.6	75.2	75.5	76.8	75.2	75.6	76.7	77.4	**75.8**
1999	75.1	75.2	76.0	75.7	76.0	77.1	75.4	75.9	76.9	77.7	**76.1**
2000	75.3	75.4	76.3	76.1	76.4	77.4	75.7	76.2	77.1	78.0	**76.4**
2001	75.6	75.9	76.4	76.3	76.7	77.6	76.0	76.2	77.3	78.2	**76.6**
2002	75.6	76.4	76.5	76.6	77.1	77.9	76.2	76.3	77.6	78.4	**76.9**
2003	75.6	76.9	76.6	76.8	77.4	78.2	76.4	76.4	77.7	78.5	**77.1**
2004	75.6	77.3	76.8	77.3	77.9	78.5	76.7	76.7	77.9	78.7	**77.3**
2005	75.8	77.6	77.1	77.4	78.2	78.8	76.8	76.9	78.1	78.9	**77.6**
2006	76.2	77.5	77.4	77.6	78.6	79.0	76.9	76.9	78.3	79.2	**77.8**
2007	76.5	77.5	77.7	77.5	78.8	79.2	77.0	77.0	78.5	79.5	**77.9**
Average	**74.1**	**74.5**	**74.3**	**74.5**	**74.5**	**75.7**	**74.7**	**75.0**	**75.5**	**76.1**	

Table 6: Male Life Expectancy at Birth by Province, Annually – 1980 to 2007

Health Outcomes: Infant Mortality

The discussion now proceeds to an examination of trends in gender separated measures of infant mortality. **Table 7** and **Table 8** contain the data on female and male infant deaths respectively. The average number of female infant deaths per year has decreased in Canada's provinces by 81 deaths from 164 to 83 between 1980 and 2010 while the average count of male infant deaths per year has decreased by 114 from approximately 219 to 105.

Year	NL	PEI	NS	NB	Qc	On	Mn	Sk	Ab	BC	Average
1980	46	5	53	52	416	501	88	81	211	183	**164**
1981	37	9	53	44	359	446	89	69	192	196	**149**
1982	33	6	43	34	340	434	67	80	192	172	**140**
1983	43	7	50	51	298	446	75	84	186	146	**139**
1984	39	8	42	32	261	440	62	70	199	160	**131**
1985	36	6	43	48	288	415	63	96	150	143	**129**
1986	26	5	41	35	259	426	72	64	168	164	**126**
1987	18	4	27	22	226	404	66	63	136	143	**111**
1988	37	5	33	30	245	383	57	61	146	152	**115**
1989	34	5	31	26	265	441	40	55	132	151	**118**
1990	32	5	38	31	258	421	58	50	149	149	**119**
1991	23	7	27	32	254	428	53	55	131	116	**113**
1992	26	0	31	23	219	377	45	57	142	110	**103**
1993	20	12	41	30	223	394	60	48	118	112	**106**
1994	24	5	31	26	214	384	47	43	126	131	**103**
1995	21	5	24	18	200	388	57	49	120	125	**101**
1996	18	5	29	17	175	341	42	56	99	104	**89**
1997	13	3	21	20	197	316	47	52	75	97	**84**
1998	13	6	25	20	195	305	41	34	77	83	**80**
1999	14	5	14	12	165	321	48	34	101	70	**78**
2000	12	1	21	11	126	336	42	29	101	63	**74**
2001	11	4	22	16	156	309	33	27	81	78	**74**
2002	4	1	11	12	158	308	42	31	136	71	**77**
2003	8	4	15	15	158	324	41	30	106	73	**77**
2004	11	2	16	12	168	338	46	30	105	89	**82**
2005	15	1	17	14	143	352	47	43	122	74	**83**
2006	8	1	18	12	192	284	41	33	107	81	**78**
2007	19	2	14	10	170	317	48	45	142	68	**84**
2008	12	1	19	8	179	325	52	31	151	72	**85**
2009	12	1	15	21	184	322	46	47	134	85	**87**
2010	11	1	20	7	198	308	41	40	133	75	**83**
Average	**20**	**4**	**26**	**22**	**206**	**363**	**50**	**48**	**128**	**107**	

Table 7: Number of Female Infant Deaths by Province, Annually – 1980 to 2010

These measures of infant mortality appear to correlate with each province's population as the smaller provinces have much lower counts and vice versa. As well, it appears that there have been fewer female infant deaths than there have been male deaths within the time frame examined.

Year	NL	PEI	NS	NB	Qc	On	Mn	Sk	Ab	BC	Average
1980	64	17	82	64	537	674	96	112	289	259	**219**
1981	61	16	86	70	448	627	102	134	260	228	**203**
1982	66	9	63	76	460	607	79	106	250	251	**197**
1983	52	9	66	61	378	567	98	96	197	231	**176**
1984	40	8	55	49	384	552	82	99	226	218	**171**
1985	56	2	55	49	338	546	107	104	202	206	**167**
1986	39	8	63	46	345	543	85	93	225	191	**164**
1987	41	9	63	45	368	484	76	92	179	216	**157**
1988	33	9	46	39	318	527	75	79	201	210	**154**
1989	30	7	42	43	367	544	75	79	193	209	**159**
1990	38	7	43	40	354	525	80	73	197	195	**155**
1991	33	6	42	26	324	525	58	71	154	182	**142**
1992	23	3	40	36	303	509	68	53	162	176	**137**
1993	30	4	41	35	306	528	58	67	150	152	**137**
1994	28	6	36	22	292	495	68	82	168	166	**136**
1995	25	3	28	23	277	482	66	74	154	155	**129**
1996	20	3	30	23	221	461	62	56	137	133	**115**
1997	15	4	23	25	247	412	63	62	103	113	**107**
1998	18	6	19	31	230	362	56	57	106	100	**99**
1999	11	5	24	26	196	384	72	45	119	90	**97**
2000	12	4	24	15	214	377	50	53	143	87	**98**
2001	12	6	28	15	193	404	65	41	129	90	**98**
2002	17	1	25	15	188	373	56	36	147	112	**97**
2003	15	3	34	14	164	368	70	46	159	97	**97**
2004	12	4	24	18	174	397	51	44	131	86	**94**
2005	13	2	17	14	210	393	47	56	164	109	**103**
2006	16	2	16	16	223	390	47	42	131	90	**97**
2007	15	5	15	21	209	406	63	32	154	108	**103**
2008	13	2	13	16	200	428	49	54	166	94	**104**
2009	19	4	16	22	205	383	54	49	150	76	**98**
2010	15	4	21	18	242	387	65	44	166	91	**105**
Average	**25**	**5**	**34**	**29**	**267**	**455**	**67**	**64**	**161**	**142**	

Table 8: Number of Male Infant Deaths by Province, Annually – 1980 to 2010

Health Outcomes: Deaths from Treatable Causes

In this section I discuss trends in the number of deaths from treatable causes. **Table 9** summarizes the data on female deaths from treatable causes while **Table 10** contains the data on male deaths from treatable causes.

	NL	PEI	NS	NB	Qc	On	Mn	Sk	Ab	BC	Average
1980	7,545	1,125	9,953	7,968	74,579	92,150	12,540	10,317	24,372	26,247	**26,680**
1981	5,801	1,272	9,611	7,656	68,923	88,124	12,952	9,362	22,202	29,983	**25,589**
1982	5,661	984	8,321	7,068	66,779	85,714	11,449	10,893	21,309	28,630	**24,681**
1983	6,409	1,186	8,902	7,904	65,916	87,702	11,492	10,521	23,715	24,407	**24,815**
1984	6,231	1,011	8,691	6,017	61,173	88,480	10,620	9,730	22,685	25,650	**24,029**
1985	5,267	1,257	9,835	7,087	62,135	85,077	11,396	11,352	17,826	24,085	**23,532**
1986	5,076	875	8,719	5,940	62,130	85,875	10,543	10,095	21,604	24,790	**23,565**
1987	4,836	1,062	6,948	5,770	58,699	83,265	11,387	8,601	19,926	22,057	**22,255**
1988	5,123	889	7,683	5,624	59,865	83,936	8,855	8,805	19,398	24,625	**22,480**
1989	5,589	947	7,126	5,967	60,761	86,597	7,861	8,114	19,823	24,391	**22,718**
1990	5,254	882	7,900	5,745	59,138	82,142	9,701	7,704	21,121	25,789	**22,538**
1991	4,295	1,070	7,002	5,843	57,605	80,116	8,760	8,421	18,764	21,084	**21,296**
1992	5,000	594	7,094	5,522	54,317	78,631	8,284	8,136	20,064	21,976	**20,962**
1993	4,251	1,418	7,592	5,730	55,033	80,668	9,805	8,231	18,239	20,582	**21,155**
1994	5,278	1,006	7,560	5,288	55,191	80,576	8,327	7,394	20,049	23,395	**21,406**
1995	4,792	1,055	6,657	4,634	52,889	82,100	9,668	7,655	18,712	23,411	**21,157**
1996	4,774	983	6,704	5,033	50,727	79,363	8,386	7,859	18,372	21,469	**20,367**
1997	4,390	865	7,021	4,782	51,476	71,664	9,525	7,261	17,593	22,561	**19,714**
1998	4,053	1,248	7,436	5,617	50,342	73,301	8,495	7,065	16,290	21,983	**19,583**
1999	4,086	1,354	5,480	4,471	47,785	75,740	8,744	6,997	17,713	20,487	**19,286**
2000	4,080	672	6,458	3,887	42,559	74,146	8,150	6,290	17,481	20,461	**18,418**
2001	3,923	992	5,900	4,246	45,628	73,103	7,230	6,301	18,581	21,608	**18,751**
2002	3,844	665	5,301	4,030	44,283	71,708	8,529	6,010	21,189	19,746	**18,531**
2003	3,281	1,035	6,326	4,296	43,674	75,922	8,784	7,002	19,719	19,826	**18,987**
2004	3,682	807	5,331	3,493	44,167	77,440	8,632	5,973	18,879	21,382	**18,979**
2005	4,276	514	5,241	3,946	43,512	77,017	8,953	6,312	19,728	20,469	**18,997**
2006	4,311	782	5,489	3,789	44,028	72,391	7,959	6,269	19,843	20,839	**18,570**
2007	4,245	763	5,678	3,270	44,953	76,186	9,088	7,364	21,492	21,579	**19,462**
2008	3,858	636	5,768	3,511	46,650	76,222	10,094	6,937	23,954	21,984	**19,961**
2009	3,204	964	5,800	4,424	47,094	73,891	8,545	7,622	22,196	21,957	**19,570**
2010	3,814	622	5,754	3,681	46,866	74,333	8,060	7,594	20,669	21,438	**19,283**
Average	**4,544**	**934**	**6,836**	**4,984**	**52,093**	**78,843**	**9,138**	**7,772**	**19,844**	**22,287**	

Table 9: Potential Years of Life Lost due to Deaths from Treatable Causes, Females, by Province, Annually – 1980 to 2010

The average yearly count of PYLL due to deaths from treatable causes has fallen by 7,397 years (26,680 to 19,283) for females over the 31 years examined while for males the average yearly count has fallen by 12,336 years (34,182 to 21,846). As with the infant mortality measures, this variable appears to correlate heavily with a province's population as the smaller provinces have much lower values than their larger counterparts. Additionally, it appears that male deaths occur more often than female deaths within the timeframe examined. We now move on to the results of the empirical analysis beginning with the efficiency evaluation of longevity.

Year	NL	PEI	NS	NB	Qc	On	Mn	Sk	Ab	BC	Average
1980	8,447	1,854	13,039	9,903	93,932	118,532	14,827	13,450	32,474	35,366	**34,182**
1981	8,519	2,011	13,501	10,287	89,817	113,029	15,047	15,287	29,308	35,220	**33,203**
1982	8,579	1,668	10,878	11,416	87,735	113,410	13,609	14,147	27,507	36,203	**32,515**
1983	7,987	1,602	12,430	9,154	82,729	106,794	15,189	12,634	25,495	32,197	**30,621**
1984	7,414	1,279	10,085	7,629	79,846	105,859	12,821	13,107	25,777	31,415	**29,523**
1985	8,427	1,368	10,342	7,964	73,427	105,778	14,648	13,709	21,235	29,387	**28,629**
1986	5,865	1,994	10,652	8,205	76,956	104,232	12,949	12,908	24,984	27,724	**28,647**
1987	6,229	1,383	9,517	8,294	75,581	93,854	11,524	11,115	22,377	30,148	**27,002**
1988	6,435	1,373	9,600	7,105	70,302	97,489	10,798	11,534	24,351	29,193	**26,818**
1989	6,141	1,463	9,263	6,966	74,914	99,742	11,282	10,895	22,334	28,237	**27,124**
1990	6,420	1,280	8,186	6,426	70,426	92,480	10,680	9,989	24,684	29,109	**25,968**
1991	5,447	1,217	8,474	5,782	66,270	89,971	11,152	9,936	20,862	26,136	**24,525**
1992	4,942	845	8,069	6,339	64,312	91,834	10,071	7,294	22,032	27,576	**24,331**
1993	6,080	934	7,698	6,513	64,309	95,590	9,845	8,706	21,332	25,240	**24,625**
1994	5,729	1,261	7,794	5,290	61,094	93,102	10,589	10,088	21,827	25,741	**24,252**
1995	5,158	943	7,006	5,856	62,346	89,505	10,431	10,725	21,820	24,980	**23,877**
1996	4,826	1,196	7,320	5,257	56,724	89,369	10,053	9,615	19,853	24,589	**22,880**
1997	4,594	706	6,683	5,543	57,958	81,729	9,614	9,107	18,409	22,638	**21,698**
1998	4,014	1,026	7,049	5,647	55,439	78,270	9,972	7,844	18,508	22,910	**21,068**
1999	4,468	1,065	6,253	6,118	51,549	81,480	11,069	7,984	19,514	23,641	**21,314**
2000	4,580	1,168	7,044	4,707	51,562	82,214	9,024	8,367	21,644	21,888	**21,220**
2001	3,978	1,394	6,687	4,885	48,748	79,903	10,760	7,812	21,268	22,497	**20,793**
2002	4,161	831	6,271	4,206	46,977	81,118	9,437	7,557	22,090	23,031	**20,568**
2003	4,144	784	7,241	4,510	47,368	81,503	10,897	8,008	22,931	22,798	**21,018**
2004	4,362	810	6,991	4,892	46,549	83,592	9,472	7,395	21,996	22,924	**20,898**
2005	4,940	967	6,873	4,912	49,514	82,047	9,484	8,996	24,833	23,783	**21,635**
2006	4,711	954	6,676	4,643	51,187	81,615	9,500	8,402	22,388	22,566	**21,264**
2007	4,256	1,356	6,376	5,128	48,452	84,892	10,663	7,359	25,002	25,157	**21,864**
2008	4,336	969	6,085	4,612	47,480	86,398	10,855	8,404	25,505	23,909	**21,855**
2009	5,073	953	6,298	5,396	48,122	84,048	10,556	7,499	24,981	21,808	**21,473**
2010	4,530	715	7,100	5,145	47,759	84,357	10,104	8,349	26,189	24,210	**21,846**
Average	**5,330**	**1,137**	**7,859**	**5,969**	**59,925**	**89,599**	**10,837**	**9,476**	**22,651**	**25,551**	

Table 10 –Number of Potential Years of Life Lost due to deaths from Treatable Causes, Males, by Province, Annually – 1980 to 2010

4.3.1 Results: Analysis of Longevity

Evaluation of Healthcare Spending Efficiency

Here I discuss the results of the analysis of the efficient production of longevity across 28 years of data and. The results indicating the provinces which were operating at most productive scale size are summarized by measure of longevity in **Table 11**. The results indicate that provinces were only operating at their most productive scale size in either 1980 or 1981, the two earliest years examined. Within the rest of the time frame, the provinces were operating at decreasing returns to scale.

FLE65	FLEB	MLE65	MLEB
• Nfld 1980	• Nfld 1980	• Nfld 1980	• Nfld 1980
• PEI 1980	• PEI 1980	• PEI 1980	• PEI 1980
• NS 1980	• NS 1980	• NS 1980	• NS 1980
• NB 1980	• NB 1980	• NB 1980	• NB 1980
• Qc 1980	• Qc 1980	• Qc 1980	• Qc 1980
• On 1980	• On 1980	• On 1980	• On 1980
• Sk 1980	• Sk 1980	• Sk 1980	• Sk 1980
• Ab 1980	• Ab 1980	• Ab 1980	• Ab 1980
• Sk 1981		• Sk 1981	

Table 11: List of DMUs operating at Most Productive Scale Size by Measure of Life Expectancy

Evaluation of Variable Importance

The results of the analysis of variable importance are summarized below. **Table 12** summarizes the results of the variable importance of the categories of the categories of healthcare spending in determining the efficient production of both male and female life expectancy at birth. **Table 13** summarizes the results of the importance of the healthcare spending categories for determining male and female life expectancy at age 65.

	FLEB	
Category & Rank	Relative Importance Score	First Difference
1. Hospitals	100	0
2. Other Health Spending	98.0239	0.7729
3. Other Institutions	97.2510	1.4348
4. Physicians	95.8162	1.389
5. Administration	94.4447	1.3715
6. Other Professionals	94.4414	4.0033
7. Public Health	1.5041	88.9373
Capital	0	1.5041
Drugs	0	0
	MLEB	
Category & Rank	**Relative Importance Score**	**First Difference**
1. Hospitals	100	0
2. Other Institutions	94.9756	5.0244
3. Other Health Spending	94.2778	0.6978
4. Physicians	93.5849	0.6929
5. Administration	92.2134	1.3715
6. Other Professionals	88.2101	4.0033
7. Public Health	0	88.2101
Capital	0	0
Drugs	0	0

Table 12: Variable Importance for CART Model examining Gender Separated Life Expectancy at Age Birth

The results indicate that spending on hospitals was the most important determinant of whether or not provinces were operating at their most productive scale size in producing all four measures of longevity. The results also indicate that spending on Drugs was the least important category for determining whether or not a province was operating at its most productive scale size in producing all four measures of longevity. Overall, while the Relative Importance Scores of spending categories differ for each measure of longevity, there appear to be common trends in both genders when examining life expectancy at age 65 versus life expectancy at birth. Therefore there are differences in the importance of spending categories based on whether one is examining life expectancy at age 65 or at birth.

In both **Table 15** and **Table 16,** the first differences columns indicate the separation in importance from one category of spending to the next. The results concerning the efficient production of life expectancy at birth indicate that there is not a drastic separation in the importance of any of the spending categories that are considered important. Additionally, only six categories of the nine healthcare spending are considered to be important to determining the efficient production of life expectancy at birth. In contrast, the results of the analysis concerning the efficient production of life expectancy at age 65 indicate that seven categories of the nine categories of life expectancy are significant. a dramatic difference between the sixth and seventh ranked categories of healthcare spending.

Category & Rank	FLE65 Relative Importance Score	First Differences
1. Hospitals	100	0
2. Physicians	95.8282	4.1718
3. Other Health Spending	91.8654	3.9628
4. Other Professionals	89.3548	1.9106
5. Other Institutions	83.5424	5.8123
6. Administration	82.9319	0.6105
7. Capital	21.0541	61.8778
8. Public Health	1.8221	19.232
Drugs	0	1.8221
Category & Rank	**MLE65 Relative Importance Score**	**First Differences**
1. Hospitals	100	0
2. Physicians	94.935	5.065
3. Other Health Spending	90.962	3.973
4. Other Professionals	88.4296	2.5324
5. Other Institutions	82.5611	5.8685
6. Administration	81.9575	0.6036
7. Capital	23.4065	58.55085
8. Public Health	1.8500	21.5565
Drugs	0	1.8500

Table 13: Variable Importance for CART Model examining Gender Separated Life Expectancy at Age 65

Scale Efficiency Window Analysis: Results

The results of the year by year analysis of the efficient production of longevity in Canada's provinces are summarized below. **Table 14** summarizes the counts of each inefficient province's instances of inefficiency by measure of life expectancy. These provinces include Manitoba, Ontario, British Columbia and New Brunswick. Prince Edward Island also has one instance in which it performs at increasing returns to scale.

	FLE65	FLEB	MLE65	MLEB	Total
Manitoba	16	16	19	16	67
Ontario	8	7	7	7	29
New Brunswick	2	4	2	5	13
British Columbia	3	3	2	3	11
Prince Edward Island	0	0	1	0	1
Total	29	30	31	31	121

Table 14: Instances of Scale Inefficiency by Province and Category of Life Expectancy Estimate

Tables 15 contains the results of the analysis of the efficient production of male life expectancy at birth and at age 65. **Table 16** contains the results of the analysis of the efficient production of female life expectancy at birth and age 65. Both tables indicate the years in which each province was inefficient and whether the province performed at increasing returns to scale or decreasing returns to scale.

	Female Life Expectancy at Birth		Female Life Expectancy at 65	
Year	**Provinces at DRS**	**Provinces at IRS**	**Provinces at DRS**	**Provinces at IRS**
1980	British Columbia, Manitoba		British Columbia, Manitoba	
1981	British Columbia	Manitoba	British Columbia, Manitoba	
1982	British Columbia, Manitoba		British Columbia, Manitoba	
1983	Manitoba		Manitoba	
1984	Manitoba		Manitoba	
1985	Manitoba		Manitoba	
1986	Manitoba		Manitoba	
1987	Manitoba		Manitoba	
1988	Ontario			Ontario
1989	Ontario			Ontario
1991	New Brunswick, Ontario			
1992	New Brunswick			Ontario
1993	New Brunswick, Ontario		New Brunswick	Ontario
1994	New Brunswick, Ontario		New Brunswick, Ontario	
1995	Ontario		Ontario	
1996	Ontario	Manitoba	Manitoba, Ontario	
1997	Manitoba		Manitoba	
1998		Manitoba		Ontario
2000		Manitoba		Manitoba
2003		Manitoba		Manitoba
2004		Manitoba		Manitoba
2005		Manitoba		Manitoba
2006		Manitoba	Manitoba	

Table 14: Scale Inefficient Provinces by Year – Female Life Expectancy at Birth and age 65

Year	Male Life Expectancy at Birth		Male Life Expectancy at 65	
	Provinces at DRS	Provinces at IRS	Provinces at DRS	Provinces at IRS
1980	British Columbia, Manitoba		British Columbia , Manitoba	
1981	British Columbia, Manitoba		British Columbia, Manitoba	
1982	British Columbia, Manitoba		Manitoba	
1983	Manitoba		Manitoba	
1984	Manitoba		Manitoba	
1985	Manitoba		Manitoba	
1986	Manitoba			Manitoba
1987	Manitoba		Manitoba	
1988	Ontario			Ontario
1989			Ontario	
1991	New Brunswick, Ontario			Ontario, Prince Edward Island
1992	New Brunswick			
1993	New Brunswick, Ontario		New Brunswick, Ontario	
1994	New Brunswick, Ontario		New Brunswick, Ontario	
1995	New Brunswick, Ontario		Ontario	
1996	Ontario	Manitoba	Manitoba, Ontario	
1997		Manitoba	Manitoba	
1998		Manitoba		Manitoba
1999				Manitoba
2000		Manitoba		Manitoba
2002				Manitoba
2003		Manitoba		Manitoba
2004		Manitoba		Manitoba
2005		Manitoba		Manitoba
2006		Manitoba		Manitoba
2007				Manitoba

Table 15: Scale Inefficient Provinces by Year – Male Life Expectancy at Birth and age 65

The results demonstrate that across all measures of life expectancy, Manitoba was inefficient the most frequently (67 total instances of inefficiency). In total Manitoba performed at decreasing returns to scale 36 times across all four window analyses and at increasing returns to scale 31 times. Ontario was scale inefficient a total of 29 times in all four window analyses (21 instances at decreasing returns to scale, eight at increasing returns to scale). British Columbia was inefficient 11 times (eight times at decreasing returns to scale and three at increasing returns to scale). New Brunswick was inefficient 13 times (12 times at decreasing returns to scale and once at increasing returns to scale). Prince Edward Island's performed at increasing returns to scale the single time it appeared inefficient. The results indicate that for both categories of female life expectancy there were less instances of inefficiency than for the male categories (29 instances for female life expectancy at age 65 and 30 instance for female life expectancy at birth, 31 for both male life expectancy at birth and 31 instance for male life expectancy at age 65).

4.3.2 Results: Analysis of Infant Mortality and Deaths from Treatable Causes

This section summarizes the results of the analyses of infant mortality and deaths due to treatable causes. The MARS settings used for this analysis included all nine categories of spending as independent variables. Additionally, two-way interactions between each dependent variable were allowed, creating models that demonstrated the relationships between each spending category. Below I provide the summary of the ranking independent variable importance (i.e. the ranking of the importance of healthcare spending categories in determining infant mortality and deaths from treatable causes), interactions between independent variables, and the performance of each model that was generated. Next I begin by stating the results of the analysis of deaths from treatable causes.

Results: Deaths from Treatable Causes

Table 17 contains data on the variable importance scores examining potential years of life lost due to deaths from treatable causes. The MARS variable importance results for both genders indicate that spending on Physicians, Hospitals, Drugs and Public Health have an effect in determining the loss of life due to treatable causes. The five other spending categories included in the models all have a relative importance score of zero. For FPYLL the order of spending categories from most to least important is Physicians, Hospitals, Drugs, and Public Health. There is a difference in ranking between FPYLL and MPYLL. Specifically for MPYLL, spending on Drugs is second in importance while spending on Hospitals is third. Spending on Physicians and spending on Public Health remain first and fourth in importance respectively.

Additionally there is a clear difference in the variable importance scores reported by the two models. An examination of first differences in variable importance scores indicates that for FPYLL, after spending on Hospitals is considered, the remaining three variables are quite similar in their importance. This contrasts the first differences of variable importance scores for MPYLL where it is clear that spending on Drugs and Physicians are closer in importance to each other than spending Hospitals and Public Health are to each other.

Variable by Rank	FPYLL Relative Importance Scores	First Differences
1. Physicians	100	0
2. Hospitals	89.69	10.31
3. Drugs	89.03	0.66
4. Public Health	87.85	1.18
Capital	0	87.85
Other Institutions	0	0
Administration	0	0
Other Professionals	0	0
Other Health Spending	0	0
Variable by Rank	**MPYLL Relative Importance Scores**	**First Differences**
1. Physicians	100	0
2. Drugs	93.17	6.83
3. Hospitals	79.07	14.1
4. Public Health	77.75	1.32
Capital	0	77.75
Other Institutions	0	0
Administration	0	0
Other Professionals	0	0
Other Health Spending	0	0

Table 17: Deaths from Treatable Causes MARS Model Variable Importance

The results on variable interactions are reported in **Table 18**. Both MARS models indicate that there are no interactions between spending on Hospitals and spending on Physicians. In both models, all other categories of spending have at least one interaction with each other.

FPYLL				
	Physicians	Hospitals	Drugs	Public Health
Physicians			✓	✓
Hospitals			✓	✓
Drugs	✓	✓		✓
Public Health	✓	✓	✓	
MPYLL				
	Physicians	Hospitals	Drugs	Public Health
Physicians			✓	✓
Hospitals			✓	✓
Drugs	✓	✓		✓
Public Health	✓	✓	✓	

Table 18: Variable interactions for MARS Models examining FPYLL and MPYLL

Finally, the measures of performance for both models are summarized in **Table 19**. These are the naïve R-square, naïve adjusted R-square, and the GCV (generalized cross validation) R-square. Next I move on to the summary of male and female infant mortality. The results indicate that both models perform well meaning that healthcare spending is a significant determinant of the number of deaths from treatable causes in Canada's provinces.

MPYLLTC	FPYLLTC
• Naïve R-Squared: 0.713 • Naïve adjusted R-Squared: 0.697 • GCV R-Squared: 0.604	• Naïve R-Squared : 0.733 • Naïve adjusted R-Squared : 0.714 • GCV R-Squared: 0.599

Table 19: Model Performance Measures of MARS Models Examining Deaths from Treatable Causes

Number of Infant Deaths: Variable Importance Results

The full results of the importance of each category of healthcare spending to determining the number of male and female infant deaths are summarized in **Table 20**. The results of the model examining female infant deaths indicate that ,from highest to lowest importance, spending on

Physicians, Drugs, Other Professionals, Hospitals and Other Health Spending are the only variables which affect female infant mortality. In the model examining male infant deaths, Other Health Spending is replaced with Public Health spending. In both models all other spending categories have a relative importance score of zero.

The first differences in relative importance scores for both models follow a fairly similar pattern. The first difference between the variables ranked first and second in each model is relatively small. The same is true for those ranked third and fourth while there is a significant difference in importance scores between the variables ranked second and third, and the variables ranked fourth and fifth. Therefore it can be said that in both models, the variables ranked first and second are relatively similar in importance as are the variables ranked third and fourth. The fifth ranked variable seems to be far less important than the other four.

		NFID	
	Variable by Rank	**Relative Importance Scores**	**First Differences**
1.	Physicians	100	0
2.	Drugs	92.35	7.65
3.	Other Professionals	73.87	18.48
4.	Hospitals	67.97	5.9
5.	Other Health Spending	35.05	32.92
	Other Institutions	0	35.05
	Capital	0	0
	Public Health	0	0
	Administration	0	0
		MID	
	Variable by Rank	**Relative Importance Scores**	**First Differences**
1.	Other Professionals	100	0
2.	Physicians	98.82	1.18
3.	Drugs	81.52	17.3
4.	Hospitals	78.64	2.88
5.	Public Health	33.42	45.22
	Capital	0	33.42
	Other Institutions	0	0
	Administration	0	0
	Other Health Spending	0	0

Table 20: Male and Female Infant Mortality MARS Model Variable Importance

Interactions between healthcare spending categories are summarized in **Table 21**. There are interactions between the top four spending categories as determined in each model. In the model examining female infant deaths there is no interaction between the Other Health Spending category and the other four significant spending categories. In contrast, the model examining male infant deaths indicates that the Public Health spending category has an interaction with spending on Other Professionals.

MARS Model Variable Interactions for NFID					
	Physicians	Drugs	Other Professionals	Hospitals	Other Health Spending
Physicians	—	✓	✓	✓	X
Drugs	✓	—	✓	✓	X
Other Professionals	✓	✓	—	✓	X
Hospitals	✓	✓	✓	—	X
Other Spending	X	X	X	X	—
MARS Model Variable Interactions for NMID					
	Other Professionals	Physicians	Drugs	Hospitals	Public Health
Other Professionals	—	✓	✓	X	✓
Physicians	✓	—	✓	✓	X
Drugs	✓	✓	—	✓	X
Hospitals	X	✓	✓	—	X
Public Health	✓	X	X	X	—

Table 21: Variable Interactions for MARS Models Examining Infant Mortality

Table 22 summarizes the performance of each of the models examining infant mortality. The model performance measures indicate that while both models performed well, the model examining male infant deaths performed slightly better than the model examining female infant deaths. This means that healthcare spending levels can be used fairly reliably to estimate the level of infant mortality in Canada's provinces and that healthcare spending is slightly better at estimating male infant mortality than female infant mortality. I now move on to a full summary and discussion of the findings of this analysis.

NFID	NMID
• Naïve R-Squared: 0.737 • Naïve adjusted R-Squared: 0.718 • GCV R-Squared: 0.612	• Naïve R- Squared Measures: 0.752 • Naïve adjusted R-squared: 0.734 • GCV R-Squared: 0.638

Table 22: Model Performance Measures of MARS Models Examining Infant Mortality

5. Summary and Discussion of Findings

This research was completed with two goals in mind. These goals were to provide evidence as to which of Canada's provinces have been most effective in their healthcare spending and to determine which categories of healthcare spending should be prioritized in improving specific health outcomes. This was achieved by modelling the efficiency of the healthcare spending in Canada's provinces and defining the categories of healthcare spending which are most significant to determining the production of health outcomes in Canada's provinces.

A review of the literature based on these criteria revealed that the theory of growth accounting provides a widely used and applicable theoretical framework for completing this research. The techniques used in this thesis were specifically selected to enable the application of this theoretical framework. These techniques were data envelopment analysis, decision tree induction, and multivariate adaptive regression splines.

Data envelopment analysis was found to be used in a number of analyses of healthcare efficiency and was selected because it facilitated the analysis of healthcare spending efficiency (Hollingsworth et al., 1999; Worthington, 2004). Decision tree induction was the other technique used to complete the analysis of spending efficiency and was primarily selected for being useful in this capacity. The technique was also selected to produce information on the importance of the independent variables used in the analysis. These two techniques were combined to construct the model for determining the effectiveness of the healthcare spending in Canada's provinces.

The multivariate adaptive regression splines technique was selected specifically as a tool for regression analysis. In addition to being useful for regression, the technique also facilitated an analysis of the importance of the independent variables included in an analysis. The technique was utilised to define the categories of healthcare spending which are most significant to determining the production of health outcomes in Canada's provinces.

The health outcomes selected for measurement in this analysis were longevity, infant mortality and deaths from treatable causes, each being gender separated. Longevity was measured using life expectancy at birth and at age 65, infant mortality was measured using the number of infant deaths, and deaths due to treatable causes was measured using the number of potential years of life lost due to deaths from treatable causes. The data on these measures of health outcomes were gathered for the years 1980 to 2010 for both infant mortality and deaths due to treatable causes. Life expectancy was not as readily available and so data for life expectancy was gathered for the years 1980 to 2007. Spending data was captured for the years 1980 to 2010 in terms of dollars per capita, standardized to the year 2015. Spending data was split into nine categories:

- spending on Hospitals;
- Other Health Spending;
- spending on Other Institutions;
- spending on Physicians;
- spending on Administration;
- spending on Other Professionals;

- Public Health spending;
- Capital spending;
- and Drug spending.

The model used to determine the efficiency of healthcare spending among Canada's provinces consists of an application of the data envelopment analysis technique and the classification and regression trees technique. The analysis targeted each province's scale efficiency based on the ability to convert health inputs (healthcare spending) to health outcomes (life expectancy in years). The primary criteria of the analysis was whether or not each province was performing at its most productive scale size within the years examined. The secondary criteria of the analysis was whether provinces were operating at increasing returns to scale (inefficiently consuming too few resources and not producing enough longevity) or decreasing returns to scale (inefficiently consuming too many resources and not producing enough longevity).

The analysis was completed as follows. First, data envelopment analysis was applied the entire 28 years of data to model the relationship between health care spending and the production of life expectancy. This means that 280 observations on the amount of healthcare spending used to produce life expectancy in Canada's provinces were used to determine how efficiently provinces spent their healthcare funds. The results of this step were efficiency levels of the provinces, and the spending levels which indicate whether or not a province was operating at its most productive scale size.

Next, the results of the data envelopment analysis were used in a decision tree analysis. The decision tree revealed which categories of healthcare spending were most important in deciding whether or not a province was operating at its most productive scale size. After this, a second application of data envelopment analysis was completed. In this step the dataset was analyzed year by year. Twenty-eight individual instances of data envelop analysis (one for each year) were conducted in which all 10 provinces were compared. The results of this analysis indicate which provinces performed at most productive scale size, increasing returns to scale and decreasing returns to scale in each year from 1980 to 2007. The results of this analysis will be used to answer the first research question posed in this thesis: “How effectively have Canada’s provinces spent their healthcare funding?”

Finally multivariate adaptive regression splines technique was used to construct four multiple regression models; two targeting number of infant deaths (one regression model for each gender) and two targeting the number of potential years of life lost due to deaths from treatable causes (again, one regression model for each gender). The models were constructed from data from the years 1980 to 2010 which means there were 310 observations for each model. The results of the analysis indicated the categories of spending which were most important to determining the levels of infant mortality and amount of deaths from treatable causes observed in each year. These results of this analysis will be used to answer the second research question posed in this thesis: “How should spending be prioritized in order to improve health outcomes?” I now proceed with a full discussion of the findings.

5.1.1 The Efficient Production of Longevity

The purpose of this analysis was to answer the first research question: "How effectively have Canada's provinces spent their healthcare funding?" In the analysis, effectiveness was measured in terms of how efficiently healthcare spending was used to produce longevity. Longevity was measured in terms of life expectancy at birth and at age 65 for both genders. This means four data envelopment analysis models were completed, one for each measure of life expectancy. Essentially, the research question was interpreted as "how efficiently have Canada's provinces produced longevity?"

The initial step of the analysis examined the entire 28 years of longevity data using data envelopment analysis. The results of this analysis can be seen in **Table 11**. The results indicate that provinces were operating at their most productive scale size within the "earliest" portion of the data (the segment of data from 1980 & 1981).

For both life expectancy at age 65 and life expectancy at birth, provinces were operating at most productive scale size in 1980. Saskatchewan was the only province to operate at most productive scale size in the year 1981. This appeared in the results of the analysis of life expectancy at age 65 for both genders. In the full results it appears that British Columbia and Manitoba were the only two provinces which didn't appear to be operating at most productive scale size.

FLE65	FLEB	MLE65	MLEB
• Nfld 1980	• Nfld 1980	• Nfld 1980	• Nfld 1980
• PEI 1980	• PEI 1980	• PEI 1980	• PEI 1980
• NS 1980	• NS 1980	• NS 1980	• NS 1980
• NB 1980	• NB 1980	• NB 1980	• NB 1980
• Qc 1980	• Qc 1980	• Qc 1980	• Qc 1980
• On 1980	• On 1980	• On 1980	• On 1980
• Sk 1980	• Sk 1980	• Sk 1980	• Sk 1980
• Ab 1980	• Ab 1980	• Ab 1980	• Ab 1980
• Sk 1981		• Sk 1981	

Table 11: List of DMUs operating at Most Productive Scale Size by Measure of Life Expectancy

These results allow us to partially answer the first research question. Based on the results, it would appear that as healthcare spending increased, the efficiency with which the provinces have been able to produce longevity has decreased. Therefore, the overall efficiency of healthcare spending in Canada's provinces has declined over time.

To understand why this occurred, we can compare the change in longevity over the time frame examined to the change in the average level of total per capita healthcare spending in each province over the same time frame. I will illustrate this point using female life expectancy at birth as an example. **Table 23** contains data on the increase in average female life expectancy at birth in each province in Canada for the years 1980 and 2007. On average, life expectancy increased by 3.77 years in each province, which is approximately a 4.8% increase in life expectancy over 27 years.

	NL	PEI	NS	NB	Qc	On	Mn	Sk	Ab	BC	Average
1980	78.1	79.7	78.1	78.6	78.5	78.9	78.8	79.9	78.9	79.9	**78.9**
2007	81.2	82.8	82.4	82.8	83.4	83.6	81.9	82.1	83.0	83.9	**82.7**
Increase	3.1	3.1	4.3	4.2	4.9	4.7	3.1	2.2	4.1	4.0	**3.77**

Table 23: Female Life Expectancy at Birth by Province – 1980 versus 2007

Table 24 contains data on the increase in total per capita health care spending by province. On average total per capita healthcare spending in Canada's province increased from $906.97 in 1980 to $4957.96 in 2007, which is an approximate increase of 447%. It is important to note that all spending figures have been standardized to their dollar value in the year 2015. Therefore we can conclude that the average increase in life expectancy has been outpaced by the average increase per capita healthcare spending in Canada's provinces. This corroborates the results of the data envelopment analysis and reveals that over time, Canada's provinces have become less effective in their healthcare spending.

Province	1980	2007	Increase
Nfld	$922.35	$5030.33	$4107.98
PEI	$988.59	$4748.57	$3759.98
NS	$770.61	$5093.38	$4322.77
NB	$796.61	$4993.10	$4196.49
Qc	$904.63	$4357.54	$3452.91
On	$872.92	$5009.50	$4136.58
Mn	$938.89	$5281.96	$4343.07
Sk	$843.21	$5116.93	$5273.72
Ab	$982.07	$5257.25	$4275.18
BC	$1049.85	$4691.05	$3641.20
Average	$906.97	$4957.96	$4050.98

Table 24: Increase in Total Per Capita Healthcare Spending by Province – 1980 versus 2007

In addition to the examination of efficiency over all 28 years of available data, data envelopment analysis was used in a year by year examination of efficiency. The results indicated that, over the 28 years examined, several provinces showed instances of inefficient performance, and that the number of instances of inefficiency varied with the measure of longevity being examined (see **Table 14**). These results summarize the total quantity of inefficiency that occurred over the 30 years examined. As a specific example, the results indicate that Prince Edward Island had a single instance of inefficiency in the production of male life expectancy at age 65.

	FLE65	FLEB	MLE65	MLEB	Total
Manitoba	16	16	19	16	67
Ontario	8	7	7	7	29
New Brunswick	2	4	2	5	13
British Columbia	3	3	2	3	11
Prince Edward Island	0	0	1	0	1
Total	29	30	31	31	121

Table 14: Instances of Scale Inefficiency by Province and Category of Life Expectancy Estimate

Based on these results we can complete our answer to our first research question. Year to year, Manitoba, British Columbia, Ontario, New Brunswick and Prince Edward Island showed inefficiency in their production of longevity between 1980 and 2007. It appears that the frequency of inefficiency varied depending on the specific measure of longevity being examined and that Prince Edward Island's inefficiency was specific to a single measure of longevity (male life expectancy at age 65). With that being said, we can conclude that five of ten provinces in Canada showed inefficiency in their healthcare spending.

5.1.2 Importance of Spending Categories to the Efficient Production of Longevity

The decision tree induction technique was used on the results of the data envelopment analysis examining efficiency over the full 28 years of spending and longevity data. This analysis was performed to discover the categories of healthcare spending that are most important to determining whether or not a province efficiently produces longevity. That is, the results indicate which categories of health care spending were most influential in determining whether or not a province produced longevity with full efficiency. Through this analysis, we are able to partially answer the second research question: "How should healthcare spending be prioritized in order to improve health outcomes?"

According to the results, the importance of the spending categories in determining the efficient production of life expectancy at birth slightly differed between the analysis targeting male life expectancy at birth and the analysis targeting female life expectancy at birth. The order of importance was broken down as follows; spending on Hospitals was the most important variable for both genders and while spending on Capital and Drug spending were both determined to have no importance on the efficient production of life expectancy at birth. After this point, the results differed between the two analyses.

The results indicate that Other Health Spending was second in importance for determining the efficient production of female life expectancy at birth while the Other

Institutions category was the third in importance. In the analysis examining male life expectancy at birth, the ranking of these categories are reversed; the Other Institutions category was second in importance for determining the efficiency with which male longevity was produced while the Other Health Spending Category was third. For both genders, the remaining categories of spending variables were ranked identically:

4. spending on Physicians;
5. spending on Administration;
6. spending on Other Professionals;
7. Public Health spending.

The results of the analysis focusing on life expectancy at age 65 indicates that the ranking of variables based on their importance to determining the efficient production of longevity at age 65 was the same for both genders. The results indicated that Drug spending was determined to have no significance. The ranking of the remaining spending categories was as follows:

1. spending on Hospitals;
2. spending on Physicians;
3. Other Health Spending;
4. spending on Other Professionals;
5. spending on Other Institutions;
6. spending on Administration;
7. Capital spending;

8. Public Health spending.

These results indicate that affecting the efficient production of longevity requires that spending on Hospitals be prioritized above all other categories of healthcare spending. It also appears that spending on Drugs does not affect the efficient production of longevity in Canada's provinces. The other categories of healthcare affect the efficient production of longevity differently depending on whether one is targeting the efficient production of life expectancy at age 65, or the efficient production of life expectancy at birth. Further, gender should be considered when attempting to affect life expectancy at birth as there is a slight difference in how the two categories of healthcare spending should be prioritized when focusing on either male life expectancy at birth or female life expectancy at birth.

5.1.3 The Causes of Inefficiency

One question raised by these results is "What caused these provinces to perform inefficiently? " Identifying the source of the observed inefficiency in a province requires an examination of that province's spending patterns in comparison to the variable importance results. To illustrate I will use Prince Edward Island which had a single instance of performing at increasing returns to scale in the year 1991 within the analysis of male life expectancy at age 65. **Table 25** contains a summary of the data on male life expectancy at age 65 and per capita health spending by category for Prince Edward Island in the year 1991.

Prince Edward Island was found to be operating at increasing returns to scale in the year 1991. A province operating at increasing returns to scale in the production of longevity is inefficient because the province is not spending enough on healthcare to produce longevity at its most productive scale size. Therefore Prince Edward Island did not spend enough on healthcare in the year 1991 to produce male life expectancy at age 65 at the province's most productive scale size. For a province operating at increasing returns to scale to operate at its most productive scale size in the production of longevity, it would need to spend more on healthcare. We can suggest changes hypothetical changes to Prince Edward Island's spending in 1991 order to have the province operate at its most productive scale size in the production of male life expectancy at age 65. To make suggestions as to how changes to healthcare spending should be prioritized requires two steps. First we will examine the ranking of spending categories produced in the previous analysis. Second we will examine the spending

LONGEVITY AND SPENDING CATEGORIES	VALUE IN 1991
MALE LIFE EXPECTANCY AT AGE 65	14.3 Years
HOSPITALS	$837.5
PHYSICIANS	$241.14
OTHER HEALTH SPENDING	$83.14
OTHER PROFESSIONALS	$198.94
OTHER INSTITUTIONS	$301.71
ADMINISTRATION	$46.93
CAPITAL	$65.36
PUBLIC HEALTH	$80.65
DRUGS	$298.14

Table 25: Male Life Expectancy at age 65 and Per Capita Healthcare Spending, Prince Edward Island, 1991

I reiterate that the variable importance results are significant here because they indicate which categories of spending are most important in determining whether or not a province was efficiently producing longevity over the 28 years examined using data envelopment analysis. The variable importance results which focused on male life expectancy at age 65 ranked the importance of each category of healthcare spending as follows:

1. spending on Hospitals;
2. spending on Physicians;
3. Other Health Spending;
4. spending on Other Professionals;
5. spending on Other Institutions;
6. spending on Administration;
7. Capital spending;
8. Public Health spending.

Additionally the results indicate that Spending on Drugs was determined to have no importance to determining the efficient production of life expectancy at age 65.

Table 26 contains data on the provincial average level of male life expectancy at age 65 in 1991 as well as the provincial average level of per capita healthcare spending by category in 1991. We can see in **Table 26** that Prince Edward Island had lower than average male life expectancy at age 65 in the year 1991. We can also see that Prince Edward Island spent less on Hospitals, Physicians, Other Health Spending, Other Professionals, Administration, Capital, and Public Health than the provincial average. As well, Prince Edward Island had higher than average per capita spending on Other Institutions and Drugs than the provincial average.

Of the categories of healthcare spending that significantly impact the efficient production of male life expectancy at age 65, spending on Other Institutions was the only category in which Prince Edward Island appeared to have a higher than average level of spending. In contrast, we can see that while spending on Drugs was found to have no significance in determining the efficient production of male life expectancy at age 65, Prince Edward Island spent more than the provincial average on Drugs in 1991. These results demonstrate the exact source of inefficiency in Prince Edward Island's production of male life expectancy.

LONGEVITY AND SPENDING CATEGORIES	PROVINCIAL AVERAGE IN 1991	PRINCE EDWARD ISLAND IN 1991	DIFFERENCE
MALE LIFE EXPECTANCY AT AGE 65	15.62	14.3	1.32
HOSPITALS	882.396	837.5	44.896
PHYSICIANS	295.61	241.14	54.47
OTHER HEALTH SPENDING	108.32	83.14	25.18
OTHER PROFESSIONALS	220.342	198.94	21.402
OTHER INSTITUTIONS	266.733	301.71	-34.977
ADMINISTRATION	55.81	46.93	8.88
CAPITAL	78.73	65.36	13.37
PUBLIC HEALTH	82.99	80.65	2.34
DRUGS	270.11	298.14	-28.04

Table 26: Male Life Expectancy at age 65 and Per Capita Healthcare Spending, Prince Edward Island, 1991

In a broader context, addressing the inefficient production of longevity caused by a province's healthcare spending is a question of specific policy. Within this example, we can discuss the possible levels of spending that would have hypothetically caused Prince Edward Island to produce male life expectancy at age 65 at its most productive scale size for the year 1991. However though the source of inefficiency is corroborated by the spending figures, other factors may have played a role in lowering the life expectancy observed in the province. The data envelopment analysis technique provides a method of examining how the provinces should have produced longevity given the resources that they consumed, however beyond a technical analysis, the method doesn't necessarily allow for assumptions to be made as to how policy should be changed to improve efficiency. These limitations will be discussed in more detail at a later point. With that being said, I now move on to discussing the results of the analysis of infant mortality and deaths due to treatable causes.

5.2.1 The Importance of Spending to Determining Non-Longevity Health Outcomes

The multivariate adaptive regression splines technique was used to analyse the relationship between healthcare spending and two specific health outcomes in Canada's provinces: infant mortality and deaths due to treatable causes. These analyses were conducted using data from 1980 to 2010 to examine the importance of healthcare spending to determining specific health outcomes. In the analysis, the number deaths due to treatable causes were represented using the number of potential years of life lost from deaths due to treatable causes while infant mortality was examined using the number of infant deaths. Two regression analyses were conducted for the analysis deaths due to treatable causes; one targeting male deaths due to treatable causes, and one targeting female deaths due to treatable causes. Two regression analyses were also conducted to model infant mortality; one targeting female infant deaths and one targeting male infant deaths. I will first discuss the findings of the analysis examining deaths due to treatable causes, following this with a discussion of the findings of the analysis examining infant mortality.

5.2.2 The Importance of Spending to Determining Deaths due to Treatable Causes

The results of the analysis examining deaths due to treatable causes indicate the importance of each individual healthcare spending category to determining the number of deaths due to treatable causes in a province. The results of the separate analyses examining male and female deaths from treatable causes both indicate that spending on Capital, spending on Other Institutions, spending on Administration, spending on Other Professionals and Other

Health Spending were all determined to have no effect in determining deaths due to treatable causes. The results of the multivariate adaptive regression splines analysis examining female deaths due to treatable causes rank the rest of the healthcare spending categories as follows:

1. spending on Physicians;
2. spending on Hospitals;
3. spending and Drugs;
4. Public Health spending;

The results of the multivariate adaptive regression splines analysis ranking the importance of healthcare spending categories to determining the numbers of male deaths due to treatable causes in Canada's provinces are as follows:

1. spending on Physicians;
2. spending and Drugs;
3. spending on Hospitals;
4. Public Health spending;

We can see from these results that while deaths due to treatable causes is primarily determined by four categories of healthcare spending: spending on Physicians, spending on Hospitals, Drugs spending, and Public Health spending. Of these categories of healthcare spending, spending on Physicians and Public Health spending are indicated as being first and fourth in importance respectively. The results also indicate that Spending on Hospitals is more significant to determining the number of female deaths due to treatable causes while spending on drugs is more important to determining the number of male deaths due to treatable causes.

In other words, we can conclude that spending on Hospitals is of primary importance to determining the number of deaths due to treatable causes in Canada's provinces. Additionally spending on Hospitals is slightly more important to preventing female deaths than it is to preventing male deaths in Canada's provinces. Finally, for both genders, Public Health Spending is fourth in terms of relevance to determining preventable deaths in Canada's provinces while spending on Capital, spending on Other Institutions, spending on Administration, spending on Other Professionals and Other Health Spending have no effect in determining deaths due to treatable causes. In both models, all other categories of spending have at least one interaction with each other. Based on these rankings I conclude that spending on Physicians is a primary determinant of the number of deaths due to treatable causes in Canada's provinces.

As a result of the analysis of deaths from treatable causes, data on two-way interactions between spending categories was generated. These results indicate the categories of healthcare spending which interacted with each other in the determination of deaths due to treatable causes. The results indicate that all for both male and female deaths due to treatable causes, spending on Hospitals and spending on Physicians had no interactions with each other. According to the results, these two categories of healthcare both contribute to determining the number of male and female deaths from treatable causes but do not affect each other. All other categories of healthcare spending that were determined to be significant in determining deaths from treatable causes interacted with each other. I now move on to discuss the results of the analysis of infant mortality.

5.2.3 The Importance of Spending to Determining Infant Mortality

The results of the analysis of infant mortality indicate the importance of each category of healthcare spending to determining the level of infant mortality in each of Canada's provinces. I will begin by examining female infant mortality. The results of the multivariate adaptive regression splines analysis of the number of female infant deaths indicate that spending on Other Institutions, spending on Capital, spending on Public Health, and spending on Administration all had no importance to determining the number of female infant deaths in Canada's provinces. The remaining categories of spending were ranked as follows:

1. spending on Physicians;
2. spending on Drugs;
3. spending on Other Professionals;
4. spending on Hospitals;
5. Other Health Spending.

The results of the analysis of male infant mortality indicate that spending on Capital, spending on Other Institutions, spending on Administration and Other Health Spending all had no significance in determining the number of male infant deaths in Canada's provinces. According to the results, the ranking of the remaining five categories of healthcare spending was as follows:

1. spending on Other Professionals;
2. spending on Physicians;
3. spending on Drugs;

4. spending on Hospitals;
5. Public Health spending.

Based on these findings, we can conclude that in Canada's provinces, male and female infant mortality are determined by two similar but slightly different sets of categories of healthcare spending. Male infant mortality is determined by spending on Other Professionals, spending on Physicians, spending on Drugs, spending on Hospitals and Public Health spending. Female infant mortality is determined by spending on Physicians, spending on Drugs, spending on Other Professionals, spending on Hospitals, and Other Health Spending. It appears that spending on Physicians ranked first in determining female infant mortality and second in determining male infant mortality. Therefore I conclude that spending on Physicians is a primary determinant of infant mortality in Canada's provinces. I will now proceed to discuss the contribution of healthcare spending to the prediction of healthcare outcomes.

Table 21 below summarizes the results of the interaction of spending categories in the determination of male and female infant mortality. The results of the analysis of female infant deaths indicates that the Other Health Spending category did not affect any other of the five other categories of healthcare spending which are significant to determining female infant mortality.

The results of the analysis of male infant deaths indicate that Public Health Spending only interacts with spending on Other Professionals in determining infant mortality. Additionally there is no interaction between spending on Hospitals and spending on Physicians in the determination of male infant mortality. Other than these exceptions, there are two-way interactions between all of the categories of healthcare spending which are significant to determining male infant mortality in Canada’s provinces.

MARS Model Variable Interactions for NFID					
	Physicians	Drugs	Other Professionals	Hospitals	Other Health Spending
Physicians		✓	✓	✓	
Drugs	✓		✓	✓	
Other Professionals	✓	✓		✓	
Hospitals	✓	✓	✓		
Other Spending					

MARS Model Variable Interactions for NMID					
	Other Professionals	Physicians	Drugs	Hospitals	Public Health
Other Professionals		✓	✓		✓
Physicians	✓		✓	✓	
Drugs	✓	✓		✓	
Hospitals		✓	✓		
Public Health	✓				

Table 21: Variable Interactions for MARS Models Examining Infant Mortality

5.4 The Contribution of Spending to the Prediction of Health Outcomes

In addition to the variable importance results, the multivariate adaptive regression splines analyses of infant mortality and deaths from treatable causes yielded results on the predictive ability of the models that were generated. In other words, the multivariate adaptive regression splines technique provides an indicator of how well the spending categories that were analysed were able to allow for the prediction of infant mortality and deaths from treatable causes. These results came in the form of the R-Squared statistics for each of the models that were generated. Each R-Squared statistics provides an indication of how well its corresponding model predicted variance in health outcome they modeled; the R-Squared statistics indicated each model's performance. An R-Squared statistic with a value of 1 would indicate that a model was perfect, while a value of 0 indicates that a model has no predictive value. As a hypothetical example, a model targeting the annual number of male infant deaths as a function of annual health care spending that reports an R-Squared statistic with a value of

.620 indicates that annual healthcare spending is able to predict 62% of observations of the annual number of male infant deaths.

As a function of the software used in this analysis, each multivariate adaptive regression splines model yielded three R-Squared measures. Listed in order from the most relaxed to most rigorous measure of performance, these were the Naïve R-Squared, Naïve adjusted R-Squared, and GCV R-Squared. **Table 27** contains the R-Squared statistics for each of the multivariate adaptive regression splines models generated in the analysis of infant mortality and treatable deaths.

The GCV R-Squared statistics of each model indicate a relatively high level of predictive performance for each of the models that were generated. The model examining number of female infant deaths reported a GCV R-Squared statistics of 0.638 while the model examining the number of male infant deaths reported an R-Squared statistic of 0.612. For all four of the models, the Naïve R-Squared. The model examining female deaths from treatable causes reported a naïve R-Squared statistic of 0.599, while the model examining male deaths from treatable causes reported a naïve R-Squared statistic of 0.604. These scores indicate that the models perform with a relative high level of predictive ability.

Health Outcome	R- Squared Statistics
Number of Female Infant Deaths	• Naïve R- Squared: 0.752 • Naïve adjusted: 0.734 • GCV R-Squared: 0.638
Number of Male Infant Deaths	• Naïve R-Squared: 0.737 • Naïve adjusted R-Squared: 0.718 • GCV R-Squared: 0.612
Female Potential Years of Life Lost due to Deaths from Treatable Causes	• Naïve R-Squared : 0.733 • Naïve adjusted R-Squared : 0.714 • GCV R-Squared: 0.599
Male Potential Years of Life Lost due to Deaths from Treatable Causes	• Naïve R-Squared: 0.713 • Naïve adjusted R-Squared: 0.697 • GCV R-Squared: 0.604

Table 27: R-Squared Statistics of Multivariate Adaptive Regression Splines Models

The results indicate that while spending levels do not account for the entirety of the variability in either infant mortality or deaths from treatable causes, from a statistical standpoint, spending is still a powerful component in determining these health outcomes. Healthcare spending in Canada's provinces has a non-negligible effect on the health outcomes experienced by the public. I now move on to a final discussion of findings.

6. Discussion and Conclusion

6.1 Discussion

In this chapter I discuss and interpret the findings made in this thesis. I then briefly discuss the limitations of this analysis and conclude the thesis with a discussion of possible options for future research.

The data used in this analysis indicates two trends. First, healthcare outcomes in Canada's provinces have improved over time (i.e. increased life expectancy, lower infant mortality, and fewer deaths due to treatable causes). Second, the absolute value of per capita healthcare spending has increased over time across all categories of spending and in all provinces. An analysis of this data reveals that while the improvements in health outcomes are an inarguably positive trend for the country's population, the amount of spending that has been used to achieve these improvements is inefficient.

The longitudinal analysis of spending efficiency indicates that, in the long run, healthcare spending has passed the point of producing significant improvements in health outcomes. This conclusion was demonstrated by specifically examining improvements in longevity (male and female life expectancy at birth and at age 65) over 28 years relative to increases in healthcare spending. In addition to this pattern of inefficiency, a cross-sectional, year by year analysis using the same data reveals more patterns of inefficiency amongst Canada's provinces in their production of longevity. The panel analysis revealed instances of both over and under-spending amongst provinces in different years based on specific measures of life expectancy.

This leads to the question of why health spending continues to increase over time while efficiency suffers. Granted, we can see that health outcomes are improving, one could say that the ends do not necessarily justify the means. In a cross-country comparison of OECD member nations is, Spinks & Hollingsworth (2009) argue that, from a political standpoint, it would be difficult for policy makers to suggest that healthcare funding be frozen or decreased without pushback. In health policy, increased healthcare spending is often linked to improved health outcomes. In reality, this isn't necessarily true. In their cross-country examination of the effect of public health spending on health outcomes, Self & Grabowski (2003) come to an interesting conclusion. When developing countries increase health spending they tend to improve their health outcomes. In contrast, the level of positive health outcomes experienced by richer countries could be thought of as a self-perpetuating cycle. Developed countries in which healthcare outcomes are largely positive tend to retain positive health outcomes over time.

While the findings of this thesis support this conclusion, they also support the conclusion that increased spending has contributed to positive trends in health outcomes, and the conclusion that healthcare spending is a significant determinant of health outcomes in Canada's provinces. The separate analyses of infant mortality and deaths from treatable causes both indicate that per-capita health care funding makes a significant contribution to determining these two health outcomes. The exclusion of any other determinants of health outcomes in these analyses allowed for the significance of spending to be isolated. Doing this has provided evidence that healthcare spending is a major influence on health outcomes. As well, these findings support conclusions reached by Crémieux et al. (1999) in their analysis of the relationship between healthcare spending and health outcomes in Canada. Crémieux et al. (1999) construct a regression model that includes spending, per capita number of physicians per capita, per capita income, population density, education level, poverty rate, alcohol use, tobacco use and nutritional data. These variables are analyzed in terms of their contribution to determining gender specific infant mortality and life expectancy. The authors determine that after removing non-spending variables from the regression model, the contribution of spending to determining the examined health outcomes was still significant. The authors attribute this to their use of homogenous, Canada specific data.

This is a trait shared with the dataset analyzed in this in this thesis; the data examined here is specific to Canada. The significance of this trait of the dataset is that in international analyses, the literature indicates that healthcare spending is not as strong of a predictor of health outcomes as other variables (Or, 2000, 2001). Therefore I have elected to focus on spending variables in lieu of non-spending variables, not because non-spending variables are irrelevant, but because the analysis being performed does not lose validity due to the exclusion of non-spending variables.

With that being said, one of the original goals of this research was to determine the categories of healthcare spending that should be prioritized to improve health outcomes. The isolation of the relationship between spending and the production of health outcomes in this analysis provides an indication of the ways in which health spending should be prioritized in order to improve health outcomes. The results indicate that, in Canada, spending on Hospitals is the primary determinant of the efficient production of longevity. Additionally spending on Physicians appears to be a primary contributor to determining infant mortality and the number of deaths due to treatable causes in Canada's provinces. Therefore we can conclude that the improvement of health outcomes in Canada's provinces requires the prioritization of changes to spending on Hospitals and Physicians. These conclusions should be framed within the context of the findings regarding the efficient production of longevity, and the marginal improvements in longevity over the timeline examined in this thesis. In this context we can claim that while these categories of healthcare spending contribute significantly to determining health outcomes in Canada's provinces, prioritizing changes to spending on Hospitals and Physicians may only create marginal improvements in the health outcomes examined. It should be clarified that changes in the prioritization of these categories of healthcare spending do not necessarily mean spending increases. Within the context of the efficient production of longevity, it has been concluded that increases in healthcare spending are inefficiently contributing to increases in life expectancy. Therefore it is recommended that changes in healthcare spending policy should prioritize modifications that increase efficiency and that, in terms of the efficient production of longevity, Hospital spending should be prioritized.

Additionally, differences in efficient production of longevity were noted in the analysis in the specific sense that beginning of the time period examined indicated a higher level of efficiency than the later period. The increases in healthcare spending over time are constitute a significant portion of these observed differences. These spending increases are often attributed to an ageing population (Crémieux et al., 2005, 1999; Nicq et al., 2010) However, there is contention on this point with the argument being that the link between increased healthcare costs in countries where a larger share of the population is elderly is false (Lubitz, Cai, Kramarow, & Lentzner, 2003; Morgan & Cunningham, 2011; Reinhardt, 2003; Zweifel, 1999). From this standpoint, one could argue that increased healthcare spending can be attributed to attempts to sustain and increase improvements in health outcomes as a common policy of health systems. In the case of the US, administration is often pointed to as a source of rising costs. While this study does not directly address the source of increases in healthcare spending, the results of the analysis imply that these increases contribute to the inefficient production of longevity. I now move on to a discussion of limitations.

6.2 Limitations

The primary limitation of this research was a lack of data availability. Specifically, data was limited in the time-span it covered which kept the analysis from being completed over more time. This is with specific regard to the longevity data which was difficult to compile compared to the other health outcomes examined. These data availability issues also affected the ability of the analysis to include non-spending variables. The inclusion of data on variables such as education, diet and lifestyle would have limited the scope of the analysis. Education data (other than literacy) was particularly difficult to compile for all of the years of the study; the gaps were too large to develop a viable data set.

Relatedly, the usefulness of life expectancy as a measure of population health status is debatable (Joumard & Häkkinen, 2007). While measures of longevity do provide information on how well health systems are able to sustain populations, they lack the qualitative component that speaks to the quality of the life that's being lived.

Joumard & Häkkinen (2007) argue that the best measures of health system outcomes in this framework would be quality-adjusted life-years, a measure which accounts for both longevity and quality of life. Because this measure hasn't been captured in a format which would facilitate this research I instead relied on multiple measures of healthcare outcomes. I now move on to the conclusion of this thesis.

6.3 Conclusion

In this conclusion I make a final reflection on the findings of this thesis, argue for the m model of research used in this analysis and discuss paths for future research studies. The findings of this research confirm the importance of healthcare spending as a major determinant of health outcomes. The results of the analysis of efficiency indicate that, as a developed country, improvements to longevity in Canada's provinces are likely to only be marginal as healthcare spending continues to increase over time. The research also indicates that spending on Hospitals is a major contributor to the efficient spending of longevity, and that spending on Physicians is a major contributor to the level of infant mortality and deaths from treatable causes. These findings answer the two research questions posed in the beginning of this thesis: "How effectively have Canada's provinces spent their healthcare funding?" and "How should spending be prioritized in order to improve health outcomes?"

This research analyzed data gathered using uniform methods, with all observations using standardized units of measure. Because of the homogenous nature of the dataset used in this analysis, these findings are limited to the Canadian context. I claim that this is a strength of the research rather than a limitation. In international analyses of healthcare systems which use blended datasets, the homogeneity of data creates inconsistencies due to differences in measurement of health outcomes. I believe that international comparisons of healthcare systems would benefit from using research models that compare the findings of multiple small studies which analyse homogenous, country-specific datasets.

Options for future research on the performance of Canada's provincial healthcare system emerge from this study. For example the inefficiency exposed within the year to year, time-series analysis of the production of longevity would benefit from investigation beyond that performed here. Analyses of policy and non-monetary factors that have contributed to the healthcare outcomes observed in the dataset would create more insight into the results observed in this thesis. However, data availability recurs as a major limiting factor in these types of studies. Longitudinal and time series analysis that include data from further into the past than the research completed here are limited by past data collection. Future studies will likely benefit from the collection of robust data from the present and later. As the economic study of healthcare continues to be a recurring issue, it is likely larger timespans than that observed here will be analysed.

Appendices

There are three appendices included in this thesis. Appendix A contains graphs and summary statistics for healthcare spending province for each of Canada's ten provinces between the years 1980 and 2010. Appendix B contains summary statistics for the healthcare outcomes examined in the empirical analysis. Appendix C contains an explanation for the proper interpretation of MARS model functions produced in the analysis of infant mortality and deaths from treatable causes.

Appendix A – Summary Statistics: Health Spending by Province

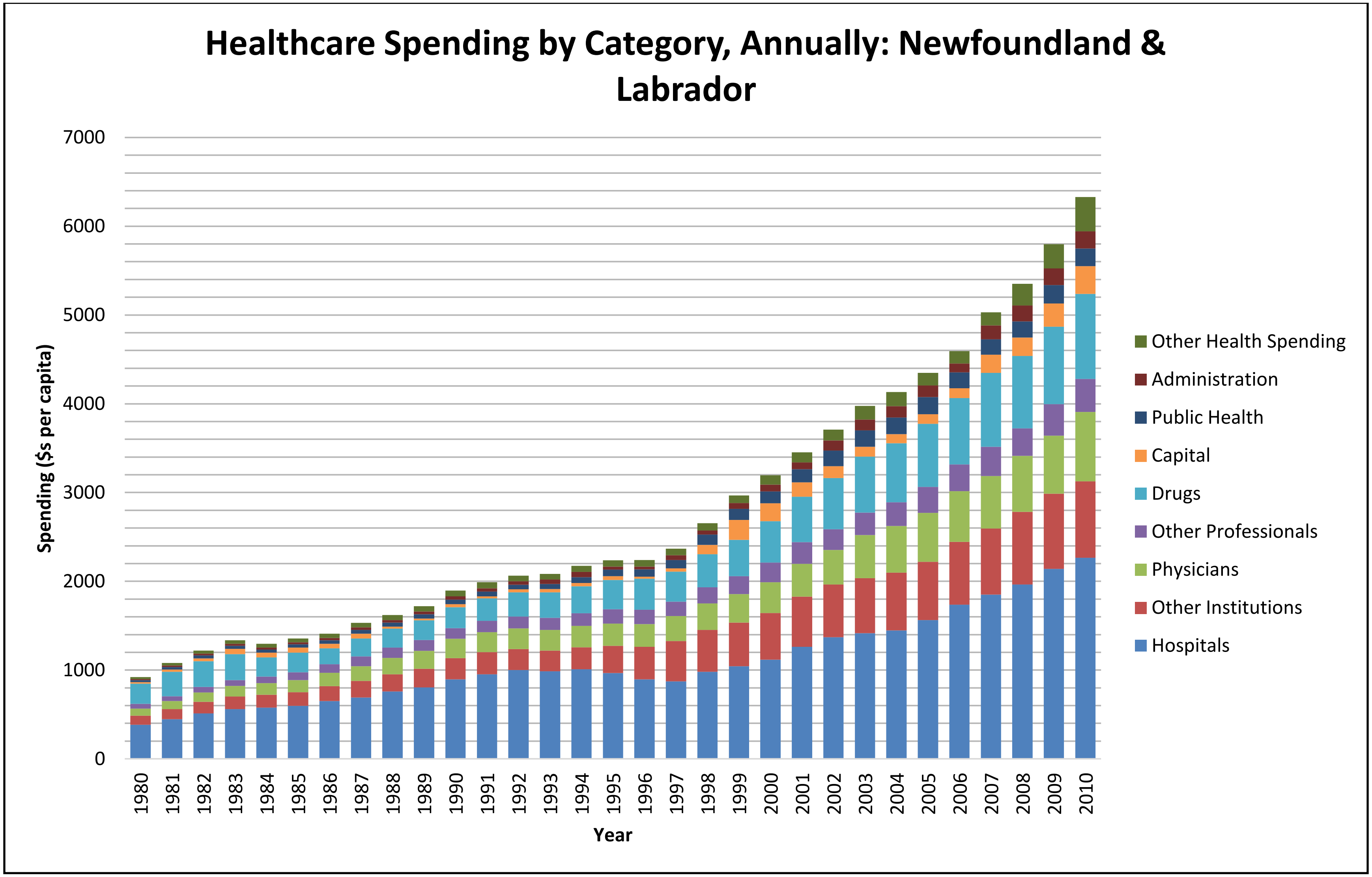

Figure 1: Healthcare Spending by Category, 1980-2010 – Newfoundland & Labrador

Hospitals		Other Institutions		Physicians		Other Professionals		Drugs	
Mean	1087.97	**Mean**	400.89	**Mean**	316.75	**Mean**	179.19	**Mean**	428.06
Standard Error	90.26	**Standard Error**	44.33	**Standard Error**	34.29	**Standard Error**	16.94	**Standard Error**	42.07
Median	981.06	**Median**	304.72	**Median**	250.71	**Median**	161.10	**Median**	329.08
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	502.57	**Standard Deviation**	246.80	**Standard Deviation**	190.90	**Standard Deviation**	94.35	**Standard Deviation**	234.21
Sample Variance	252571.97	**Sample Variance**	60909.00	**Sample Variance**	36441.99	**Sample Variance**	8901.12	**Sample Variance**	54854.70
Kurtosis	-0.04	**Kurtosis**	-1.18	**Kurtosis**	-0.29	**Kurtosis**	-0.87	**Kurtosis**	-0.48
Skewness	0.83	**Skewness**	0.49	**Skewness**	0.84	**Skewness**	0.53	**Skewness**	0.93
Range	1880.96	**Range**	758.74	**Range**	703.85	**Range**	317.00	**Range**	777.04
Minimum	384.32	**Minimum**	102.91	**Minimum**	78.22	**Minimum**	54.50	**Minimum**	180.75
Maximum	2265.28	**Maximum**	861.65	**Maximum**	782.07	**Maximum**	371.50	**Maximum**	957.79
Sum	33727.15	**Sum**	12427.51	**Sum**	9819.34	**Sum**	5554.93	**Sum**	13269.94
Count	31	**Count**	31	**Count**	31	**Count**	31	**Count**	31

Table 1a: Healthcare Spending by Category of Spending, Summary Statistics – Newfoundland & Labrador

Capital		Public Health		Administration		Other Health Spending	
Mean	93.76	**Mean**	99.87	**Mean**	69.22	**Mean**	101.36
Standard Error	14.58	**Standard Error**	11.56	**Standard Error**	9.90	**Standard Error**	14.23
Median	54.53	**Median**	71.95	**Median**	45.17	**Median**	71.45
Mode	37.52	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	81.20	**Standard Deviation**	64.39	**Standard Deviation**	55.09	**Standard Deviation**	79.24
Sample Variance	6592.88	**Sample Variance**	4145.53	**Sample Variance**	3035.40	**Sample Variance**	6279.55
Kurtosis	0.43	**Kurtosis**	-1.52	**Kurtosis**	-0.13	**Kurtosis**	5.16
Skewness	1.18	**Skewness**	0.44	**Skewness**	1.05	**Skewness**	2.12
Range	292.90	**Range**	185.10	**Range**	180.25	**Range**	364.13
Minimum	17.88	**Minimum**	22.15	**Minimum**	11.60	**Minimum**	23.98
Maximum	310.78	**Maximum**	207.25	**Maximum**	191.85	**Maximum**	388.11
Sum	2906.49	**Sum**	3095.86	**Sum**	2145.80	**Sum**	3142.04
Count	31	**Count**	31	**Count**	31	**Count**	31

Table 1b: Healthcare Spending by Category of Spending, Summary Statistics – Newfoundland & Labrador

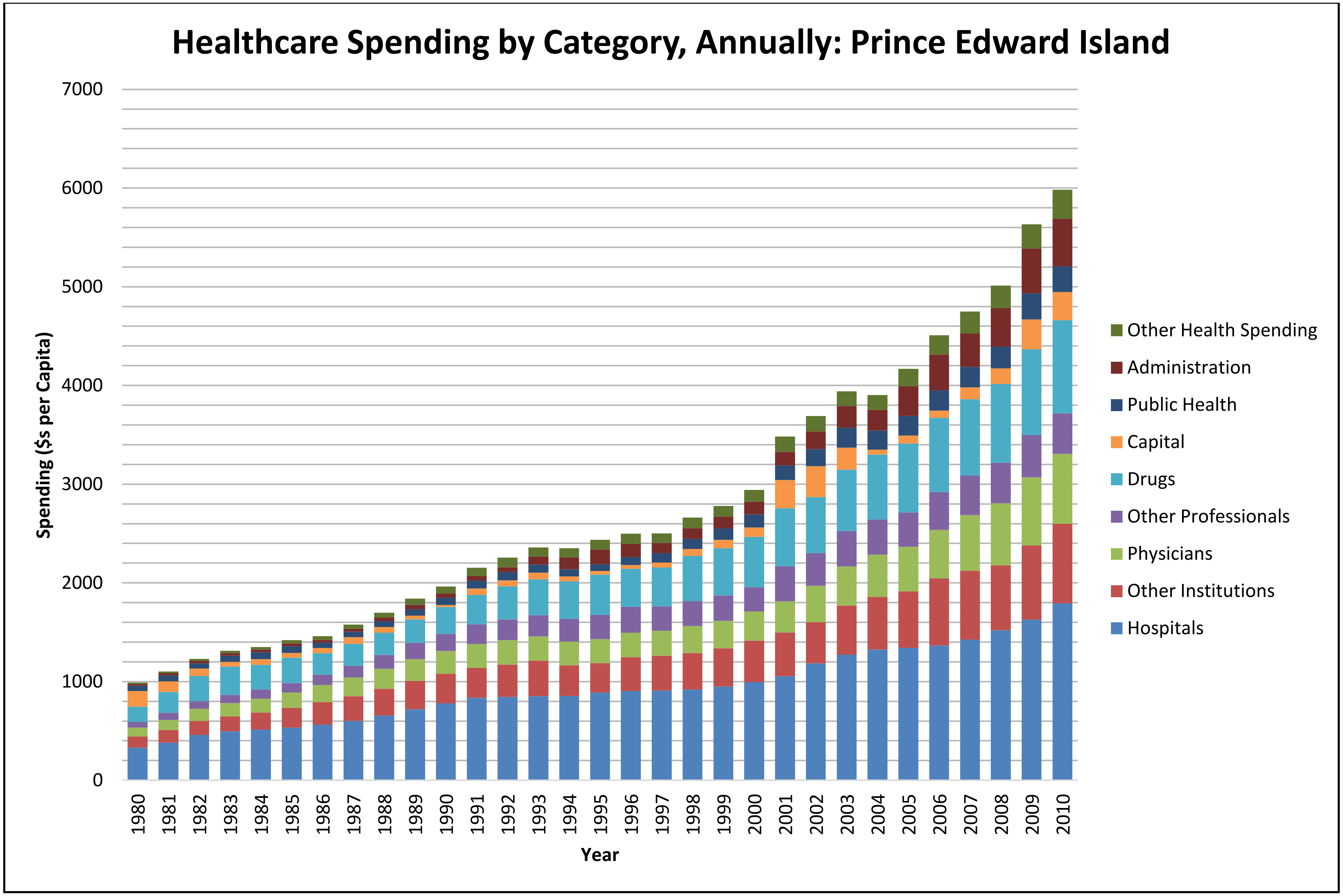

Figure 2: Healthcare Spending by Category, 1980-2010 – Prince Edward Island

Hospitals		Other Institutions		Physicians		Other Professionals		Drugs	
Mean	932.03	**Mean**	379.71	**Mean**	302.47	**Mean**	235.91	**Mean**	447.91
Standard Error	68.44	**Standard Error**	34.02	**Standard Error**	30.19	**Standard Error**	21.05	**Standard Error**	39.94
Median	887.94	**Median**	342.53	**Median**	247.87	**Median**	243.74	**Median**	386.90
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	381.06	**Standard Deviation**	189.41	**Standard Deviation**	168.07	**Standard Deviation**	117.21	**Standard Deviation**	222.38
Sample Variance	145203.75	**Sample Variance**	35876.81	**Sample Variance**	28246.93	**Sample Variance**	13737.47	**Sample Variance**	49452.99
Kurtosis	-0.49	**Kurtosis**	-0.24	**Kurtosis**	0.53	**Kurtosis**	-1.26	**Kurtosis**	-0.63
Skewness	0.47	**Skewness**	0.72	**Skewness**	1.12	**Skewness**	0.08	**Skewness**	0.71
Range	1462.18	**Range**	691.36	**Range**	620.09	**Range**	368.99	**Range**	789.27
Minimum	330.67	**Minimum**	113.76	**Minimum**	88.15	**Minimum**	58.23	**Minimum**	156.36
Maximum	1792.85	**Maximum**	805.12	**Maximum**	708.24	**Maximum**	427.22	**Maximum**	945.63
Sum	28892.79	**Sum**	11770.91	**Sum**	9376.62	**Sum**	7313.31	**Sum**	13885.20
Count	31	**Count**	31	**Count**	31	**Count**	31	**Count**	31

Table 2a: Healthcare Spending by Category of Spending, Summary Statistics – Prince Edward Island

Capital		Public Health		Administration		Other Health Spending	
Mean	104.30	**Mean**	118.03	**Mean**	143.31	**Mean**	108.75
Standard Error	15.48	**Standard Error**	12.12	**Standard Error**	24.64	**Standard Error**	13.24
Median	67.97	**Median**	81.05	**Median**	106.34	**Median**	96.82
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	86.18	**Standard Deviation**	67.46	**Standard Deviation**	137.18	**Standard Deviation**	73.74
Sample Variance	7426.87	**Sample Variance**	4550.89	**Sample Variance**	18817.84	**Sample Variance**	5438.08
Kurtosis	1.13	**Kurtosis**	-0.68	**Kurtosis**	0.45	**Kurtosis**	0.01
Skewness	1.54	**Skewness**	0.88	**Skewness**	1.22	**Skewness**	0.77
Range	295.24	**Range**	208.91	**Range**	464.49	**Range**	280.40
Minimum	18.74	**Minimum**	52.68	**Minimum**	17.67	**Minimum**	14.33
Maximum	313.98	**Maximum**	261.59	**Maximum**	482.16	**Maximum**	294.73
Sum	3233.34	**Sum**	3659.06	**Sum**	4442.63	**Sum**	3371.25
Count	31	**Count**	31	**Count**	31	**Count**	31

Table 2b: Healthcare Spending by Category of Spending, Summary Statistics – Prince Edward Island

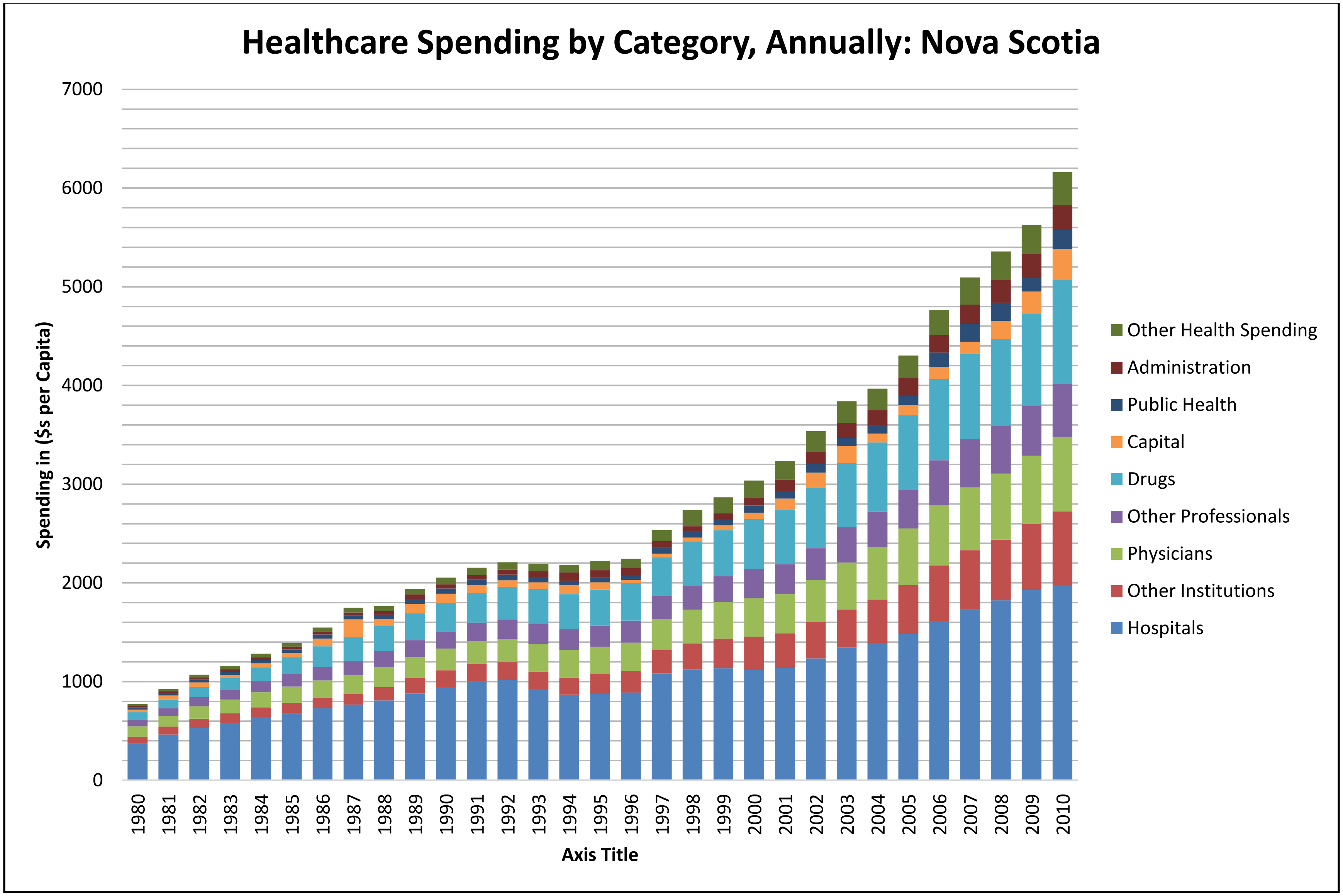

Figure 3: Healthcare Spending by Category, 1980-2010 – Nova Scotia

Hospitals		Other Institutions		Physicians		Other Professionals		Drugs	
Mean	1066.97	**Mean**	281.62	**Mean**	340.69	**Mean**	253.19	**Mean**	440.98
Standard Error	76.36	**Standard Error**	35.15	**Standard Error**	34.11	**Standard Error**	24.57	**Standard Error**	49.37
Median	1002.87	**Median**	204.15	**Median**	280.13	**Median**	216.82	**Median**	362.43
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	425.14	**Standard Deviation**	195.72	**Standard Deviation**	189.93	**Standard Deviation**	136.81	**Standard Deviation**	274.87
Sample Variance	180743.66	**Sample Variance**	38308.09	**Sample Variance**	36072.84	**Sample Variance**	18717.00	**Sample Variance**	75554.96
Kurtosis	-0.26	**Kurtosis**	-0.11	**Kurtosis**	-0.60	**Kurtosis**	-0.53	**Kurtosis**	-0.60
Skewness	0.61	**Skewness**	0.99	**Skewness**	0.74	**Skewness**	0.70	**Skewness**	0.63
Range	1601.63	**Range**	682.50	**Range**	647.53	**Range**	476.43	**Range**	972.98
Minimum	369.96	**Minimum**	70.62	**Minimum**	104.76	**Minimum**	67.12	**Minimum**	76.55
Maximum	1971.59	**Maximum**	753.12	**Maximum**	752.29	**Maximum**	543.55	**Maximum**	1049.53
Sum	33076.17	**Sum**	8730.10	**Sum**	10561.43	**Sum**	7848.83	**Sum**	13670.49
Count	31	**Count**	31	**Count**	31	**Count**	31	**Count**	31

Table 3a: Healthcare Spending by Category of Spending, Summary Statistics – Nova Scotia

Capital		Public Health		Administration		Other Health Spending	
Mean	95.16	**Mean**	72.12	**Mean**	90.88	**Mean**	129.68
Standard Error	11.74	**Standard Error**	8.44	**Standard Error**	12.99	**Standard Error**	17.20
Median	76.12	**Median**	56.33	**Median**	60.46	**Median**	91.89
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	65.35	**Standard Deviation**	47.00	**Standard Deviation**	72.33	**Standard Deviation**	95.77
Sample Variance	4271.02	**Sample Variance**	2208.66	**Sample Variance**	5230.95	**Sample Variance**	9171.83
Kurtosis	2.98	**Kurtosis**	1.47	**Kurtosis**	-0.16	**Kurtosis**	-0.97
Skewness	1.62	**Skewness**	1.52	**Skewness**	1.04	**Skewness**	0.61
Range	285.10	**Range**	169.98	**Range**	236.93	**Range**	316.34
Minimum	27.91	**Minimum**	22.27	**Minimum**	16.07	**Minimum**	15.35
Maximum	313.01	**Maximum**	192.25	**Maximum**	253.00	**Maximum**	331.69
Sum	2949.92	**Sum**	2235.80	**Sum**	2817.22	**Sum**	4020.15
Count	31	**Count**	31	**Count**	31	**Count**	31

Table 3b: Healthcare Spending by Category of Spending, Summary Statistics – Nova Scotia

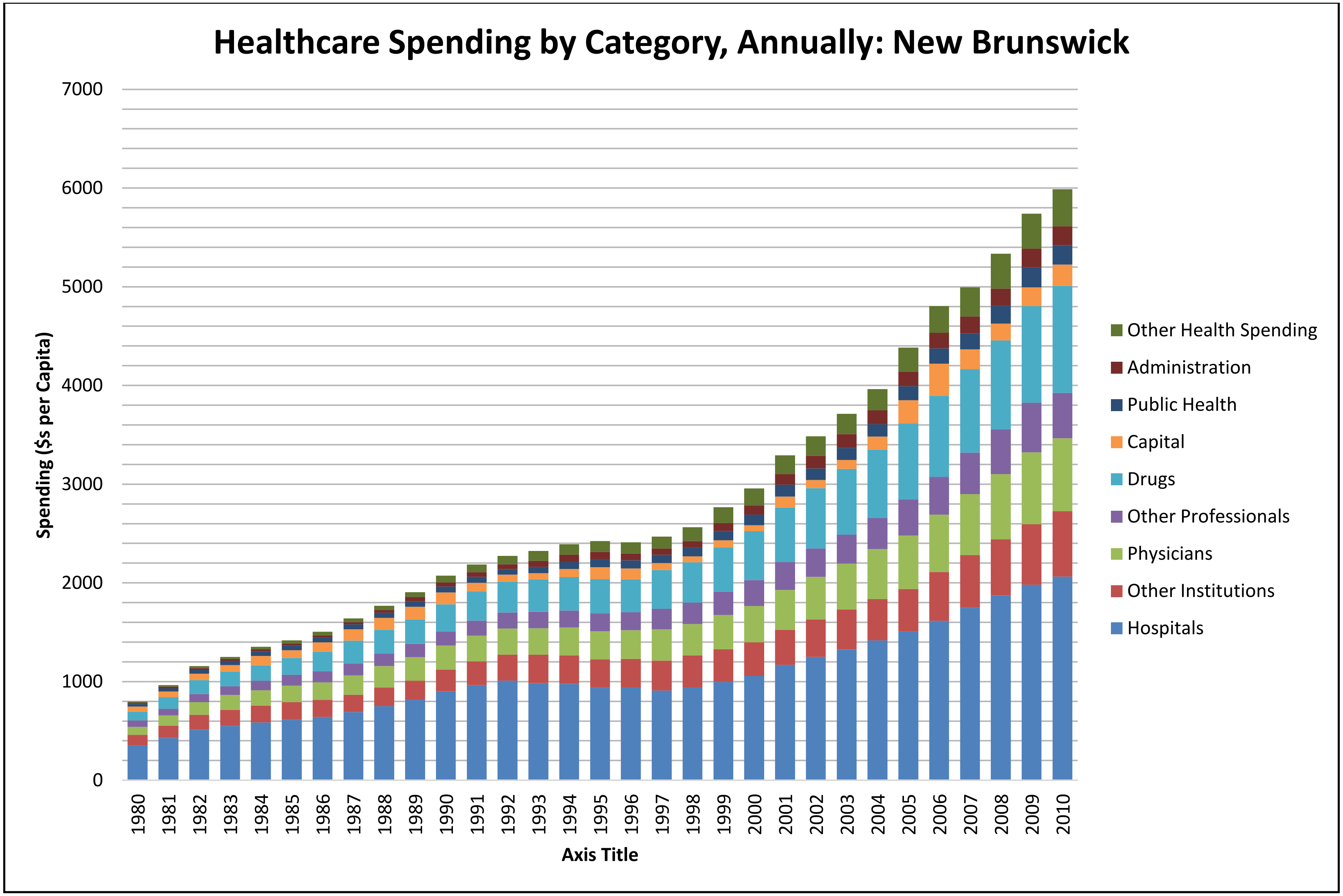

Figure 4: Healthcare Spending by Category, 1980-2010 – New Brunswick

Hospitals		Other Institutions		Physicians		Other Professionals		Drugs	
Mean	1048.39	**Mean**	311.85	**Mean**	340.08	**Mean**	221.18	**Mean**	439.80
Standard Error	81.67	**Standard Error**	26.51	**Standard Error**	33.13	**Standard Error**	22.66	**Standard Error**	50.15
Median	963.53	**Median**	289.06	**Median**	286.05	**Median**	179.98	**Median**	337.88
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	454.70	**Standard Deviation**	147.59	**Standard Deviation**	184.46	**Standard Deviation**	126.18	**Standard Deviation**	279.24
Sample Variance	206755.16	**Sample Variance**	21782.46	**Sample Variance**	34024.08	**Sample Variance**	15921.55	**Sample Variance**	77977.03
Kurtosis	-0.14	**Kurtosis**	-0.06	**Kurtosis**	-0.33	**Kurtosis**	-0.37	**Kurtosis**	-0.44
Skewness	0.73	**Skewness**	0.79	**Skewness**	0.76	**Skewness**	0.81	**Skewness**	0.80
Range	1708.40	**Range**	557.52	**Range**	657.91	**Range**	440.34	**Range**	993.74
Minimum	354.16	**Minimum**	106.27	**Minimum**	81.80	**Minimum**	64.19	**Minimum**	88.47
Maximum	2062.56	**Maximum**	663.79	**Maximum**	739.71	**Maximum**	504.53	**Maximum**	1082.21
Sum	32500.22	**Sum**	9667.27	**Sum**	10542.53	**Sum**	6856.46	**Sum**	13633.88
Count	31	**Count**	31	**Count**	31	**Count**	31	**Count**	31

Table 4a: Healthcare Spending by Category of Spending, Summary Statistics – New Brunswick

Capital		Public Health		Administration		Other Health Spending	
Mean	114.01	**Mean**	90.61	**Mean**	81.07	**Mean**	136.22
Standard Error	11.25	**Standard Error**	8.92	**Standard Error**	10.42	**Standard Error**	19.59
Median	95.44	**Median**	80.20	**Median**	67.88	**Median**	110.33
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	62.63	**Standard Deviation**	49.66	**Standard Deviation**	58.04	**Standard Deviation**	109.08
Sample Variance	3921.95	**Sample Variance**	2466.30	**Sample Variance**	3368.43	**Sample Variance**	11897.37
Kurtosis	3.32	**Kurtosis**	-0.31	**Kurtosis**	-0.94	**Kurtosis**	-0.37
Skewness	1.75	**Skewness**	0.85	**Skewness**	0.62	**Skewness**	0.79
Range	274.28	**Range**	173.43	**Range**	182.01	**Range**	366.05
Minimum	51.84	**Minimum**	28.47	**Minimum**	12.15	**Minimum**	9.26
Maximum	326.12	**Maximum**	201.90	**Maximum**	194.16	**Maximum**	375.31
Sum	3534.20	**Sum**	2808.87	**Sum**	2513.31	**Sum**	4222.72
Count	31	**Count**	31	**Count**	31	**Count**	31

Table 4b: Healthcare Spending by Category of Spending, Summary Statistics – New Brunswick

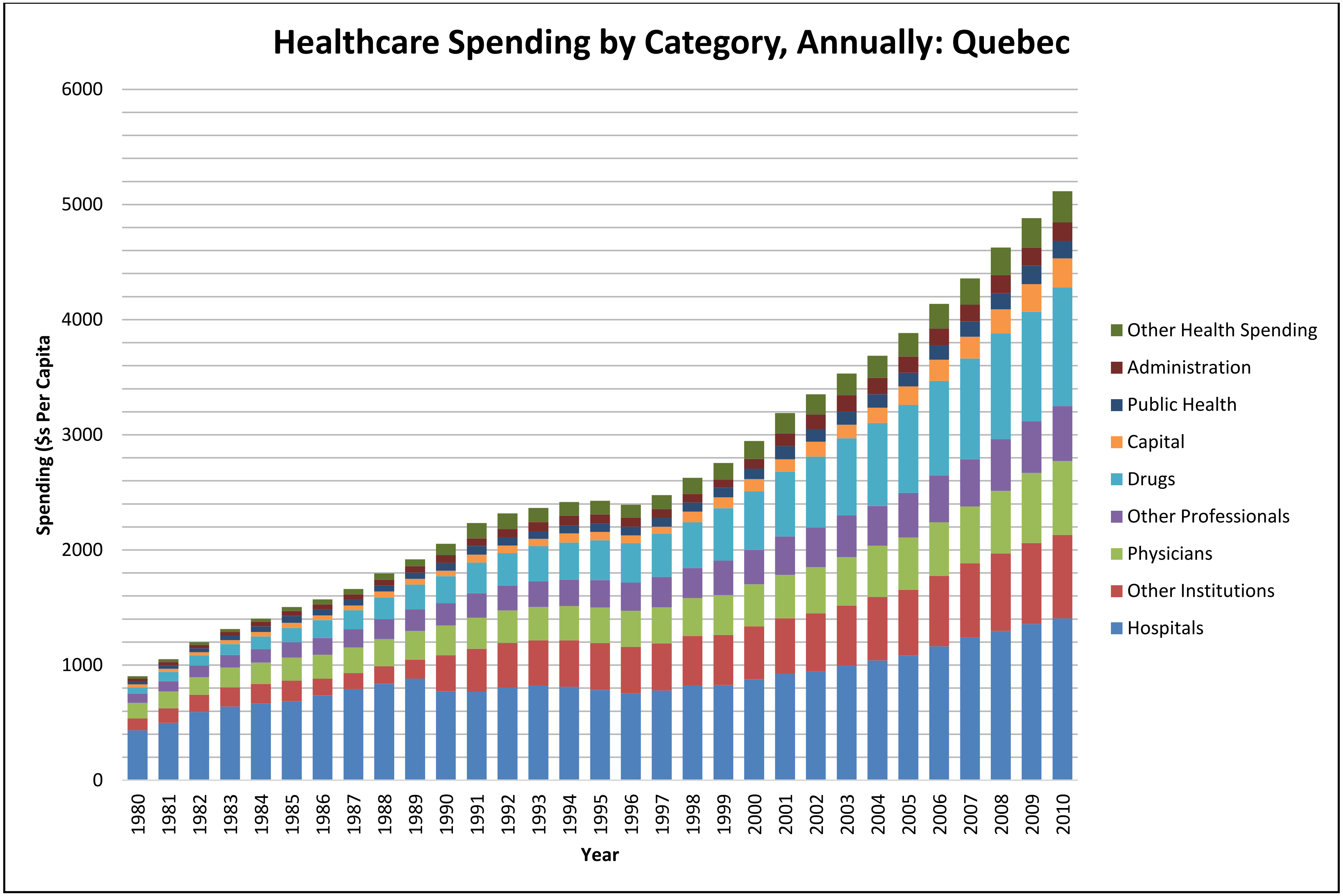

Figure 5: Healthcare Spending by Category – Quebec

Hospitals		Other Institutions		Physicians		Other Professionals		Drugs	
Mean	872.18	**Mean**	384.33	**Mean**	326.47	**Mean**	256.67	**Mean**	420.09
Standard Error	42.12	**Standard Error**	34.33	**Standard Error**	24.00	**Standard Error**	20.84	**Standard Error**	52.95
Median	821.52	**Median**	404.44	**Median**	308.30	**Median**	238.60	**Median**	342.82
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	234.52	**Standard Deviation**	191.16	**Standard Deviation**	133.63	**Standard Deviation**	116.02	**Standard Deviation**	294.79
Sample Variance	54999.59	**Sample Variance**	36542.09	**Sample Variance**	17856.54	**Sample Variance**	13460.95	**Sample Variance**	86901.32
Kurtosis	0.27	**Kurtosis**	-1.12	**Kurtosis**	-0.09	**Kurtosis**	-0.99	**Kurtosis**	-0.82
Skewness	0.66	**Skewness**	0.05	**Skewness**	0.67	**Skewness**	0.27	**Skewness**	0.65
Range	971.99	**Range**	620.84	**Range**	506.98	**Range**	395.35	**Range**	979.58
Minimum	434.40	**Minimum**	103.51	**Minimum**	134.25	**Minimum**	80.52	**Minimum**	52.49
Maximum	1406.39	**Maximum**	724.35	**Maximum**	641.23	**Maximum**	475.87	**Maximum**	1032.07
Sum	27037.58	**Sum**	11914.34	**Sum**	10120.44	**Sum**	7956.79	**Sum**	13022.72
Count	31	**Count**	31	**Count**	31	**Count**	31	**Count**	31

Table 5a: Healthcare Spending by Category of Spending, Summary Statistics – Quebec

Capital		Public Health		Administration		Other Health Spending	
Mean	94.37	**Mean**	82.44	**Mean**	85.96	**Mean**	125.73
Standard Error	11.52	**Standard Error**	6.55	**Standard Error**	7.95	**Standard Error**	13.65
Median	70.50	**Median**	74.45	**Median**	78.84	**Median**	122.23
Mode	#N/A	**Mode**	50.32	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	64.13	**Standard Deviation**	36.45	**Standard Deviation**	44.28	**Standard Deviation**	76.01
Sample Variance	4112.41	**Sample Variance**	1328.45	**Sample Variance**	1960.90	**Sample Variance**	5777.45
Kurtosis	0.34	**Kurtosis**	-0.69	**Kurtosis**	-1.17	**Kurtosis**	-1.01
Skewness	1.13	**Skewness**	0.49	**Skewness**	0.39	**Skewness**	0.19
Range	223.88	**Range**	132.28	**Range**	136.87	**Range**	250.26
Minimum	27.75	**Minimum**	26.63	**Minimum**	23.32	**Minimum**	21.62
Maximum	251.63	**Maximum**	158.91	**Maximum**	160.19	**Maximum**	271.88
Sum	2925.57	**Sum**	2555.75	**Sum**	2664.65	**Sum**	3897.55
Count	31	**Count**	31	**Count**	31	**Count**	31

Table 5b: Healthcare Spending by Category of Spending, Summary Statistics – Quebec

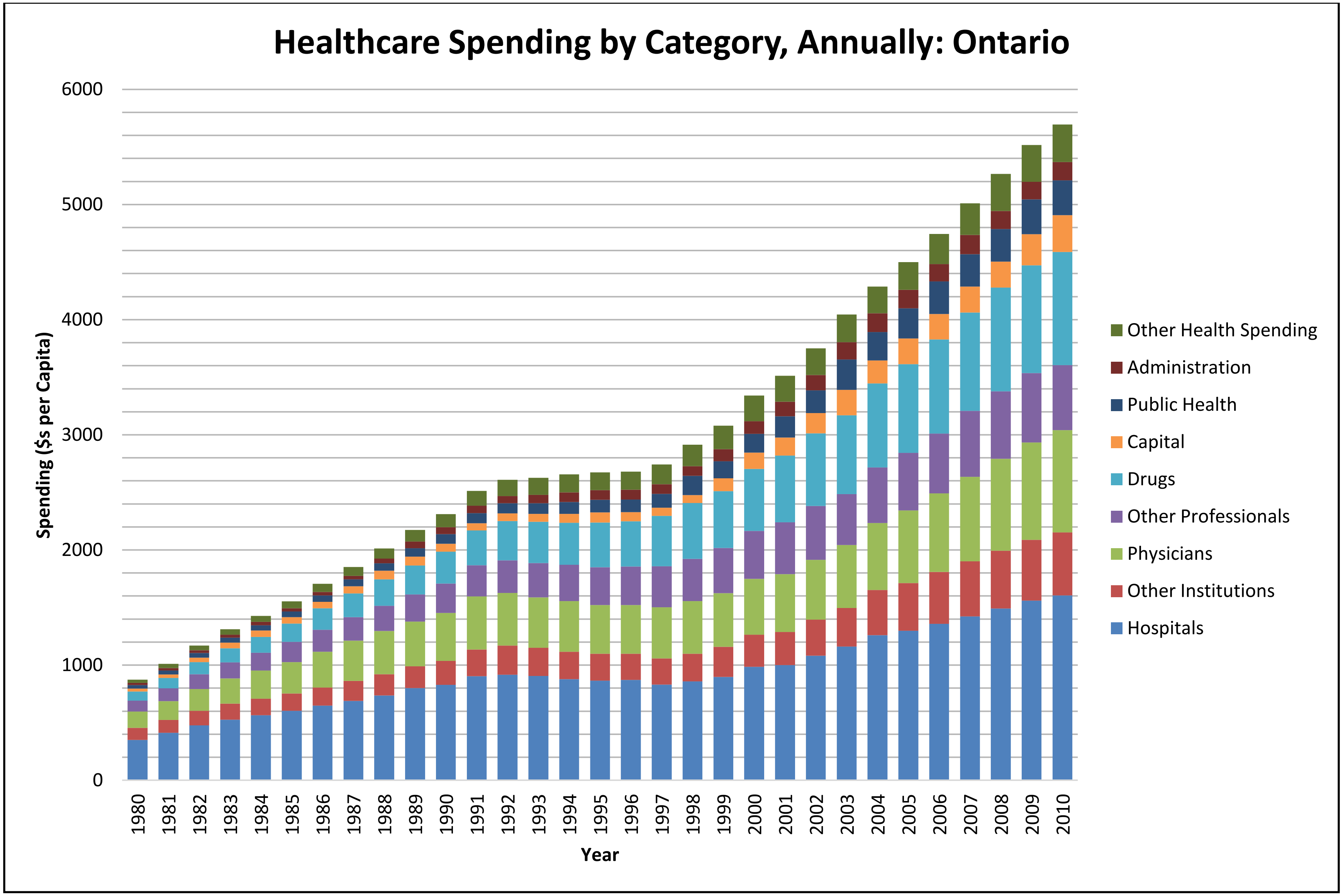

Figure 6: Healthcare Spending by Category – Ontario

Hospitals		Other Institutions		Physicians		Other Professionals		Drugs	
Mean	928.80	**Mean**	270.20	**Mean**	460.87	**Mean**	337.49	**Mean**	445.99
Standard Error	60.16	**Standard Error**	22.83	**Standard Error**	34.14	**Standard Error**	27.49	**Standard Error**	49.65
Median	878.86	**Median**	238.26	**Median**	445.15	**Median**	327.14	**Median**	388.72
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	334.95	**Standard Deviation**	127.11	**Standard Deviation**	190.09	**Standard Deviation**	153.04	**Standard Deviation**	276.46
Sample Variance	112193.60	**Sample Variance**	16156.88	**Sample Variance**	36135.80	**Sample Variance**	23420.46	**Sample Variance**	76429.11
Kurtosis	-0.45	**Kurtosis**	-0.26	**Kurtosis**	0.06	**Kurtosis**	-1.11	**Kurtosis**	-0.97
Skewness	0.40	**Skewness**	0.86	**Skewness**	0.49	**Skewness**	0.16	**Skewness**	0.48
Range	1255.09	**Range**	441.38	**Range**	747.78	**Range**	508.73	**Range**	904.83
Minimum	350.82	**Minimum**	105.53	**Minimum**	140.36	**Minimum**	95.51	**Minimum**	77.50
Maximum	1605.91	**Maximum**	546.91	**Maximum**	888.14	**Maximum**	604.24	**Maximum**	982.33
Sum	28792.67	**Sum**	8376.30	**Sum**	14287.08	**Sum**	10462.14	**Sum**	13825.70
Count	31	**Count**	31	**Count**	31	**Count**	31	**Count**	31

Table 6a: Healthcare Spending by Category of Spending, Summary Statistics – Ontario

Capital		Public Health		Administration		Other Health Spending	
Mean	118.16	**Mean**	141.26	**Mean**	87.76	**Mean**	163.13
Standard Error	14.56	**Standard Error**	16.72	**Standard Error**	9.25	**Standard Error**	16.21
Median	75.86	**Median**	109.56	**Median**	83.25	**Median**	156.12
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	81.09	**Standard Deviation**	93.09	**Standard Deviation**	51.51	**Standard Deviation**	90.26
Sample Variance	6575.20	**Sample Variance**	8665.70	**Sample Variance**	2652.84	**Sample Variance**	8147.41
Kurtosis	-0.34	**Kurtosis**	-1.18	**Kurtosis**	-1.41	**Kurtosis**	-1.03
Skewness	0.94	**Skewness**	0.58	**Skewness**	0.23	**Skewness**	0.18
Range	293.61	**Range**	273.74	**Range**	147.99	**Range**	296.34
Minimum	25.79	**Minimum**	30.53	**Minimum**	18.86	**Minimum**	28.02
Maximum	319.40	**Maximum**	304.27	**Maximum**	166.85	**Maximum**	324.36
Sum	3662.90	**Sum**	4378.99	**Sum**	2720.51	**Sum**	5057.06
Count	31	**Count**	31	**Count**	31	**Count**	31

Table 6b: Healthcare Spending by Category of Spending, Summary Statistics – Ontario

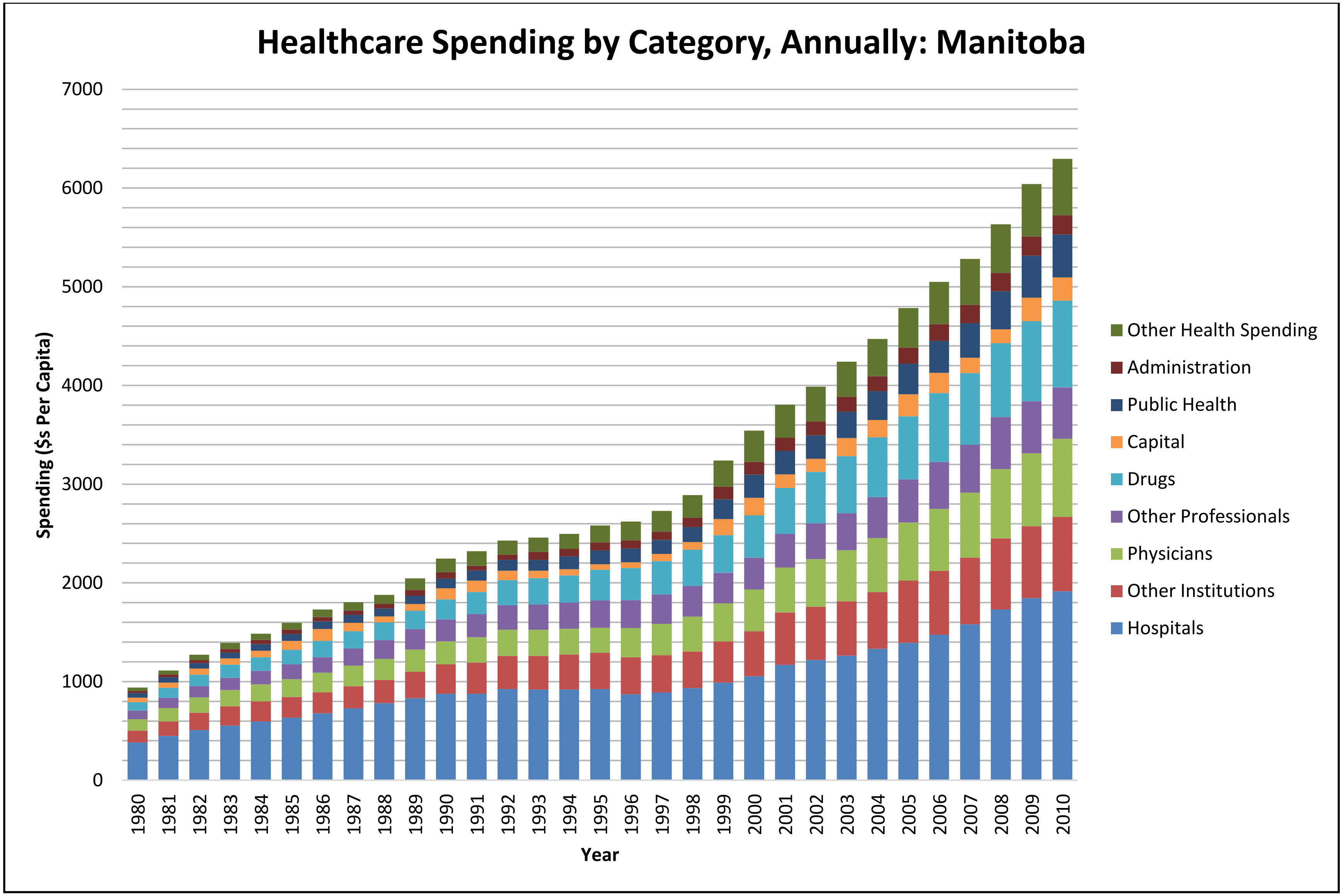

Figure 7: Healthcare Spending by Category – Manitoba

Hospitals		Other Institutions		Physicians		Other Professionals		Drugs	
Mean	1008.13	**Mean**	398.12	**Mean**	360.88	**Mean**	288.73	**Mean**	370.07
Standard Error	71.97	**Standard Error**	33.95	**Standard Error**	35.40	**Standard Error**	23.79	**Standard Error**	42.21
Median	920.29	**Median**	368.25	**Median**	265.11	**Median**	278.74	**Median**	308.90
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	400.73	**Standard Deviation**	189.02	**Standard Deviation**	197.08	**Standard Deviation**	132.45	**Standard Deviation**	234.99
Sample Variance	160587.07	**Sample Variance**	35728.48	**Sample Variance**	38839.58	**Sample Variance**	17542.18	**Sample Variance**	55221.50
Kurtosis	-0.07	**Kurtosis**	-0.97	**Kurtosis**	-0.61	**Kurtosis**	-0.85	**Kurtosis**	-0.71
Skewness	0.71	**Skewness**	0.46	**Skewness**	0.78	**Skewness**	0.38	**Skewness**	0.72
Range	1531.94	**Range**	632.57	**Range**	676.89	**Range**	440.42	**Range**	792.29
Minimum	383.26	**Minimum**	121.34	**Minimum**	115.03	**Minimum**	87.85	**Minimum**	84.88
Maximum	1915.20	**Maximum**	753.91	**Maximum**	791.92	**Maximum**	528.27	**Maximum**	877.17
Sum	31252.18	**Sum**	12341.68	**Sum**	11187.35	**Sum**	8950.73	**Sum**	11472.02
Count	31	**Count**	31	**Count**	31	**Count**	31	**Count**	31

Table 7a: Healthcare Spending by Category of Spending, Summary Statistics – Manitoba

Capital		Public Health		Administration		Other Health Spending	
Mean	116.12	**Mean**	177.70	**Mean**	95.71	**Mean**	229.88
Standard Error	10.64	**Standard Error**	21.26	**Standard Error**	10.24	**Standard Error**	28.92
Median	97.28	**Median**	138.88	**Median**	79.95	**Median**	174.50
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	59.23	**Standard Deviation**	118.37	**Standard Deviation**	57.03	**Standard Deviation**	161.01
Sample Variance	3508.50	**Sample Variance**	14010.68	**Sample Variance**	3252.30	**Sample Variance**	25922.75
Kurtosis	-0.72	**Kurtosis**	-0.51	**Kurtosis**	-1.23	**Kurtosis**	-0.84
Skewness	0.70	**Skewness**	0.84	**Skewness**	0.46	**Skewness**	0.63
Range	193.22	**Range**	386.83	**Range**	177.63	**Range**	534.76
Minimum	44.01	**Minimum**	46.77	**Minimum**	19.91	**Minimum**	35.84
Maximum	237.23	**Maximum**	433.60	**Maximum**	197.54	**Maximum**	570.60
Sum	3599.64	**Sum**	5508.64	**Sum**	2966.95	**Sum**	7126.43
Count	31	**Count**	31	**Count**	31	**Count**	31

Table 7b: Healthcare Spending by Category of Spending, Summary Statistics – Ontario

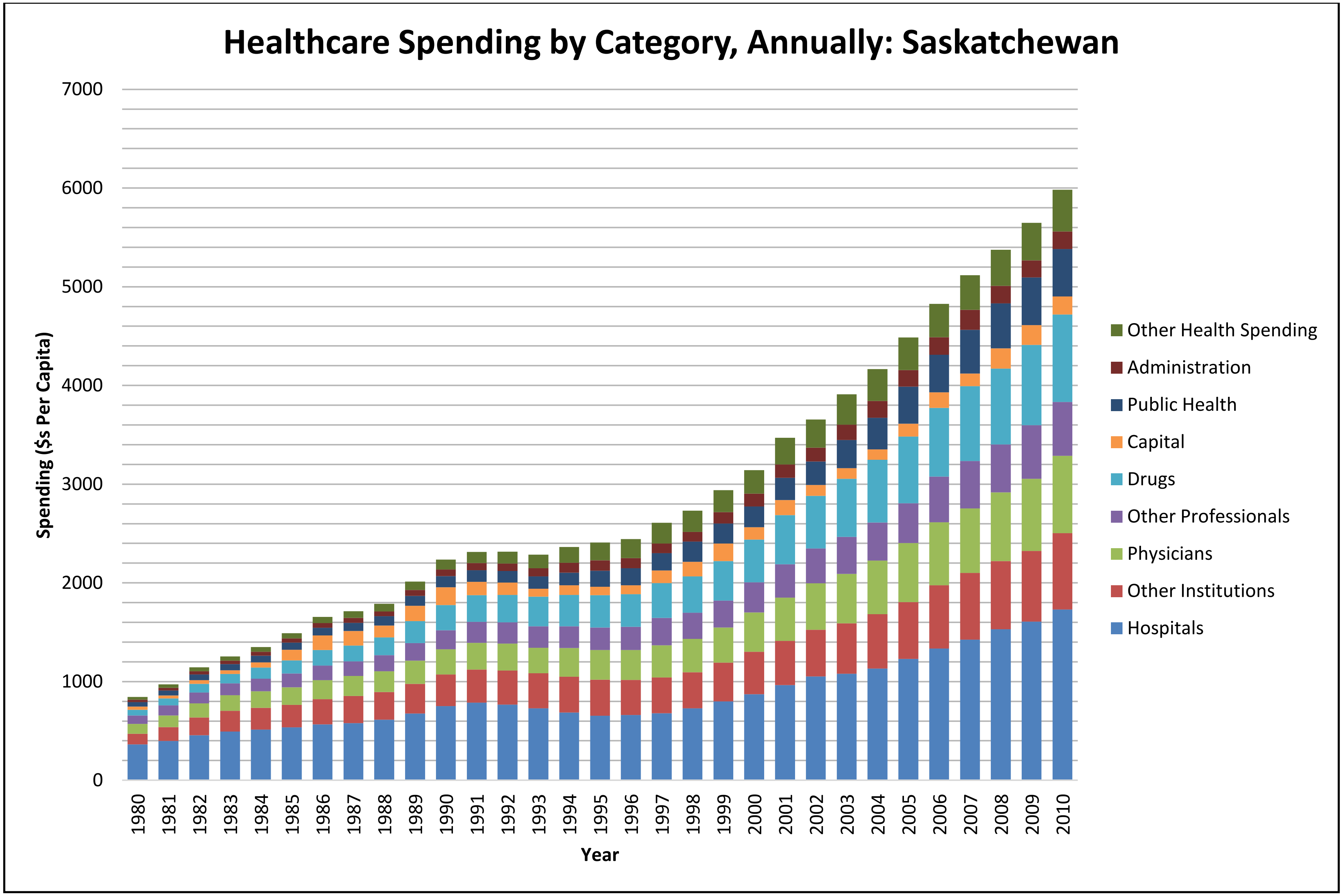

Figure 8: Healthcare Spending by Category – Saskatchewan

Hospitals		Other Institutions		Physicians		Other Professionals		Drugs	
Mean	851.67	**Mean**	394.77	**Mean**	359.07	**Mean**	268.68	**Mean**	379.40
Standard Error	66.10	**Standard Error**	31.41	**Standard Error**	35.09	**Standard Error**	24.36	**Standard Error**	43.87
Median	729.47	**Median**	363.05	**Median**	300.54	**Median**	227.40	**Median**	329.14
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	368.00	**Standard Deviation**	174.87	**Standard Deviation**	195.36	**Standard Deviation**	135.63	**Standard Deviation**	244.24
Sample Variance	135426.11	**Sample Variance**	30580.07	**Sample Variance**	38165.29	**Sample Variance**	18395.47	**Sample Variance**	59655.26
Kurtosis	0.03	**Kurtosis**	-0.37	**Kurtosis**	-0.55	**Kurtosis**	-0.64	**Kurtosis**	-0.82
Skewness	0.96	**Skewness**	0.59	**Skewness**	0.76	**Skewness**	0.65	**Skewness**	0.56
Range	1367.40	**Range**	666.75	**Range**	681.26	**Range**	460.10	**Range**	828.47
Minimum	363.08	**Minimum**	106.96	**Minimum**	101.76	**Minimum**	85.76	**Minimum**	56.26
Maximum	1730.48	**Maximum**	773.71	**Maximum**	783.02	**Maximum**	545.86	**Maximum**	884.73
Sum	26401.89	**Sum**	12237.97	**Sum**	11131.08	**Sum**	8329.18	**Sum**	11761.26
Count	31	**Count**	31	**Count**	31	**Count**	31	**Count**	31

Table 8a: Healthcare Spending by Category of Spending, Summary Statistics – Saskatchewan

Capital		Public Health		Administration		Other Health Spending	
Mean	119.97	**Mean**	197.81	**Mean**	101.06	**Mean**	187.21
Standard Error	8.73	**Standard Error**	24.79	**Standard Error**	9.81	**Standard Error**	22.03
Median	125.68	**Median**	163.59	**Median**	98.29	**Median**	180.54
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	48.60	**Standard Deviation**	138.03	**Standard Deviation**	54.61	**Standard Deviation**	122.64
Sample Variance	2362.04	**Sample Variance**	19051.80	**Sample Variance**	2982.69	**Sample Variance**	15039.38
Kurtosis	-0.45	**Kurtosis**	-0.37	**Kurtosis**	-1.28	**Kurtosis**	-1.25
Skewness	-0.30	**Skewness**	0.93	**Skewness**	0.27	**Skewness**	0.32
Range	175.99	**Range**	434.88	**Range**	177.47	**Range**	395.45
Minimum	29.54	**Minimum**	46.16	**Minimum**	24.16	**Minimum**	27.60
Maximum	205.53	**Maximum**	481.04	**Maximum**	201.63	**Maximum**	423.05
Sum	3719.09	**Sum**	6131.97	**Sum**	3132.75	**Sum**	5803.55
Count	31	**Count**	31	**Count**	31	**Count**	31

Table 8b: Health Spending Descriptive Statistics by Category of Spending – Saskatchewan

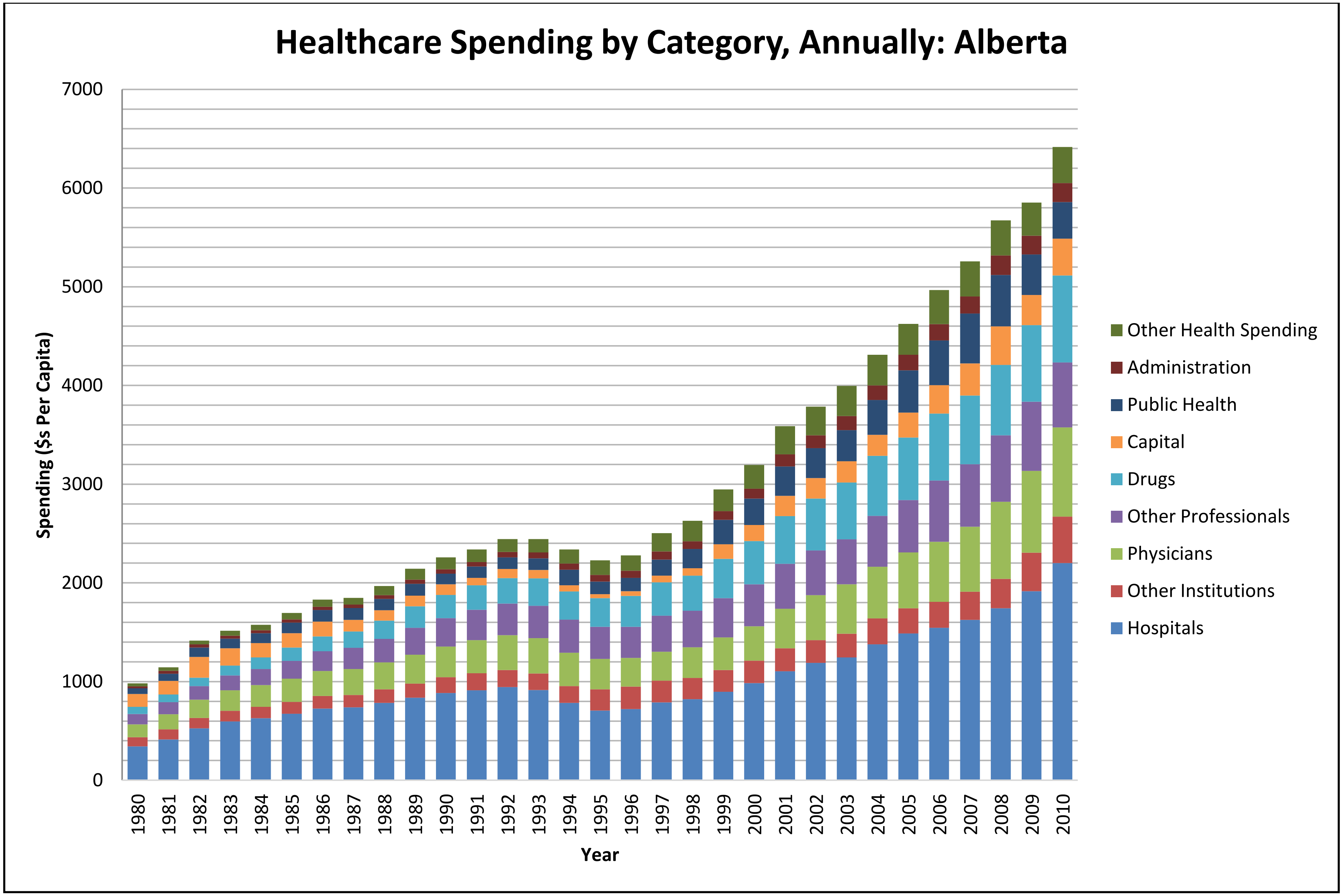

Figure 9: Healthcare Spending by Category – Alberta

	Hospitals		Other Institutions		Physicians		Other Professionals		Drugs	
	Mean	1001.93	Mean	202.55	Mean	387.34	Mean	363.36	Mean	364.93
	Standard Error	80.07	Standard Error	15.27	Standard Error	35.25	Standard Error	31.15	Standard Error	41.74
	Median	883.38	Median	215.98	Median	331.03	Median	327.74	Median	290.28
	Mode	#N/A	Mode	#N/A	Mode	#N/A	Mode	#N/A	Mode	#N/A
	Standard Deviation	445.80	Standard Deviation	85.04	Standard Deviation	196.24	Standard Deviation	173.46	Standard Deviation	232.42
	Sample Variance	198739.27	Sample Variance	7232.63	Sample Variance	38511.98	Sample Variance	30089.41	Sample Variance	54018.43
	Kurtosis	0.63	Kurtosis	2.22	Kurtosis	0.92	Kurtosis	-0.72	Kurtosis	-0.74
	Skewness	1.05	Skewness	1.22	Skewness	1.23	Skewness	0.44	Skewness	0.61
	Range	1858.43	Range	377.07	Range	772.84	Range	594.50	Range	811.00
	Minimum	343.13	Minimum	92.79	Minimum	130.20	Minimum	106.36	Minimum	70.93
	Maximum	2201.56	Maximum	469.86	Maximum	903.04	Maximum	700.86	Maximum	881.93
	Sum	31059.96	Sum	6279.07	Sum	12007.51	Sum	11264.20	Sum	11312.81
	Count	31	Count	31	Count	31	Count	31	Count	31

Table 9a: Healthcare Spending by Category of Spending, Summary Statistics – Alberta

Capital		Public Health		Administration		Other Health Spending	
Mean	166.45	**Mean**	216.58	**Mean**	86.97	**Mean**	183.44
Standard Error	16.90	**Standard Error**	25.12	**Standard Error**	10.33	**Standard Error**	20.41
Median	145.40	**Median**	133.71	**Median**	69.20	**Median**	146.57
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	94.09	**Standard Deviation**	139.89	**Standard Deviation**	57.51	**Standard Deviation**	113.62
Sample Variance	8852.96	**Sample Variance**	19568.19	**Sample Variance**	3307.77	**Sample Variance**	12908.64
Kurtosis	0.10	**Kurtosis**	-0.56	**Kurtosis**	-0.98	**Kurtosis**	-1.40
Skewness	0.88	**Skewness**	0.88	**Skewness**	0.69	**Skewness**	0.28
Range	352.49	**Range**	462.45	**Range**	176.09	**Range**	337.02
Minimum	38.94	**Minimum**	57.32	**Minimum**	21.78	**Minimum**	29.57
Maximum	391.43	**Maximum**	519.77	**Maximum**	197.87	**Maximum**	366.59
Sum	5159.80	**Sum**	6713.91	**Sum**	2696.13	**Sum**	5686.66
Count	31	**Count**	31	**Count**	31	**Count**	31

Table 9b: Healthcare Spending by Category of Spending, Summary Statistics – Alberta

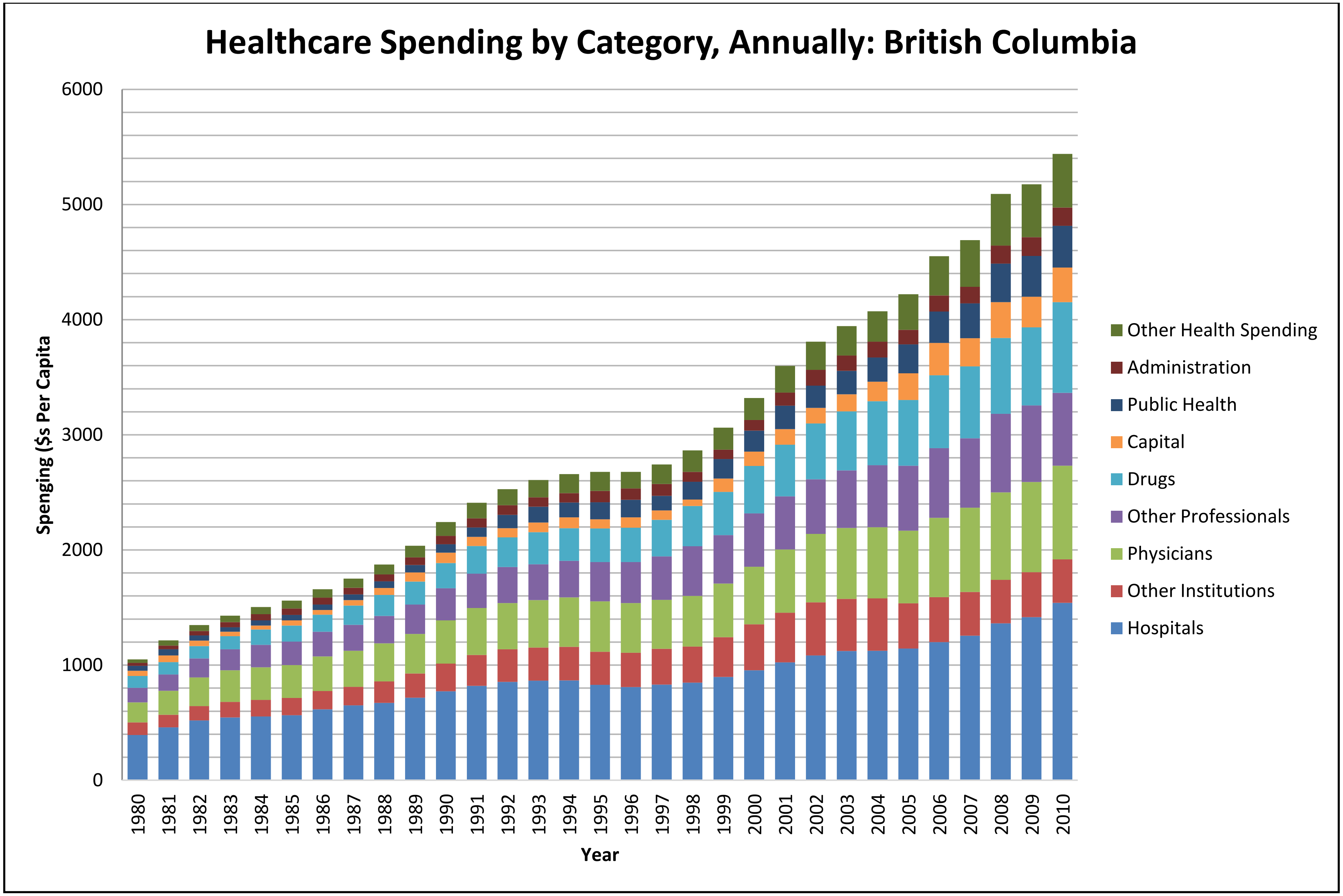

Figure 10: Healthcare Spending by Category – British Columbia

Hospitals		Other Institutions		Physicians		Other Professionals		Drugs	
Mean	881.3632	**Mean**	287.6758	**Mean**	460.25	**Mean**	373.8371	**Mean**	344.2155
Standard Error	52.26051	**Standard Error**	20.28305	**Standard Error**	31.72337	**Standard Error**	29.77216	**Standard Error**	36.01021
Median	847.92	**Median**	292.56	**Median**	428.77	**Median**	341.27	**Median**	290.53
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	290.9742	**Standard Deviation**	112.9313	**Standard Deviation**	176.6282	**Standard Deviation**	165.7644	**Standard Deviation**	200.4964
Sample Variance	84665.98	**Sample Variance**	12753.47	**Sample Variance**	31197.54	**Sample Variance**	27477.83	**Sample Variance**	40198.8
Kurtosis	-0.37284	**Kurtosis**	-1.27041	**Kurtosis**	-0.70595	**Kurtosis**	-1.03687	**Kurtosis**	-0.79993
Skewness	0.441047	**Skewness**	-0.15316	**Skewness**	0.469874	**Skewness**	0.350804	**Skewness**	0.595843
Range	1147.79	**Range**	350.69	**Range**	640.53	**Range**	557.05	**Range**	684.01
Minimum	393.33	**Minimum**	109.47	**Minimum**	172.62	**Minimum**	126.52	**Minimum**	103.01
Maximum	1541.12	**Maximum**	460.16	**Maximum**	813.15	**Maximum**	683.57	**Maximum**	787.02
Sum	27322.26	**Sum**	8917.95	**Sum**	14267.75	**Sum**	11588.95	**Sum**	10670.68
Count	31	**Count**	31	**Count**	31	**Count**	31	**Count**	31

Table 10a: Healthcare Spending by Category of Spending, Summary Statistics – British Columbia

Capital		Public Health		Administration		Other Health Spending	
Mean	119.4345	**Mean**	149.7071	**Mean**	92.37613	**Mean**	188.1877
Standard Error	15.12742	**Standard Error**	17.88016	**Standard Error**	7.132178	**Standard Error**	22.90958
Median	84.45	**Median**	136.67	**Median**	83.16	**Median**	163.8
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	84.22593	**Standard Deviation**	99.55254	**Standard Deviation**	39.71029	**Standard Deviation**	127.5551
Sample Variance	7094.007	**Sample Variance**	9910.708	**Sample Variance**	1576.907	**Sample Variance**	16270.31
Kurtosis	0.147835	**Kurtosis**	-0.41978	**Kurtosis**	-1.00152	**Kurtosis**	0.00087
Skewness	1.178926	**Skewness**	0.734127	**Skewness**	0.258654	**Skewness**	0.936512
Range	274.31	**Range**	323.17	**Range**	137.38	**Range**	433.64
Minimum	36.1	**Minimum**	40.54	**Minimum**	24.92	**Minimum**	30.18
Maximum	310.41	**Maximum**	363.71	**Maximum**	162.3	**Maximum**	463.82
Sum	3702.47	**Sum**	4640.92	**Sum**	2863.66	**Sum**	5833.82
Count	31	**Count**	31	**Count**	31	**Count**	31

Table 10b: Healthcare Spending by Category of Spending, Summary Statistics – British Columbia

Appendix B – Summary Statistics: Health Outcomes

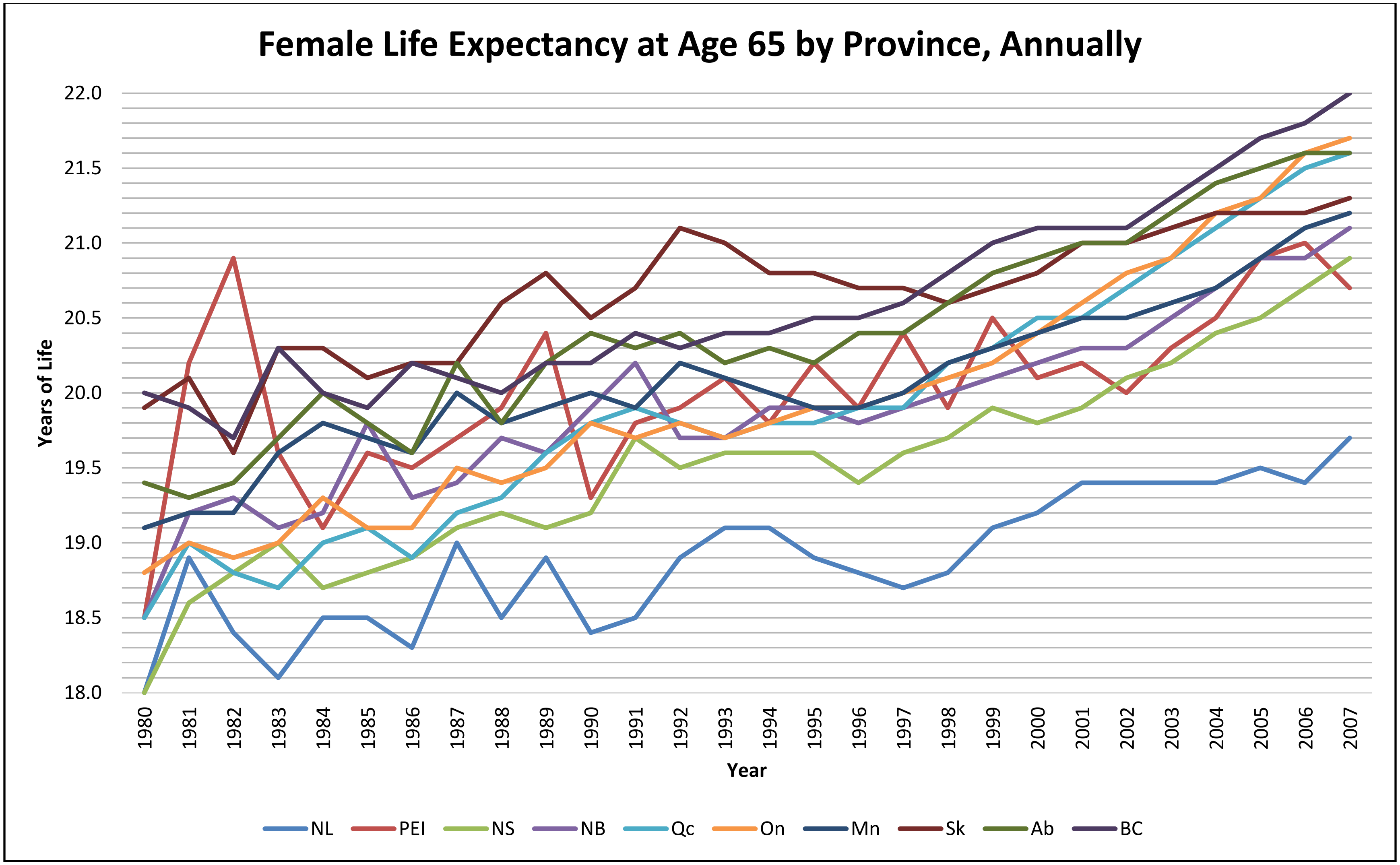

Figure 1: Female Life Expectancy at Age 65 by Province, Annually

Newfoundland & Labrador		Prince Edward Island		Nova Scotia		New Brunswick		Quebec	
Mean	18.89	Mean	20.03	Mean	19.52	Mean	19.90	Mean	19.90
Standard Error	0.09	Standard Error	0.11	Standard Error	0.13	Standard Error	0.11	Standard Error	0.16
Median	18.90	Median	20.05	Median	19.60	Median	19.90	Median	19.80
Mode	19.40	Mode	19.90	Mode	19.60	Mode	19.90	Mode	19.80
Standard Deviation	0.45	Standard Deviation	0.56	Standard Deviation	0.68	Standard Deviation	0.60	Standard Deviation	0.87
Sample Variance	0.20	Sample Variance	0.31	Sample Variance	0.46	Sample Variance	0.36	Sample Variance	0.75
Kurtosis	-0.82	Kurtosis	0.91	Kurtosis	-0.10	Kurtosis	0.08	Kurtosis	-0.68
Skewness	-0.15	Skewness	-0.53	Skewness	0.06	Skewness	0.04	Skewness	0.36
Range	1.70	Range	2.50	Range	2.90	Range	2.60	Range	3.10
Minimum	18.00	Minimum	18.50	Minimum	18.00	Minimum	18.50	Minimum	18.50
Maximum	19.70	Maximum	21.00	Maximum	20.90	Maximum	21.10	Maximum	21.60
Sum	528.80	Sum	560.90	Sum	546.50	Sum	557.10	Sum	557.30
Count	28	Count	28	Count	28	Count	28	Count	28

Table 1a: Female Life Expectancy at Age 65 by Province, Summary Statistics

Ontario		Manitoba		Saskatchewan		Alberta		British Columbia	
Mean	19.96	**Mean**	20.08	**Mean**	20.66	**Mean**	20.41	**Mean**	20.61
Standard Error	0.16	**Standard Error**	0.10	**Standard Error**	0.08	**Standard Error**	0.13	**Standard Error**	0.12
Median	19.80	**Median**	20.00	**Median**	20.70	**Median**	20.35	**Median**	20.40
Mode	19.80	**Mode**	20.00	**Mode**	20.80	**Mode**	20.20	**Mode**	20.00
Standard Deviation	0.83	**Standard Deviation**	0.53	**Standard Deviation**	0.44	**Standard Deviation**	0.67	**Standard Deviation**	0.63
Sample Variance	0.69	**Sample Variance**	0.28	**Sample Variance**	0.19	**Sample Variance**	0.46	**Sample Variance**	0.40
Kurtosis	-0.45	**Kurtosis**	-0.04	**Kurtosis**	-0.23	**Kurtosis**	-0.76	**Kurtosis**	-0.45
Skewness	0.64	**Skewness**	0.24	**Skewness**	-0.60	**Skewness**	0.22	**Skewness**	0.73
Range	2.90	**Range**	2.10	**Range**	1.70	**Range**	2.30	**Range**	2.30
Minimum	18.80	**Minimum**	19.10	**Minimum**	19.60	**Minimum**	19.30	**Minimum**	19.70
Maximum	21.70	**Maximum**	21.20	**Maximum**	21.30	**Maximum**	21.60	**Maximum**	22.00
Sum	559.00	**Sum**	562.30	**Sum**	578.50	**Sum**	571.60	**Sum**	577.00
Count	28	**Count**	28	**Count**	28	**Count**	28	**Count**	28
Table 1b: Female Life Expectancy at Age 65 by Province, Summary Statistics									

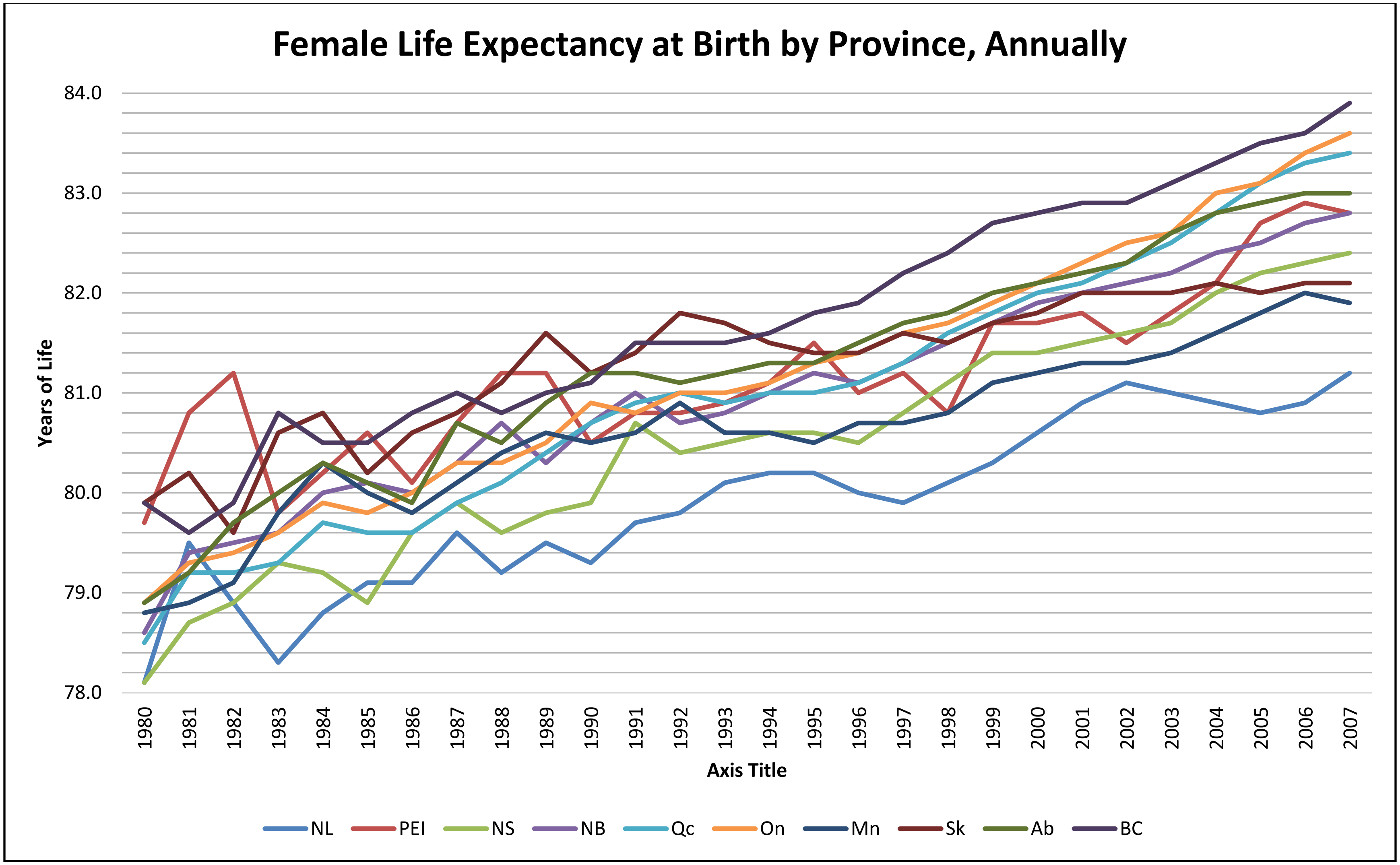

Figure 2: Female Life Expectancy at Birth by Province, Annually

Newfoundland & Labrador		Prince Edward Island		Nova Scotia		New Brunswick		Quebec	
Mean	79.90	Mean	81.18	Mean	80.49	Mean	81.00	Mean	81.01
Standard Error	0.16	Standard Error	0.16	Standard Error	0.22	Standard Error	0.21	Standard Error	0.26
Median	79.95	Median	81.15	Median	80.55	Median	81.00	Median	81.00
Mode	80.90	Mode	80.80	Mode	78.90	Mode	80.70	Mode	81.00
Standard Deviation	0.85	Standard Deviation	0.82	Standard Deviation	1.18	Standard Deviation	1.09	Standard Deviation	1.36
Sample Variance	0.73	Sample Variance	0.67	Sample Variance	1.40	Sample Variance	1.20	Sample Variance	1.84
Kurtosis	-0.66	Kurtosis	0.02	Kurtosis	-0.87	Kurtosis	-0.61	Kurtosis	-0.86
Skewness	-0.28	Skewness	0.39	Skewness	-0.14	Skewness	-0.17	Skewness	0.10
Range	3.10	Range	3.20	Range	4.30	Range	4.20	Range	4.90
Minimum	78.10	Minimum	79.70	Minimum	78.10	Minimum	78.60	Minimum	78.50
Maximum	81.20	Maximum	82.90	Maximum	82.40	Maximum	82.80	Maximum	83.40
Sum	2237.10	Sum	2273.10	Sum	2253.60	Sum	2268.10	Sum	2268.30
Count	28	Count	28	Count	28	Count	28	Count	28

Table 2a: Female Life Expectancy at Birth by Province, Summary Statistics

Ontario		Manitoba		Saskatchewan		Alberta		British Columbia	
Mean	81.19	**Mean**	80.62	**Mean**	81.31	**Mean**	81.26	**Mean**	81.75
Standard Error	0.25	**Standard Error**	0.16	**Standard Error**	0.14	**Standard Error**	0.22	**Standard Error**	0.23
Median	81.05	**Median**	80.60	**Median**	81.50	**Median**	81.25	**Median**	81.55
Mode	80.30	**Mode**	80.60	**Mode**	82.00	**Mode**	81.20	**Mode**	80.80
Standard Deviation	1.31	**Standard Deviation**	0.84	**Standard Deviation**	0.71	**Standard Deviation**	1.15	**Standard Deviation**	1.21
Sample Variance	1.72	**Sample Variance**	0.70	**Sample Variance**	0.51	**Sample Variance**	1.32	**Sample Variance**	1.47
Kurtosis	-0.88	**Kurtosis**	0.07	**Kurtosis**	-0.09	**Kurtosis**	-0.68	**Kurtosis**	-1.00
Skewness	0.15	**Skewness**	-0.50	**Skewness**	-0.91	**Skewness**	-0.25	**Skewness**	0.07
Range	4.70	**Range**	3.20	**Range**	2.50	**Range**	4.10	**Range**	4.30
Minimum	78.90	**Minimum**	78.80	**Minimum**	79.60	**Minimum**	78.90	**Minimum**	79.60
Maximum	83.60	**Maximum**	82.00	**Maximum**	82.10	**Maximum**	83.00	**Maximum**	83.90
Sum	2273.30	**Sum**	2257.30	**Sum**	2276.70	**Sum**	2275.40	**Sum**	2289.00
Count	28	**Count**	28	**Count**	28	**Count**	28	**Count**	28

Table 2b: Female Life Expectancy at Birth by Province, Summary Statistics

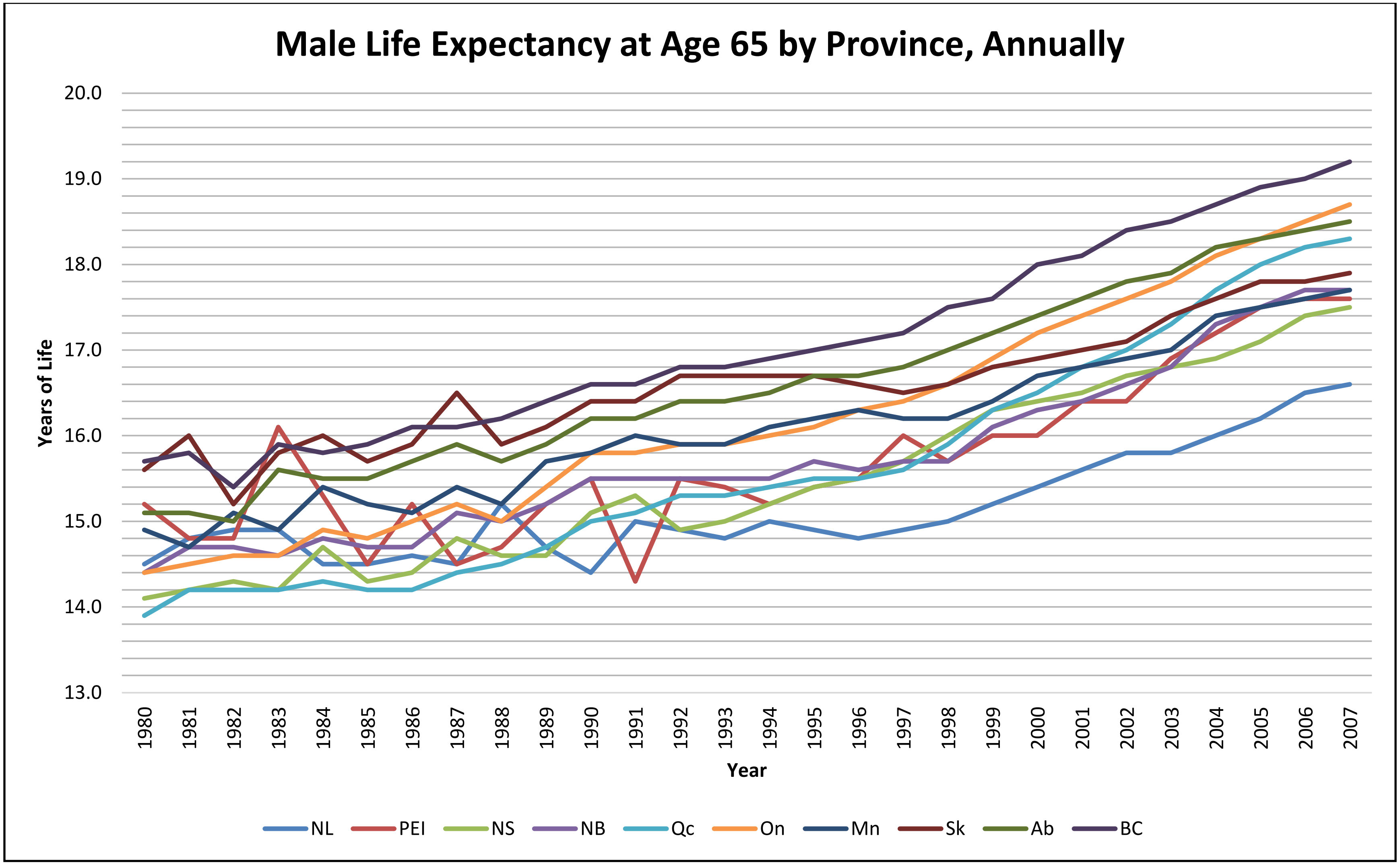

Figure 3: Male Life Expectancy at Age 65 by Province, Annually

Newfoundland & Labrador		Prince Edward Island		Nova Scotia		New Brunswick		Quebec	
Mean	15.14	**Mean**	15.73	**Mean**	15.50	**Mean**	15.73	**Mean**	15.63
Standard Error	0.12	**Standard Error**	0.18	**Standard Error**	0.20	**Standard Error**	0.18	**Standard Error**	0.26
Median	14.90	**Median**	15.50	**Median**	15.25	**Median**	15.50	**Median**	15.35
Mode	14.90	**Mode**	15.20	**Mode**	14.20	**Mode**	15.50	**Mode**	14.20
Standard Deviation	0.62	**Standard Deviation**	0.95	**Standard Deviation**	1.07	**Standard Deviation**	0.98	**Standard Deviation**	1.37
Sample Variance	0.38	**Sample Variance**	0.91	**Sample Variance**	1.15	**Sample Variance**	0.96	**Sample Variance**	1.87
Kurtosis	0.20	**Kurtosis**	-0.37	**Kurtosis**	-1.13	**Kurtosis**	-0.40	**Kurtosis**	-0.77
Skewness	1.05	**Skewness**	0.65	**Skewness**	0.44	**Skewness**	0.73	**Skewness**	0.65
Range	2.20	**Range**	3.30	**Range**	3.40	**Range**	3.30	**Range**	4.40
Minimum	14.40	**Minimum**	14.30	**Minimum**	14.10	**Minimum**	14.40	**Minimum**	13.90
Maximum	16.60	**Maximum**	17.60	**Maximum**	17.50	**Maximum**	17.70	**Maximum**	18.30
Sum	423.90	**Sum**	440.40	**Sum**	433.90	**Sum**	440.50	**Sum**	437.50
Count	28	**Count**	28	**Count**	28	**Count**	28	**Count**	28

Table 3a: Male Life Expectancy at Age 65 by Province, Summary Statistics

Ontario		Manitoba		Saskatchewan		Alberta		British Columbia	
Mean	16.20	**Mean**	16.08	**Mean**	16.58	**Mean**	16.61	**Mean**	17.08
Standard Error	0.25	**Standard Error**	0.17	**Standard Error**	0.13	**Standard Error**	0.20	**Standard Error**	0.21
Median	15.95	**Median**	16.05	**Median**	16.60	**Median**	16.45	**Median**	16.85
Mode	14.60	**Mode**	16.20	**Mode**	16.70	**Mode**	15.10	**Mode**	15.80
Standard Deviation	1.32	**Standard Deviation**	0.88	**Standard Deviation**	0.70	**Standard Deviation**	1.07	**Standard Deviation**	1.14
Sample Variance	1.75	**Sample Variance**	0.77	**Sample Variance**	0.49	**Sample Variance**	1.15	**Sample Variance**	1.29
Kurtosis	-0.98	**Kurtosis**	-0.85	**Kurtosis**	-0.42	**Kurtosis**	-1.04	**Kurtosis**	-1.02
Skewness	0.42	**Skewness**	0.30	**Skewness**	0.22	**Skewness**	0.30	**Skewness**	0.44
Range	4.30	**Range**	3.00	**Range**	2.70	**Range**	3.50	**Range**	3.80
Minimum	14.40	**Minimum**	14.70	**Minimum**	15.20	**Minimum**	15.00	**Minimum**	15.40
Maximum	18.70	**Maximum**	17.70	**Maximum**	17.90	**Maximum**	18.50	**Maximum**	19.20
Sum	453.70	**Sum**	450.20	**Sum**	464.30	**Sum**	465.20	**Sum**	478.20
Count	28	**Count**	28	**Count**	28	**Count**	28	**Count**	28

Table 3b: Male Life Expectancy at Age 65 by Province, Summary Statistics

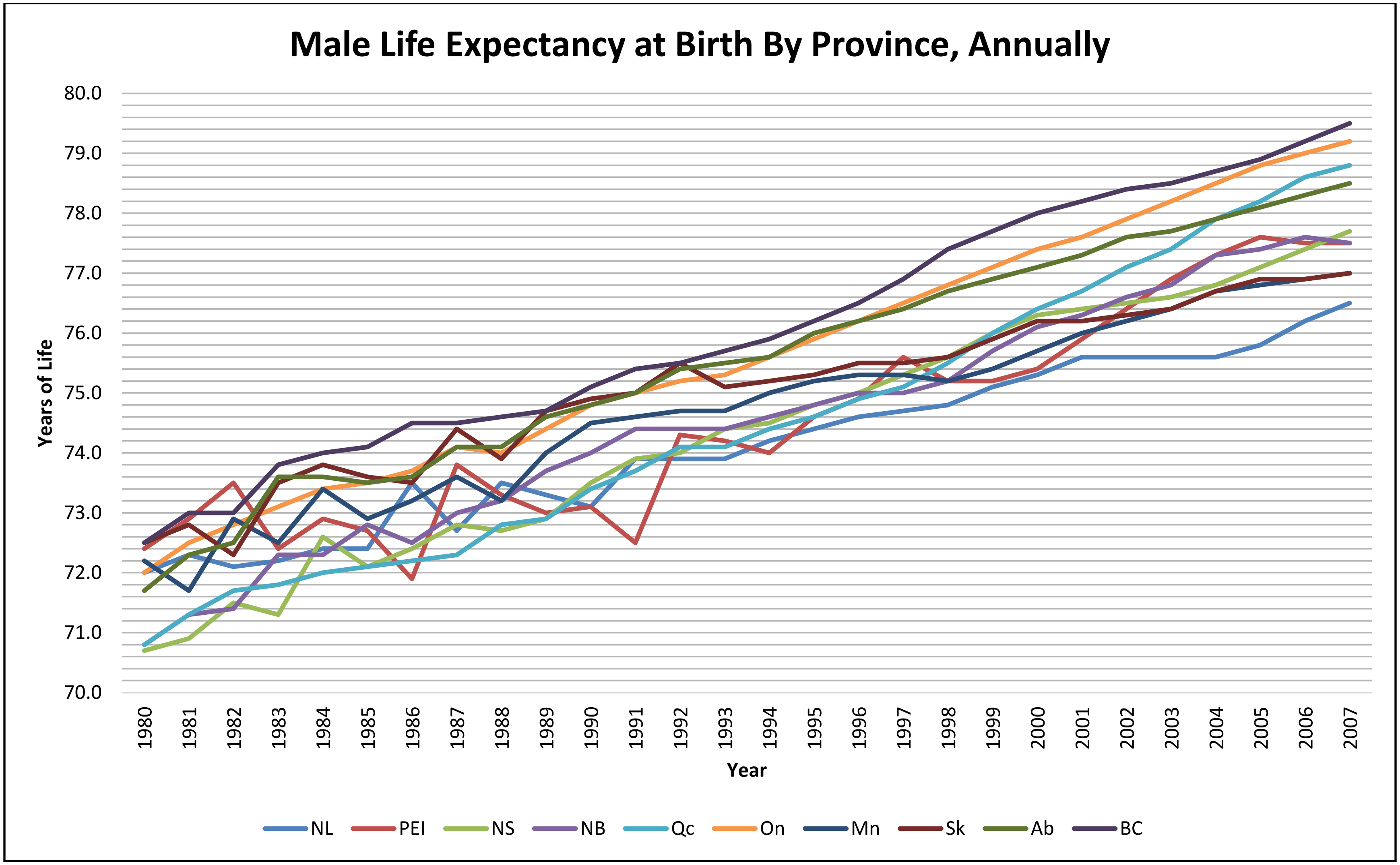

Figure 4: Male Life Expectancy at Birth by Province, Annually

Newfoundland & Labrador		Prince Edward Island		Nova Scotia		New Brunswick		Quebec	
Mean	74.11	Mean	74.53	Mean	74.35	Mean	74.51	Mean	74.53
Standard Error	0.26	Standard Error	0.34	Standard Error	0.40	Standard Error	0.38	Standard Error	0.46
Median	74.05	Median	74.25	Median	74.45	Median	74.50	Median	74.25
Mode	75.60	Mode	72.40	Mode	#N/A	Mode	74.40	Mode	74.10
Standard Deviation	1.38	Standard Deviation	1.78	Standard Deviation	2.11	Standard Deviation	2.00	Standard Deviation	2.41
Sample Variance	1.90	Sample Variance	3.16	Sample Variance	4.46	Sample Variance	3.99	Sample Variance	5.81
Kurtosis	-1.23	Kurtosis	-1.06	Kurtosis	-1.19	Kurtosis	-0.94	Kurtosis	-1.11
Skewness	-0.03	Skewness	0.40	Skewness	-0.13	Skewness	-0.11	Skewness	0.29
Range	4.50	Range	5.70	Range	7.00	Range	6.80	Range	8.00
Minimum	72.00	Minimum	71.90	Minimum	70.70	Minimum	70.80	Minimum	70.80
Maximum	76.50	Maximum	77.60	Maximum	77.70	Maximum	77.60	Maximum	78.80
Sum	2075.20	Sum	2086.90	Sum	2081.70	Sum	2086.40	Sum	2086.80
Count	28	Count	28	Count	28	Count	28	Count	28

Table 4a: Male Life Expectancy at Birth by Province, Summary Statistics

Ontario		Manitoba		Saskatchewan		Alberta		British Columbia	
Mean	75.66	**Mean**	74.69	**Mean**	75.04	**Mean**	75.52	**Mean**	76.09
Standard Error	0.41	**Standard Error**	0.29	**Standard Error**	0.26	**Standard Error**	0.37	**Standard Error**	0.39
Median	75.45	**Median**	74.85	**Median**	75.25	**Median**	75.55	**Median**	75.80
Mode	#N/A	**Mode**	72.90	**Mode**	75.50	**Mode**	73.60	**Mode**	73.00
Standard Deviation	2.15	**Standard Deviation**	1.52	**Standard Deviation**	1.37	**Standard Deviation**	1.96	**Standard Deviation**	2.08
Sample Variance	4.60	**Sample Variance**	2.32	**Sample Variance**	1.87	**Sample Variance**	3.83	**Sample Variance**	4.34
Kurtosis	-1.16	**Kurtosis**	-0.94	**Kurtosis**	-0.74	**Kurtosis**	-1.00	**Kurtosis**	-1.21
Skewness	0.08	**Skewness**	-0.23	**Skewness**	-0.44	**Skewness**	-0.22	**Skewness**	0.05
Range	7.20	**Range**	5.30	**Range**	4.70	**Range**	6.80	**Range**	7.00
Minimum	72.00	**Minimum**	71.70	**Minimum**	72.30	**Minimum**	71.70	**Minimum**	72.50
Maximum	79.20	**Maximum**	77.00	**Maximum**	77.00	**Maximum**	78.50	**Maximum**	79.50
Sum	2118.50	**Sum**	2091.20	**Sum**	2101.10	**Sum**	2114.60	**Sum**	2130.40
Count	28	**Count**	28	**Count**	28	**Count**	28	**Count**	28

Table 4b: Male Life Expectancy at Birth by Province, Summary Statistics

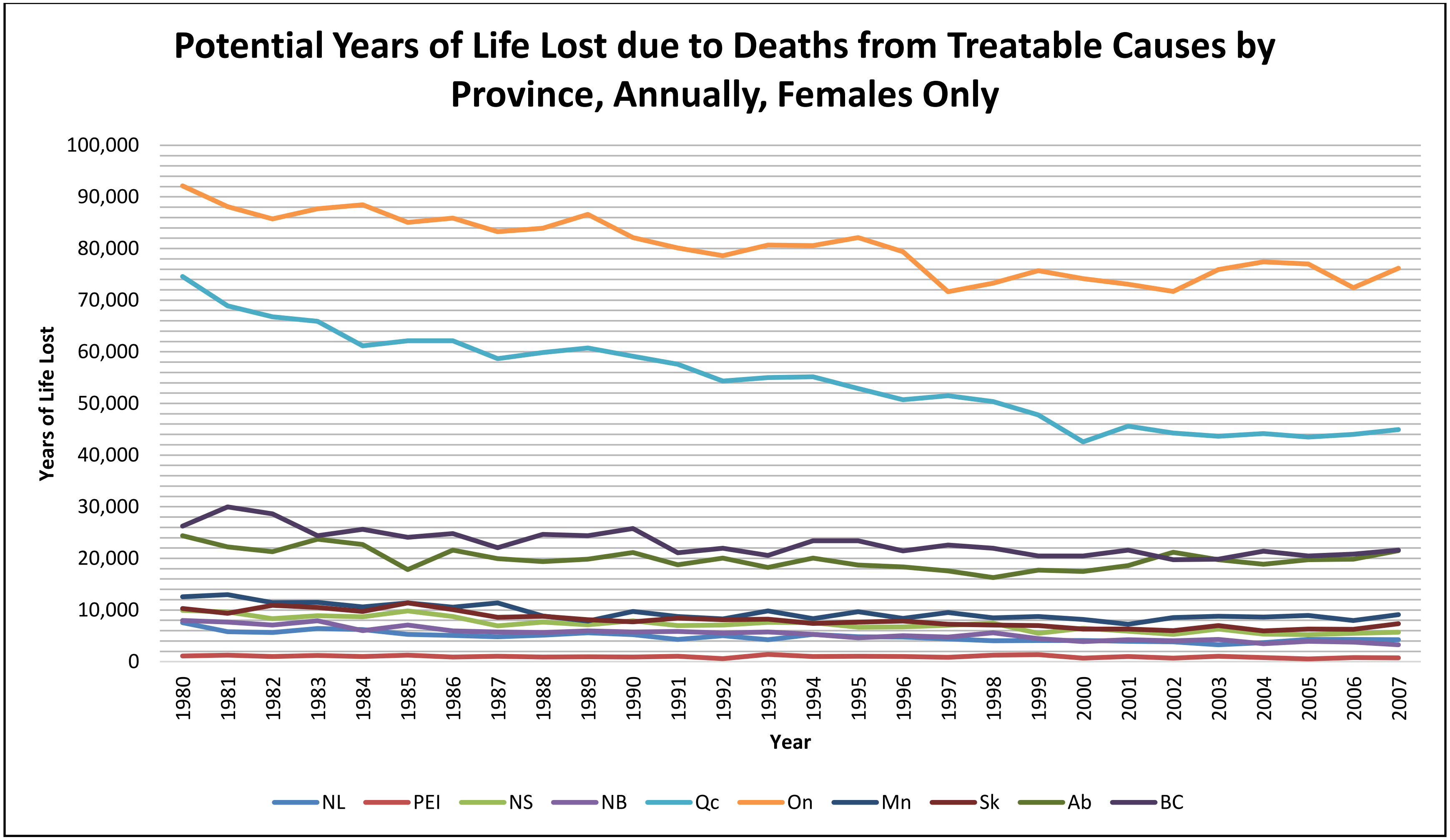

Figure 5: Potential Years of Life Lost due to Deaths from Treatable Causes by Province, Annually, Females Only

Newfoundland & Labrador		Prince Edward Island		Nova Scotia		New Brunswick		Quebec	
Mean	4717.06	**Mean**	952.74	**Mean**	7073.58	**Mean**	5233.52	**Mean**	53834.74
Standard Error	173.45	**Standard Error**	41.45	**Standard Error**	250.86	**Standard Error**	239.72	**Standard Error**	1569.70
Median	4390	**Median**	983	**Median**	7002	**Median**	5288	**Median**	52889
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	965.73	**Standard Deviation**	230.77	**Standard Deviation**	1396.71	**Standard Deviation**	1334.72	**Standard Deviation**	8739.72
Sample Variance	932636.40	**Sample Variance**	53256.26	**Sample Variance**	1950786.92	**Sample Variance**	1781484.86	**Sample Variance**	76382624.73
Kurtosis	1.08	**Kurtosis**	-0.52	**Kurtosis**	-0.60	**Kurtosis**	-0.51	**Kurtosis**	-0.62
Skewness	0.91	**Skewness**	0.04	**Skewness**	0.55	**Skewness**	0.51	**Skewness**	0.52
Range	4341	**Range**	904	**Range**	4712	**Range**	4698	**Range**	32020
Minimum	3204	**Minimum**	514	**Minimum**	5241	**Minimum**	3270	**Minimum**	42559
Maximum	7545	**Maximum**	1418	**Maximum**	9953	**Maximum**	7968	**Maximum**	74579
Sum	146229	**Sum**	29535	**Sum**	219281	**Sum**	162239	**Sum**	1668877
Count	31	**Count**	31	**Count**	31	**Count**	31	**Count**	31

Table 5a: Potential Years of Life Lost due to Deaths from Treatable Causes by Province, Females Only: Descriptive Statistics

Ontario		Manitoba		Saskatchewan		Alberta		British Columbia	
Mean	79792.90	**Mean**	9445.61	**Mean**	8006.03	**Mean**	20113.16	**Mean**	22867.45
Standard Error	1031.52	**Standard Error**	260.66	**Standard Error**	269.25	**Standard Error**	364.14	**Standard Error**	448.63
Median	79363	**Median**	8855	**Median**	7655	**Median**	19843	**Median**	21983
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	5743.25	**Standard Deviation**	1451.28	**Standard Deviation**	1499.11	**Standard Deviation**	2027.44	**Standard Deviation**	2497.88
Sample Variance	32984964.62	**Sample Variance**	2106216.18	**Sample Variance**	2247332.70	**Sample Variance**	4110496.21	**Sample Variance**	6239390.72
Kurtosis	-0.96	**Kurtosis**	-0.03	**Kurtosis**	-0.36	**Kurtosis**	-0.41	**Kurtosis**	1.19
Skewness	0.34	**Skewness**	0.89	**Skewness**	0.69	**Skewness**	0.37	**Skewness**	1.18
Range	20486	**Range**	5722	**Range**	5379	**Range**	8082	**Range**	10237
Minimum	71664	**Minimum**	7230	**Minimum**	5973	**Minimum**	16290	**Minimum**	19746
Maximum	92150	**Maximum**	12952	**Maximum**	11352	**Maximum**	24372	**Maximum**	29983
Sum	2473580	**Sum**	292814	**Sum**	248187	**Sum**	623508	**Sum**	708891
Count	31	**Count**	31	**Count**	31	**Count**	31	**Count**	31

Table 5b: Potential Years of Life Lost due to Deaths from Treatable Causes by Province, Females Only: Descriptive Statistics

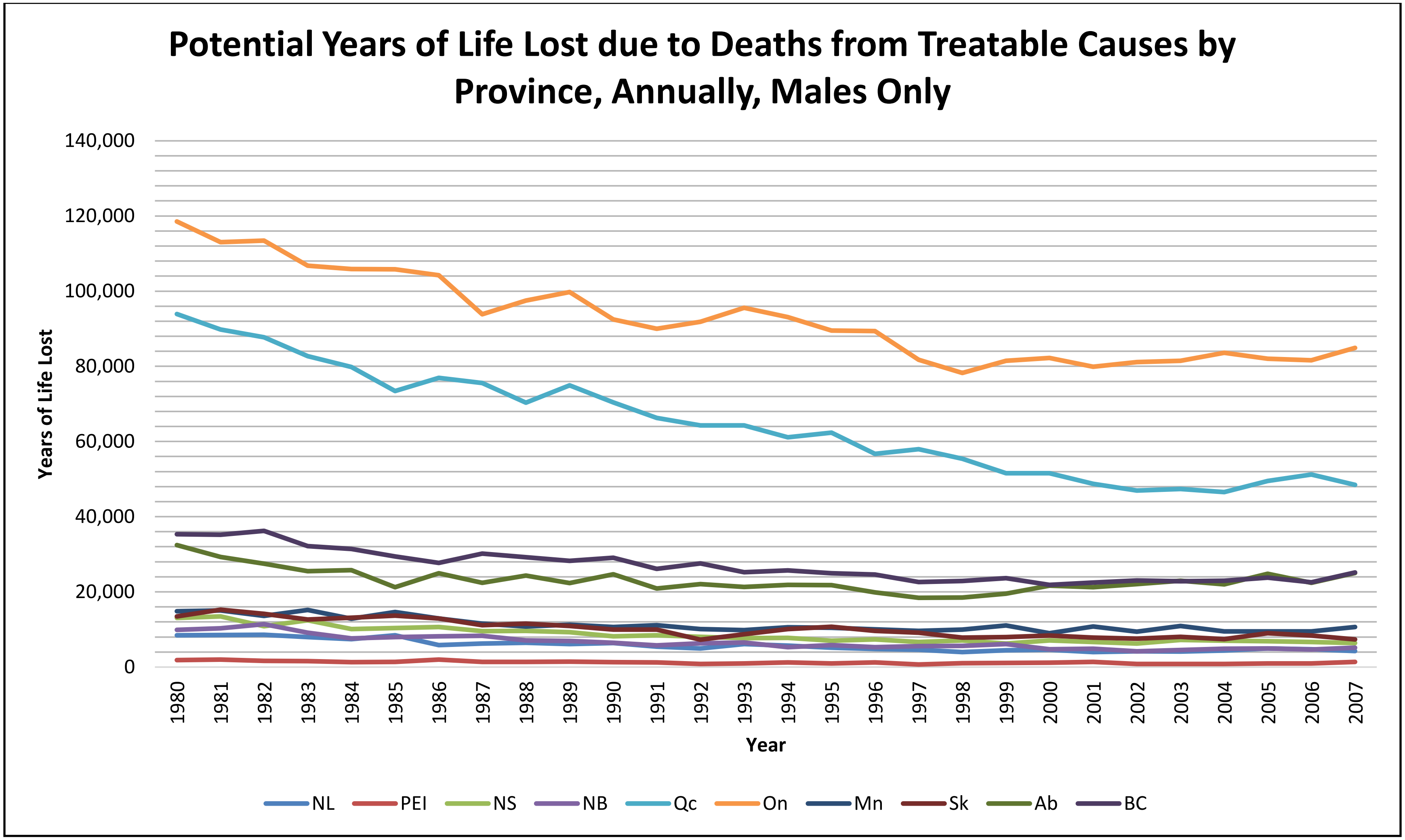

Figure 6: Potential Years of Life Lost due to Deaths from Treatable Causes by Province, Annually, Males Only

Newfoundland & Labrador		Prince Edward Island		Nova Scotia		New Brunswick		Quebec	
Mean	5638.45	**Mean**	1205.45	**Mean**	8305.84	**Mean**	6410.65	**Mean**	62883.35
Standard Error	267.04	**Standard Error**	64.07	**Standard Error**	376.43	**Standard Error**	335.81	**Standard Error**	2597.99
Median	5073	**Median**	1196	**Median**	7320	**Median**	5782	**Median**	61094
Mode	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A	**Mode**	#N/A
Standard Deviation	1486.80	**Standard Deviation**	356.70	**Standard Deviation**	2095.85	**Standard Deviation**	1869.72	**Standard Deviation**	14465
Sample Variance	2210563.99	**Sample Variance**	127237.92	**Sample Variance**	4392580.87	**Sample Variance**	3495840.30	**Sample Variance**	209236316.10
Kurtosis	-0.42	**Kurtosis**	-0.05	**Kurtosis**	0.38	**Kurtosis**	0.61	**Kurtosis**	-0.81
Skewness	0.90	**Skewness**	0.71	**Skewness**	1.14	**Skewness**	1.15	**Skewness**	0.59
Range	4601	**Range**	1305	**Range**	7416	**Range**	7210	**Range**	47383
Minimum	3978	**Minimum**	706	**Minimum**	6085	**Minimum**	4206	**Minimum**	46549
Maximum	8579	**Maximum**	2011	**Maximum**	13501	**Maximum**	11416	**Maximum**	93932
Sum	174792	**Sum**	37369	**Sum**	257481	**Sum**	198730	**Sum**	1949384
Count	31	**Count**	31	**Count**	31	**Count**	31	**Count**	31

Table 6a: Potential Years of Life Lost due to Deaths from Treatable Causes by Province, Males Only: Descriptive Statistics

Ontario		Manitoba		Saskatchewan		Alberta		British Columbia	
Mean	92056	Mean	11191.03	Mean	9942.65	Mean	23339.03	Mean	26523.26
Standard Error	2031.08	Standard Error	321.61	Standard Error	421.96	Standard Error	550.60	Standard Error	751.67
Median	89505	Median	10680	Median	9107	Median	22377	Median	25157
Mode	#N/A	Mode	#N/A	Mode	#N/A	Mode	#N/A	Mode	#N/A
Standard Deviation	11308.58	Standard Deviation	1790.65	Standard Deviation	2349.37	Standard Deviation	3065.61	Standard Deviation	4185.11
Sample Variance	127884042.00	Sample Variance	3206427.97	Sample Variance	5519535.70	Sample Variance	9397969.63	Sample Variance	17515157.00
Kurtosis	-0.35	Kurtosis	0.32	Kurtosis	-0.62	Kurtosis	1.44	Kurtosis	0.02
Skewness	0.84	Skewness	1.18	Skewness	0.76	Skewness	0.91	Skewness	0.97
Range	40262	Range	6165	Range	7993	Range	14065	Range	14395
Minimum	78270	Minimum	9024	Minimum	7294	Minimum	18409	Minimum	21808
Maximum	118532	Maximum	15189	Maximum	15287	Maximum	32474	Maximum	36203
Sum	2853736	Sum	346922	Sum	308222	Sum	723510	Sum	822221
Count	31	Count	31	Count	31	Count	31	Count	31

Table 6b: Potential Years of Life Lost due to Deaths from Treatable Causes by Province, Males Only: Descriptive Statistics

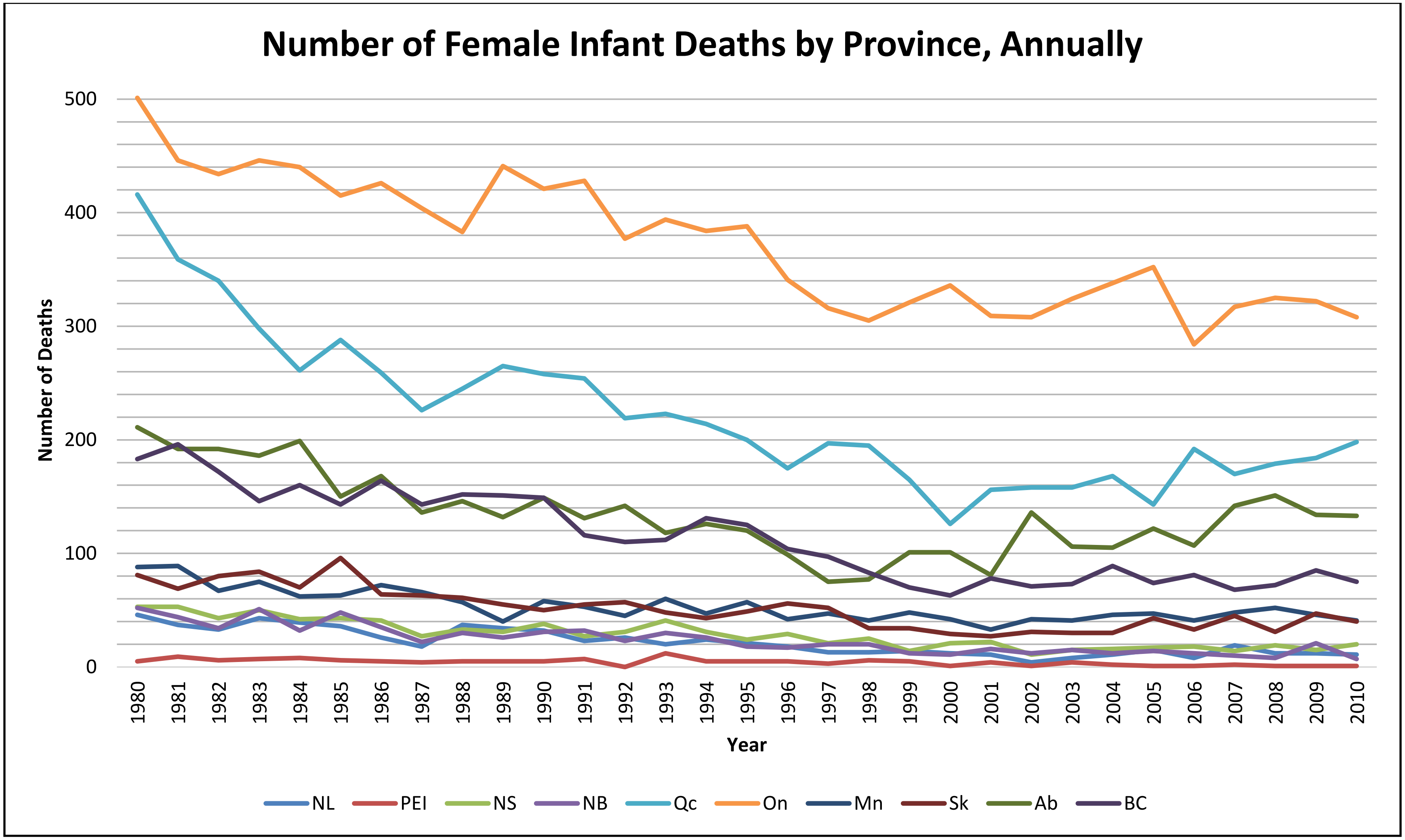

Figure 7: Number of Female Infant Deaths by Province, Annually

Newfoundland & Labrador		Prince Edward Island		Nova Scotia		New Brunswick		Quebec	
Mean	21.81	**Mean**	4.26	**Mean**	28.55	**Mean**	23.90	**Mean**	222.23
Standard Error	2.09	**Standard Error**	0.50	**Standard Error**	2.21	**Standard Error**	2.28	**Standard Error**	12
Median	19	**Median**	5	**Median**	27	**Median**	21	**Median**	200
Mode	12	**Mode**	5	**Mode**	31	**Mode**	12	**Mode**	158
Standard Deviation	11.62	**Standard Deviation**	2.77	**Standard Deviation**	12.32	**Standard Deviation**	12.69	**Standard Deviation**	66.79
Sample Variance	135.09	**Sample Variance**	7.66	**Sample Variance**	151.72	**Sample Variance**	160.96	**Sample Variance**	4460.91
Kurtosis	-0.90	**Kurtosis**	0.56	**Kurtosis**	-0.79	**Kurtosis**	-0.15	**Kurtosis**	1.24
Skewness	0.53	**Skewness**	0.57	**Skewness**	0.54	**Skewness**	0.79	**Skewness**	1.13
Range	42	**Range**	12	**Range**	42	**Range**	45	**Range**	290
Minimum	4	**Minimum**	0	**Minimum**	11	**Minimum**	7	**Minimum**	126
Maximum	46	**Maximum**	12	**Maximum**	53	**Maximum**	52	**Maximum**	416
Sum	676	**Sum**	132	**Sum**	885	**Sum**	741	**Sum**	6889
Count	31	**Count**	31	**Count**	31	**Count**	31	**Count**	31

Table 7a: Number of Female Infant Deaths by Province: Descriptive Statistics

Ontario		Manitoba		Saskatchewan		Alberta		British Columbia	
Mean	372.06	**Mean**	53.42	**Mean**	51.19	**Mean**	134.45	**Mean**	114.0645
Standard Error	10.22	**Standard Error**	2.51	**Standard Error**	3.28	**Standard Error**	6.37	**Standard Error**	7.102315
Median	377	**Median**	48	**Median**	49	**Median**	133	**Median**	110
Mode	446	**Mode**	41	**Mode**	55	**Mode**	192	**Mode**	143
Standard Deviation	56.91	**Standard Deviation**	13.95	**Standard Deviation**	18.26	**Standard Deviation**	35.48	**Standard Deviation**	39.54401
Sample Variance	3238.66	**Sample Variance**	194.72	**Sample Variance**	333.49	**Sample Variance**	1258.52	**Sample Variance**	1563.729
Kurtosis	-1	**Kurtosis**	0.77	**Kurtosis**	-0.18	**Kurtosis**	-0.24	**Kurtosis**	-1.12745
Skewness	0.33	**Skewness**	1.10	**Skewness**	0.66	**Skewness**	0.43	**Skewness**	0.406277
Range	217	**Range**	56	**Range**	69	**Range**	136	**Range**	133
Minimum	284	**Minimum**	33	**Minimum**	27	**Minimum**	75	**Minimum**	63
Maximum	501	**Maximum**	89	**Maximum**	96	**Maximum**	211	**Maximum**	196
Sum	11534	**Sum**	1656	**Sum**	1587	**Sum**	4168	**Sum**	3536
Count	31	**Count**	31	**Count**	31	**Count**	31	**Count**	31

Table 7b: Number of Female Infant Deaths by Province – Descriptive Statistics

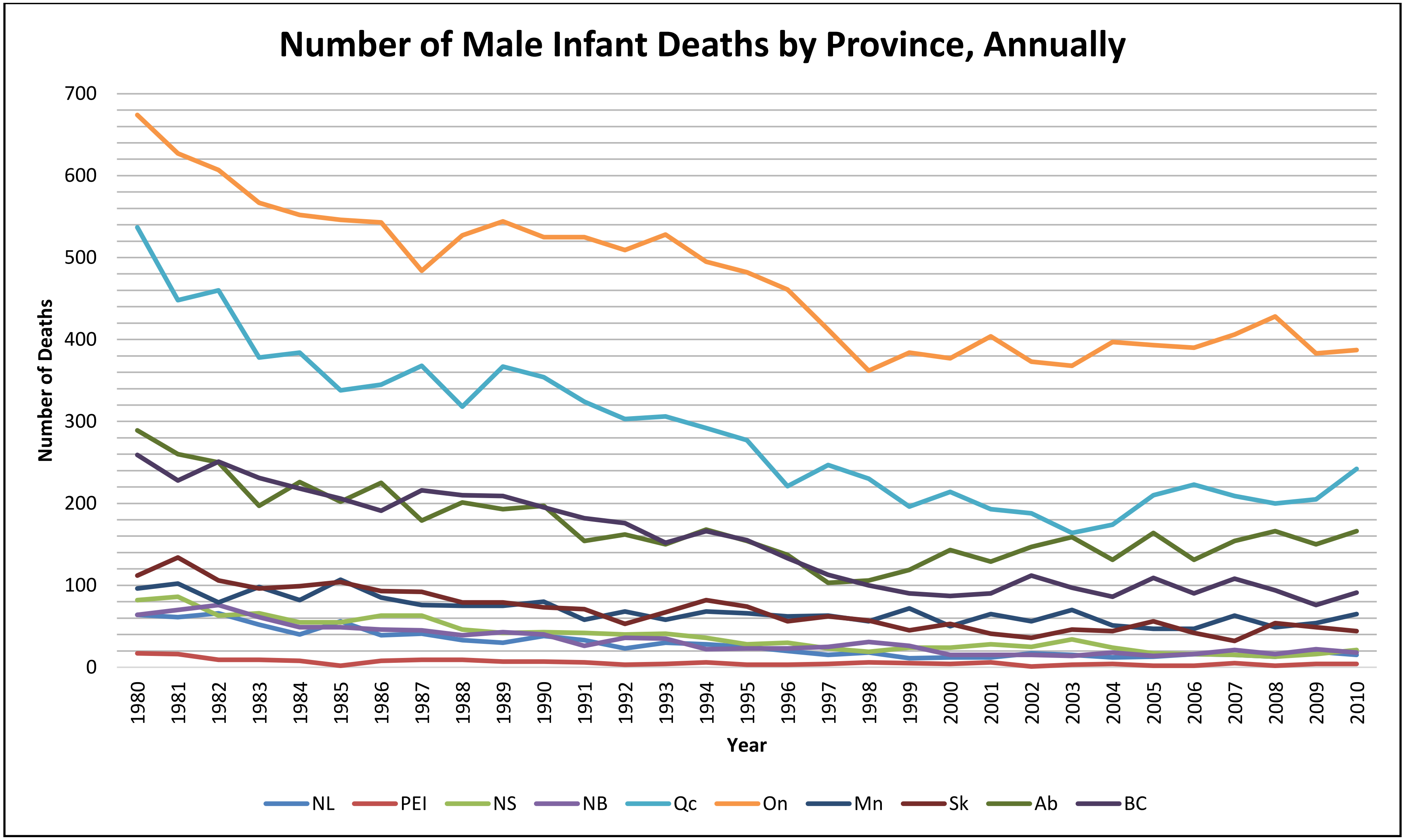

Figure 8: Number of Male Infant Deaths by Province, Annually

Newfoundland & Labrador		Prince Edward Island		Nova Scotia		New Brunswick		Quebec	
Mean	28.45	Mean	5.74	Mean	38.06	Mean	32.68	Mean	287.58
Standard Error	3.02	Standard Error	0.67	Standard Error	3.61	Standard Error	3.19	Standard Error	16.86
Median	23	Median	5	Median	34	Median	26	Median	277
Mode	15	Mode	4	Mode	63	Mode	15	Mode	#N/A
Standard Deviation	16.83	Standard Deviation	3.72	Standard Deviation	20.07	Standard Deviation	17.75	Standard Deviation	93.86
Sample Variance	283.39	Sample Variance	13.86	Sample Variance	403	Sample Variance	315.23	Sample Variance	8809.78
Kurtosis	-0.14	Kurtosis	2.86	Kurtosis	-0.13	Kurtosis	0.01	Kurtosis	0.14
Skewness	0.97	Skewness	1.55	Skewness	0.82	Skewness	0.95	Skewness	0.80
Range	55	Range	16	Range	73	Range	62	Range	373
Minimum	11	Minimum	1	Minimum	13	Minimum	14	Minimum	164
Maximum	66	Maximum	17	Maximum	86	Maximum	76	Maximum	537
Sum	882	Sum	178	Sum	1180	Sum	1013	Sum	8915
Count	31	Count	31	Count	31	Count	31	Count	31

Table 8a: Number of Male Infant Deaths by Province – Descriptive Statistics

Ontario		Manitoba		Saskatchewan		Alberta		British Columbia	
Mean	472.90	**Mean**	69.13	**Mean**	68.74	**Mean**	171.35	**Mean**	152.29
Standard Error	15.59	**Standard Error**	2.91	**Standard Error**	4.62	**Standard Error**	7.96	**Standard Error**	10.49
Median	482	**Median**	66	**Median**	62	**Median**	162	**Median**	152
Mode	525	**Mode**	75	**Mode**	79.	**Mode**	154	**Mode**	90
Standard Deviation	86.78	**Standard Deviation**	16.23	**Standard Deviation**	25.70	**Standard Deviation**	44.31	**Standard Deviation**	58.39
Sample Variance	7531.16	**Sample Variance**	263.38	**Sample Variance**	660.40	**Sample Variance**	1963.30	**Sample Variance**	3408.88
Kurtosis	-0.76	**Kurtosis**	-0.04	**Kurtosis**	-0.24	**Kurtosis**	0.59	**Kurtosis**	-1.44
Skewness	0.46	**Skewness**	0.73	**Skewness**	0.69	**Skewness**	0.89	**Skewness**	0.28
Range	312	**Range**	60	**Range**	102	**Range**	186	**Range**	183
Minimum	362	**Minimum**	47	**Minimum**	32	**Minimum**	103	**Minimum**	76
Maximum	674	**Maximum**	107	**Maximum**	134	**Maximum**	289	**Maximum**	259
Sum	14660	**Sum**	2143	**Sum**	2131	**Sum**	5312	**Sum**	4721
Mean	472.90	**Mean**	69.13	**Mean**	68.74	**Mean**	171.35	**Mean**	152.29

Table 8b: Number of Male Infant Deaths by Province – Descriptive Statistics

Appendix C – MARS Models from Analyses of Infant Mortality & Deaths from Treatable Causes

Explanation of Basis Functions

In order to avoid an overly prolonged discussion of the basis functions within each model, three of the basis functions which resulted from the analysis of PYLL will be used to explain how each should be interpreted. This will aid in the interpretation of the overall models which will be discussed below.

We begin by examining with the simple basis function BF1 from the MARS model analyzing FPYLL. BF1 indicates that from 1980 to 2010, when spending on Drugs was below $223.76 per person it had no effect in determining FPYLL in the overall model. In BF2 from the FPYLL MARS model we see that, over the same time period, when spending on Drugs was greater than $223.76 it had no effect on the final model. BF1 represents the influence of spending on Drugs before the knot point where spending levels reach $223.76 per person while BF2 represents the influence of the same variable after this knot point.

BF7 from the FPYLL MARS model represents a complex basis function as it is composed of the product of two simple basis functions. In examining BF7 we see that when spending on Physicians was less than $78.22 per person between 1980 and 2010, it had no effect on determining FPYLL in the final model. We also see that this first simple basis function is multiplied by the previously discussed BF1. Therefore in order for BF7 to have an effect on determining FPYLL in the final model, spending on Physicians must be greater than $78.22 per person, and spending on Drugs must be greater than $233.76 per person.

These same interpretations can be applied to the simple and complex basis functions contained in both final MARS models examining both PYLLTC (Tables 1 and 2) and Infant Deaths (Tables 3 and 4).

FPYLL	
Simple Basis Functions	**Complex Basis Functions**
BF1 = max(0, DRUGS - 223.76); BF2 = max(0, 223.76 - DRUGS); BF3 = max(0, PHYSICIANS - 439.57); BF5 = max(0, HOSPITALS - 773.94); BF8 = max(0, PUBLIC_HEALTH - 153.47); BF9 = max(0, 153.47 - PUBLIC_HEALTH); BF18 = max(0, HOSPITALS - 1506.4)	BF7 = max(0, PHYSICIANS - 78.22) * BF1; BF10 = max(0, DRUGS - 140.04) * BF9; BF11 = max(0, 140.04 - DRUGS) * BF9; BF12 = max(0, PHYSICIANS - 234.03) * BF2; BF13 = max(0, 234.03 - PHYSICIANS) * BF2; BF14 = max(0, PHYSICIANS - 178.55) * BF9; BF15 = max(0, 178.55 - PHYSICIANS) * BF9; BF16 = max(0, HOSPITALS - 1136.56) * BF1; BF17 = max(0, 1136.56 - HOSPITALS) * BF1; BF21 = max(0, 1474.85 - HOSPITALS) * BF8; BF22 = max(0, PHYSICIANS - 428.47) * BF8; BF23 = max(0, 428.47 - PHYSICIANS) * BF8; BF24 = max(0, HOSPITALS - 526.74) * BF2; BF26 = max(0, HOSPITALS - 1055.79) * BF9; BF27 = max(0, 1055.79 - HOSPITALS) * BF9; BF28 = max(0, DRUGS - 305.3) * BF9;
Final Model	
Y = -21368.2 - 188.868 * BF1 - 176.007 * BF3 + 56.1723 * BF5 + 0.855825 * BF7 + 238.447 * BF8 - 1.57102 * BF10 + 6.72884 * BF11 - 13.9948 * BF12 - 2.95269 * BF13 + 4.66213 * BF14 - 3.21607 * BF15 - 0.66042 * BF16 + 0.71892 * BF17 + 333.072 * BF18 - 1.24937 * BF21 - 1.09897 * BF22 + 4.20016 * BF23 + 2.11627 * BF24 + 1.68031 * BF26 + 0.966344 * BF27 - 3.36202 * BF28;	
Table 1: MARS Model Examining Potential Years of Life Lost by Females	

MPYLL	
Simple Basis Functions	**Complex Basis Functions**
BF1 = max(0, DRUGS - 223.76); BF2 = max(0, 223.76 - DRUGS); BF3 = max(0, PHYSICIANS - 439.57); BF6 = max(0, 773.94 - HOSPITALS); BF8 = max(0, PUBLIC_HEALTH - 138.88); BF9 = max(0, 138.88 - PUBLIC_HEALTH); BF18 = max(0, HOSPITALS - 1506.4); BF19 = max(0, 1506.4 - HOSPITALS);	BF7 = max(0, PHYSICIANS - 78.22) * BF1; BF10 = max(0, PHYSICIANS - 234.03) * BF2; BF11 = max(0, 234.03 - PHYSICIANS) * BF2; BF12 = max(0, DRUGS - 116.8) * BF9; BF13 = max(0, 116.8 - DRUGS) * BF9; BF14 = max(0, PHYSICIANS - 178.55) * BF9; BF16 = max(0, HOSPITALS - 1119.82) * BF1; BF17 = max(0, 1119.82 - HOSPITALS) * BF1; BF20 = max(0, PUBLIC_HEALTH - 33.44) * BF19; BF21 = max(0, 33.44 - PUBLIC_HEALTH) * BF19; BF22 = max(0, PHYSICIANS - 78.22) * BF8; BF24 = max(0, 43.75 - PUBLIC_HEALTH) * BF6;
Final Model	
Y = 50790.3 - 322.566 * BF1 + 290.738 * BF2 - 220.201 * BF3 + 1.02461 * BF7 + 569.371 * BF8 - 17.6286 * BF10 - 6.75225 * BF11 - 4.19211 * BF12 + 14.8095 * BF13 + 6.19353 * BF14 - 0.588008 * BF16 + 0.863894 * BF17 + 323.291 * BF18 - 0.745951 * BF20 - 7.46035 * BF21 - 1.05875 * BF22 + 9.96406 * BF24;	
Table 2: MARS Model Examining Potential Years of Life Lost by Males	

NFID	
Simple Basis Functions	**Complex Basis Functions**
BF1 = max(0, DRUGS - 223.76); BF2 = max(0, 223.76 - DRUGS); BF4 = max(0, 439.57 - PHYSICIANS); BF8 = max(0, 804.43 - HOSPITALS); BF15 = max(0, OTHER_PROFESSIONALS - 383.85); BF16 = max(0, 383.85 - OTHER_PROFESSIONALS); BF29 = max(0, 335.5 - OTHER_HEALTH_SPENDING);	BF5 = max(0, PHYSICIANS - 270.97) * BF1; BF6 = max(0, 270.97 - PHYSICIANS) * BF1; BF9 = max(0, PHYSICIANS - 137.65) * BF2; BF10 = max(0, 137.65 - PHYSICIANS) * BF2; BF12 = max(0, 514.91 - HOSPITALS) * BF4; BF13 = max(0, OTHER_PROFESSIONALS - 95.51) * BF2; BF17 = max(0, HOSPITALS - 1219.72) * BF16; BF18 = max(0, 1219.72 - HOSPITALS) * BF16; BF19 = max(0, DRUGS - 748.51) * BF15; BF22 = max(0, 757.78 - PHYSICIANS) * BF15; BF23 = max(0, OTHER_PROFESSIONALS - 104.39) * BF4; BF25 = max(0, OTHER_PROFESSIONALS - 54.5) * BF1; BF26 = max(0, HOSPITALS - 1563.51) * BF1; BF27 = max(0, 1563.51 - HOSPITALS) * BF1;
Final Model	
Y = -58.1241 - 2.85776 * BF1 + 2.4002 * BF2 - 3.24257 * BF4 + 0.00139846 * BF5 + 0.017306 * BF6 - 0.537652 * BF8 + 0.0246415 * BF9 - 0.0532958 * BF10 + 0.00341132 * BF12 - 0.0548413 * BF13 - 3.24687 * BF15 + 1.71777 * BF16 + 0.0051001 * BF17 + 0.00175204 * BF18 - 0.00678571 * BF19 + 0.00601778 * BF22 + 0.0101466 * BF23 + 0.00698606 * BF25 - 0.000207216 * BF26 + 0.00126495 * BF27 + 0.762673 * BF29;	
Table 3: MARS Model Examining Number of Female Infant Deaths	

NMID	
Simple Basis Functions	**Complex Basis Functions**
BF1 = max(0, DRUGS - 223.76); BF2 = max(0, 223.76 - DRUGS); BF3 = max(0, PHYSICIANS - 439.57); BF4 = max(0, 439.57 - PHYSICIANS); BF8 = max(0, 804.43 - HOSPITALS); BF11 = max(0, HOSPITALS - 514.91); BF18 = max(0, 383.85 - OTHER_PROFESSIONALS);	BF5 = max(0, PHYSICIANS - 270.97) * BF1; BF6 = max(0, 270.97 - PHYSICIANS) * BF1; BF9 = max(0, PHYSICIANS - 137.65) * BF2; BF10 = max(0, 137.65 - PHYSICIANS) * BF2; BF13 = max(0, OTHER_PROFESSIONALS - 95.51) * BF2; BF15 = max(0, HOSPITALS - 651.64) * BF2; BF19 = max(0, PHYSICIANS - 507.76) * BF18; BF20 = max(0, 507.76 - PHYSICIANS) * BF18; BF21 = max(0, OTHER_PROFESSIONALS - 383.85) * BF1; BF22 = max(0, 383.85 - OTHER_PROFESSIONALS) * BF1; BF24 = max(0, 843.63 - HOSPITALS) * BF4; BF25 = max(0, HOSPITALS - 1080.9) * BF1; BF26 = max(0, 1080.9 - HOSPITALS) * BF1; BF27 = max(0, PUBLIC_HEALTH - 175.9) * BF18; BF28 = max(0, 175.9 - PUBLIC_HEALTH) * BF18; BF29 = max(0, HOSPITALS - 1563.51) * BF3;
Final Model	
Y = -103.348 + 2.33712 * BF2 - 1.43098 * BF3 + 0.00247316 * BF5 + 0.0253861 * BF6 - 2.29838 * BF8 + 0.0616209 * BF9 - 0.060763 * BF10 + 0.213914 * BF11 - 0.098403 * BF13 + 0.0251088 * BF15 + 5.51872 * BF18 + 0.0455656 * BF19 - 0.0205505 * BF20 + 0.00136348 * BF21 - 0.0128709 * BF22 + 0.011363 * BF24 - 0.00128932 * BF25 + 0.00437602 * BF26 - 0.0538521 * BF27 + 0.00570746 * BF28 + 0.00107148 * BF29;	

Table 4: MARS Model Examining Number of Male Infant Deaths

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List of Acronyms

BF: Basis Function

BCC: Banker, Charnes, and Cooper

CRS: Constant Returns to Scale

CCR: Charnes Cooper and Rhodes

DEA: Data Envelopment Analysis

DRS: Decreasing Returns to Scale

DT: Decision Tree

EMS: Efficiency Measurement System

FLE65: Female Life Expectancy at age 65

FLEB: Female Life Expectancy at Birth

FPYLLTC: Female Potential Years of Life Lost due to Deaths from Treatable Causes

IRS: Increasing Returns to Scale

MARS: Multivariate Adaptive Regression Splines

MLE65: Male Life Expectancy at age 65

MLEB: Male Life Expectancy at Birth

MPSS: Most Productive Scale Size

MPYLLTC: Male Potential Years of Life Lost due to Deaths from Treatable Causes

NIRS: Non-Increasing Returns to Scale

NMID: Number of Male Infant Deaths

NFID: Number of Female Infant Deaths

PYLLTC: Potential Years of Life Lost due to Deaths from Treatable Causes

StatsCan: Statistics Canada

SPM: Salford Predictive Modeler

Glossary of Terms

Algorithm: A process or set of rules used to perform calculations or solve problems.

Categorical/Nominal Variable: A variable whose value may fall into multiple, un-ranked categories.

Continuous variable: A variable which can take an infinite number of possible values between the minimum and maximum.

Decision Making Unit: A term used in DEA referring to a system which converts inputs to outputs.

Decision Tree: A category of predictive induction algorithms which, when visualized, resemble an inverted tree.

Dependent Variable: A variable whose value/variation depends on another variable; usually notated as the "y" variable.

Function: A relationship expressed using multiple variables.

Independent Variable: A variable whose value/variation does not depend on that of another; usually notated as the "x" variable.

Induction: A method of inference that uses assumptions taken from sample of observations to make generalizations to a broader conclusion.

Over-fitting: Over-fitting occurs when a statistical model is constructed in a way that demonstrates the trends in sample of data it is constructed from and therefore cannot be generalized.

Piecewise Function: A function that is composed of a combination of multiple, smaller functions.

Regression Analysis: A statistical method for estimating and modeling the relationships between variables. A simple regression analysis usually focuses on the relationship between two variables, one dependent and one independent. A multiple regression analysis includes upwards of two independent variables.

R-Squared Statistic: A measure of the proportion of variance in the dependent variable that is predicted by the independent variable(s) used a regression analysis.

Technical Efficiency: The effectiveness with which a set of inputs is transformed into output. To be technically efficient means to minimize the amount of input used to produce a maximized amount of output.

Variance: The description of how widely individual observations in a group differ from the average observation.