Vaccine Hesitancy & Its Effect on COVID-19 Mortality in Canada

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April 7th, 2022
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ECO446H1S: Advanced Public Economics
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Contents

Abstract

Although vaccines have proven essential in tackling the COVID-19 pandemic, not all Canadians are choosing to get vaccinated. Better understanding these individuals is necessary to develop effective strategies to address their vaccine hesitancy. The goal of this study is to describe how socio-cultural and political indicators can explain variation in COVID-19 vaccination rates and mortality rates across communities of Canada.

Methods

We used instrumental variables to isolate vaccination's causal effect on COVID-19 mortality and a two-step regression methodology was utilised. To estimate the COVID-19 vaccination rate, this study used two instrument variables: sense of belonging and PPC vote share in the first step. Next, we examined the causal effect of vaccination rates on COVID-19 mortality using the instrumented vaccination rates. For both regression models, we included controls such as immigration status, income level, provinces, rurality, and age range.

Results

Our micro-analysis of CCHS data confirmed a clear positive relationship ($p < 0.01$) between sense of belonging and likelihood of getting the H1N1 and seasonal flu shots. We found that increasing sense of belonging increased COVID-19 vaccination rates and increasing (instrumented) vaccination rates decreased COVID-mortality rates, even though these results were not statistically significant at the 5% level (though, $p < 0.1$). With PPC vote share as an IV, our estimates show a 1 percentage point increase in PPC vote share in a health region leads to a decrease of around 1000 vaccinated individuals per 100,000 people. Our second stage revealed that a 1 percentage point increase in vaccination rates reduces COVID-related deaths by about 2 per 100,000 people in the second half of 2021. Both first and second stage results were statistically significant ($p < 0.01$).

Conclusion

Sense of belonging to the local community is significantly and positively related to getting vaccinated at the individual level. However, this relationship loses significance once aggregated to the health region, where instead high PPC vote share, reflecting low trust in institutions, plays a more important role. This can be seen in certain health regions (e.g. Sante Sud and North Alberta) which have high sense of belonging but low vaccination rate, and two of the highest PPC vote shares in the country. These regions have especially high mortality rates — reflecting the critical importance of addressing this lack of institutional trust for the well-being of these communities.

1 Introduction

Vaccines are a proven health intervention for reducing the spread and burden of flu epidemics and other infectious illnesses. Despite its track record, a small portion of Canadians are refusing COVID-19 vaccines due not only to scientific scepticism but also to local, political, socio-cultural reasons (Vaccine Hesitancy Primer, n.d.). Moreover, according to the most recent figures from the federal government's Health Infobase data, unvaccinated individuals account for the vast majority of COVID-19 related cases, hospitalizations, and fatalities (2021). Vaccine hesitancy is especially important in Canada, where many provinces have repealed COVID-19 mandates for masks, vaccination proof and social distancing (Hopper, 2022). As a result, vaccination is now the single most important protection measure against COVID-19 and its variants.

Therefore, our paper aims to answer the question "How do socio-cultural and political indicators, namely, sense of belonging and political affiliation explain variation in COVID-19 vaccination rates and mortality rates across communities of Canada?" Specifically, our analysis has two primary goals: (1) understand the variation in vaccination rates due to one's sense of belonging or party affiliation at the health region level (2) use the estimates from (1) to derive a causal effect of vaccination on COVID-19 mortality rates and thus determine if the socio-political indicators explain the severity of the COVID-19 pandemic in certain regions. We hypothesize that there is a positive correlation between sense of belonging and vaccination rates: stronger sense of one's belonging makes an individual more likely to get vaccinated. On the other hand, we hypothesize that the People's Party of Canada (PPC) vote share is negatively correlated with vaccination rates because the PPC appeals to groups that have less trust in government institutions and that strongly oppose COVID-19 restrictions and vaccine guidelines.

We hope that the findings of our research will assist federal and provincial public health officials to invest in targeted vaccine programmes to overcome the stark variation in vaccination rates, and consequently COVID-19 mortality rates, at the community level. By learning more about the characteristics of communities with low vaccination rates (e.g., their level of sense of belonging, their (mis)trust in governments and experts, their compliance with mandates), governments and regional health authorities can better understand how to make sustained efforts to earn community trust or improve sense of belonging to create effective COVID-19 vaccination campaigns.

The remainder of this section discusses relevant literature. Section 2 outlines our empirical strategy. Section 3 discusses our major datasets. Section 4 discusses COVID-19 vaccination and mortality across Canada, and also discusses a geographic classification that is relevant to our analysis. Section 5 presents our major empirical results. Section 6 discusses particular health regions of note in greater detail, and their socio-demographic characteristics. Finally, Section 7 provides a discussion of our results and highlights further research directions.

Literature Review

To gain a better understanding of vaccine hesitancy and its determinants, we analyzed and compared contributions from various literature on the subject. For our review of the literature, Frankel and Kotti's "The Virus, Vaccination, and Voting" (2021) and Carla Valle Painter's "Sense of belonging: literature review" (2021) served as guiding papers for designing our empirical strategy, identifying valid instrument variable(s), and including important control variables for our analysis. In addition to these two papers, our literature review also mentions four other relevant studies (discussed further below).

The Virus, Vaccination, and Voting (2021)

Our paper closely follows the instrumental variable (IV) approach used in Frankel and Kotti's "The Virus, Vaccination, and Voting" . The approach allows for the possibility of making causal inferences from observational data. In this working paper, the authors examined vaccine hesitancy in the United States and its impact on COVID-19 mortality. Simply regressing vaccination on mortality would give a misleading estimate of the effect of vaccination due to omitted variables (e.g. poverty rate) and more importantly, potential reverse causality (i.e. people living in regions with higher mortality may have more incentive to get vaccinated). To address this issue, the authors used vote share in the 2020 US presidential election as an IV. As the vaccination campaign has been greatly politicized in the United States, it is likely that the percent of a county that voted for Donald Trump is correlated with the percent of the population that is unvaccinated. By checking for variation in the vaccination decision that is exclusively due to Trump-affinity, the authors found that Trump voters are less likely to get vaccinated (even after controlling for other factors). Using these findings, the authors were able to estimate that a 1 percentage point increase in vaccination rate decreased the death rate by 9.4 per 100,000 inhabitants.

This study signifies that party affiliation or voting patterns can be used to explain variation in vaccine uptake and consequently health outcomes (i.e., deaths due to COVID-19). In our paper, we adopt the same IV approach but use two different IVs: sense of belonging to one's local community and vote share of People's Part of Canada (PPC). Our rationale for two different IVs is explained in Section 2. Besides the main IV method, the authors' control variables were very important to our research. Many variables are correlated with our IV measures and may bias our estimates if not considered. The age distribution of a community is one of the most important, and one that Frankel and Kotti considered.

Sense of belonging: literature review (2013)

Carla Valle Painter's "Sense of belonging: literature review" (2013) is a comprehensive overview of the determinants of "sense of belonging" (SB) in Canada. The paper's discussion was extremely relevant to our work as it aided our understanding of SB as an IV for vaccination. To ensure that IV estimates are unbiased, it is necessary to understand how SB varies with individual traits that may be correlated with vaccination. Painter's review provides an excellent starting point for understanding how SB is correlated with confounding variables.

First, Painter discusses how SB trends vary by geographic scale (local, provincial, and national). However, sense of belonging to local communities (SBLC) varies little across provinces, and the data we have is only on sense of belonging to local communities (SBLC). This means that our analysis will accurately reflect trust at the community level, but will not measure how individuals relate to their province or the country as a whole.

Second, Painter also highlights how other types of geography are relevant for SB, especially the rural-urban divide. Painter refers to work by Carpiano and Hystad (2009, 2011) in discussing that rural respondents tend to have a higher SBLC than urban respondents. The distinction between urban and rural communities is significant in terms of both SB levels and the characteristics with which SB is correlated. For example, the correlation between SB and certain health characteristics (e.g., engagement in health-promoting behaviours) is lower in rural areas than in urban areas. Painter's review also suggests that having many connections leads to health benefits and SB which only holds true in the urban context (whereas connections tend to be fewer but deeper in the rural context). This suggests that the correlation between SB and vaccination may be higher in urban than rural areas because those concerned about health are more likely to be vaccinated, and those with many connections may feel more at risk of exposure, which is important for our analysis.

Third, SB, especially SBLC, also varies by age. Painter explains that SB increases until around age 35, then drops sharply before rising again (around age 45) and remaining high until death (largest at least 80 years old). Age has been linked to COVID-19 vaccinations and death in Canada, and its relation to SB should not be overlooked.

Fourth, Painter's work highlights the role of ethnicity and immigration in SB – ethnic groups residing in low diversity neighbourhoods show lower SB as compared to non-visible minorities residing in diverse neighbourhoods and immigrants' SB grows over time in Canada.

Lastly, Painter discusses that low income individuals see themselves as part of a narrowed social network, whereas high income individuals see themselves as part of a multi-tiered social network made up of multiple institutions, organisations, and communities. Thus, low income individuals tend to have a lower SB to their local community due to the stigma that comes with poverty and limited financial ability to engage with the community.

The above analysis is relevant to our project because it emphasises the importance of including aforementioned control variables and highlights where there may be heterogeneity in the causal relationship between SB and vaccination rates. Painter's work supports our rationale behind the use of SB as an IV—if one feels a stronger connection to their community it is feasible that they will be more willing to engage in activities (such as getting vaccinated and following other COVID-19 health measures) that benefit their community.

Social and political determinants of vaccine hesitancy: Lessons learned from the H1N1 pandemic of 2009-2010 (2015)

Mesch and Schwirian (2015) investigated the social and political determinants of vaccine hesitancy in the US during the 2009-10 H1N1 pandemic, specifically looking at recreancy, perceived risk of infection and political partisanship. This paper also closely aligns with our analysis as the authors isolated and studied determinants that influence vaccination rates other than the disease itself. Their results showed that vaccination rates differed by 28 percentage points between those who had high and low trust in the government and healthcare systems. The paper also found that Republicans and younger people were less likely to be vaccinated due to their lack of trust in the government compared to Democrats and older people. Intersectionality is an analytical framework for understanding the interconnection of one's economic, social, political and cultural identities that creates unique experiences or barriers for an individual. The above trends demonstrate the intersectionality between age and political affiliation, which is useful for our work as we used PPC vote share to estimate vaccination rates along with age controls.

Influenza vaccination coverage across ethnic groups in Canada (2012)

Quach (2012) identifies that apart from the comparison of ethnic and non-ethnic groups, there is variation in vaccination coverage levels even within ethnic communities in Canada. The authors were able to determine this by employing weighted logistic regression models to investigate the relationship between ethnicity and influenza vaccination while controlling for sociodemographic factors and health status. Although analysing variation in vaccine hesitancy among ethnic groups is beyond the scope of our current research objectives, this analysis does provide us with information about important socio-cultural factors such as religion, cultural beliefs, and previous exposure to pandemics that may influence vaccine uptake. For example, because two influenza pandemics and the severe acute respiratory syndrome (SARS) originated in Asia, Asian-Canadians are more likely to get vaccinated against COVID-19. This approach inspired us to also analyze whether low vaccination communities are dominated by specific ethnic or cultural groups, as well as any unique barriers and misconceptions that influence these groups differently in Section 6.

COVID-19 Vaccine Hesitancy & Refusal and Associated Factors in an Adult Population in Saskatchewan, Canada: Evidence from Predictive Modelling (2021)

Similar to the Quach (2012) paper, Muhajarine et al. (2021) also used survey data to model the relationship between vaccine intentions and multiple independent variables (25) within the categories of sociodemographic characteristics, risk exposure behaviours, COVID-19 mitigating factors, and perceptions of the pandemic in Saskatchewan. To do so, the authors used a conventional statistical approach of multinomial logistic regression as well as a predictive machine learning algorithm for classification and regression (decision) tree. Some of the key results of the paper estimated that lower education level, financial insecurity, Indigenous status, and lack of concern about the spread of the coronavirus were all factors that raised vaccination rejection and reluctance. In fact, the degree of perceived threat of the pandemic in the community was the initial deciding factor (first-level node) of COVID-19 vaccination intent in Saskatchewan as it placed the highest in order of relative importance. Furthermore, their results also showed that perceiving COVID-19 as a greater threat to one's community and perceiving that one was at a larger risk of infection or death due to COVID-19 reduced the chance of both vaccination rejection and hesitancy. The study also found that immigrants (i.e., living in Canada for ¡ 20 years) were more likely to be hesitant to get vaccinated. Also, according to the authors' findings, respondents who did not intend to be vaccinated were less likely to use face masks and engage in social distancing. One of their key findings is especially important for our work – even with a strong SB, it is possible that people (and their community) may choose not to get vaccinated if they perceive the threat of COVID-19 to themselves and their community is small. While our empirical strategy differs from that of this paper and our focus is on health regions across Canada, the paper helped us better understand social characteristics (like SB and following mandates) and its impact on COVID-19 vaccine hesitancy in a Canadian context.

COVID-19 Vaccination Mandates and Vaccine Uptake (2021)

A recent paper by Karaivanov et al. (2021) asked a similar research question as us: if COVID-19 vaccines have proven effective, why aren't more people getting vaccinated? In particular, the authors quantified the effect of government proof of vaccination mandates (which prevented unvaccinated people from attending non-essential social activities in public venues) on first dose vaccination rates across Canadian provinces, and touches on the social aspect we are looking at. Using a difference-in-differences approach, their results showed that the announcement of a mandate is associated with a rapid and significant surge in new vaccinations (more than a 60% spike in average weekly first doses). The authors also estimated cumulative gains in provincial vaccination rates of up to 5 percentage points from their time series analysis for each province. While this paper adds to existing research on the effectiveness of current COVID-19 vaccination policies, we focused on the underlying social and political factors (i.e., SB and lack of trust in government institutions) causing vaccine hesitancy. In particular, there is still scope to add to existing work by studying social capital indicators that might affect the incentive to get vaccinated. Their paper's conclusion of a significant effect on vaccination uptake is promising for us as it suggests that people are in fact motivated by social factors to get vaccinated. Our analysis will also differ in a few ways – we will use a different empirical strategy (an IV regression model) and we will not analyse at the province level, but at the health region level. Also, the fully vaccinated (having received the recommended number of doses (1 or 2) of a given vaccine) rate will be used instead of the first dose rate as the former is more suitable for our study.

2 Empirical Strategy

Our paper aims to answer the question "How do socio-cultural and political indicators, specifically SB and political affiliation explain variation in COVID-19 vaccination rates and differing mortality rates in diverse communities of Canada?" To answer our research question, we followed a two-step empirical methodology, as outlined in Figure 1. In our first stage, we regressed COVID-19 vaccination rate on our two identified IVs — SB and party affiliation (PPC vote share). Second, we examined the causal effect of instrumented vaccination rates on COVID-19 mortality.

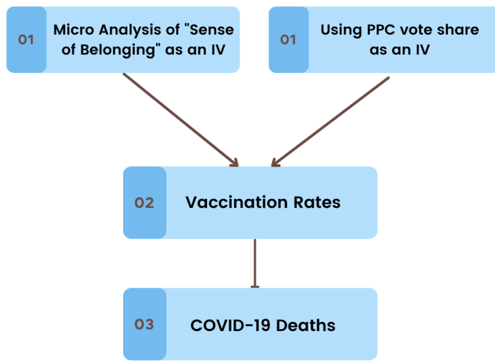


Figure 1

The IV method is used to determine exogenous variance in treatment, which is then used to estimate causal inferences when endogenous variables are present in the model (Pokropek, 2016). This method is appropriate for our analysis because the relationship between getting vaccinated and COVID-19 mortality may be confounded by various factors. For example, people who choose to get vaccinated may base their decision due to perceived risk of developing serious illness from COVID-19 or the likelihood of getting infected with COVID-19 due to high exposure levels at work. That is why we need to include variables such as SBLC or PPC vote share as an IV.

Our hypothesis for selecting SB as an IV is that if one feels a strong connection to their community, it is feasible that they will be more willing to engage in activities such as getting vaccinated that will benefit their community. Painter also highlights that SB is also an indicator of desirable broad societal outcomes such as social inclusion, well-being, social cohesion, social capital, and nationhood.

However, the variable still has its limitations. Depending on who responds and where, people's perceptions of what constitutes a local community may differ significantly. Similarly, as discussed in the literature review, SB to local communities (SBLC) varies little across provinces. This is not ideal for our work as this variable has to be aggregated at the health region level, and thus will not serve as a sufficiently strong IV if it doesn't have much variation. Also previously mentioned in our literature review, studies have found that SBLC impacts health indicators positively in urban areas (Painter 2013). This could be a concern for violating one of the IV assumptions, namely the exclusion requirement. An IV's effect on a dependent variable must be measured solely through the IV. As a result, the mortality rate of a health region may be affected if people living in rural (urban) areas engage in less (more) health-promoting behaviours. Lastly, studies by both Painter and Muhajarine et al. found that strong SB does not necessarily always translate into positive health indicators (e.g., engagement in health-promoting behaviours and getting vaccinated). All these limitations can hinder second stage analysis and interpretation.

Given the limitations of SBLC, we identified another IV that may be a better predictor for estimating vaccine uptake, namely People's Party of Canada (PPC) vote share in Canada. PPC is a right-wing to far-right federal political party founded in 2018 by a former Conservative Party of Canada election candidate (Pannett, 2021). While the PPC did not win any seats in the 2021 federal election, it received 841,000 votes, making it the country's fifth most popular party (Tahirali, 2021). Currently what distinguishes current PPC voters from most Conservative Party voters is their perspective on the COVID-19 pandemic, particularly on vaccination, vaccine passports and mandates (Perkin & Savoie, 2021).

Our hypothesis is that PPC vote share is negatively correlated with vaccination rates because the PPC appeals to groups that have less trust in government institutions and that strongly oppose COVID-19 restrictions and vaccine guidelines. It is possible to use the PPC's ideology as a proxy for the lack of social capital, distrust of institutions, and a disregard for COVID-19 mandates and regulations set forth by the federal and provincial governments. As we noted in our literature review of the guiding paper, Frankel and Kotti's "The Virus, Vaccination, and Voting", party affiliation or voting patterns can be used to explain geographic variation in vaccine coverage and health outcomes. Similar findings can be inferred from Mesch and Schwirian's study. Therefore, it makes sense to use PPC vote share as an IV for our research.

However, using PPC as an IV also raises concerns about the exclusion requirement being violated. This is because PPC voters are more likely to go without masks or fail to practice social distancing or even live in regions with looser local COVID-19 related mandates, which may affect the health region's mortality rate. We will address this issue specifically in Section 5.2.2.

3 Data

To implement our empirical strategy, we made use of multiple datasets that span over different sets of years to study both the current vaccination response to COVID-19 and also the vaccination behaviour of Canadians during previous disease outbreaks such as the 2010 H1N1 flu pandemic. A broad overview of our data sources is given in Table 1.

The first stage of our work (the analysis of vaccination and sense of belonging) used microdata from the Canadian Community Health Survey (CCHS). This is an annual cross-sectional survey dataset about health habits and outcomes, which was last completed in 2017-2018 . Most importantly, this data tracks responses to multiple questions surrounding one's sense of belonging to their community, as well as vaccination status (i.e., self-reporting whether respondents received seasonal flu and H1N1 flu shots or not). The CCHS covers the population of 12 years and older in the ten

Data Source	Unit of Observation	Key Variables	Used in
CCHS (2010)	Individual	Sense of Belonging, Income, HR, Flu Shot, H1N1 Shot, Age	Micro Analysis
CCHS (2017-18)	Individual	Sense of Belonging, Income, HR, Flu Shot, Age	Micro Analysis & COVID Analysis (by HR)
CCODWG (API)	HR*, Province	Mortality (Daily)	COVID Analysis
CovidTracker (API)	HR**	Vaccinations (Daily)	COVID Analysis
	Province, Canada	Vaccinations by Age Group (Daily)	COVID Analysis
2016 Census	Health Region	Population Estimates (by ages)	COVID Analysis & "Expected Vaccination"
Statistics Canada	Various	Shape Files, Peer Groups Trust in Fed. and Mun. Gov't	
Elections Canada	Riding	2021 Election results	COVID Analysis

Table 1: Primary data sources used throughout the project.
HR*: data not available for Saskatchewan.
HR**: data not available for Saskatchewan and the Maritime provinces (except P.E.I).

provinces and three territories with an exception of certain groups excluded from the survey coverage. These excluded groups include persons living on reserves and other Aboriginal settlements in the provinces, full-time members of the Canadian Forces, the institutionalised population, children aged 12-17 that are living in foster care, and persons living in the Quebec health regions of Région du Nunavik and Région des Terres-Cries-de-la-Baie-James. To provide an equitable sample distribution to health regions and provinces, a multi-stage sample allocation technique has been adopted by the CCHS. Also, the size of the CCHS respondent pool allows us to both perform micro analysis on individuals' decisions to be vaccinated, as well as use aggregated statistics from the survey in our macro analysis at the health region level. While the self-reported surveys administered by the CCHS have a wide-reaching sample size, it asks only one question on sense of belonging at the community level. Specifically, it records the strength of a person's sense of belonging to their local community on a four-point scale ranging from very weak to very strong.

Our COVID-19 aggregated data has been collected from two online sources—COVID-19 Tracker Canada and the COVID-19 Canada Open Data Working Group—which independently collect available provincial data on mortality and vaccination. The COVID-19 Canada Open Data Working Group has been our data source for cumulative and daily death counts at the health region level. We have used several dates in our analyses, and have collected daily death data for each health region from the beginning of the pandemic until February 2022. Our second online source is the COVID-19 Tracker Canada Project for data on cumulative vaccination numbers at the health region level. The statistic collected is the total number of individuals fully vaccinated—understood to be having received the recommended number of doses (1 or 2) of a given vaccine—within a health region. Importantly, these numbers do not include the number of individuals who have received booster shots. At the provincial, territorial, and national level (but importantly, not the health region level universally), the total number of individuals vaccinated within age groups is also published. Note that throughout our analysis, we use vaccination data until the beginning of February 2022.

Importantly, there are several provinces whose data we are unable to use due to it not being published. The Maritimes publish no vaccination data at the health region level, so they were excluded from our analysis (PEI is included because it only contains one health region). Similarly, Saskatchewan publishes no data at the health region level, but instead uses a unique geographic indicator that is not consistent with health regions. Saskatchewan (as of 2017-18), stopped using their previous classification of health regions, merging all of its regions into one provincial health authority. For COVID-19, they adopted a new classification system for geography, but did not make this consistent with previous health regions. Aggregating these provinces' data to the provincial level would mask many of the heterogeneities between health regions, and as such they have been excluded from our aggregated analysis.

Notably, the collected data that we use is not population normalised (they are total numbers of deaths and vaccinated individuals). Provincial governments independently convert the number of individuals vaccinated and COVID-19 deaths into rates by using population estimates from Statistics Canada. However, as there is no consistency in provincial approaches, and the population estimates used by different provinces have changed over the course of the pandemic, we do not use these provincially calculated rates. Instead, we use Statistics Canada 2020 population estimates at the health region level calculated using 2016 census data (Statistics Canada 2018, Table 17-10-0134). This approach has the limitation of using only somewhat current estimates, but it means that our data will be internally consistent and also provides us the opportunity to update our results as soon as the population estimates are published for the 2021 census. Note, the descriptive analysis in our paper also made use of 2016 census data.

Statistics Canada's classification of health regions based on different demographic characteristics (the Peer Group system) has proved useful as we aim to control for these characteristics in our analysis. These are discussed in Section 4.2. Statistics Canada maintains shapefiles for health regions nationally, which have been used in conjunction with Elections Canada results from the 2021 federal election at the riding level to estimate the proportion of voters for a given party at the health region level.

To construct the share of votes in each health region, we made use of a few datasets. Firstly, given that votes are not reported by health region, we had to determine estimates of voters in each region. This was accomplished using geospatial data on the health regions and Federal electoral districts (FED) in Canada, where we overlaid these two maps to find the FEDs each health region covered. We then took data on the results of the 2021 General Election by FED, and aggregated the results over each health region to generate our estimates. This led to estimates for votes of the 5 most popular parties in Canada at the time, the Conservatives, Liberals, NDPs, Green Party, and PPC party. We chose to use the PPC party estimates in this case given the party's far-right values and historical opposition to Covid mandates, and also because it could be an indication for trust (or lack thereof) in institutions. We felt that these characteristics would have very strong effects on the rates of vaccination in a region, and thus lead to more significant results, as will be demonstrated below.

4 Descriptive Analysis I

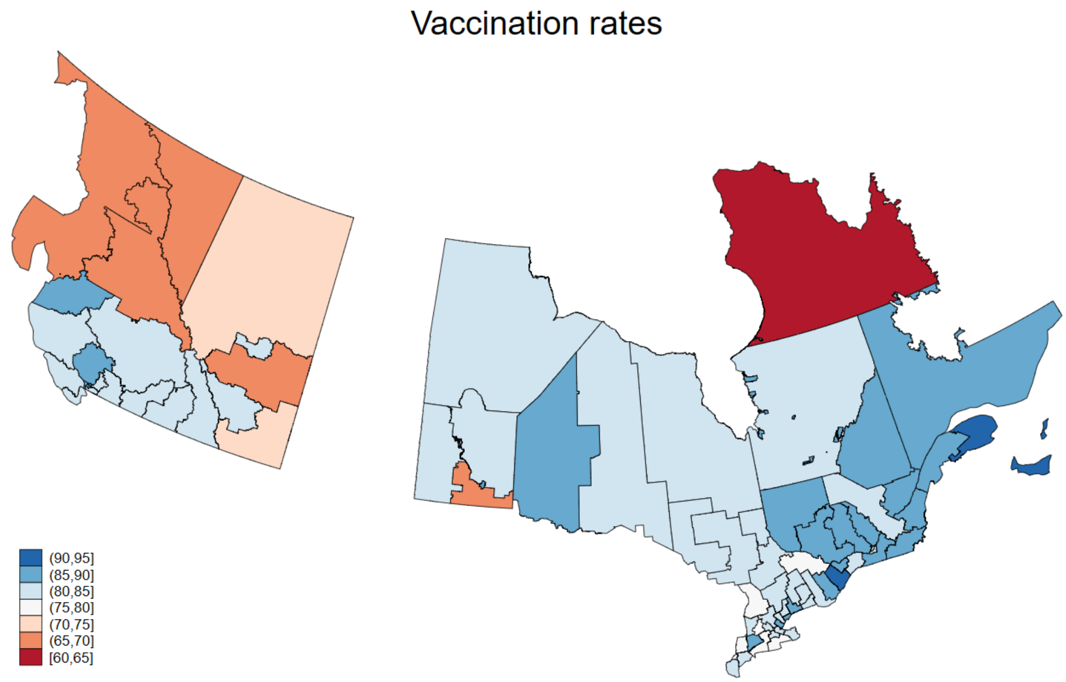
4.1 COVID-19 vaccination and mortality across health regions

Before our analysis of predictors of vaccination and the impact of vaccination on COVID-19 mortality, it is important to understand the variation in vaccination and mortality due to COVID-19 at the health region level. Figure 2a gives the vaccination rate for those 5 and up in a given health region (note that in all of our maps, the territories are excluded simply for readability). We can see high vaccination rates (85%+) in Southern Quebec and PEI, and low vaccination rates (70% and below) in Northern Quebec and the Territories. A single number for vaccination at the health region level, however, does little to explain the sources of this variation. As has been well-documented by national and provincial figures, there is significant variation in the rates at which different Canadians are being vaccinated. In both our own estimates and current figures from the Canadian government (Health Infobase, 2022), there is an over 10 percentage point difference in the rates at which Canadians between 18-29 years old and Canadians over 60 are vaccinated.

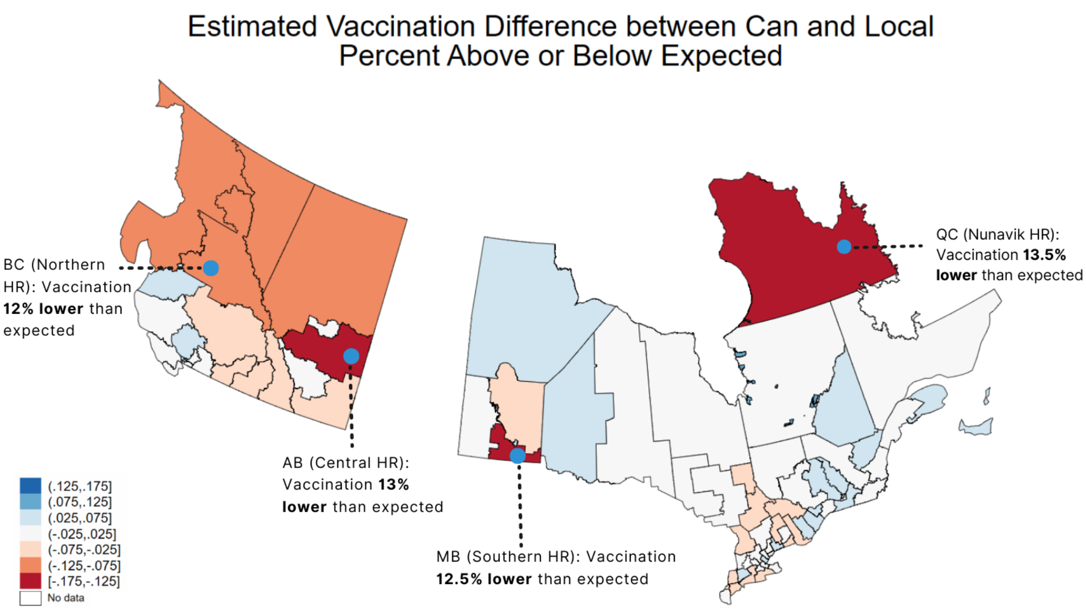
A natural question is to ask whether variation in vaccination rates at the health region level are simply explained by differences in age distribution. To answer this, we used our estimated national vaccination rates for different age groups. We were able to construct an "expected" number of individuals vaccinated in a given health region by taking the number of people in a given health region and calculating the number of people who would have been vaccinated if they had been vaccinated at the Canadian average.

For some health regions, this does away with the fewer-than-expected number of individuals vaccinated. Nunavut, for example, has very low vaccination (only 76% of individuals 5 and up are fully vaccinated). However, Nunavut is a very young territory (over 35% of its population is under 18 according to Statistics Canada's estimates). As we are using vaccination data from February 2022, few individuals aged 5-12 were fully vaccinated at the time of data collection. This is reflected in our estimated vaccination rates for Nunavut. By this calculation, Nunavut has a slightly higher rate of vaccination than expected (approximately 1 percentage point higher). However, Nunavut is a special case. As Figure 2b shows, there is still significant variation in vaccination rates across health regions. Notably, three health regions (Southern Manitoba, Central Alberta, and Nunavik in northern Quebec) have the shortfall between their observed and estimated vaccination rates (of those aged 5 and up) greater than 12.5 percentage points.

Beginning now to look at mortality, Figure 3a shows deaths per 100 thousand residents due to COVID-19, as of February 2022. We see some regional trends, but it is hard to determine a pattern at this stage in the analysis. However, since our primary focus is on the effect of vaccination, we

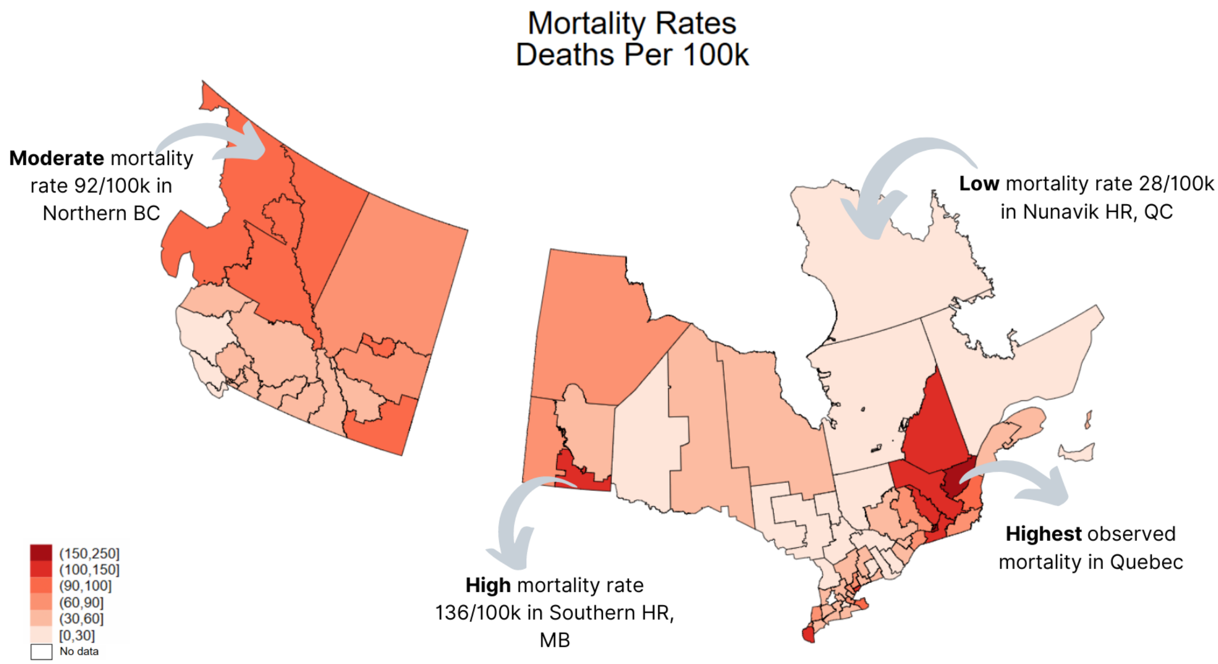


(a) COVID-19 vaccination rates for those 5 and up, in each health region. Sources: COVID-19 Tracker, Statistics Canada

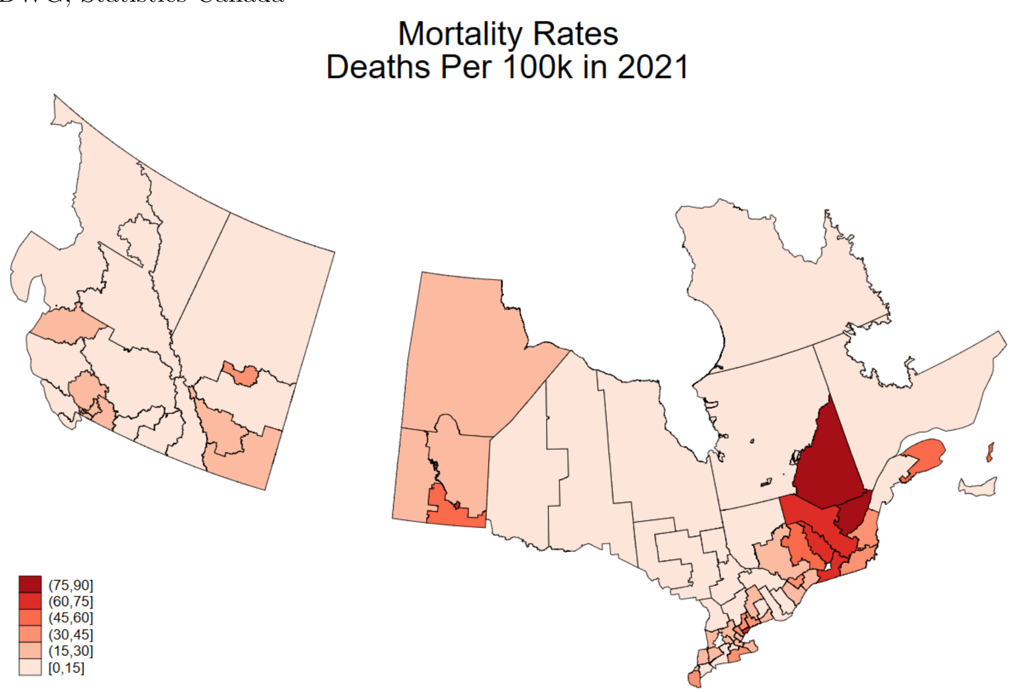


(b) Difference between observed vaccination and expected vaccination, if each age group in a health region were vaccinated at the Canadian average for that age group. Sources: COVID-19 Tracker, Statistics Canada

Figure 2: Vaccination rates



(a) COVID-19 deaths per 100 thousand residents since the beginning of the pandemic. Sources: CCODWG, Statistics Canada



(b) COVID-19 deaths per 100 thousand residents since the beginning of 2021. Sources: CCODWG, Statistics Canada

Figure 3: COVID-19 deaths at the health region level.

are not interested in the death rates since the beginning of the pandemic. The daily nature of our mortality data allows us the ability to easily analyze mortality in different time windows. This will become relevant in later stages for testing the validity of our instruments, but for now it should be emphasized that while there is some variation, it seems that there is not a significant difference in the regions most hard-hit by the pandemic if we look only at mortality in 2021. Figure 3b emphasizes this.

4.2 Peer Groups

Peer groups are a method of comparing regions with similar socioeconomic health determinants. Figure 4 shows health regions by their peer groups. StatCanada defines the rationale behind peer health region groups is that once the effects of various social and economic characteristics known to influence health are removed, it is possible to compare between and within peer groups based on health status measures. It is also possible to compare the relative efficacy of health promotion and prevention activities across different regions. Thus, using a clustering technique, the health regions were divided into groups with similar socioeconomic characteristics, and these groups are referred to as 'peer groups' by StatCanada. However, it should be noted that in terms of the socio-economic factors used in the cluster analysis, there may be significant variation among health regions within a peer group. When comparing regions within a peer group, this should be taken into account. These peer groups are based on 2016 Census data and the health region boundaries are as of December 2018. Every peer group is represented across provincial and/or territorial boundaries. Lastly, the five predictor variables used by StatCanada to differentiate these groups are: population density (population per square kilometre), proportion of visible minority, proportion of population aged 0 to 19 years old, long-term unemployment rate (labour force aged 15 and over) and internal migrant mobility (5-year internal migration, proportion of population aged 5 years and over). In terms of these five variables, each peer group has at least one differentiating factor. In our analysis, depending on the scenario, we control for peer group fixed effects, or group them more coarsely into rural and less-rural and include rurality fixed effects. The regions we have marked as rural for this analysis are peer groups A,D,E, and F.

It is worth noting that the health regions with the lowest vaccination rates are from peer groups F, D, and A. Peer group F has five health regions which consists of the province Nunavut and health regions within Saskatchewan, Manitoba, Quebec (Région du Nunavik, Région des Terres-Cries-de-la-Baie-James, Northern Regional Health Authority, Mamawetan/Keewatin/Athabasca). These regions have a very low ($\leq$ 15th percentile) population density, especially northern and remote regions. This peer health region also has a very low immigrant and visible minority population but a high aboriginal population and a low (between 15th percentile and 35th percentile) five-year internal migration. This peer group had high population growth from 2011 to 2016. The population under 20 years old for this peer group is very high ($>$ 85th percentile) while the long term unemployment rate is also very high. The proportion of postsecondary graduates is low.

Peer group D has 29 health regions and includes mainly rural health regions of Quebec, Ontario

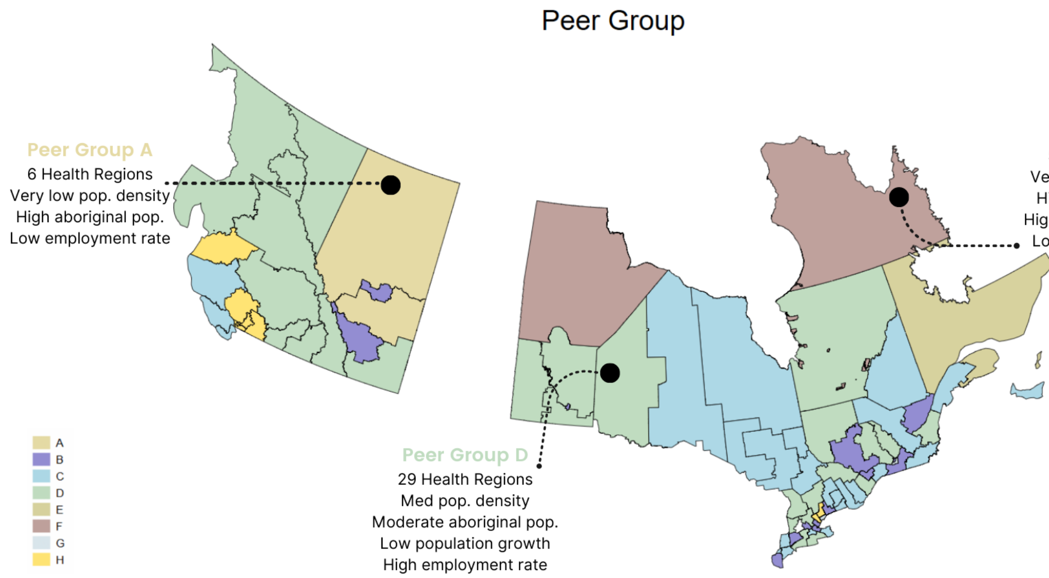


Figure 4: Peer groups of health regions. Source: Statistics Canada

and the Prairies. These regions have a medium (between 35th percentile and 65th percentile) population density. The peer group has a medium proportion of visible minority population, moderate proportion of Aboriginal population and a high internal migrant mobility rate. The regions within this peer group had low population growth from 2011 to 2016. Lastly, the proportion of children under 19 years old is also medium and the long-term employment rate for labour aged 15 and over is high in this peer group.

Peer group A has 6 health regions and includes Yukon, Northwest Territories, and rural/remote regions in the Western provinces (British Columbia's Northeast Health Service Delivery Area region, Saskatchewan's Prairie North Regional Health Authority region, and Alberta's Central Zone and North Zone). Since this peer group consists of rural regions, it has a very low population density. Both the proportion of visible minority and Aboriginal population is high in this peer group and the proportion of the children below 20 years of age is very high. Lastly, the long-term unemployment rate for this region is high.

Using this urban-rural classification allows us to see how the pandemic has impacted these different regions in an extremely disparate manner. This is important to note, considering there was not a significant difference when we looked at mortality geographically in Figure 3. Looking at Figure 5, we can see that non-rural health regions experienced many more deaths at the onset of the pandemic. As time has progressed, this has shifted, and in the late-summer and early fall of 2021 it was rural health regions that suffered more deaths than their non-rural counterparts. As this was during the period when vaccines were first becoming available, it is important to include this consideration in our analysis. As we will see, there are other predictors that better explain the differing outcomes than rurality, but this is an important consideration nonetheless, and we will regularly include rurality fixed effects to account for this.

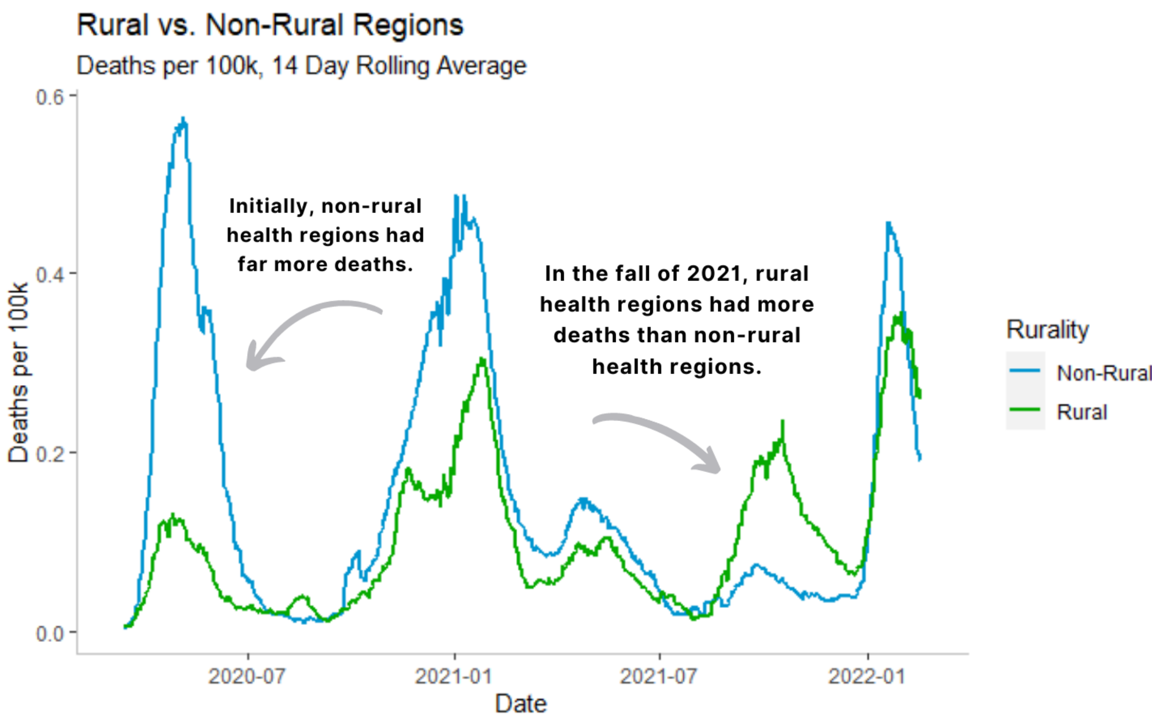


Figure 5: Time series of 14 day rolling average of deaths per 100 thousand residents for both rural and non rural health regions. Sources: CCODWG, Statistics Canada

5 Results

5.1 Micro analysis

In the first stage of the analysis, we used micro-level CCHS data to determine the relationship at the individual level between our chosen measure of social capital/trust and the likelihood of having been vaccinated. Specifically, we investigated whether there existed a positive relationship between having a strong 'sense of belonging' and having received the 2010 H1N1 shot or the 2017-2018 seasonal flu shot. In particular, our model takes the following form:

$$\text{Vacc}_i = \alpha + \beta_1 \text{Belonging}_i + \overline{\gamma}\text{Controls}_i + e_i$$

For example, for the H1N1 analysis, the outcome variable is whether the individual had gotten the H1N1 shot in 2010. The treatment variable is whether the individual reported having a strong sense of belonging (i.e. reported 3 or above out of a 4 point scale). This is in line with how Statistics Canada (2017, Table 13-10-0096-15) reports their summary results for the sense of belonging variable. The control variables are immigration status, income group (5 levels), age group (16 levels), and province of residence fixed effects. Age was used as control variables because individuals of different ages are differently susceptible to viruses, which would influence their decision to get vaccinated, as well as influences SBLC (Painter 2013); the H1N1 and seasonal flu vary across provinces in the extent of the outbreak and thus would similarly affect vaccine hesitancy. Further, the review by Painter (2013) highlighted the importance of controlling for immigration status and income, as they both influence SBLC to some extent.

	Dependent variable:			
	H1N1 Shot		Seasonal Flu Shot	
	OLS	*logistic*	*OLS*	*logistic*
	(1)	(2)	(3)	(4)
Sense of belonging	0.052***	0.233***	0.020***	0.091***
	(0.005)	(0.021)	(0.003)	(0.014)
Immigrant	−0.035***	−0.157***	−0.057***	−0.250***
	(0.006)	(0.028)	(0.004)	(0.018)
...				
80,000+	0.141***	0.630***	0.079***	0.352***
	(0.008)	(0.034)	(0.005)	(0.024)
...				
Age 20-24	−0.230***	−1.040***	−0.023**	−0.084*
	(0.014)	(0.063)	(0.010)	(0.045)
Age 60-64	0.051***	0.225***	0.093***	0.402***
	(0.012)	(0.055)	(0.009)	(0.040)
...				
Constant	0.638***	0.624***	0.415***	−0.397***
	(0.017)	(0.080)	(0.013)	(0.056)
Observations	50,082	50,082	106,177	106,177
R^2	0.103		0.072	
Adjusted R^2	0.102		0.071	
Note: Controlling for immigration status, income group, age group, and province of residence.			*p<0.1; **p<0.05; ***p<0.01 () = Std. Error	

Table 2: Results from micro-analysis on H1N1 and Seasonal Flu Vaccination. Source: 2010 and 2017-18 CCHS. Full results in Appendix

For robustness, we ran the regression equation in this section using both OLS and the corresponding logistic regression model. The results for the H1N1 analysis are given in Table 2 (1) and (2). For the H1N1 shot, we can see that sense of belonging was significantly related ($p < 0.01$) and had a coefficient of 0.052 in the OLS estimate (1). In other words, having a strong sense of belonging increased the chance of an individual of having gotten the H1N1 shot in 2010 by 5.2%

on average. There are similar results in the logistic model, where the probability of having gotten the H1N1 shot increased by 5.1% on average (65.1% in the baseline to 70.2%). Further, all of our control variables are statistically significant ($p < 0.01$) in both models, except for one age category. Having immigrant status reduces the odds of having received the shot, while having higher income and being older increases this probability.

As seen in Table 2 (3) and (4), sense of belonging is also significantly ($p < 0.01$) positively related to likelihood of getting the seasonal flu shot. Having a strong sense of belonging increases the odds on average of being vaccinated by 2% in the OLS estimate (3) and 2.2% in the logistic specification (4) (baseline of 40.2% to 42.4%). All of the control variables are statistically significant ($p < 0.01$), except for several age categories (ranging from 15-19 and 30-54) which are not significant (even at the 0.1 significance level). Once again, we can see similar trends here to the H1N1 shot: having immigrant status is negatively related, while the probability increases as you get older or have higher income. Further, the directions of these relationships match what we expect, given what we found in our literature review. Importantly, provincial fixed effects are important in all of the above specifications. The importance of these fixed effects can be seen even in a visual inspection of SBLC across Canada, as shown in Figure 6.

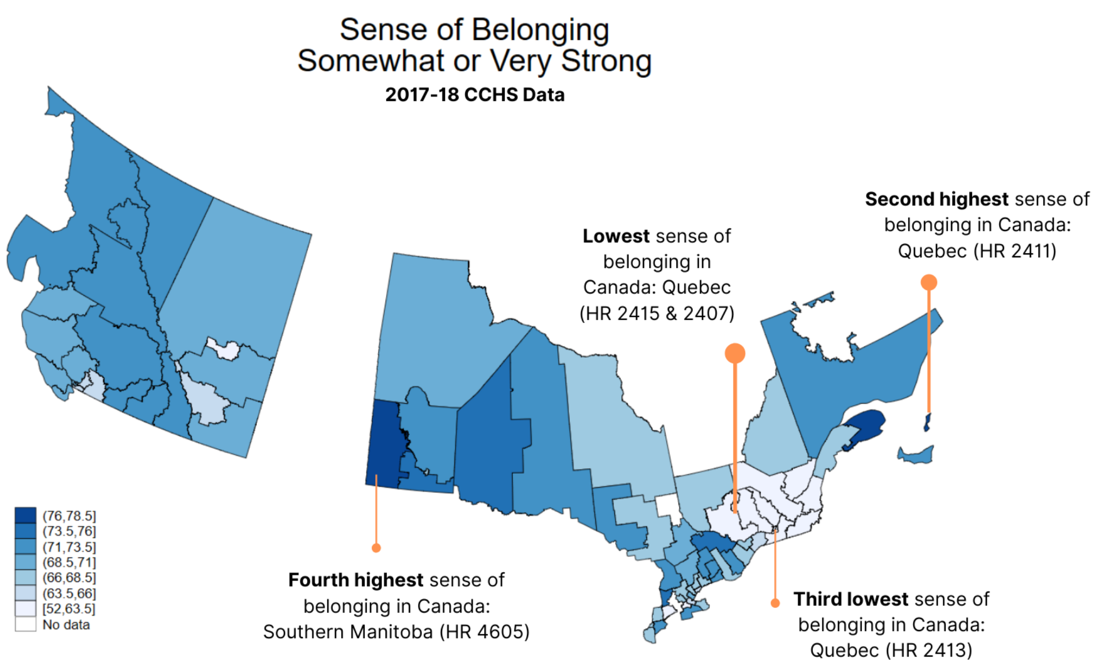
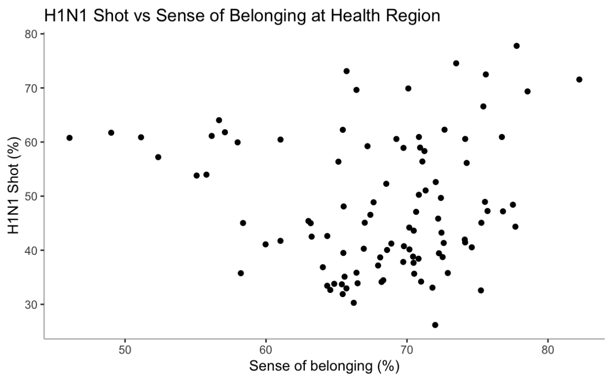
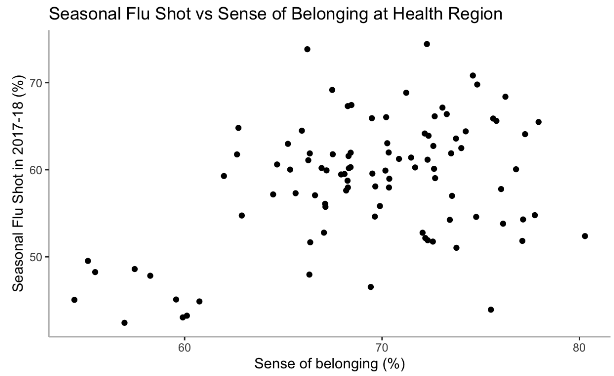


Figure 6: Map of sense of belonging to local community (CCHS 2017-18) at the health region level. Source: 2017-18 CCHS

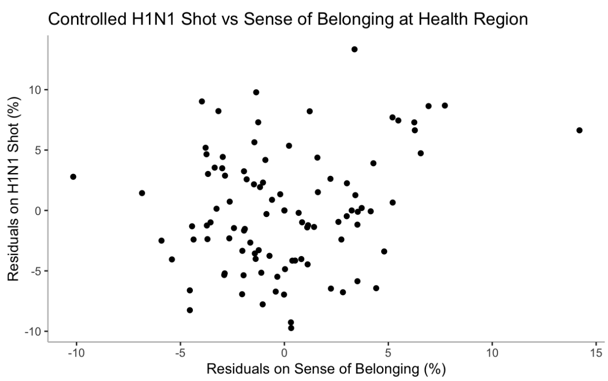
The significant positive relationship between sense of belonging and being vaccinated can also be seen in the scatterplots above (Figures 7a and 7b). Here, the data has been aggregated to the health region level; therefore, the variables now represent shares of the population (percent vaccinated and percent with strong sense of belonging). Both the H1N1 and seasonal flu graphs



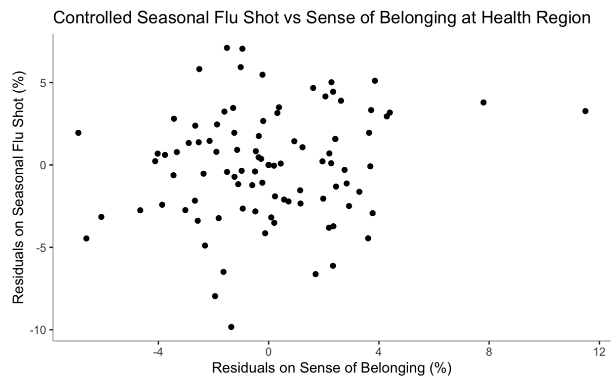
(a) Scatterplot of SBLC and H1N1 vaccination at the health region level. Source: 2010 CCHS



(b) Scatterplot of SBLC and Seasonal Flu vaccination at the health region level. Source: 2017-18 CCHS



(c) Scatterplot of SBLC and H1N1 vaccination at the health region level, after controlling. That is, these are the residual plots of SBLC and vaccination rates after controlling for Age, Income, and other controls. Source: 2010 CCHS.



(d) Scatterplot of SBLC and Seasonal Flu vaccination at the health region level, after controlling. That is, these are the residual plots of SBLC and vaccination rates after controlling for Age, Income, and other controls. Source: 2017-18 CCHS.

Figure 7: SBLC, Seasonal Flu, and H1N1 vaccination

show an upward trend as predicted by our hypothesis and the results of our above specifications. In order to ensure that these results do not disappear in the presence of controls, we computed the residuals of these aggregated variables in the presence of our aggregated controls, and then plotted these results against one another (in Figures 7c and 7d). That is, we estimated models of the form (where r here refers to the health region level):

$$\text{Vacc}_r = \alpha + \overline{\gamma}\text{Controls}_r + e_r$$
$$\text{Belonging}_r = \alpha' + \overline{\gamma}'\text{Controls}_r + e_r$$

We then took the residuals $\text{Vacc}_r - \hat{\text{Vacc}}_r$ (and similarly for SBLC), and then plotted the two residuals against one another. The remaining result shows the relationship in these two variables, holding all of our controls constant. At this aggregated level, we can begin to see a possible breakdown in the predictive power of sense of belonging, despite the significant individual effect.

We have observed that at the individual level, a stronger sense of belonging is significantly related to likelihood of being vaccinated for both viruses we studied. As we are most interested in predicting COVID-19 vaccination, does this relationship also hold in this case? Micro-data on COVID-19 vaccination is not yet available for Canada, but we can use the aggregated relationship between seasonal flu vaccination and COVID-19 vaccination to provide some evidence for the applicability of this analysis. Figure 8 shows vaccination rates for the 2017-18 seasonal flu and COVID-19 at the health region level. We can see a positive correlation, but not an extremely strong relationship. This suggests that our individual level analysis on seasonal flu should translate reasonably well to the individual level relationship for COVID-19.

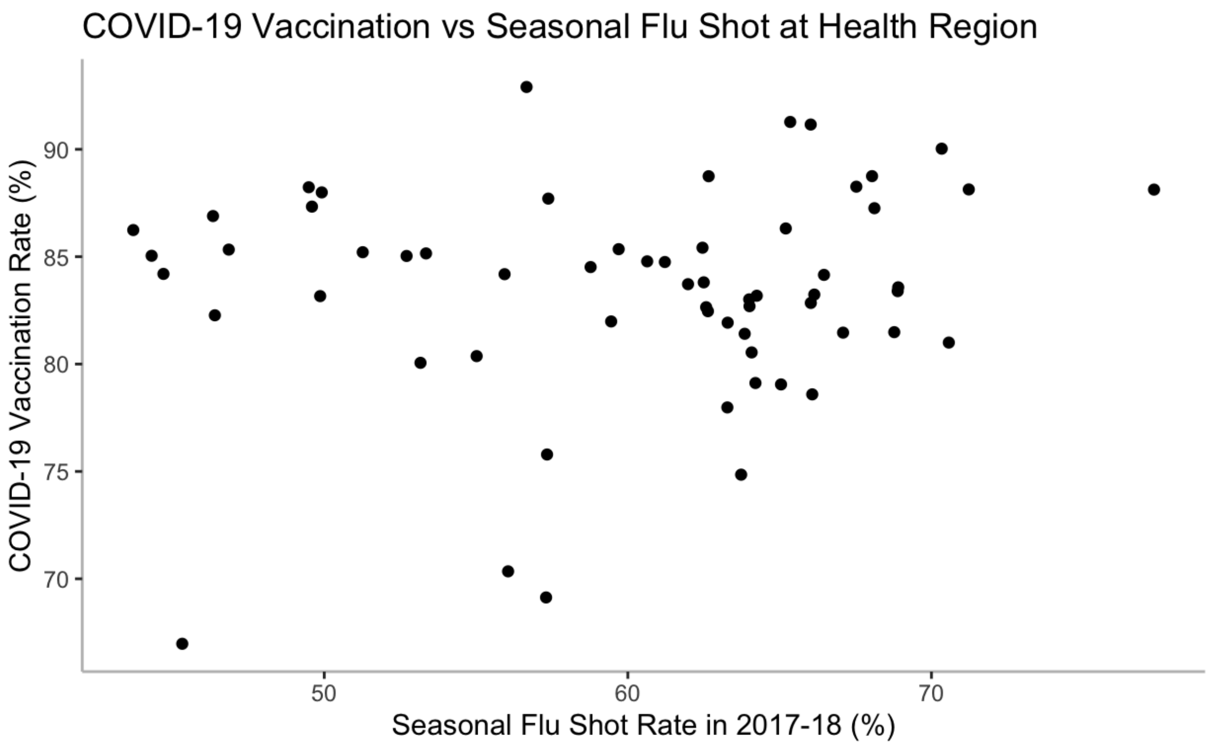


Figure 8: Scatterplot of 2017-18 Seasonal flu vaccination rates and COVID-19 vaccination rates at the health region level. Source: 2017-18 CCHS and COVID-19 Tracker

As mentioned in the Section 3, the latest CCHS cycle available is from 2017-18. Thus, in the next stage of our analysis, we use 2018 information on sense of belonging to estimate the effect of COVID-19 vaccination. In order to claim that it is SBLC that is motivating vaccination, we must assume that the share of the population with a strong SBLC at the health region level stayed consistent in the past 4 years. This is a reasonable assumption, especially considering that SBLC has stayed consistent at both the provincial and health region level in the years preceding 2018. See Figure 9 for a depiction of the provincial levels (the health region story is the same, but the figure is omitted for readability).

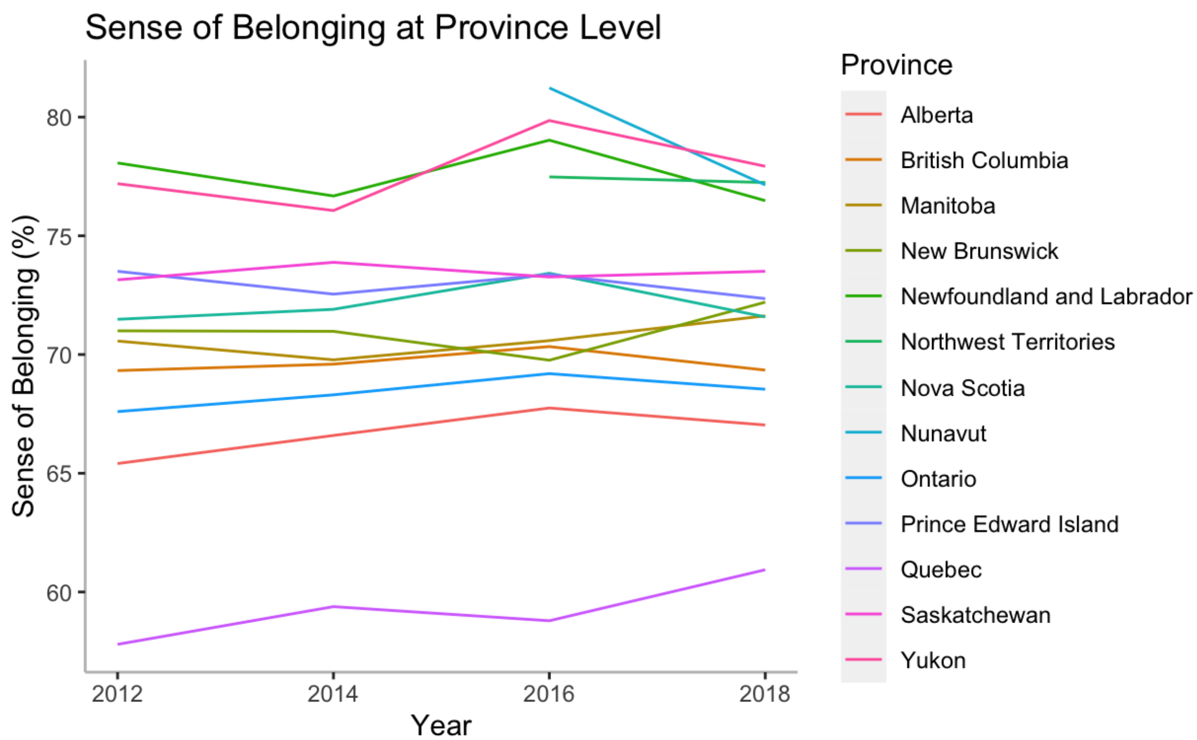


Figure 9: Time series of sense of belonging measures from different CCHS cycles, 2010 to 2017-2018. Source: 2010 to 2017-18 CCHS

A larger concern for our aggregated analysis is the thought that SBLC could affect vaccination in both directions. The idea here is that, as observed above, SBLC will motivate individuals in some health regions to be vaccinated, but will dissuade individuals in some health regions to be inoculated. In order to properly interpret the estimates from our aggregated IV estimation, if this were the case then this would violate the monotonicity assumption central to clean interpretation. Fundamentally, this is an untestable assumption. However, our micro data provides us a way to provide evidence that this assumption is met. We created a subset of health regions that looked to be defiers (i.e. had above average sense of belonging rate, but below average COVID-19 vaccination rate). This consisted of 19 health regions across Alberta, British Columbia, Manitoba, Nunavut and Ontario.

After creating this data set, we repeated the above seasonal flu specification only for individuals from those health regions to see if the relationship between sense of belonging and seasonal flu vaccination rate would shift to either being negative or insignificantly positive. As can be seen in Table 3 (1) and (2), this is not the case. Sense of belonging continues to be significantly positively ($p < 0.01$) related to seasonal flu vaccination rate. This is also the case for the further reduced defier set, consisting of health regions (in Manitoba and Alberta) that looked to be the more extreme potential defiers (see Table 3 (3) and (4)). While satisfying this test is not sufficient to meet the monotonicity assumption, it is a good sign that the presence of defiers in the dataset is limited.

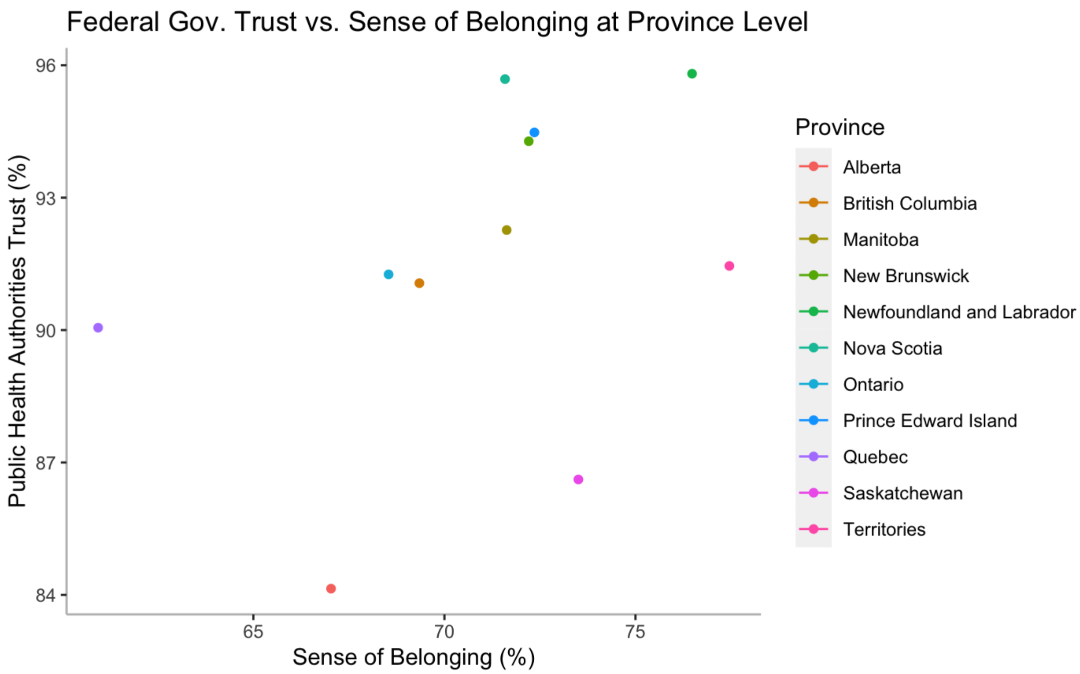
	Dependent variable:			
	Full Defier Set		Reduced Defier Set	
	OLS	*logistic*	*OLS*	*logistic*
	(1)	(2)	(3)	(4)
Sense of belonging	0.023***	0.099***	0.028**	0.120**
	(0.007)	(0.032)	(0.013)	(0.056)
Observations	22,247	22,247	7,175	7,175
R^2	0.056		0.054	
Adjusted R^2	0.055		0.051	

Note: Controlling for immigration status, income group, age group, and province of residence. *p<0.1; **p<0.05; ***p<0.01 () = Std. Error

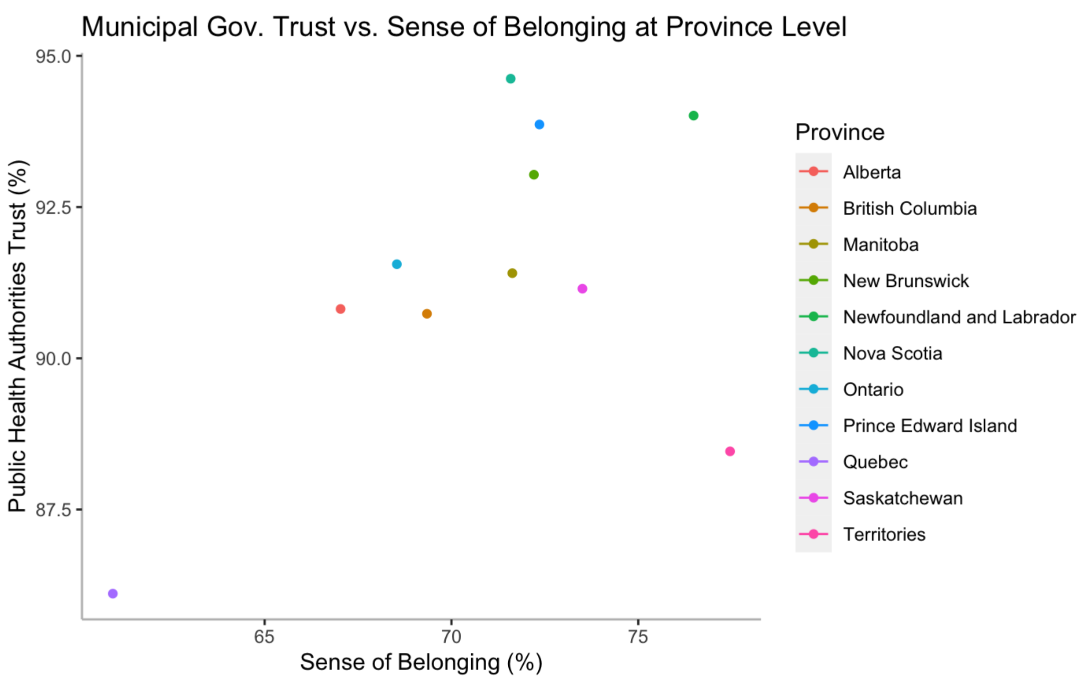
Table 3: Results from micro-analysis on Seasonal Flu vaccination for defier health regions. Source: 2017-18 CCHS. Full results in Appendix

As discussed, there is reason to suspect that SBLC will fail to be a sufficiently strong instrument when we aggregate it to the health region level. This is possibly because the measure of social capital which SBLC is measuring is too local to have a great effect at the aggregate level. If it is a lack of institutions that is largely responsible for individuals' decision to not be vaccinated, then it is possible that because SBLC is measuring sense of belonging to one's *local* community, it fails to grasp what is motivating some vaccine-hesitant. Evidence for this is suggested in Figure 10, where we have plotted SBLC at the provincial level to social trust during COVID-19 (using data collected from Statistics Canada, 2020, table 45-25-0005). In the survey, federal and municipal government trust were scored out of 10, and thus we used a score of 5 or above to designate trust in the particular institution (although the results were not sensitive to this particular choice). It should be noted that this dataset has several important limitations in that it consists of crowdsourced data and only has information at the provincial level. Nonetheless, although we can see a clear positive trend in both graphs, the trend is much clearer at the municipal level and gets muddier at the federal level — suggesting that SBLC fails to capture aspects of trust at the institutional and governmental level.

Our micro analysis provides strong evidence that at the individual level, a strong SBLC leads to increased probability of vaccination. As we have seen, this does not mean that it will necessarily be a good instrument for COVID-19 vaccination at the health region level. The next stage of our analysis explores this question.



(a) A comparison of SBLC and trust in the federal government. Sources: 2017-18 CCHS and Statistics Canada 45-23-0005 (2020)



(b) A comparison of SBLC and trust in municipal governments. Sources: 2017-18 CCHS and Statistics Canada 45-23-0005 (2020)

Figure 10: A comparison of SBLC and other measures of social capital.

5.2 IV results

5.2.1 Sense of belonging

In the second stage of our analysis, we aim to estimate the causal effect of vaccination on mortality during COVID-19. Vaccines were only available a year into the pandemic; therefore, using a cumulative death figure would misrepresent the actual effect vaccination had on COVID-19 mortality. Instead, we will use only COVID-19 deaths in the second half of 2021, which is when vaccines were widely available and thus will better allow us to isolate the effect of vaccination. For our first IV model, we used just sense of belonging as our instrument:

$$\begin{aligned}
\text{Vacc}_r &= \alpha + \beta_1 \text{Belonging}_r + \overline{\gamma}\text{Controls}_r + e_r \\
\text{MortalityRate}_r &= \alpha' + \beta_1' \text{Vacc}_r + \gamma' \text{Controls} + e_r' \\
&= \alpha' + \beta_1' \left(\alpha + \beta_1 \text{Belonging}_r + \overline{\gamma}\text{Controls} + e_r\right) + \overline{\gamma}'\text{Controls}_r + e_r'
\end{aligned}$$

Here, in the first stage, our model measures the vaccination rate of a health region, Vacc_r, against our primary independent variable, sense of belonging, Belonging_r, as well as all our controls, Controls_r, with an error term e_r, and constant α. The second stage then measures the mortality rate of each health region, $MortalityRate_r$ against our instrumented vaccination rates, again using our controls for each region as well as an error term and constant.

As stated, this was an instrumental variable regression model, with the upper levels of SBLC proportions (that being somewhat and very strong) as an instrument to vaccination rates. Here, we are controlling for: the Peer Group the health region belonged to, the breakdown of age proportions, and immigration rate in the region. Our reasoning for these controls largely stems from the factors available to us that we believe most influence one's intentions of getting vaccinated, and how they may perceive sense of belonging. Naturally, age is likely an important factor here given the significant difference of effects the virus can have against younger and older people. Furthermore, we believe a region's immigration rate may impact this as well, given the history of Canada and the rest of North America's treatment of immigrants and other minorities in the health care systems. Controlling by Peer groups allows us to capture more general aspects about the regions, such as population density, Aboriginal population, and rurality, which we believe all have an effect on vaccinations and sense of belonging. The results of both the first and second stage are displayed above in (Table 4).

When viewing just the first stage of this model, we see some interesting results for sense of belonging's relationship with vaccination rates. Holding other factors constant, with a coefficient of 0.203, we find that a 1 percentage point increase in the share of the population that reports strong sense of belonging leads to an increase of almost 203 fully vaccinated individuals per 100,000. The direction of this effect was to be expected, but this result is well outside of our bounds for significance at the 5% level. With a p value 0.13 and standard error of 0.13, we cannot confirm this effect to be existent in the data, thus we fail to reject our null hypothesis here. This is not

	Dependent variable:	
	Vaccination Rate	Second half 2021 Deaths per 100k
	OLS	*instrumental variable*
	(1)	(2)
Social Belonging Level	0.203 (0.132)	
Vaccination Rate (Instr.)		-0.002^{*} (0.001)
Peer Group B	0.048 (0.033)	-0.0002^{***} (0.0001)
Peer Group C	0.024 (0.033)	-0.0002^{***} (0.0001)
Peer Group D	0.029 (0.029)	-0.0002^{***} (0.0001)
Peer Group E	0.014 (0.042)	-0.0001 (0.0001)
Peer Group F	0.265^{***} (0.067)	-0.0001 (0.0004)
Peer Group G	0.029 (0.055)	-0.0003^{***} (0.0001)
Peer Group H	0.041 (0.045)	-0.0003^{***} (0.0001)
Ages 5 - 11	-3.464^{*} (2.017)	-0.006 (0.007)
Ages 12 - 17	-3.127 (2.783)	-0.002 (0.006)
Ages 30 - 39	-2.550^{**} (1.101)	-0.005 (0.004)
Ages 40 - 49	3.025^{***} (0.996)	0.004 (0.003)
Ages 50 - 59	-1.430 (1.079)	-0.009^{***} (0.003)
Ages 60 - 69	0.233 (1.021)	0.002 (0.002)
Ages 70 - 79	-1.747 (1.615)	-0.002 (0.004)
Ages 80+	-1.899 (1.612)	-0.006 (0.004)
Immigration Rate	-0.118 (0.102)	0.0001 (0.0002)
Constant	1.566^{***} (0.479)	0.005^{*} (0.002)
Observations	66	66
R^2	0.598	0.707
F Statistic		2.377 (df = 1; 48)
Note: ( ) = Std. Error		*p<0.1; **p<0.05; ***p<0.01

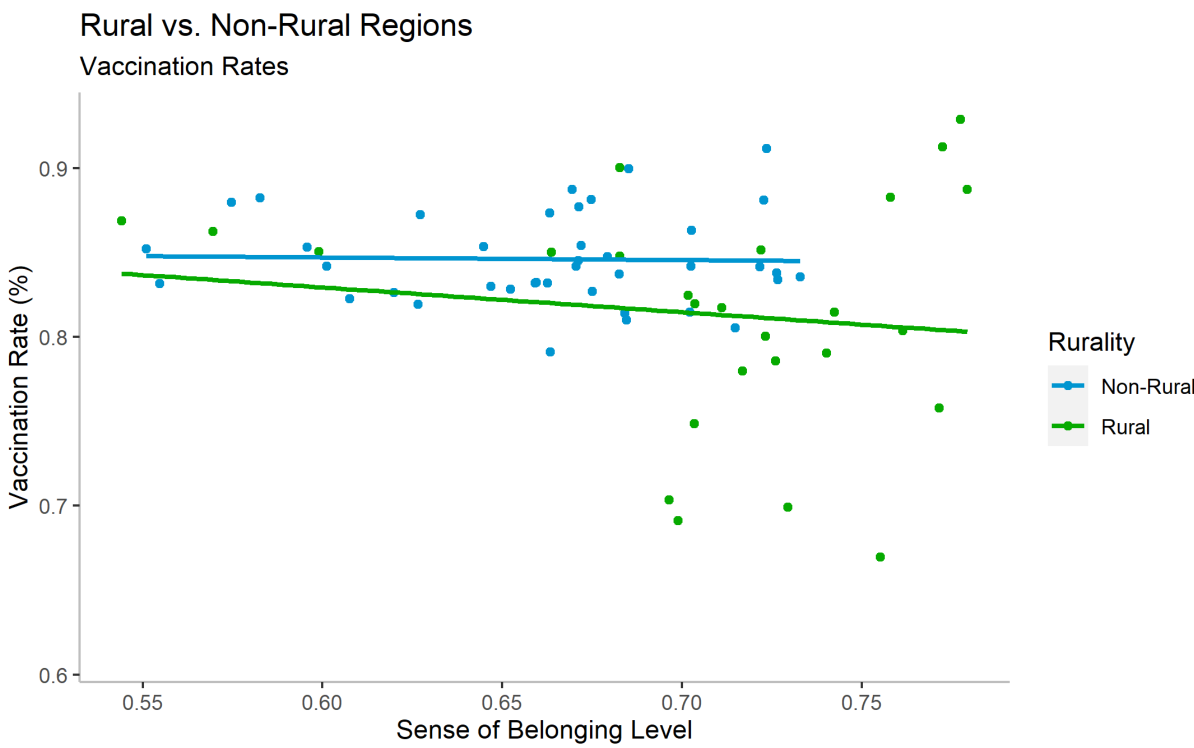
Table 4: Results from our IV estimation of vaccination on mortality using SBLC as an instrument for vaccination. Sources: 2017-18 CCHS, CCODWG, COVID-19 Tracker.

unexpected when we view the residual scatter plot in (Figure 11b) of this relationship where there is almost no correlation between the two variables after adding controls. Moreover, on the raw data in (Figure 11a) we can see this lack of a strong connection again, with almost opposite effects across rural and non-rural regions, and extremely high levels of variation in rural regions with a high sense of belonging.

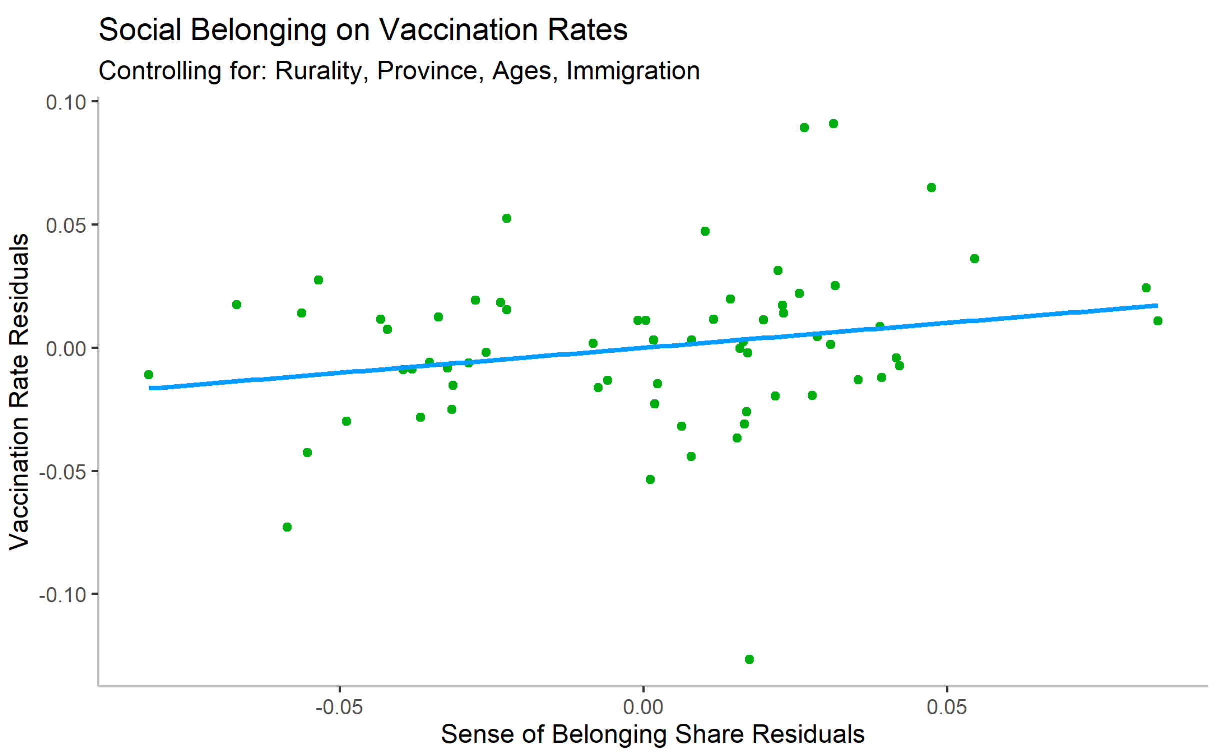
On the controls of this model, there is very little significance overall, but we are still able to observe some trends in their coefficients. Firstly, compared to group A, a health region in Peer Group F appears to have a much higher level of vaccinations, and is the only group that passes our basic significance test ($p < 0.05$). This is relatively surprising when we consider the overall makeup of this peer group, which tends to feature very high aboriginal and minority populations, with a very low population density. Aside from this, however, we can see that the more urban and heavily populated groups, such as B and H, tend to have much higher rates of vaccinations than the more rural groups, like E. Among the age groups we see a strong amount of variation in their estimates with no clear trends. However, there are some points of interest here. When compared to the age group between 18 and 29 years, a 1 percentage point increase in the proportion of those aged 40 to 49 years leads to an increase of about 3 percentage points in vaccination rates. This makes sense and is consistent with the effects of COVID, which are much stronger in the older populations and thus would prod them to get vaccinated more often. Conversely, however, a 1 percentage point increase in the proportion of those aged 30 to 39 leads to a decrease of about 2.6 percentage points in vaccination rates. Immigration rates are also insignificant, but its estimate does appear to point in the direction we anticipated, suggesting a lower level of vaccination rates for higher levels of immigration in a region.

In the second stage of this model we use the same controls, but are now measuring the effect of the instrumented vaccination rates on a health region's COVID mortality rate. In this model, we find that a 1 percentage point increase in the vaccination rate of a health region's population leads to a decrease of about 2 deaths per 100,000. Again, however, this estimate is just shy of our bounds at the standard 95% level, with a p-value of 0.07, preventing us from rejecting the model's null hypothesis. On the control groups, we see very little significance across age groups, with extremely large standard errors on most of them, preventing us from being able to cleanly interpret these results or the directions of the estimates. The only point of significance here is within the age group between 50 and 59, where, compared to ages 18 to 29, a 1 percentage point increase in this proportion leads to a decrease of almost 9 deaths per 100,000. While this conflicts with our hypothesis, we believe it may be due to the increased attempts to have this population vaccinated first. Moving to the peer groups, we do see some interesting patterns where when compared to group A, health regions in all other peer groups see slightly lower rates of mortality, with statistically significant changes between 0.0002% and 0.0003% in groups B, C, D, G, and H.

The biggest issue with this model, however, is the result of its F-statistic from the weak instruments test. At 2.377, this is considerably lower than the standard benchmark of 10.0 for an instrumental variable estimation. As a result, this suggests that there is a lack of a strong connec-



(a) Scatterplot of SBLC and COVID-19 vaccination at the health region level. Sources: 2017-18 CCHS and COVID-19 Tracker



(b) Scatterplot of SBLC and COVID-19 vaccination at the health region level, after controlling. That is, these are the residual plots of SBLC and vaccination rates after controlling for Ages, Rurality, Immigrant population. Sources: 2017-18 CCHS and COVID-19 Tracker.

Figure 11: SBLC and COVID-19 vaccination

tion between our instrument of social belonging and a health region's mortality. There are many likely reasons for this, and we believe it has primarily been due to the aggregation of our data where social belonging levels become tangled up within many variables, greatly affecting the outcomes we observe. As is visible from this graph (Figure 12) factors like rurality clearly complicate things: we can observe a significant difference in the relationship between social belonging and mortality in rural and non-rural regions. Moreover, the overall subtle strength of this outcome hinders our ability to use it as an instrument, likely contributing to the failure of the model's weak-instruments tests.

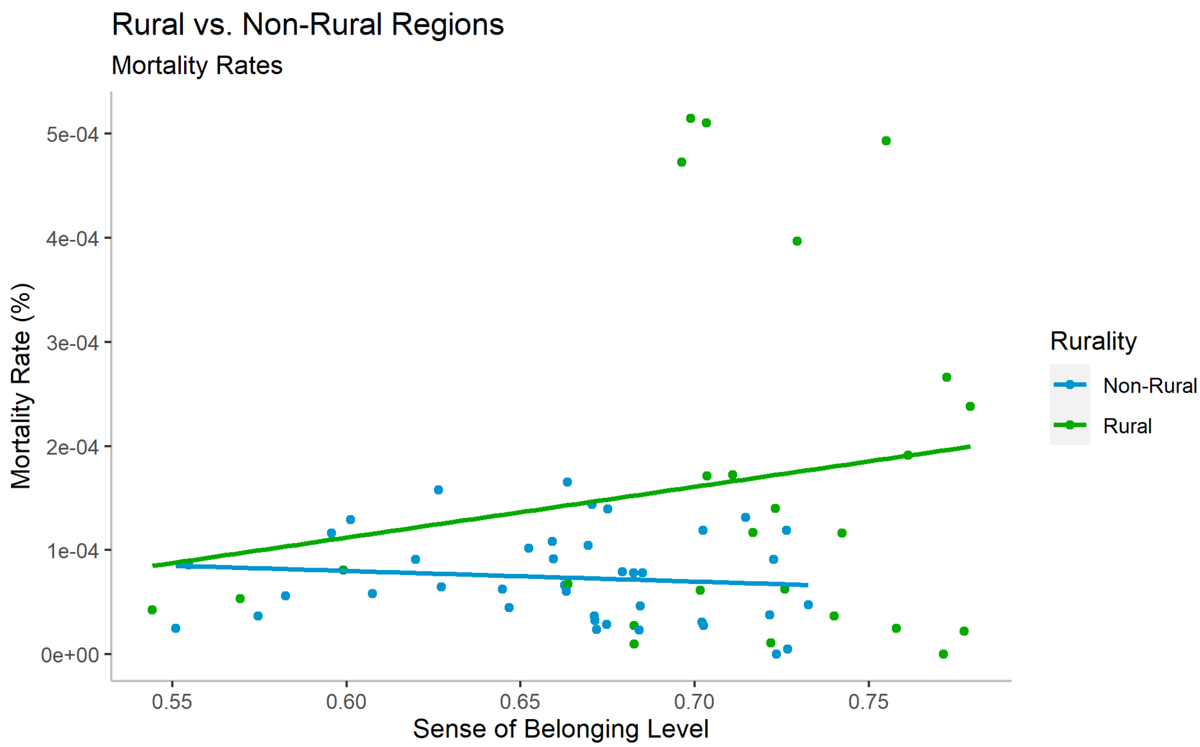


Figure 12: Scatterplot of SBLC and COVID-19 death rates at the health region level. Sources: 2017-18 CCHS and CCODWG

After trying many models, controlling for additional factors, and varying the way we defined collections of each Peer Group, we were led to similar results, which could pass the basic significance tests, but fail the larger weak-instrument tests. This has caused us to believe that there are too many factors influencing our sense of belonging measure that we have not controlled for, which hold us back from reaching "significance". As a result, to find an instrumental variable model that could better explain vaccine hesitancy, we moved to analyze political affiliation within health regions.

5.2.2 PPC vote share

Specifically, we estimated the share of the voting population in each health region that supported the PPC party in the most recent 2021 Federal Election, and used this percentage as our new instrumental variable. The map in (Figure 13) displays the share of the population in each health region that voted for the PPC party, where the deeper purple areas suggest higher shares. As we notice for example, in Southern Manitoba and Northern Alberta, we see a similar pattern wherein the few regions with the highest shares of PPC voters also see some of the highest rates of mortality (see Figure 3), as well as some of the lowest rates of vaccinations (see Figure 2). This suggests a clear trend regarding vaccine opinion and PPC support.

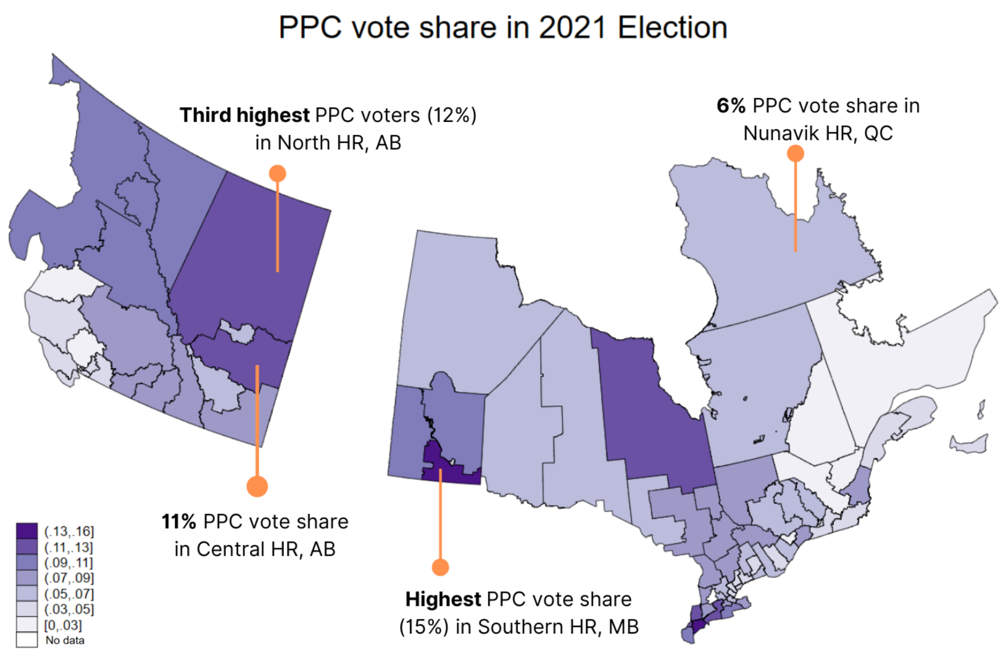


Figure 13: PPC vote share (2021 election) at the health region level. Source: Elections Canada

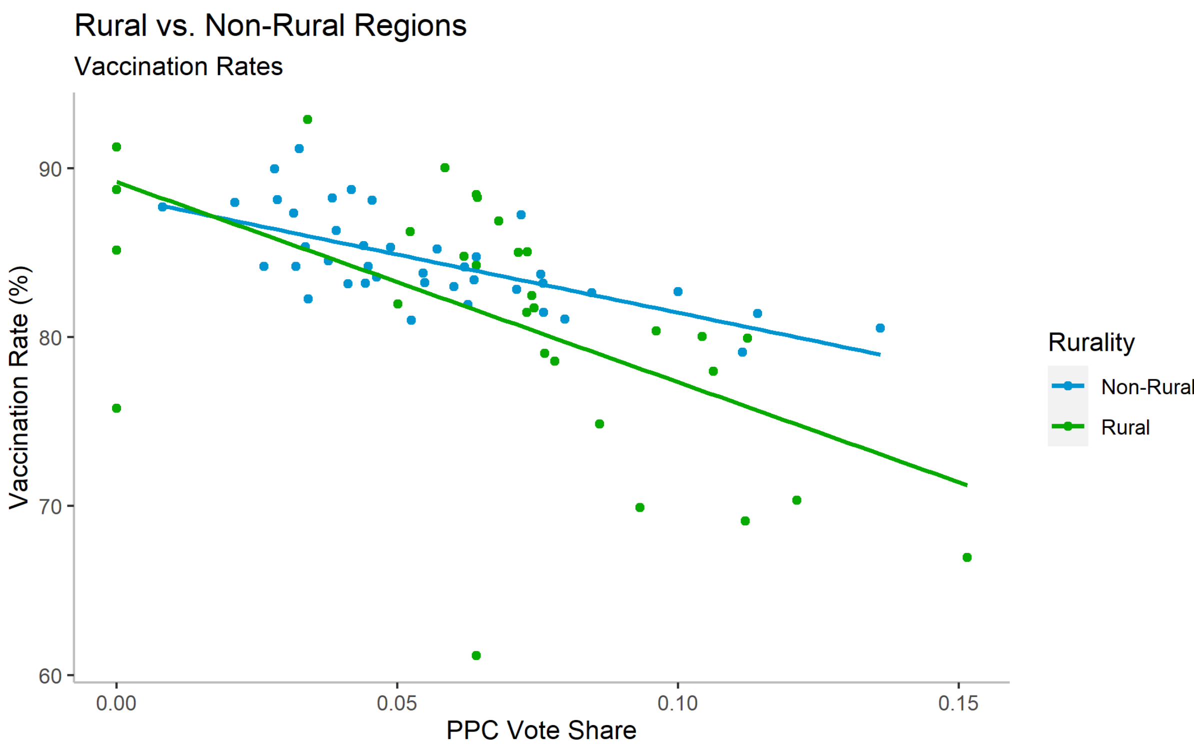
When viewing the scatter plots in (Figure 14 and Figure 15) we can see that there is a much stronger relationship between PPC share and both vaccination and mortality rates as compared to what was seen earlier with SBLC. Further, the directions line up well with our initial hypotheses: higher PPC voting regions are tied to lower vaccination rates and higher mortality rates. More importantly, these relationships hold fairly well across rural and non-rural regions, minimizing the complication created by such differences. As these raw results look especially promising, we went ahead with using PPC vote share as an instrumental variable in our model model. Results are given in Table 5.

For this model, we used a very similar framework from our SBLC model, but instead using the PPC share as our primary instrument. Now, for each health region we control for the province of the health region, the proportion of each age group and proportion of immigrants in the region, and its classification as rural or non-rural as described in Section 3.

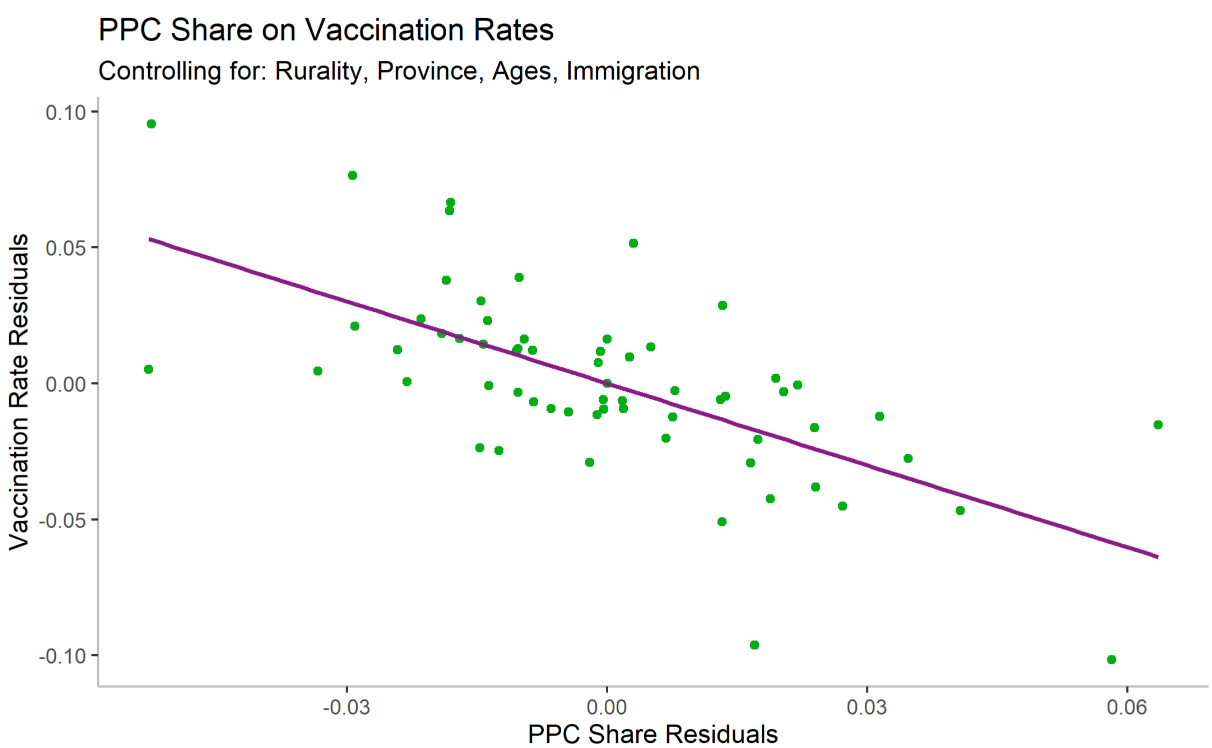
After controlling, we find a very strong negative relationship between the share of voters for the PPC Party and the rate of vaccinations in a health region. This relationship can be observed in (Figure 14b) which plots the residuals of these variables after controlling for other factors. With an

	Dependent variable:	
	Vaccination Rate	Second half 2021 Deaths per 100k
	OLS	*IV*
	(1)	(2)
PPC Share	-1.004^{***} (0.170)	
Vaccination Rate (Instr.)		-0.002^{***} (0.0003)
Rurality	0.002 (0.011)	0.00003 (0.00002)
British Columbia	0.013 (0.024)	-0.0001^{**} (0.00004)
Manitoba	0.080^{***} (0.026)	-0.0001 (0.0001)
Nunavut	0.043 (0.056)	-0.0003^{***} (0.0001)
Northwest Territories	0.055 (0.043)	0.0002^{***} (0.0001)
Ontario	0.057^{**} (0.025)	-0.0002^{***} (0.00005)
PEI	0.058 (0.042)	-0.0002^{**} (0.0001)
Quebec	0.042 (0.031)	-0.0001 (0.0001)
Yukon	-0.0002 (0.046)	0.0003^{***} (0.0001)
Ages 5 - 11	-3.415^{*} (2.013)	-0.010^{***} (0.004)
Ages 12 - 17	1.512 (3.050)	0.010^{*} (0.005)
Ages 30 - 39	-0.573 (1.174)	-0.001 (0.002)
Ages 40 - 49	1.377 (1.023)	-0.002 (0.002)
Ages 50 - 59	-1.651^{*} (0.981)	-0.005^{**} (0.002)
Ages 60 - 69	0.667 (0.921)	-0.001 (0.002)
Ages 70 - 79	-0.137 (1.274)	0.001 (0.002)
Ages 80+	-2.042 (1.253)	-0.003 (0.002)
imm_perc	-0.085 (0.064)	-0.00003 (0.0001)
Constant	1.199^{***} (0.423)	0.003^{***} (0.001)
Observations	66	66
R^2	0.762	0.874
F Statistic		34.845^{***} (df = 1; 46)
Note: ( ) = Std. Error		*p<0.1; **p<0.05; ***p<0.01

Table 5: Results from our IV estimation of vaccination on mortality using PPC vote share as an instrument for vaccination. Sources: 2017-18 CCHS, Elections Canada, CCODWG, COVID-19 Tracker.



(a) Scatterplot of PPC vote share and COVID-19 vaccination at the health region level. Sources: Elections Canada and COVID-19 Tracker



(b) Scatterplot of 2021 PPC vote share and COVID-19 vaccination at the health region level, after controlling. That is, these are the residual plots of SBLC and vaccination rates after controlling for Ages, Rurality, Immigrant population. Sources: Elections Canada and COVID-19 Tracker

Figure 14: 2021 PPC vote share and COVID-19 vaccination

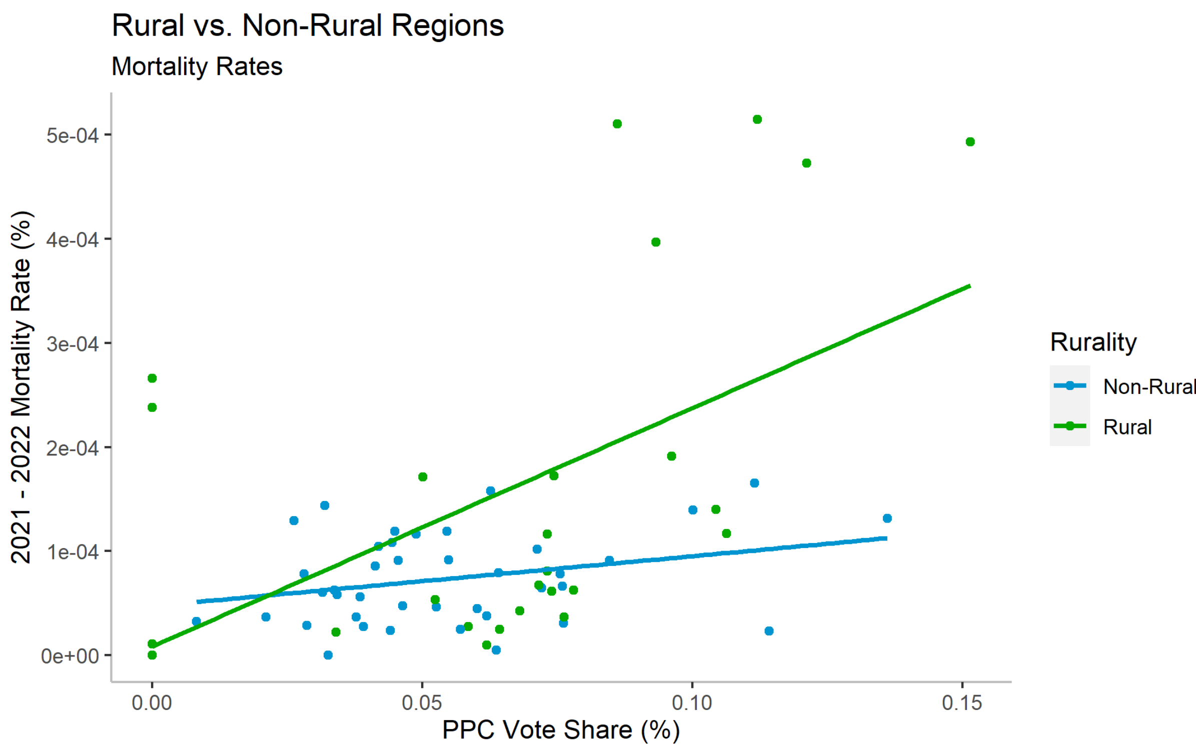


Figure 15: Scatterplot of PPC vote share and COVID-19 death rates at the health region level. Sources: Elections Canada and CCODWG

estimate of -1.004, the model suggests that a 1 percentage point increase in the share of PPC voters in a health region leads to a decrease of around 1000 vaccinated individuals per 100,000 people. With a p-value $\ll 0.001$, this is much lower than our 5% desired level, meaning we can comfortably reject the null hypothesis in this case and confirm its significance.

The controls for this model had little significance overall, but there are a few notable factors. We can see that health regions in Manitoba and Ontario, as compared to Alberta, see higher rates of vaccination, at about 0.08% and 0.06% higher, respectively. All other provinces appear to have slightly higher rates as well, besides Yukon, but the standard errors on them reduce our ability to firmly interpret their results.

Within the age groups, we could not find any significance at the 5% level, but we can see at the 10% level, compared to the age group between 18 and 29 years, a higher proportion of those aged 5 to 11 and 50 to 59 actually lead to a decrease in the health region's overall vaccination. This is opposite from what we had observed in the social belonging model but this is likely due to the large standard errors on these estimates, which prevent us from being confident about this conclusion. The remaining controls, being rurality and immigration both had large standard errors, which again hurts our interpretability, but we can note the possibly negative relationship between immigration and vaccination rates.

In the second stage of the model, now using the instrumented vaccination rates, we find that, after controlling, a 1 percentage point increase in the vaccination rate of a health region leads to a decrease of almost 2 COVID-related deaths per 100,000 people during the second half of 2021. Firstly, our rurality control suggests that the more rural health regions tend to see higher rates of Covid mortality, but its p-value fails to pass our 5% significance test. Across the province controls, we can observe some fascinating results. As compared to Alberta, health regions in almost every other province see a slight decrease in mortality rates, with the exception of the Northwest Territories, and Yukon, which show slightly higher mortality rates. Among the age groups, we can see that, compared to ages between 18 and 29, regions with higher proportions of those aged 50 to 59 actually see lower rates of covid-related mortality. This is somewhat contrary to our understanding of the virus' effects, but may be the result of these groups seeing higher vaccination rates. The other age controls show a somewhat mixed pattern with most of them suggesting lower mortality rates as well. Lastly, our model suggests that higher rates of immigration actually lead to lower rates of mortality, but again, due to its high standard error we cannot be certain that this effect is significant.

Most importantly, when looking at this model's weak instrument test, we find an F-statistic of 34.845. As this is much greater than the desired 10.0, we can be fairly confident in rejecting the null hypothesis and confirming our instrument to be sufficiently strong. We do notice that there is a slightly 'U' shaped pattern through the fitted vs. residual plot, which suggests the possible need to analyze a non-linear relationship between mortality and vaccination, but at the expense of interpretability, we felt that this linear model had done a sufficient job.

Naturally, however, we have some skepticism about using PPC share as an instrumental variable. We are primarily concerned with the exclusion requirements. To estimate a proper instrumental variable effect we require them to have an effect on the dependent variable only through the variable it is instrumenting. In this case, the worry is that PPC voters may be more likely to go without masks or fail to practice social distancing, which may in turn affect the mortality rate of the health region. The best situation would be one in which we can control for these additional confounders, however, there is a great difficulty with tracking down this data. The authors of our guiding paper (Frankel & Kotti 2021) were able to obtain an estimate for the level of mask use in each state and control for this in their models. While we have not yet been able to find the same data, we believe that this may be an avenue of alleviating this problem.

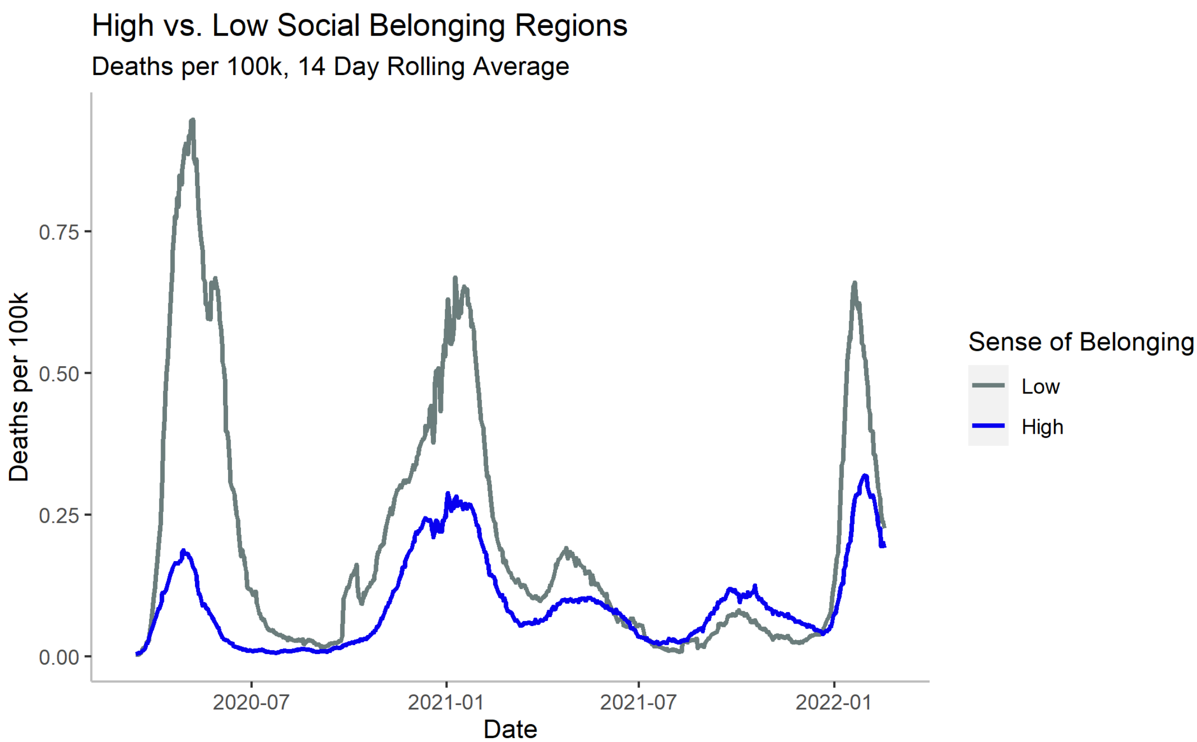
To understand this effect over time, we have created a time series of a 14 day rolling average of deaths per 100 000 people across Canada, and grouped these results by high and low PPC voting regions (see Figure 16b). Here we are classifying regions as "high" by those with a PPC share in the upper 25% of health regions (i.e., a PPC vote share of greater than 7.5%). As we can see, the two groups have followed a fairly similar trend over time, especially between the first wave and the summer of 2021. However, as we approach the fall of 2021, deaths massively spike for regions with high PPC vote share, while the other regions saw little change until the end of the year. This is consistent with our hypothesis that it is through vaccination that PPC vote share influences COVID-19 mortality. Our model's results suggest that these high PPC regions would be more vaccine hesitant and thus become more susceptible to succumbing from the disease, while the vaccinated lower PPC regions would fare much better. This relationship holds until the beginning of 2022 where we see deaths spike in both groups, which has likely been perpetuated by the rise of the Omicron variant and possibly the previous spike in high PPC region mortality. This results helps to prove some satisfaction with our exclusion requirement worries as we see the most significant result coming only after the introduction of vaccinations, signaling the PPC share's strong effect through this variable. Looking at a similar graph separating now on SBLC (Figure 16a), we see not nearly as strong a difference during 2021. We would predict that high SBLC health regions would have low mortality during this period, but this is not reflected in this time series, suggesting again that SBLC may not be the best instrument to use.

As we can see from these results, political affiliation does in fact appear to be strongly correlated with COVID vaccine hesitancy and mortality. Specifically, we find that regions with higher shares of voters for the PPC party tend to have lower vaccination rates, and as a result, higher COVID-related mortality rates. This is quite unsurprising when we consider the stance the party has taken in response to COVID-19 and lockdown measures. In many ways these PPC voters can be attributed to feelings of social belonging and trust in institutions. Considering the party's somewhat far-right ideologies, coupled with the extremely low proportion of voters seen throughout health regions (highest was only 15%), we can see a clear social identity form around these health regions. Given these low proportions and harsh views, we might expect those who favour this party to have a smaller pool of people to surround themselves with, ultimately limiting the level of comfort they might feel within their own community. Moreover, it is clear that as a political group, the PPC party receives a large amount of criticism for their extreme views, which if passed on to these individuals through the media or their peers can exacerbate these feelings of social disconnect.

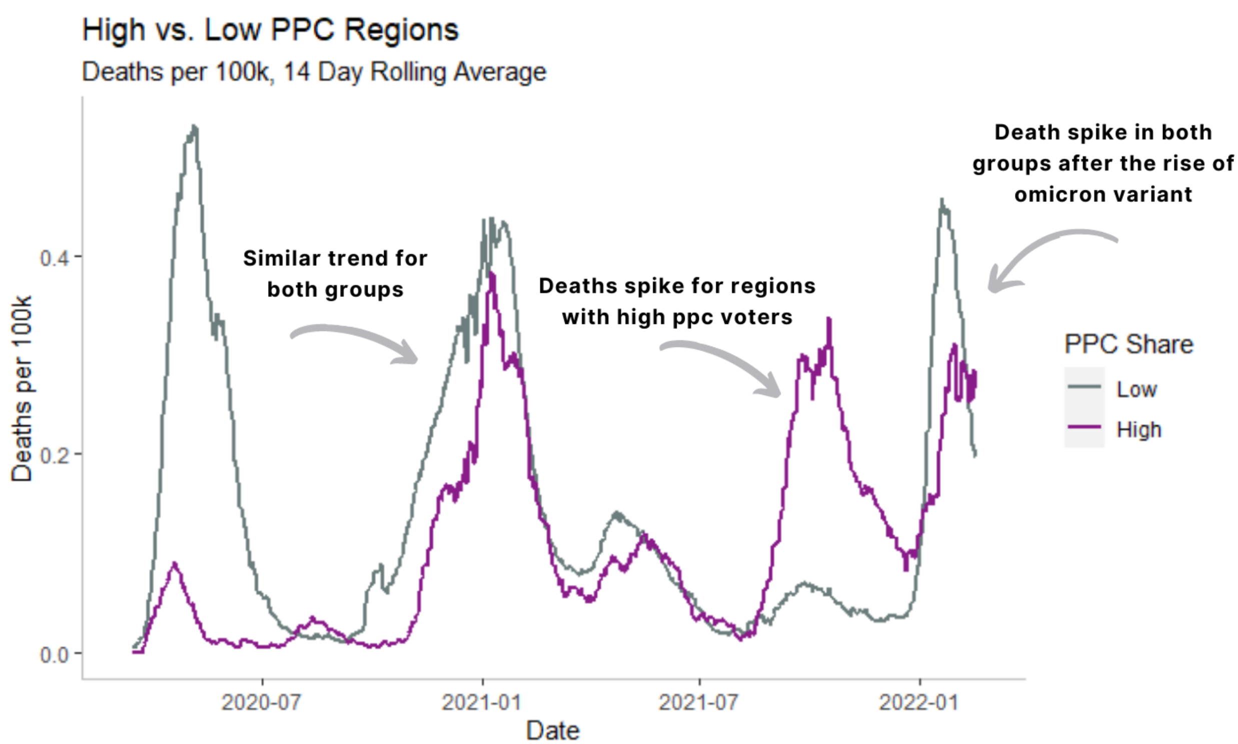
Solving this issue, however, can be much more difficult than simply improving one's connection to their community. More often than not, people are quite adamant about their political affiliation and unshakable in the face of conflicting evidence. This means that any governmental efforts to reduce vaccine hesitancy in these areas has to be carefully navigated, given their already pervasive mistrust of institutional authorities.

6 Descriptive Analysis II

Canada's demographic composition is ethnically heterogeneous, which means that citizens have come from many countries of origins and cultural backgrounds. That being the case, other than scientific scepticism, there are cultural and religious factors that may cause vaccine hesitancy. As seen in Figure 2, the least vaccinated health regions are found in Northern Quebec, Southern Manitoba and Northern Alberta. The common denominator among these regions is that they are classified as rural according to our peer group study, have a dominant ethnic group residing in these regions and the ethnic groups residing have all experienced historic and/ or ongoing systemic/ institutional oppression of some kind by Canadian or foreign governments. These factors suggest that institutional distrust is the leading factor that drives vaccine hesitancy in low vaccinated health



(a) Time series of deaths due to COVID-19 in the health regions with the greatest proportion SBLC, versus all remaining health regions. Sources: 2017-18 CCHS and CCODWG



(b) Time series of deaths due to COVID-19 in the 20% of health regions with the greatest proportion of PPC voters, versus all remaining health regions. Sources: Elections Canada and CCODWG

Figure 16: 2021 PPC vote share and COVID-19 vaccination

regions.

We assessed the following health regions in the following section based on socio-demographic factors like education, income, age of population, ethnic group composition, language, etc. Income is the single most important indicator of population health (Southern Health, 2019). This means having higher income results in better living conditions, higher investment in health and healthcare as well as high nutritional intake which lowers your likelihood of contracting COVID-19 (Patel et al., 2020). Given that education improves income potential and health literacy, education also becomes an important indicator of population health (Patel et al., 2020). Finally, including language in our analysis is important in order to identify any language barrier in improving health literacy or vaccine awareness that may translate to low vaccination rates.

Nunavik (Quebec)

Nunavik, a sparsely populated territory with 13,000 people, has the lowest vaccination rate in Canada, at just 61% (Statistics Canada, 2017). Since Nunavik is the northernmost region of Quebec and covers a large portion of reserve lands and Indian settlements, Nunavik was excluded from the CCHS coverage and so data for sense of belonging is not available. Therefore, on the basis of other health regions with high Indigenous population and similar characteristics, we speculate that the sense of belonging to one's local community in Nunavik is average to above average i.e., 68% or higher. Nunavik consists of five most populous villages that account for two-thirds of the population in Quebec's rural north (Lévesque and Duhaime). About 91% of residents identify as Aboriginal, with the Innuit community being the most populous community (Statistics Canada, 2017).

Over 6,000 residents are below the age of 25 years old which would correctly reflect low vaccination rates either due to hesitancy to vaccinate teens or young adults who have a low perceived threat of COVID-19 (CRCCAC, 2015; Lévesque & Gérard, 2019). Despite the high share of younger population, we see that over 69% of Inuit residents have no formal education qualification and therefore their average income per year is only around $30,000 before tax (CRCCAC, 2015). Findings of the Canadian Household Survey indicate that poverty is much higher up north and in Indigenous communities at 31.1% as opposed to 9.9% in non-Indigenous households and in Southern Canada (Daley, Burton & Phipps, 2015). Therefore, the lack of social support and economic investment by the government is seen as a form of neglect among Indigenous communities which can also be driving institutional distrust towards the different levels of government. These characteristics align with the low population density, high Aboriginal population, high density of population under 20, low education and high unemployment rate factors used to describe socio-demographic composition in peer group F. While it is reported that the population has knowledge of Canada's official languages (English or French), the 2016 census data shows us that over 87% of residents speak Indigenous languages (like Algonquain, Inuit, Siouan languages and many more) most often at home (Statistics Canada, 2017).

Given that Nunavik houses a majority of the Inuit population, we observe vaccine hesitancy among this community because of their negative historic and contemporary experiences with mainstream healthcare systems and vaccine providers in Canada. This includes hesitancy due to federally sanctioned medical experiments done on Indigenous communities in the past (MacDonald, Stanwick, & Lynk, 2014). These were non-consensual research experiments performed on Indigenous individuals, for example, the nutritional experiments done on Indigenous children in residential schools (MacDonald, Stanwick, & Lynk, 2014). These unethical experiments lowered the confidence of Indigenous communities in Canada's public healthcare system and was seen as neglecting welfare of Indigenous peoples. Therefore, we see that Indigenous communities' vaccination decisions are guided by the history of colonization and past trauma (Mosby & Swidrovich, 2021). Overall, the data presented above can mean two things. First, there may be a language barrier in appealing to the Indigenous populations. Second, historical injustice and lack of progress in reconciliation efforts are acting as a barrier in improving trust in public health efforts and vaccine confidence.

Southern Health - Sante Sud (Manitoba)

The vaccination rate in Sante Sud, the rural south of Manitoba, stands at about 67%. Sante Sud is located on the homeland of the Metis and covers Treaty 1 and Treaty 3 territory (Southern Health, 2019). The sense of belonging in Sante Sud stands at 76% which is well above average of the CCHS reported sense of belonging. Sante Sud is an outlier to our study because there is a high sense of belonging (8 percentage points above our average) in the region with low vaccination rates. Given that this health region covers large parts of treaty land, the first dominant community includes 13% of whom identify as Indigenous (lower than the Manitoba average, but higher than the regional average).

The Southern health region has a higher population of residents under 25 as opposed to other adult age groups (Southern Health, 2019). Unlike Nunavik, Sante Sud performs better in income education with median household income of around $60,000 before tax and only 29% of residents have no formal education qualifications (Southern Health, 2019). In addition to socio-economic characteristics, there are multilingual residents in Sante Sud that account for different levels of awareness about the benefits of COVID-19 vaccines in the region. Among Sante Sud residents, about 85% of the population speaks one of Canada's official languages at home and the percentage of Francophones is the highest in rural Manitoba. Considering the high level of Francophone residents, the region takes special efforts to ensure bilingual healthcare service delivery to their Francophone population (Southern Health, 2019).

The second dominant group includes 14% of residents that have an immigrant status and are classified as visible minorities (Southern Health, 2019). The health region has experienced a large influx of immigrants and refugees in the past decade especially from Germany, Mexico and the Philippines. Given this influx of immigrants, data shows that German is the most commonly spoken non-official language at home (Statistics Canada, 2017). Steinbach city, the third largest city in Manitoba, located in zone 4 of Sante Sud is home to over 40% of residents with German or Mennonite ancestry (originally from South Germany) (Neufeld, 2009). Mennonites are a pacifist group of Christians who follow a biblically-based doctrine and settled in South-west Manitoba during the Soviet revolution. Historical distrust in government services is one of the major reasons for low vaccination rates among this religious community (Hoye, 2021). This is because of their persecution during the Russian revolution and Reformation movement where Mennonites died at the hands of the state – the roots of distrust go further back (Neufeld, 2009). We see lingering sentiments of hesitancy in public programs even after their immigration to Manitoba from Europe, claiming public health mandates and vaccination efforts are a form of 'tyranny' (Hoye, 2021). Therefore, we see low vaccination rates in Steinback city and areas in its boundary (Hoye, 2021).

Despite the release of an official statement encouraging vaccination efforts by the Mennnite Church Canada, it seems to have less impact on vaccination efforts than expected. The statement read "the command to love God and love our neighbor is paramount... vaccinations allow us to live out this command" (MCC, 2021). The Mennonite Church teachings says that "the command to love our neighbor is paramount", on that account we presume that the Mennonite community has a high sense of belonging to their local community and would be encouraged to get vaccinated. However, our analysis shows that this community has low vaccination rates so the plausible conclusion would be the distrust in institutions which is likely driving hesitancy. The slow vaccination efforts in the Mennonite community is likely to lower the overall recorded vaccination rate in the Southern health region. Although this is not surprising given the low recorded vaccination in reference to past immunization efforts, specifically during the influenza epidemic (Southern Health, 2019). It was recorded that only 48% of vulnerable adults (aged 65+) were immunized against influenza which is much below the national target as mentioned in the Sante Sud Community Health Assessment Report (Southern Health, 2019). This shows a consistent pattern in vaccine hesitancy over the years most likely due to institutional distrust.

North Zone (Alberta)

The North Zone is Alberta's largest health region geographically, and it is also one of the least vaccinated regions in Canada, with a vaccination rate of 70%. The sense of belonging in the North Zone stands at 70% which is slightly above average of the CCHS reported sense of belonging. Only 9.8% of residents have received their first dose of vaccination in the High Level region of the North, and that is likely lowering the health region and provincial vaccination average (Gibson, 2021). The north also comprises rural municipalities, villages and Indian reserves that have about 5% of Aboriginal populations, which is lower as compared to other low vaccinated health regions, but higher than the national average (Statistics Canada, 2017). On average, the northern population is younger i.e., about 34% of the region population lies in the 0-24 age group and are more educated (a higher percentage holding trade certificates and diplomas) than the other low vaccinated health regions (Statistics Canada, 2017). It is therefore surprising to see high levels of education and low levels of vaccination. So, vaccine hesitancy is likely driven by factors other than socio-economic characteristics like cultural or religious experiences and beliefs (discussed more below).

The small town of La Crete located in the massive stretch of farmland, or the Mackenzie County in northwest Alberta is popular for resisting public health orders like mask, social distancing and vaccine mandates (Parsons, 2021). Mackenzie County houses many people who belong to the Mennonite community (Parsons, 2021). As discussed in the descriptive analysis of Sante Sud, historical distrust in government services is one of the major reasons for low vaccination rates among the Mennonite community. The low vaccine rates were also fueled by beliefs that capacity limits in church were interpreted as curtailing religious freedom and government overreach which is "moving Canada towards a communist state" (Parsons, 2021).

The periphery of La Crete has Metis and several First Nation settlements who live and work around the area. The presence of Indigenous communities also supplement our argument on why the North zone is largely vaccine hesitant. The Northern region had a high per-capita case rate and COVID-19 death rate in Mackenzie County that worried health officials in October of 2021 (Parsons, 2021). To combat low vaccination, a \$100 incentive was introduced by the Alberta provincial government to encourage COVID-19 vaccination, but this had an opposite effect on the community. This incentive in turn seemed "forced" and increased skepticism among residents (Small, 2021). This is because monetary incentives do not change deep rooted beliefs, associated fears and existing value systems that drive vaccine hesitancy. Nonetheless, the effort did have a slight impact where vaccination rates increased at a diminishing rate (Small, 2021).

PPC votes and lowest vaccinated regions

In reference to our second instrumental variable analysis, we find that the PPC vote share is the highest in Sante Sud (Manitoba) at 15%, third highest in North Zone (Alberta) at 12% and one of the lowest in Nunavik (Quebec) at 6% (as seen in Figure 13). With the exception of Nunavik, least vaccinated health regions have high PPC vote share which aligns with the findings of our analysis. This is because the PPC are rallying against COVID-19 health restrictions and mandatory vaccine mandates as well as placing a high value on individual freedoms, rights and liberties (Keller, 2021). As a consequence they are attracting support of the unvaccinated or vaccine hesitant minority across Canada, specifically found in the lowest vaccinated health regions. In the Portage-Lisgar and Provencher riding located in the Sante Sud (southern) health region in Manitoba, the PPC had almost 22% and 16% of support respectively, which was second to the Conservatives (Keller, 2021). Further, the PPC also gained 18% votes in Beauce located in Southern Quebec (Luft, 2021). These examples show us that PPC votes were smallest in densely populated urban ridings and highest in rural or suburban ridings, where residents largely opposed COVID-19 health guidelines and vaccine mandates (Keller, 2021). From our descriptive analysis, we see a pattern where health regions that indicate average to above average sense of belonging have low vaccination rates – contradicting our initial hypothesis that high sense of belonging to local community positively correlates with high vaccination – and this is most likely because of high PPC vote share at the national level in the corresponding health regions.

7 Discussion and Conclusion

Our paper evaluated potential sources of vaccine hesitancy across health regions in Canada and its effect on mortality. We were able to conclude that sense of belonging has a strong positive correlation ($p < 0.05$) to vaccination rates at the community level (micro analysis) while PPC vote share has a negative correlation ($p < 0.05$) to vaccination rates at the national level (macro analysis). Using the instrumental variable approach, we isolated the impact of sense of belonging on vaccination uptake while controlling for immigration status, age, health, income and rurality. Through this approach, it is interesting to see that among ethnic groups like Mennonites and Indigenous communities there is a high sense of belonging at the community level but low vaccination rates, and and that vaccine hesitancy is mainly fueled by institutional distrust i.e., low trust in governments and public institutions based on past experiences. Low trust in public institutions leads to low confidence in public health regulations and government operations that drive particular communities to be skeptical of COVID-19 mandates and vaccination. Our research complements Dalla Lana School of Public Health's assistant professor Akwatu Khenti's statement, "There are a lot of challenges in combating vaccine hesitancy, but the biggest one is trust deficit and institutions have not made a sustained effort to earn community trust." (Wang, 2021)

Encouraging vaccination is much more nuanced than regular marketing, especially to people who have low trust in the government. It is a belief-behaviour change that requires much more fundamental issues to be addressed. Many countries in Africa and India have adopted celebrity-led campaigns, songs and films that address roots of vaccine hesitancy (UNICEF, 2021). Learning from this, Canadian provincial and local governments should identify vaccine programs and initiatives that can better connect with least vaccinated communities. A community or social group-centred policy approach is likely to be the most effective. Specifically, developing culturally sensitive education materials in various languages and for various literacy levels. Second, engaging influential leaders to promote vaccination in their community can be another effective tool. On the community-level, a stronger sense of belonging does positively correlate with vaccination rates, therefore this strategy would be most effective in increasing vaccination rates, especially in rural and remote communities where local leaders have more influence than federal authorities. Third, integrating technology in mass appeal efforts and developing online campaigns that address myths and conspiracy theories. This includes encouraging people to read published scientific articles on the effectiveness of vaccines. Finally, focus vaccination efforts on politically and religiously motivated groups that are more susceptible to conspiracy theories and misinformation by addressing their concerns with scientific facts.

For further research, including data from the Maritime provinces and Saskatchewan is important while assessing vaccine hesitancy across Canada. Since the Maritime provinces and Saskatchewan do not publish data at the health region level, this is a challenge. Moving forward, we should consider performing analysis at the riding, provincial or other level common to all provinces and territories to keep our research uniform. We can also update our analysis as newer data becomes available, for example from the 2021 Census data, the next available CCHS dataset, or any other micro-level data on COVID-19 and trust.

Further, while sense of belonging is one of the instruments for analyzing socio-cultural indicators of vaccine hesitancy there are other important indicators, like political affiliation, that have been introduced in our paper but should be studied in-depth specifically across different parties and political ideologies. Race, religion, literacy and trust in institutions are other factors that are likely to influence one's decision to get vaccinated. For instance, a critical area for future research on policy application is the role of media content in fostering trust in the government's and other institutions, as well as fostering trust in vaccines. These factors will help public health officials understand the root cause of vaccine hesitancy and take appropriate measures to improve vaccination levels, bringing us one step closer towards the end of the COVID-19 pandemic.

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9 Appendix

	Dependent variable:	
	H1N1 Shot (2010)	
	OLS	*logistic*
	(1)	(2)
Sense of belonging	0.052*** (0.005)	0.233*** (0.021)
Immigrant	−0.035*** (0.006)	−0.157*** (0.028)
20,000-39,999	0.041*** (0.008)	0.188*** (0.035)
40,000-59,999	0.063*** (0.008)	0.283*** (0.036)
60,000-79,999	0.089*** (0.008)	0.402*** (0.038)
80,000+	0.141*** (0.008)	0.630*** (0.034)
Age 15-17	−0.064*** (0.015)	−0.273*** (0.066)
Age 18-19	−0.201*** (0.018)	−0.891*** (0.082)
Age 20-24	−0.230*** (0.014)	−1.040*** (0.063)
Age 25-29	−0.169*** (0.013)	−0.741*** (0.057)
Age 30-34	−0.108*** (0.013)	−0.462*** (0.057)
Age 35-39	−0.069*** (0.013)	−0.295*** (0.056)
Age 40-44	−0.089*** (0.013)	−0.379*** (0.057)
Age 45-49	−0.111*** (0.013)	−0.479*** (0.058)
Age 50-54	−0.073*** (0.013)	−0.311*** (0.055)
Age 55-59	0.0001 (0.012)	0.003 (0.054)
Age 60-64	0.051*** (0.012)	0.225*** (0.055)
Age 65-69	0.104*** (0.013)	0.460*** (0.057)
Age 70-74	0.147*** (0.014)	0.651*** (0.061)
Age 75-79	0.159*** (0.014)	0.702*** (0.064)
Age 80+	0.182*** (0.014)	0.804*** (0.062)
Prince Edward Island	−0.094*** (0.021)	−0.452*** (0.095)
Nova Scotia	−0.096*** (0.016)	−0.463*** (0.076)
New Brunswick	−0.083*** (0.016)	−0.405*** (0.076)
Quebec	−0.082*** (0.013)	−0.399*** (0.062)
Ontario	−0.324*** (0.013)	−1.448*** (0.061)
Manitoba	−0.275*** (0.015)	−1.235*** (0.070)
Saskatchewan	−0.213*** (0.015)	−0.973*** (0.070)
Alberta	−0.313*** (0.014)	−1.397*** (0.066)
British Columbia	−0.325*** (0.014)	−1.453*** (0.065)
Yukon	−0.066*** (0.018)	−0.332*** (0.083)
Constant	0.638*** (0.017)	0.624*** (0.080)
Observations	50,082	50,082
R^2	0.103	
Adjusted R^2	0.102	
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 6: Full regression table for H1N1 analysis

	Dependent variable:	
	Seasonal Flu Shot (2017-18)	
	OLS	*logistic*
	(1)	(2)
Sense of belonging	0.020*** (0.003)	0.091*** (0.014)
Immigrant	−0.057*** (0.004)	−0.250*** (0.018)
20,000-39,999	−0.003 (0.006)	−0.017 (0.027)
40,000-59,999	0.018*** (0.006)	0.082*** (0.027)
60,000-79,999	0.030*** (0.006)	0.140*** (0.028)
80,000+	0.079*** (0.005)	0.352*** (0.024)
Age 15-17	0.001 (0.011)	0.005 (0.047)
Age 18-19	−0.006 (0.014)	−0.016 (0.059)
Age 20-24	−0.023** (0.010)	−0.084* (0.045)
Age 25-29	−0.037*** (0.010)	−0.142*** (0.042)
Age 30-34	0.005 (0.009)	0.026 (0.041)
Age 35-39	−0.001 (0.010)	0.003 (0.041)
Age 40-44	0.012 (0.010)	0.054 (0.042)
Age 45-49	−0.003 (0.010)	−0.005 (0.042)
Age 50-54	0.001 (0.009)	0.010 (0.041)
Age 55-59	0.026*** (0.009)	0.113*** (0.040)
Age 60-64	0.093*** (0.009)	0.402*** (0.040)
Age 65-69	0.172*** (0.009)	0.756*** (0.040)
Age 70-74	0.245*** (0.010)	1.129*** (0.043)
Age 75-79	0.288*** (0.010)	1.374*** (0.049)
Age 80+	0.330*** (0.010)	1.645*** (0.049)
Prince Edward Island	0.113*** (0.014)	0.502*** (0.063)
Nova Scotia	0.188*** (0.011)	0.882*** (0.051)
New Brunswick	0.092*** (0.012)	0.404*** (0.053)
Quebec	−0.048*** (0.009)	−0.202*** (0.040)
Ontario	0.104*** (0.009)	0.462*** (0.039)
Manitoba	0.025** (0.011)	0.108** (0.047)
Saskatchewan	0.076*** (0.011)	0.333*** (0.049)
Alberta	0.090*** (0.010)	0.393*** (0.042)
British Columbia	0.071*** (0.009)	0.312*** (0.042)
Yukon	0.157*** (0.018)	0.698*** (0.083)
Northwest Territories	0.137*** (0.018)	0.598*** (0.080)
Nunavut	0.091*** (0.020)	0.394*** (0.087)
Constant	0.415*** (0.013)	−0.397*** (0.056)
Observations	106,177	106,177
R^2	0.072	
Adjusted R^2	0.071	
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 7: Full regression table for flu micro-analysis

	Dependent variable:	
	Full Defier Set	
	OLS	*logistic*
	(1)	(2)
Sense of belonging	0.023*** (0.007)	0.099*** (0.032)
Immigrant	−0.041*** (0.010)	−0.176*** (0.046)
20,000-39,999	0.007 (0.014)	0.020 (0.063)
40,000-59,999	0.016 (0.014)	0.069 (0.063)
60,000-79,999	0.030** (0.015)	0.132** (0.064)
80,000+	0.075*** (0.013)	0.327*** (0.056)
Age 15-17	−0.003 (0.024)	−0.013 (0.101)
Age 18-19	−0.021 (0.030)	−0.079 (0.126)
Age 20-24	−0.027 (0.023)	−0.103 (0.098)
Age 25-29	−0.005 (0.021)	−0.015 (0.090)
Age 30-34	0.018 (0.021)	0.078 (0.088)
Age 35-39	−0.001 (0.021)	0.003 (0.089)
Age 40-44	0.017 (0.021)	0.073 (0.090)
Age 45-49	−0.013 (0.021)	−0.048 (0.090)
Age 50-54	−0.014 (0.021)	−0.051 (0.087)
Age 55-59	0.034* (0.020)	0.145* (0.085)
Age 60-64	0.098*** (0.020)	0.414*** (0.086)
Age 65-69	0.175*** (0.020)	0.762*** (0.087)
Age 70-74	0.237*** (0.021)	1.068*** (0.094)
Age 75-79	0.291*** (0.022)	1.378*** (0.105)
Age 80+	0.317*** (0.022)	1.530*** (0.103)
Mantiba	−0.121*** (0.010)	−0.534*** (0.044)
Alberta	−0.055*** (0.008)	−0.249*** (0.037)
British Columbia	−0.068*** (0.009)	−0.306*** (0.039)
Nunavut	−0.017 (0.019)	−0.089 (0.084)
Constant	0.517*** (0.022)	0.070 (0.095)
Observations	22,247	22,247
R^2	0.056	
Adjusted R^2	0.055	
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 8: Full regression table for Defiers flu analysis

	Dependent variable:	
	Reduced Defier Set	
	OLS	*logistic*
	(1)	(2)
Sense of belonging	0.028^{**} (0.013)	0.120^{**} (0.056)
Immigrant	-0.043^{**} (0.017)	-0.184^{**} (0.073)
20,000-39,999	0.046 (0.028)	0.196 (0.122)
40,000-59,999	0.016 (0.028)	0.067 (0.121)
60,000-79,999	0.036 (0.029)	0.155 (0.123)
80,000+	0.113^{***} (0.025)	0.479^{***} (0.109)
Age 15-17	−0.023 (0.041)	−0.094 (0.173)
Age 18-19	0.028 (0.051)	0.121 (0.215)
Age 20-24	−0.064 (0.040)	−0.255 (0.168)
Age 25-29	−0.022 (0.037)	−0.088 (0.154)
Age 30-34	0.009 (0.035)	0.040 (0.147)
Age 35-39	−0.004 (0.036)	−0.013 (0.151)
Age 40-44	0.004 (0.037)	0.019 (0.154)
Age 45-49	−0.048 (0.037)	−0.190 (0.154)
Age 50-54	-0.082^{**} (0.036)	-0.334^{**} (0.152)
Age 55-59	0.017 (0.035)	0.075 (0.147)
Age 60-64	0.072^{**} (0.035)	0.302^{**} (0.149)
Age 65-69	0.138^{***} (0.036)	0.588^{***} (0.152)
Age 70-74	0.212^{***} (0.038)	0.937^{***} (0.166)
Age 75-79	0.260^{***} (0.040)	1.192^{***} (0.185)
Age 80+	0.281^{***} (0.039)	1.295^{***} (0.178)
Alberta	0.123^{***} (0.017)	0.521^{***} (0.071)
Constant	0.333^{***} (0.042)	-0.719^{***} (0.178)
Observations	7,175	7,175
R^2	0.054	
Adjusted R^2	0.051	
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 9: Full regression table for Reduced defiers flu analysis