

Optimal Canadian Healthcare Resource Allocation

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Non-Technical Executive Summary

Problem Statement:

Since the inception of Medicare, the Canadian universal healthcare system has been a prominent model for other public health care structures and approaches around the world. With the program's implementation across the country, millions of citizens are able to access their essential health care services through this system. Because of this, it is imperative for the Canadian government to understand and represent its entire population equitably, regardless of a province/territory's economic impact. In our analysis, we attempt to answer the following questions:

1. Considering differing Canadian state wealth and industry, does the Canadian healthcare system adapt to changing Provincial/Territorial needs?
2. How have resources been allocated in relation to a province's Gross Domestic Product (GDP)?

Key Findings and Significance:

Our statistical analysis and data analysis clearly demonstrated an inconsistency between Canadian Healthcare allocation and how individual consumers of the service utilize it.

We conclude that the policies put in place by the Canadian government to impact Healthcare budgeting led to a negative impact on private healthcare spending for less rich provinces.

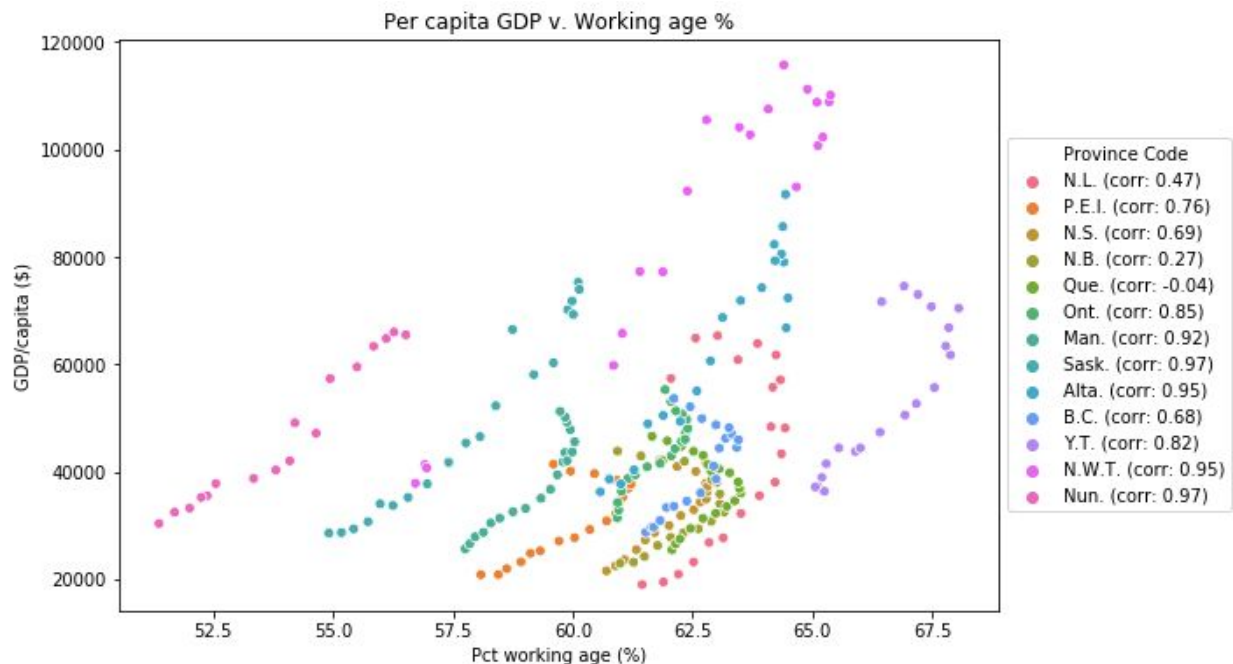
Background and Theory Concerning Policy Making:

When people think of Canada, the universal healthcare system is often one of the first things that come to mind. Free healthcare for all citizens, at any time. At first glance, this may seem optimal for a large majority. However, the reality of Canada's healthcare implementation is far from perfect, and is much more complex than simply using government funds to cover every health-related expense.

Historically, universal healthcare laws are far from stagnant, and have seen quite a bit of turmoil throughout the past decades. Since the unification of federal healthcare and social welfare

funding under the Canada Health and Social Transfer policy (CHST) in 1995, funding has been doled out in two portions — a cash portion and a tax points portion. The cash system gives an equal amount of funding per capita to a region. The tax points system evaluates how much revenue a region generates per percent of tax collected, and increases financing towards regions with less economic productivity in an attempt to mitigate for less intrinsic financial resources. In 2004, the CHST split into two entities, Canada Health Transfer and Canada Social Transfer, with the former in charge of only healthcare-related funding and the latter concerned with other social welfare funding initiatives. The dual-track funding patterns continued under this new system until 2014, when policy changes eliminated the tax point funding system entirely. This meant that regions received federal healthcare funding solely on a per-capita basis, with no regard to economic productivity. No longer would more economically prosperous regions sacrifice less-needed funding to help the welfare of less prosperous ones.

While in theory this new policy seems to promote treating all regions equally, the consequences are far-reaching. For example, regions with lower economic productivity often also have a lower proportion of a working age population (figure below), but conversely children and the elderly are populations more in need of quality healthcare. The change itself decreases the overall per capita healthcare allotments for economically less prosperous regions as well, and the act of decreasing these funds may negatively motivate citizens in seeking out care in general. We seek to better understand these shifting trends in healthcare expenditure across the country, and correlate them with policy shifts in the same period of time.



Technical Exposition

Data Cleaning & Feature Extraction:

First and foremost, we manipulated the `consolidated_legend` table to more easily map data to corresponding regions. To do so, we examined the table and found that province names were often specified within the “Legend” column. Using regular expressions, we stripped out the province names into a separate column, and mapped the names to their province codes using the mapping provided in the schema. This table was the first one we tackled because of its relevance to all the other datasets necessary for analysis.

Next, we decided which datasets were most important to our research. We decided to focus on the `provincial_level` and `expenditure_by_type` datasets, which gave us relevant information about demographic and economic data as well as healthcare costs. We used regular expressions to strip the legend code from each dataset’s “Category” column, allowing us to join both datasets with `consolidated_legend`. This granted us the ability to join `expenditure_by_type` with other datasets that broke down the data by year and province. Since the `provincial_level` dataset was stored in wide form, we used the `pandas melt` function to convert it to long form for joining with other datasets. One major complication was that age demographic data was stored under a different legend code for each year, so we had to perform multiple aggregation steps to distill it into a useful feature.

We conducted basic cleaning on the data as well, as some of the columns and fields contained extra whitespace that caused a loss of data when joining to other datasets.

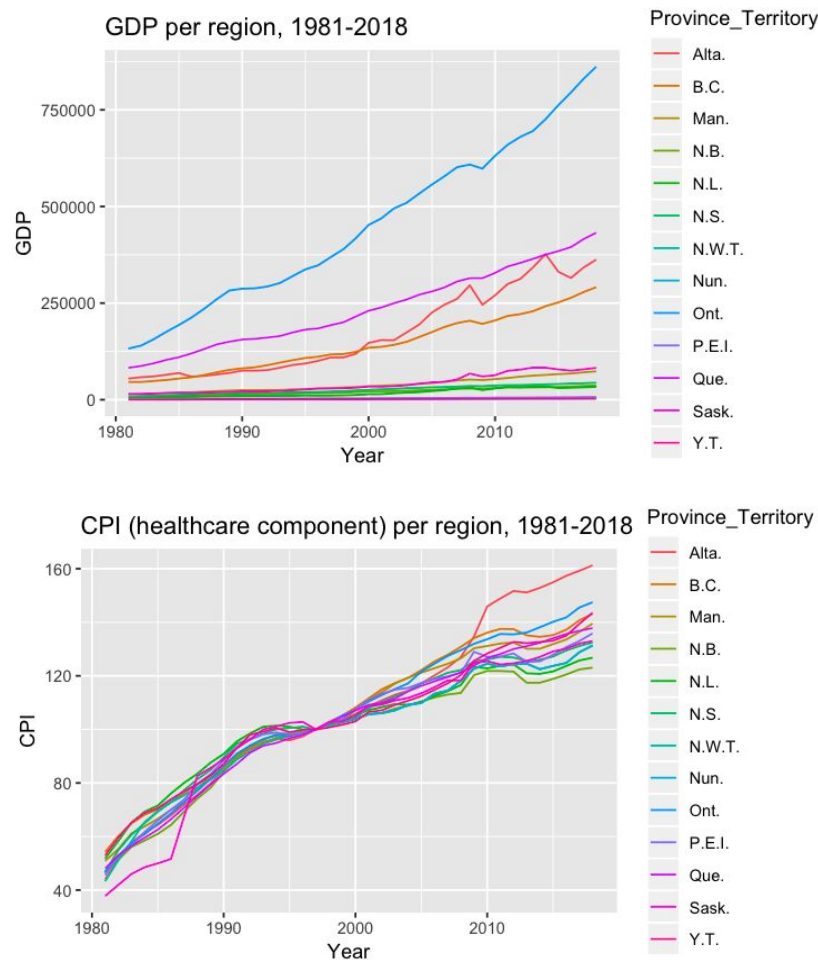
The features we finally extracted were population, economic data (GDP, CPI), and public/private healthcare spending (total, drugs, hospitals) broken down by province and year. We also extracted the percentage of working age residents per province per year.

Exploratory Data Analysis:

First, we wanted to have a better understanding of the economic landscape of Canadian provinces and territories. To do so, we plotted the growth of total GDP (in millions of \$) and CPI (for healthcare spending) for all the different regions throughout the years. It is apparent that there are 4 regions with significantly higher GDP than others: Ontario (Ont.), Quebec (Que.), Alberta (Alta.) and British Columbia (B.C.).

However, it is interesting that the high cost of healthcare, as indexed by the relevant CPI, is quite comparable over the years. In fact, at one point it was almost equal between the provinces and

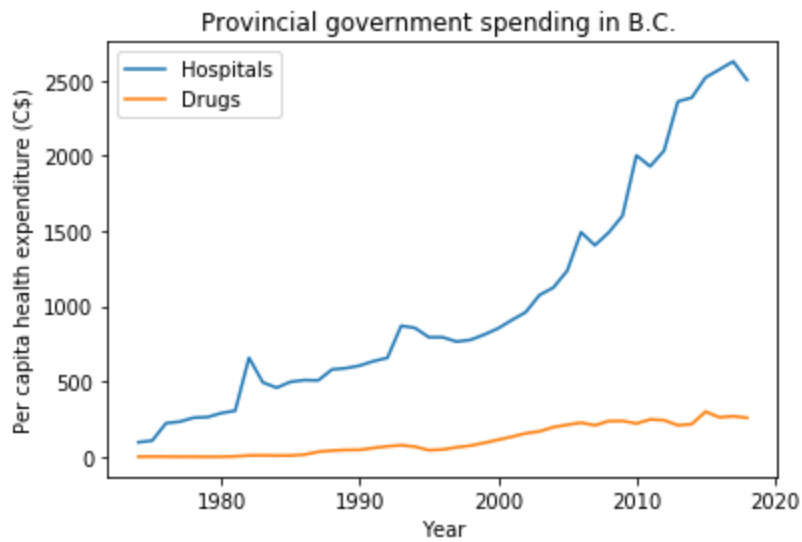
territories, and this time coincides with the consolidation of universal healthcare funding into the CHST policy.



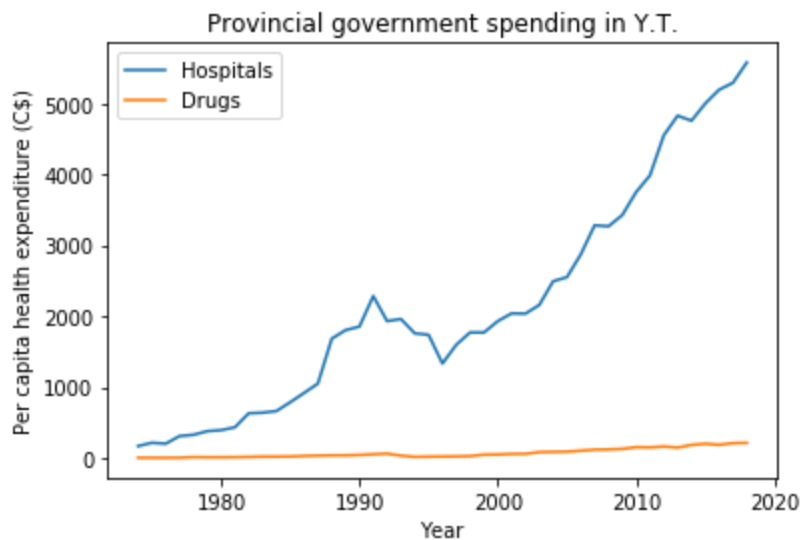
If the general affordability of basic healthcare grows at comparable rates over time, but there is such a large disparity in the economic prosperity of different regions, it is highly likely that there are different healthcare spending behaviors as well.

We investigated the development of healthcare spending to determine the types of growth in these differing states and track their developments. We focused on the expenditure data which differed between locales, and analyzed how Drug and Hospital spending was affected for both the public and private markets. These factors were chosen due to their significance in regards to the healthcare market, and also because hospital spending is covered by universal healthcare while drug costs are not.

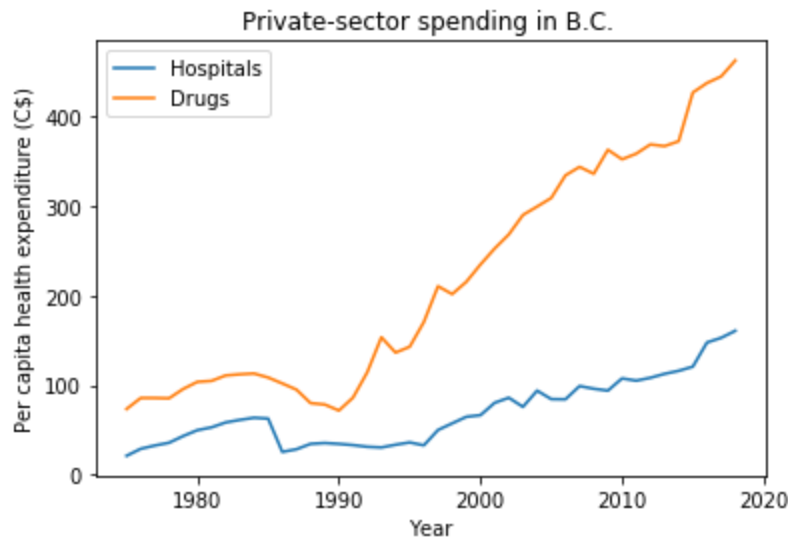
First, a representative high GDP Province such as British Columbia has had a public increase of spending on hospitals, with a disproportionately low growth in drug spending.



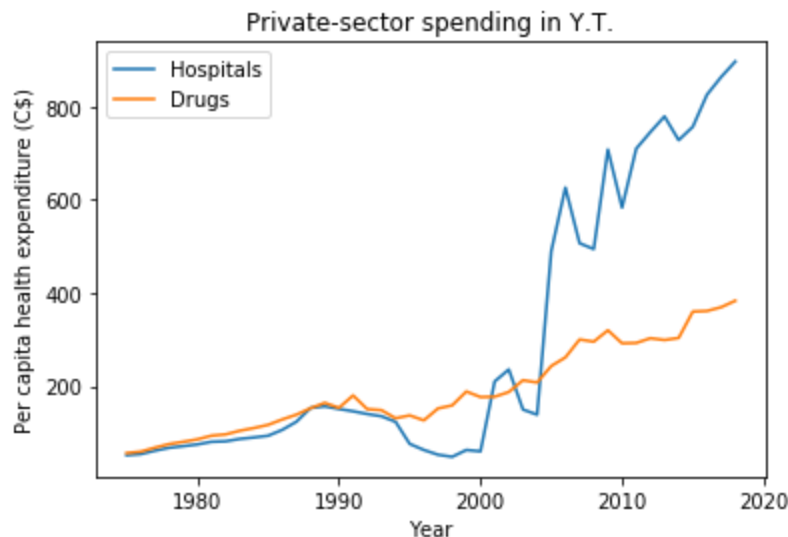
If we take a look at the same data for a lower GDP Territory, such as the Yukon Territories, we see that the public Drug spending and Hospital spending follows the same trend as in British Columbia.



If we then compare this expenditure to similar private expenditures in these regions (which is burdened by the citizens in these regions), we can see that in British Columbia, private sector spending is primarily directed towards drug costs, with some directed spending towards hospitals.

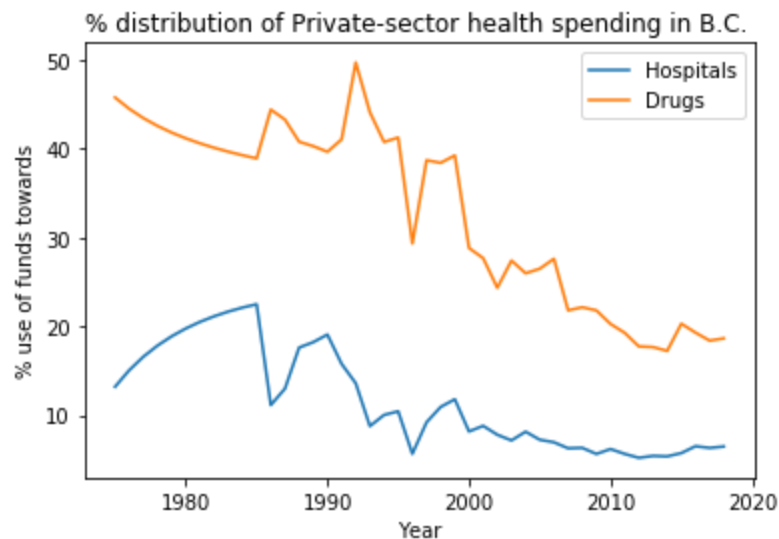


On the other hand, in a less economically-driven region such as the Yukon Territories, we see the inverse relationship, with private spending directed towards hospitals and less so on drugs.

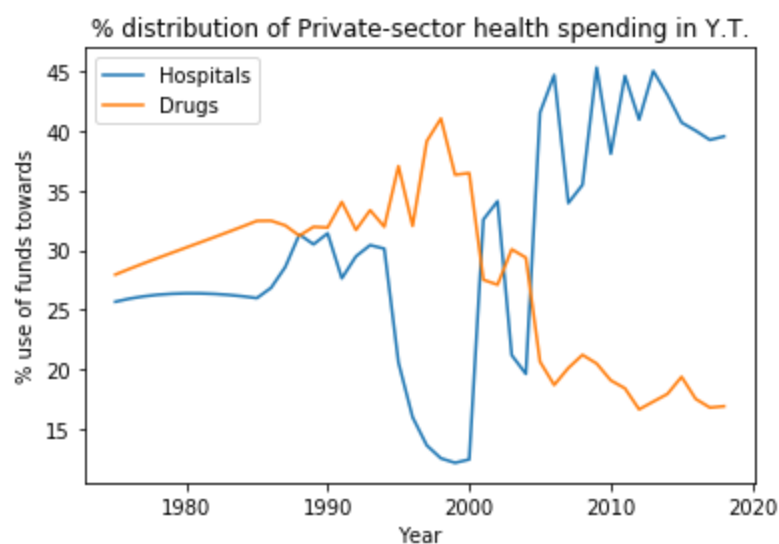


This inverted relationship from what the states usually follow is surprising. Since this system is supposed to reduce the heavier burden of healthcare costs towards citizens, the fact that private healthcare spending is more-focused on areas which the public sector should be focusing, which is economically poorer regions, is indicative of a system inconsistently designed towards different populations. As well, the total per-capita cost from these two categories is greater in the richer British Columbia than in the Yukon Territories, also representing a lack of focused capital.

In addition, in a higher GDP area such as British Columbia, the percent of private healthcare spent towards these two high spending areas is decreasing with time. This may be interpreted as an efficacy in the public system, as the public system is working to efficiently reduce spending in these areas.



On the other hand, the Yukon Territories is characterized by an increase in private costs towards Hospitals. This clearly demonstrates the lack of adaptability of the Canadian single-payer healthcare platform to differing needs of different states. While the same policy applies across the country, in practice its effects are inconsistent and are much more volatile in some areas than in others.



Statistical Testing:

Through various data visualizations, we notice that there are obvious discrepancies in the allocation of healthcare spending between regions with different economic prosperity levels. We seek to quantify this discrepancy in more statistical terms.

A metric describing the efficacy of healthcare funding was initialized to see the proportion of private to public money spent.

$$\text{Spending ratio} = \frac{\text{Private funds spent}}{\text{Public funds spent}}$$

Since the major policy change occurred in 2014, we wanted to test whether there was a statistically significant discrepancy between the 4 high-GDP regions and the other regions in terms of spending ratio. Thus, the two study populations are the 4 high-GDP regions (Quebec, Ontario, Alberta, and British Columbia) vs. the rest of the regions. For every year from 4 years before until 4 years after 2014 (2010-2017), we perform a nonparametric Wilcoxon Rank-Sum Test to test the null hypothesis that there is no significant difference between spending ratios for these high- vs. low-GDP regions (more technically, the chance that one is greater than the other is 50%), with the alternative hypothesis being that poorer regions use less public funding and thus have lower spending ratios than richer ones. Although there are no parametric assumptions for this test, we must assume that spending ratios are independent between regions. We adjust for multiple hypothesis testing, using a significance level of $\alpha=0.10$ divided by 8 test performed for the years. This means that we declare significance only if the unadjusted p-value is lower than 0.0125. The results are as below:

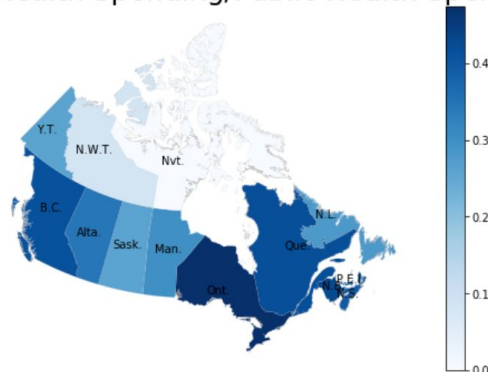
P-Value for low-GDP vs Spend Ratios

Year	P-Value
2010	0.053147
2011	0.025175
2012	0.016783
2013	0.025175
2014	0.025175
2015	0.025175
2016	0.009790
2017	0.005594

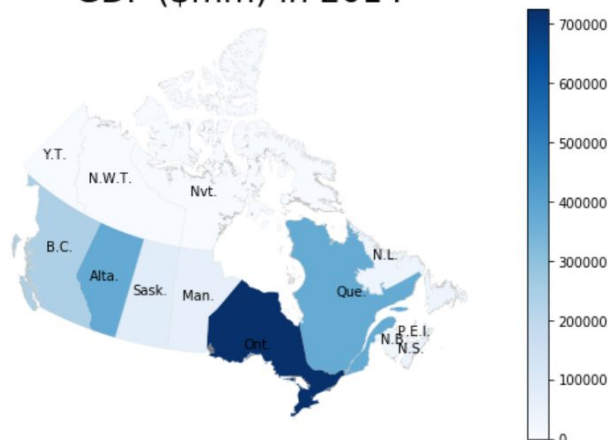
The results are intriguing! Although poorer regions' spending ratio is only significantly lower in current years, the discrepancy seems to be becoming more and more significant each year. Although p-values should not be directly compared this way, this pattern warrants further investigation into why this phenomenon is occurring, but no conclusive results can be drawn as of present.

There are a couple possible interpretations to this result. One interpretation is that as funds were diverted away from more prosperous regions under the new policy, more prosperous regions were forced more and more towards private insurance coverage. Another possible interpretation is that people in prosperous regions feel more secure and are willing to spend on health insurance whereas poorer regions, after funds were diverted away from them, felt less secure and thus does not spend as much proportionately in general. No matter what the truth is, the new policy after 2014 was accompanied by shifted healthcare funding in general, with results differing drastically throughout different regions with different economic productivity levels.

Ratio of Private Health Spending/Public Health Spending 2014



GDP (\$mm) in 2014



Future directions:

Through this exploration, we have found that a region's GDP is quite associated with discrepancies between healthcare spending areas. The prevalence of drug spending and low private insurance spending in low-GDP regions signal insecurities in those regions, meaning that these governmental policies are NOT catering as