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Article

Provincial healthcare expenditures and household spending: Impact on life expectancy trends in Canada

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Abstract

Life expectancy reflects a multitude of factors and mirrors the cultural, social, economic, and health conditions prevalent in a society. Calculated at birth, life expectancy is the average number of years an individual anticipates living. The focus of this inquiry is to understand the distinctive contributions of public healthcare expenditures and household healthcare costs in individual Canadian provinces and their implications for life expectancy trend. A random effects regression approach to panel data model, which assumes individual differences are random and not correlated with the independent variables, was applied to analyze the relationship between independent variables, public healthcare expenditure, household healthcare spending, $\ln(GDP)$, education levels on life expectancy as dependent variable. Data were collected for nine Canadian provinces, grouped according to life expectancy, public healthcare expenditure, household healthcare spending, $\ln(GDP)$, and education levels, over 16 years (2007-2022). Results show a positive correlation between household healthcare spending, $\ln(GDP)$, and education levels with life expectancy, while there is a negative correlation between public healthcare expenditure and life expectancy. The findings of this study suggest the need for efficient allocation of public health funds, support for household healthcare expenditures, economic growth, and investment in education to improve health outcomes. Policymakers may consider these findings to formulate comprehensive strategies that address the diverse determinants of health and enhance the overall well-being of Canadians.

Keywords: life expectancy, public healthcare expenditure, household healthcare spending

Introduction

The World Health Organization emphasizes that understanding the nature of health and its influencing factors is essential for achieving higher levels of health. Failure to recognize the factors posing threats to health and their significance introduces uncertainty into measures and services aimed at enhancing individual and societal health (Kruk et al., 2018). The assessment of life expectancy proves beneficial in appraising the effectiveness of services rendered (Behera & Dash, 2020). The relationship between public healthcare expenditures, household healthcare spending (out-of-pocket expenses), and life expectancy has been a central focus of research in health economics and public policy for decades (Behera & Dash, 2020; Filmer & Pritchett, 1999; Jaba et al., 2014; Kaplan & Bush, 1982; Nixon & Ulmann, 2006).

Numerous studies have investigated the relationship between public healthcare expenditures and life expectancy, revealing important variation across countries, these differences underscore the importance of context-specific factors, such as economic structures and healthcare delivery models, in influencing health outcomes (Jaba et al., 2014). While higher public health spending is generally linked to improved health outcomes and longer life expectancy, notable exceptions highlight that this relationship is not universally consistent. For example, studies on healthcare spending in Asian countries have shown that increased healthcare expenditures lead to long-term improvements in health outcomes and life expectancy, emphasizing the importance of sustained investment in public health systems (Polcyn et al., 2023). Similarly, research focusing on OECD countries found that higher healthcare spending positively influences population-level life expectancy, supporting the allocation of adequate public resources to health services (Roffia et al., 2023).

Detailed analyses of public healthcare expenditures have identified specific mechanisms that contribute to improved life expectancy. For instance, a study in Japan found that spending on public healthcare—including the availability of medical professionals such as doctors and therapists, financial support for healthcare facilities and clinics, and per capita spending on dentistry—was positively correlated with life expectancy (Hosokawa et al., 2020). These findings highlight the critical role of both the quantity and quality of healthcare provisions in shaping health outcomes in Japan. Another study using OECD health data suggested that doubling annual pharmaceutical expenditures could increase life expectancy by approximately one year for males at age 40 and slightly less for females at age 65 (Shaw et al., 2005). This underscores the potential life-extending benefits of targeted spending in the pharmaceutical sector.

In Canada, the relationship between healthcare spending and health outcomes has been examined. Studies on Canada have demonstrated that both public and private pharmaceutical spending play crucial roles in determining health outcomes, particularly in relation to infant mortality and life expectancy at age 65 (Crémieux et al., 2005; Emmanuel Guindon & Contoyannis, 2012). Interestingly, private pharmaceutical expenditures were found to have a stronger statistical association with health improvements than public spending, highlighting concerns about the efficiency and allocation of resources within public health systems (Crémieux et al., 2005). However, not all studies align with these findings. Some research suggests a negative or negligible relationship between public healthcare expenditure and life expectancy. For example, research on healthcare spending in European Union countries found that while increased expenditures were notably linked to reductions in infant mortality, their impact on life expectancy was marginal (Nixon & Ulmann, 2006). This suggests that after a certain threshold, additional spending may not yield proportional improvements in life expectancy. Similarly, a study in Canada found no notable association between spending on private or public pharmaceutical products and key health outcomes, such as infant mortality or life expectancy at age 65, suggesting that factors beyond expenditure levels may play a more substantial role in shaping these outcomes (Emmanuel Guindon & Contoyannis, 2012).

Numerous studies have investigated the impact of household healthcare spending (out-of-pocket expenditure) on life expectancy (Behera & Dash, 2020; Stabile & Allin, 2012; van Doorslaer & Masseria, 2004). Generally, higher household healthcare spending is associated with improved health outcomes and increased life expectancy, though exceptions exist. For example, out-of-pocket healthcare spending was found to positively influence life expectancy and reduce infant mortality in the South-East Asia region (Behera & Dash, 2020). Similarly, out-of-pocket expenditures in OECD countries have been suggested to help bridge gaps left by public healthcare systems, especially in regions with limited public funding (van Doorslaer & Masseria, 2004). However, the financial burden of healthcare costs on households can exacerbate inequalities in access to care. High out-of-pocket expenses might discourage low-income households from seeking essential medical care, leading to poorer health outcomes and lower life expectancy (Stabile & Allin, 2012). This underscores the complex role of household healthcare spending, which can both enhance and impede health, depending on the socio-economic context.

In Canada, a country renowned for its publicly funded healthcare system, the analysis of this relationship takes on unique dimensions due to the federal-provincial structure of health funding and delivery (Bayati et al., 2013). Provincial governments are primarily responsible for the administration and delivery of healthcare services, leading to variations in public health expenditures and healthcare policies across the country (Baltagi & Moscone, 2010). Concurrently, household healthcare spending, which includes out-of-pocket expenses for services not covered by provincial health plans, also varies notably among provinces. These expenditures can have a profound impact on individuals' access to healthcare services and, consequently, on life expectancy (van Doorslaer & Masseria, 2004).

This paper aims to fill a gap in the existing literature by focusing on the impact of provincial public healthcare expenditures and household healthcare spending on life expectancy trends specifically across Canadian provinces. While previous studies have explored healthcare spending and its effects on life expectancy at national levels, there is a lack of research on provincial variations in Canada, which are crucial for understanding regional disparities in health outcomes. By utilizing a panel data model, this research will provide a more in-depth analysis of how public healthcare expenditure and household out-of-pocket costs at the provincial level influence life expectancy trends over time.

Methods

This study investigates the impact of provincial public healthcare expenditures and household healthcare spending on life expectancy trends across Canadian provinces from 2007 to 2022. The datasets consist of annual observations gathered from Statistics Canada for all Canadian provinces except Prince Edward Island (Statistics Canada, 2024f, 2024c, 2024d, 2024e, 2024a, 2024b). These observations are categorized by life expectancy (LE), public healthcare expenditure (PHC), household healthcare spending (HHC), $\ln(GDP)$, and education levels (below upper secondary, simply referred to as $Below$; upper secondary and post-secondary non-tertiary, referred to as $Upper$; and tertiary education, $Tertiary$) over a 16-year period (2007-2022). The variables used in this study are presented in Table 1.

This study employs a panel data model to examine the dynamic interplay between several key input parameters—namely, life expectancy, public health expenditures, household healthcare spending, $\ln(GDP)$, and education levels—across nine Canadian provinces from 2007 to 2022. The panel data model was chosen for its robustness and versatility in accommodating both inter-provincial differences and temporal changes over the study period (Gujarati, 2003). By incorporating both cross-sectional and time-series variations, this model allows for the exploration of individual heterogeneity among provinces while capturing temporal trends within each province. Notably, the analysis is based on a balanced panel, as all cross-sectional data possess measurements for all periods.

Table 1. Definitions of the variables used in this study.

Variable	Description
Dependent variable	
Life expectancy (LE)	The average number of years a person is expected to live (Hosokawa et al., 2020)
Independent variables	
Public healthcare expenditure (PHC)	The amount of public funds spent on provincial public healthcare in Canada (Baltagi & Moscone, 2010)
Household healthcare spending (HHC)	The amount of money that households allocate to cover their healthcare-related costs (out of pocket cost) in different provinces of Canada (van Doorslaer & Masseria, 2004)
GDP	The GDP per capita for each province in Canada to account for the overall economic development of the region (Statistics Canada, 2024c)
$\ln(GDP)$	Refers to the natural logarithm (ln) of the gross domestic product (GDP). $\ln(GDP)$ is a logarithmic transformation to the GDP. This transformation can make further statistical analysis and interpretation more manageable.
Education Levels • Below upper secondary ($Below$) • Upper secondary and post-secondary non-tertiary ($Upper$) • $Tertiary$	The educational attainment level of the population in each Canadian province (Statistics Canada, 2024f)

To investigate the relationship between the aforementioned input parameters and life expectancy, a multivariate linear regression model was employed. This choice was made due to the model's capability to consider multiple independent variables simultaneously and their collective impact on the dependent variable. Linear regression coefficients offer straightforward interpretation, indicating the change in the dependent variable corresponding to a one-unit change in an independent variable. Moreover, a linear regression model provides a clear method for quantifying the strength and direction of the relationship between the dependent variable (life expectancy) and the independent variables (public health expenditures, household healthcare spending, GDP, and education levels). The model (Gujarati, 2003) is:

$$LE_{xt} = \beta_0 + \beta_1 PHC_{xt} + \beta_2 HHC_{xt} + \beta_3 GDP_{xt} + \beta_4 Below_{xt} + \beta_5 Upper_{xt} + \beta_6 Tertiary_{xt} + \beta_7 DUM_{xt} + v_{xt} \quad (1)$$

In the initial regression model, the GDP coefficient (Table A in supplementary materials) was comparatively large (25.04, $p < 0.05$), resulting unjustifiable values for life expectancy. To rectify this, a logarithmic transformation was applied exclusively to the GDP variable. This transformation can make further statistical analysis and interpretation more manageable. Following this adjustment, the regression model was redefined and re-estimated using the transformed data:

$$LE_{xt} = \beta_0 + \beta_1 PHC_{xt} + \beta_2 HHC_{xt} + \beta_3 \ln(GDP)_{xt} + \beta_4 Below_{xt} + \beta_5 Upper_{xt} + \beta_6 Tertiary_{xt} + \beta_7 DUM_{xt} + v_{xt} \quad (2)$$

Where, LE is defined as dependent variable, representing the life expectancy. The independent variables include public healthcare expenditure (PHC), household healthcare spending (HHC), gross domestic product (GDP) per capita, $\ln(GDP)$ logarithmic transformation to the GDP per capita variable, the level of education is categorized in three groups: below upper secondary ($Below$), upper secondary and post-secondary non-tertiary ($Upper$), and tertiary education ($Tertiary$). DUM is a dummy variable that for the years and v_{xt} is the regression composite error term. Also, the subscripts x ($x = 1 \dots n$) and t ($t = 1 \dots T$) indicate, respectively, the Canadian province and year. The unknown coefficients in equation 2, β, are estimated using STATA software through panel data method.

To ensure the reliability and accuracy of the estimates, bootstrap standard errors were used. Bootstrap standard errors help to assess the variability and precision of the estimated regression coefficients without relying on the assumptions of traditional parametric methods, such as normality of errors or large sample sizes. This is particularly useful when dealing with small samples or complex data distributions. This method accounts for the potential variability and ensures that the conclusions drawn about the relationships between life expectancy and the independent variables are reliable, even in the presence of small sample sizes or non-normal data distributions (Hesterberg, 2011).

Results

The analysis begins with examining of the dependent variable (life expectancy) across Canadian provinces. The kernel density distribution for the life expectancy in years across various Canadian provinces was explored (Figure 1). Each province is represented by distinct lines and colours, facilitating a clear comparison of life expectancy trends across the provinces. Provinces like British Columbia, Ontario, and Québec show higher, consistent peaks, likely reflecting effective health policies and investments, while Newfoundland and Labrador, Saskatchewan, and Manitoba, with lower peaks, may need targeted healthcare interventions to enhance life expectancy.

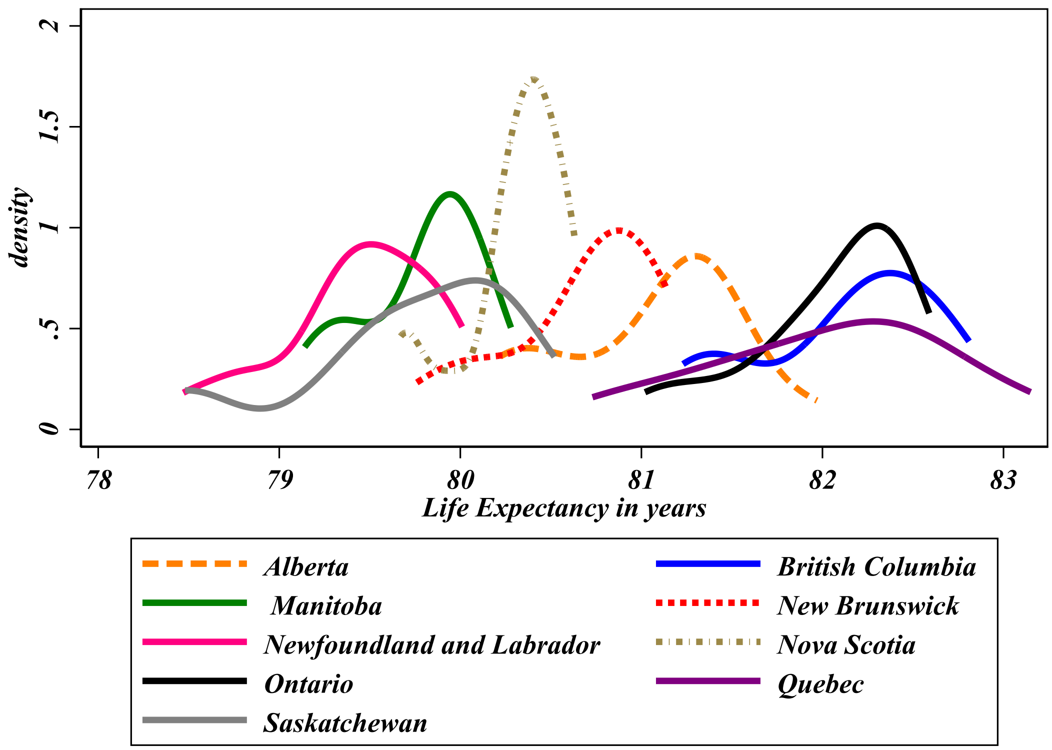

Figure 1. Kernel density estimation of life expectancy (in years) across various Canadian provinces.

The rest of the graphs are provided in the supplementary materials for the sake of brevity. Life expectancy trends (2007–2022) for nine Canadian provinces are shown in Figure A1 (supplementary materials), highlighting each province's trajectory over the 16-year period. Provincial trends in public healthcare expenditures and household healthcare spending over the same timeframe are presented in Figures A2 and A3 (supplementary materials), respectively.

The descriptive statistics in Table 2 summarize the key panel variables, including provincial public health expenditures (PHC), household healthcare spending (HHC), ln (GDP), and education levels, across 144 observations for 9 Canadian provinces over 16 years (2007–2022). An in-depth analysis of each variable is provided as follows:

Table 2. Descriptive statistics of key variables in the model. The 'overall' statistics are the descriptive statistics for the dataset, while 'between' and 'within' statistics denote the between-group and within-group variations. N represents the total number of observations, n represents the number of groups (provinces), and T represents the number of time periods in years (Statistics Canada, 2024f, 2024c, 2024d, 2024e, 2024a, 2024b).

Variable		Mean	Std. dev.	Min	Max	Observations
LE	overall	80.8	1.1	78.5	83.2	$N = 144$
	between		1.07	79.4	82.1	$n = 9$
	within		0.5	79.5	81.9	$T = 16$
PHC	overall	1326.7	1528.1	87.6	8838.1	$N = 144$
	between		1524.5	137.1	4933.0	$n = 9$
	within		504.7	−18.0	5231.7	$T = 16$
HHC	overall	5170.8	5767.5	413.2	24834.0	$N = 144$
	between		5920.4	606.3	18190.9	$n = 9$
	within		1374.7	394.0	11813.9	$T = 16$
$\ln(GDP)$	overall	−2.9	0.20	−3.27	−2.52	$N = 144$
	between		0.21	−3.22	−2.60	$n = 9$
	within		0.03	−3.07	−2.90	$T = 16$
$Below$	overall	11.3	3.6	5.0	22.0	$N = 144$
	between		2.6	7.5	15.6	$n = 9$
	within		2.6	4.7	17.7	$T = 16$
$Upper$	overall	38.4	5.2	25.0	52.0	$N = 144$
	between		4.6	30.4	47.3	$n = 9$
	within		2.8	30.4	43.2	$T = 16$
$Tertiary$	overall	50.3	7.4	34.0	69.0	$N = 144$
	between		5.6	41.8	61.2	$n = 9$
	within		5.1	40.9	64.9	$T = 16$

Life expectancy averages 80.8 years across provinces, with moderate variability (SD: 1.1) and lower within-group variability (0.5), indicating more stability within provinces over time than between them.

The mean public healthcare expenditure of $1326.7 per capita, with a high standard deviation of $1528.1, reveals significant disparities among provinces, driven more by differences between provinces ($1524.5) than within provinces over time ($504.7). Household healthcare spending averages $5170.8, with a high standard deviation of $5767.5, reflecting significant disparities, primarily between provinces ($5920.4) rather than within provinces over time ($1374.7).

The average $\ln(GDP)$ growth rate is -2.9, with a standard deviation of 0.20, indicating low variation. The GDP growth rates range from -3.22 to -2.60 between provinces, with minimal annual changes within provinces (range: -3.07 to -2.90, variation: 0.03). The $\ln(GDP)$ growth rate reflects stable economic conditions.

Education levels vary across provinces, with tertiary education having the highest mean at 50.3%, followed by upper secondary (38.4%) and below secondary (11.3%). Tertiary education shows the greatest variability both between and within provinces.

The descriptive statistics reveal notable variations in public healthcare expenditure, household healthcare spending, $\ln(GDP)$, and education levels across Canadian provinces. These disparities are key to understanding how funding and out-of-pocket expenses influence life expectancy. The analysis will further explore these relationships to assess the effectiveness and equity of healthcare investments in improving public health outcomes.

Three versions of the empirical model were estimated: pooled regression, fixed effects (FE), and random effects (RE). The error components model is: $y_x = \alpha + \beta x_{xt} + \nu_{xt}$, where $\nu_{xt} = \mu_t + \varepsilon_{xt}$ with μ_t capturing unobserved time heterogeneity and ε_{xt} representing idiosyncratic errors, which are random variations not explained by the independent variables. Each model differs in how it accounts for unobserved time-based heterogeneity.

As shown, individual heterogeneity is random, with random effects assumed to be normally distributed with a mean of zero and non-zero variance. Tests (Breusch-Pagan, F-test, and Hausman test) confirm that the random effects model is suitable for accounting for unobserved province-specific factors affecting life expectancy. This model provides more reliable estimates by considering time-constant province-specific factors that influence life expectancy, particularly regarding the timing of spending on mortality (Table 3).

The Breusch-Pagan test was used to compare the random effects and pooled models. The null hypothesis states that individual effects variance equals zero, suggesting a pooled OLS model. If the test rejects the null, indicating variance greater than zero, the random effects model is appropriate. With a p-value below 0.05 (Table 3), the alternative hypothesis is accepted, favoring the random effects model. The F-test evaluated the presence of fixed effects. The results (p-value < 0.05) support the alternative hypothesis, indicating significant fixed effects, and suggest that fixed effects better explain province-specific variances. The Hausman test differentiates between fixed and random effects models. The null hypothesis posits that the random effects model is consistent and efficient. Given the p-value exceeds 0.05 (Table 3), The null hypothesis is accepted, favoring the random effects model.

Table 3. Regression result of the effect of independent variables on life expectancy. Bootstrap standard errors are reported in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1. Comparison Tests: The Breusch and Pagan, F-test and Hausman test was conducted to assess the suitability of each regression model. The p-values for these tests are reported in front of each model. pro_id represents provinces of Canada.

Variables	Pooled OLS		Fixed effects		Random effects	
PHC	-0.000807	***	-0.000463	***	-0.000469	***
	(0.0000994)		(0.0000957)		(0.0000918)	
HHC	0.000319	***	0.000287	***	0.000269	***
	(0.0000258)		(0.0000377)		(0.0000301)	
ln (GDP)	1.219	***	1.290		1.183	**
	(0.306)		(0.963)		(0.599)	
Upper	0.0744	***	0.0470		0.0395	
	(0.0270)		(0.0318)		(0.0291)	
Tertiary	0.0781	***	0.0500		0.0454	*
	(0.0189)		(0.0305)		(0.0240)	
_IYear_2008			0.0695		0.0771	
			(0.127)		(0.128)	
_IYear_2009			0.389	***	0.399	***
			(0.135)		(0.133)	
_IYear_2010			0.513	***	0.533	***
			(0.144)		(0.138)	
_IYear_2011			0.587	***	0.611	***
			(0.150)		(0.139)	
_IYear_2012			0.654	***	0.681	***
			(0.173)		(0.151)	
_IYear_2013			0.540	***	0.576	***
			(0.189)		(0.159)	
_IYear_2014			0.474	**	0.514	***
			(0.209)		(0.170)	
_IYear_2015			0.327		0.372	**
			(0.230)		(0.181)	
_IYear_2016			0.416	*	0.465	**
			(0.248)		(0.192)	
_IYear_2017			0.247		0.306	
			(0.275)		(0.207)	
_IYear_2018			0.212		0.274	
			(0.303)		(0.223)	
_IYear_2019			0.472		0.539	**
			(0.325)		(0.236)	
_IYear_2020			0.141		0.199	
			(0.338)		(0.252)	
_IYear_2021			-0.296		-0.222	
			(0.396)		(0.285)	
_IYear_2022			-0.705	*	-0.617	**
			(0.423)		(0.301)	
Constant	77.08	***	79.21	***	79.47	***
	(2.458)		(3.827)		(3.031)	

Variables	Pooled OLS	Fixed effects	Random effects
Comparison Tests			
Breusch and Pagan	0.0000		
F-test	0.0000		
Hausman test	0.9530		
Observations	144	144	144
R^2	0.718	0.747	
Number of pro_id		9	9

The panel regression analysis, which examines factors influencing life expectancy, includes independent variables such as public healthcare expenditure (PHC), household healthcare spending (HHC), ln (GDP), and education levels (upper secondary and tertiary), along with year dummy variables to account for time-specific effects. The results of this analysis are shown in the random effects column (Table 3), and interpreted as follows:

PHC: Public healthcare expenditure

The coefficient of PHC is -0.000469 (***), with a standard error of 0.0000918, and it is statistically significant at the 1% level. The negative coefficient suggests that higher public healthcare expenditure is linked to a slight decrease in life expectancy, possibly due to inefficiencies in spending or increased PHC in response to declining health rather than proactive health investments.

An unexpected finding is the negative coefficient for PHC, indicating a negative relationship between public healthcare expenditure and life expectancy. However, a closer examination of provincial data from 2007 to 2019 (Figure 2) revealed a positive relationship between public healthcare spending and life expectancy. This trend shifted in 2019 with the onset of the COVID-19 pandemic, during which life expectancy declined despite increased healthcare spending. The negative relationship observed during the pandemic can likely be attributed to overwhelmed healthcare systems and higher mortality rates, which mitigated the expected health benefits of increased public healthcare expenditure. These findings are consistent with other studies examining the impact of the COVID-19 pandemic on life expectancy (Huang et al., 2023).

HHC: Household healthcare spending

The coefficient is 0.000269 (***), with a standard error of 0.0000301, and it is statistically significant at the 1% level. The positive coefficient indicates that higher household healthcare spending is associated with increased life expectancy, suggesting it may effectively address gaps not covered by public expenditures.

$ln\ (GDP)$

The coefficient is 1.183 (**), with a standard error of 0.599, and it is statistically significant at the 5% level. The positive and significant coefficient for ln (GDP) suggests a strong association between higher economic output and increased life expectancy, indicating that wealthier provinces can invest more in healthcare and related services.

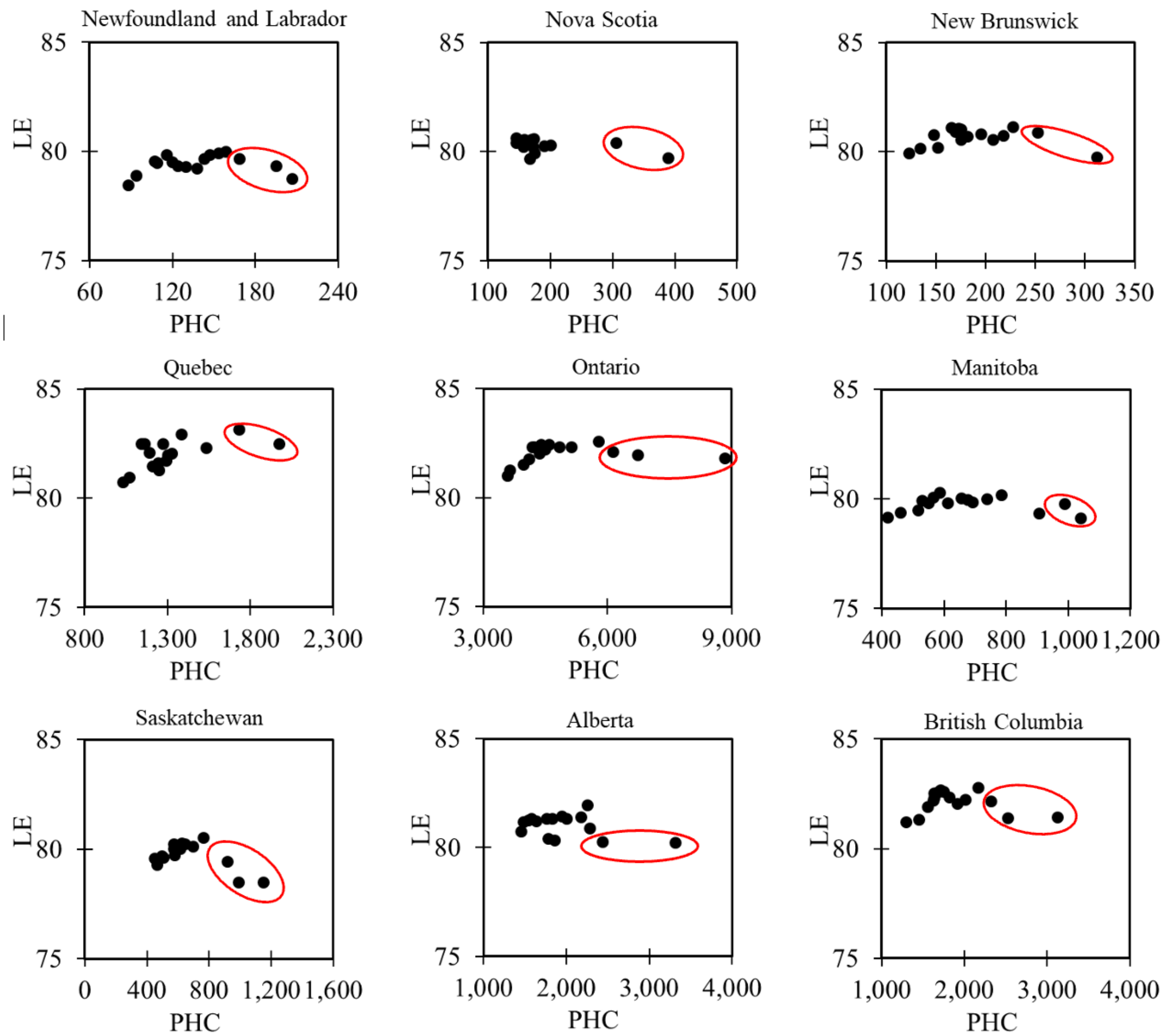

Figure 2. Scatter plot of the relationship between life expectancy and public healthcare expenditure.

Upper: Upper secondary education

The coefficient is 0.0395, with a standard error of 0.0291, and it is not statistically significant. Upper secondary education is associated with a 0.0395-year increase in life expectancy compared to below secondary education, but the effect is not statistically significant.

Tertiary: Tertiary education

The coefficient is 0.0454 (*), with a standard error of 0.0240, and it is statistically significant at the 10% level. Tertiary education is associated with a 0.0454-year increase in life expectancy, indicating that higher education levels are positively linked to longer life expectancies.

Year dummy variables

The year dummy variables capture time-specific effects on life expectancy across provinces. Coefficients for several years (e.g., 2009, 2010, 2012, 2013, 2014, 2015, 2019) show significant positive impacts, indicating that specific years had conditions or interventions, such as policy changes or public health initiatives, that notably influenced life expectancy.

Discussion

This paper investigates the factors influencing life expectancy in Canadian provinces. It underscores the need for efficient public healthcare spending, the role of household contributions, the benefits of economic growth, and the importance of education in improving health outcomes. The negative relationship between public healthcare expenditure (PHC) and life expectancy is counterintuitive and suggests potential inefficiencies or misallocation of resources within the public healthcare system. This finding aligns with the results of Nkemgha et al. (2021), whose study on Cameroon found that public healthcare expenditure by the government had no notable effect on life expectancy, while private healthcare expenditure (out-of-pocket costs) has a positive and important impact on life expectancy. Similarly, Emmanuel Guindon and Contoyannis (2012) found no notable relationship between spending on private or public pharmaceutical products and health outcomes such as infant mortality or life expectancy at age 65. This finding highlights the necessity for policymakers to critically evaluate how public funds are being spent and to identify areas where health investments can be optimized to improve outcomes effectively. Ensuring that public health expenditures are directed towards interventions with proven efficacy could mitigate this issue.

The positive relationship between household healthcare spending (HHC) and life expectancy indicates that out-of-pocket expenditures by households play an important role in filling gaps left by public healthcare systems. This finding aligns with the result of van Doorslaer and Masseria (2004) indicated that there is a positive relationship between out-of-pocket cost and life expectancy. Out-of-pocket cost could mitigate some gaps left by public healthcare systems, particularly in regions with limited public funding. This suggests that household healthcare spending on healthcare is essential in addressing unmet needs and improving health outcomes. Policymakers should consider strategies to reduce the financial burden on households, such as expanding coverage for essential services and improving the accessibility and affordability of healthcare.

The positive association between $\ln(GDP)$ and life expectancy emphasizes the broader socioeconomic determinants of health. Swift (2011) found similar results, showing that both total GDP and GDP per capita notably influence life expectancy in most countries. According to the result of paper, wealthier provinces can allocate more resources towards healthcare and related services, which enhances overall health outcomes. Economic policies that foster growth and equitable distribution of resources can thus have a substantial impact on improving population health. Educational attainment, particularly tertiary education, is also shown to positively influence life expectancy. This result is consistent with the findings of Luy et al. (2019) found that higher education levels positively affect life expectancy in Italy, Denmark, and the USA. This highlights the importance of investing in education as a long-term strategy for health improvement. Higher levels of education contribute to better health literacy, healthier lifestyles, and increased access to health services, all of which contribute to longer life expectancy. Educational policies that promote higher education can therefore play a vital role in enhancing public health.

The notable year effects suggest that broader temporal factors, such as nationwide health policies, economic conditions, or epidemics (COVID-19), notably influence life expectancy. Continuous monitoring and adaptation of policies in response to these temporal changes are crucial. This underscores the importance of adaptive and responsive health policies that can address emerging challenges and leverage opportunities to improve health outcomes over time.

As part of this research, the impact of public healthcare expenditure (PHC) on life expectancy (LE) in Canadian provinces from 2007 to 2022 was examined. An unexpected finding was observed in the form of a negative coefficient for PHC, indicating a negative relationship between public healthcare expenditure and life expectancy. Two distinct trends were identified across the provinces: a positive relationship between PHC and LE from 2007 to 2019 and a negative relationship from 2019 to 2022, likely attributed to the disruptive effects of the COVID-19 pandemic. For future studies, it is suggested that a variable accounting for the pandemic's influence be included to provide a clearer understanding of its impact on the relationship between PHC and LE.

Conclusion

This study examines the key factors affecting life expectancy across Canadian provinces, emphasizing the interactions between public healthcare expenditure, household healthcare spending, economic growth, and education. The main results are (1) the negative relationship between public healthcare expenditure and life expectancy suggests inefficiencies in fund allocation, highlighting the need for strategic targeting of public spending, (2) the positive impact of household healthcare spending fills gaps left by public systems but also calls for reducing financial burdens on households, (3) economic growth (GDP) is strongly linked to better life expectancy, as wealthier provinces can invest more in healthcare, and (4) higher education levels, particularly tertiary education, also improve life expectancy by promoting health literacy and healthier lifestyles. Improving life expectancy in Canada requires optimizing public healthcare spending, alleviating financial barriers, and fostering economic and educational policies. The notable year effects highlight the need for adaptable policies that can address emerging challenges and continuously improve public health outcomes.

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Supplementary materials

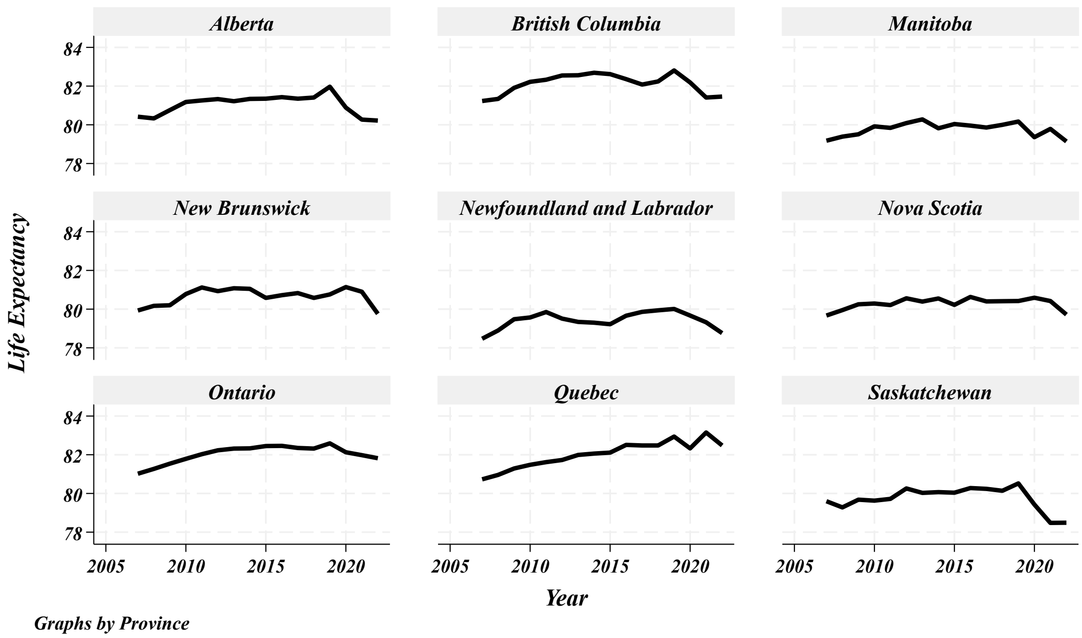

Figure A1. Life expectancy.

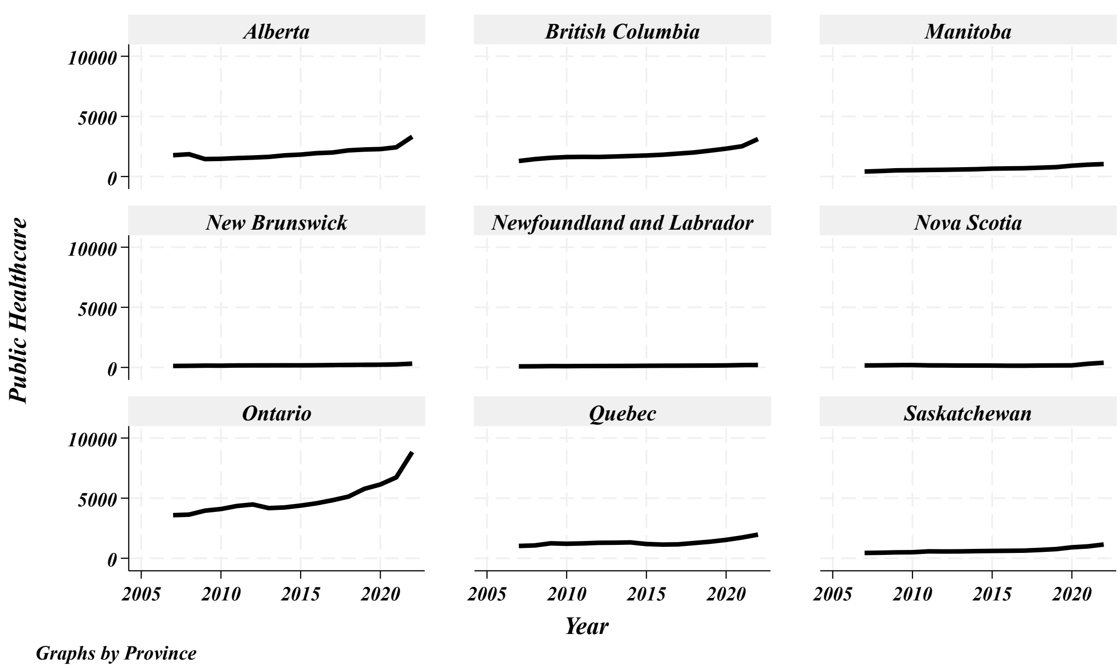

Figure A2. Public healthcare expenditure.

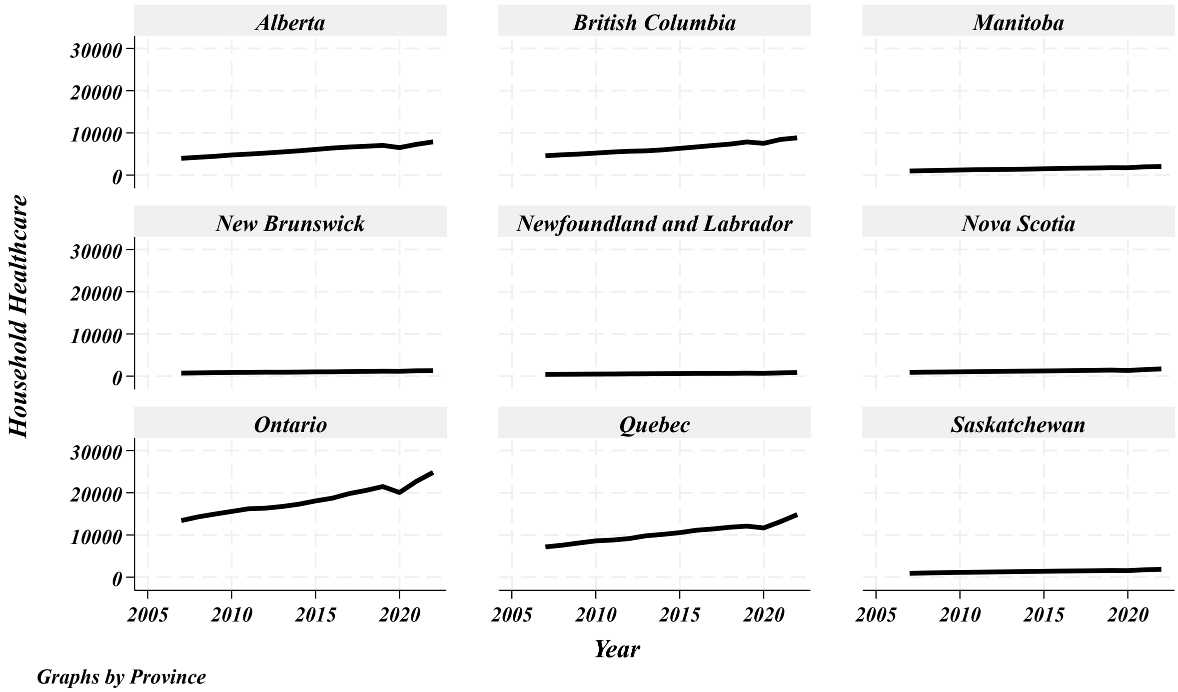

Figure A3. Household healthcare spending.

Table A. Regression result of the effect of independent variables on life expectancy. Bootstrap standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Comparison tests: Breusch and Pagan, F-test, and Hausman tests were conducted to assess the suitability of each regression model. The p-values for these tests are reported in front of each model. pro_id represents provinces of Canada.

Variables	Pooled OLS		Fixed effects		Random effects	
PHC	-0.000817	***	-0.000464	***	-0.000473	***
	(0.0000957)		(0.0000934)		(0.0000897)	
HHC	0.000321	***	0.000289	***	0.000269	***
	(0.0000250)		(0.0000373)		(0.0000298)	
GDP	26.92	***	27.47	*	25.04	**
	(5.42)		(16.23)		(10.41)	
$Upper$	0.0638	**	0.0524	*	0.0422	
	(0.0258)		(0.0305)		(0.0278)	
$Tertiary$	0.0710	***	0.0569	*	0.0487	**
	(0.0183)		(0.0300)		(0.0234)	
_IYear_2008			0.066		0.0757	
			(0.126)		(0.127)	
_IYear_2009			0.375	***	0.392	***
			(0.136)		(0.133)	
_IYear_2010			0.507	***	0.535	***
			(0.142)		(0.136)	
_IYear_2011			0.555	***	0.590	***
			(0.153)		(0.140)	
_IYear_2012			0.633	***	0.673	***
			(0.171)		(0.150)	
_IYear_2013			0.507	***	0.560	***
			(0.189)		(0.158)	
_IYear_2014			0.423	**	0.484	***
			(0.212)		(0.170)	
_IYear_2015			0.283		0.350*	
			(0.230)		(0.181)	
_IYear_2016			0.361		0.435	**
			(0.253)		(0.194)	
_IYear_2017			0.213		0.296	
			(0.270)		(0.203)	
_IYear_2018			0.156		0.248	
			(0.302)		(0.222)	
_IYear_2019			0.408		0.508	**
			(0.326)		(0.236)	
_IYear_2020			0.086		0.179	
			(0.337)		(0.251)	
_IYear_2021			-0.366		-0.25	
			(0.395)		(0.283)	
_IYear_2022			-0.777	*	-0.644	**
			(0.421)		(0.299)	
Constant	72.81	***	73.42	***	74.39	***
	(1.741)		(2.636)		(2.036)	

Variables	Pooled OLS	Fixed effects	Random effects
Comparison Tests			
Breusch and Pagan	0.000		
F-test	0.000		
Hausman test	1		
Observations	144	144	144
R^2	0.734	0.75	
Number of pro_id		9	9