An uneven recovery: Measuring COVID-19 vaccine equity in Ontario

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Table of Contents

Introduction

A recent report released by the Institute for Clinical and Evaluative Sciences (ICES) demonstrated a serious inequity in the rollout of COVID-19 vaccines. Areas of Ontario with the highest cumulative incidence of COVID-19 are the areas with the lowest levels of vaccination.[1]

This finding has received widespread media attention,[2–4] and suggests that social inequalities in Ontario are driving who gets vaccinated and who does not.

This paper quantifies inequities in vaccination within Ontario, displaying a baseline to help monitor our progress towards vaccine equity.

This paper will ask three questions:

> *1) How unevenly are vaccinations distributed across the province?*
> *2) How much of a discrepancy is there between cumulative COVID-19 rates and vaccination rates at the neighbourhood level?*
> *3) What demographics are associated with vaccination at the neighbourhood level, and do these demographics interact with COVID-19 rates to predict vaccination rates?*

Methods

Data and measures

The data used for this analysis were downloaded from the Institute for Clinical and Evaluative Sciences' (ICES) COVID-19 dashboard on April 7, 2021. They cover the period from December 14, 2020 to March 27, 2021.[1] ICES data gives the proportion of people living in a neighbourhood (excluding long-term care) that have ever tested positive for COVID-19 and the proportion of the population that has received at least one dose of any COVID-19 vaccine.

The first three characters of a Canadian postal code (the forward sortation area) were used to define each neighbourhood. Data on neighbourhood demographics came from the 2016 Canadian census.

Analytic approach

This paper uses the *Index of Dissimilarity* [5–8] to measure how unevenly vaccinations are distributed across neighbourhoods. It produces a number ranging from 0 to 1, which shows the proportion of the population that would have to be relocated to create a completely even distribution (a score of .50 would mean that half the population would have to be relocated). That is, it shows how much of the population would have to be moved around to obtain evenness.

This paper uses the Index of Dissimilarity first to show how unevenly vaccines are distributed across Toronto neighbourhoods (question 1) and then investigates how well vaccination rates match the cumulative COVID-19 burden (question 2).

Generalized Linear Models were used to analyze what demographics are associated with vaccination at the neighbourhood level and whether these demographics interact with COVID-19 burden to predict

vaccination rates. Since this outcome is bounded at 0 and 1, the models employ a logit link function. Results are given in odds ratio format, and all predictor variables are standardized to have a mean of 0 and a standard deviation of 1. Models predict vaccination rates using COVID-19 rates, per cent low-income after tax (LICO-AT), per cent over 65, region, per cent South Asian, per cent Black, per cent Chinese, per cent South East Asian, and per cent Latin American. Models also test for interactions between COVID-19 burden and region, as well as LICO-AT and region. The analysis focuses on specific racialized groups as the three largest visible minority groups in Ontario (Chinese, Black, South Asian) and those that have experienced especially high rates of COVID-19 infection.[9] The LICO-AT measure was chosen for comparability to other projects on neighbourhood economic disadvantage in Ontario,[10] as well as because the LICO takes into account costs of living (i.e. food, shelter, and clothing) that may have been negatively impacted under the recent economic downturn.[11] The robustness of findings were checked using the Low-Income Measure-After Tax (LIM-AT), as an alternative measure of poverty.[12] The data did not provide the market basket measure for further comparison.

Results

1) How unevenly are vaccines being distributed across the province?

The Index of Dissimilarity gave a sense of what proportion of vaccinations would have had to be redistributed for a completely even distribution across the province. Table 1 gives the Dissimilarity scores first for Toronto ('M' postal codes), then areas around Toronto ('L' codes) and all other Part of Ontario (all else).

Table 1. The unevenness of vaccine distribution.

	Toronto ('M' postal codes)	Around Toronto ('L' postal codes)	All else
Index score	0.12	0.13	0.14

The results show that vaccination coverage is fairly even across Ontario neighbourhoods. Between 12-15 per cent of vaccinations would need to be redistributed for an even distribution across neighbourhoods.

2) How much of a discrepancy is there between COVID-19 rates and vaccination at the neighbourhood level?

An even distribution may not meet the needs of different neighbourhoods in Ontario because they have different cumulative rates of COVID-19. If the Index of Dissimilarity is used to investigate the difference between COVID-19 rate and vaccination rates, there is a starker difference between neighbourhoods. There is about double (approximately 2.2 times) the difference between vaccination rates and need for vaccinations measured by COVID-19 infection rates, and this *discrepancy* is relatively similar across region, according to the Index of Dissimilarity.

However, the results from Table 2 do not reflect the full story on the negative correlation between COVID-19 rates and vaccination by region. A simple calculation of covariance shows that the covariance between COVID-19 rates and vaccination is -3.86 in Toronto, -1.68 in the surrounding areas, and 0.26 in all other areas. This means that for every per cent difference in COVID-19 rates, *the expected difference*

in vaccination is about four per cent lower in Toronto and about a quarter of a per cent higher outside of the GTA.

This could be the result of other demographic factors, such as age structure. The next section addresses this with a multivariable analysis.

Table 2. The dissimilarity between vaccination rates and cumulative COVID-19 rates by area.

	Toronto ('M' postal codes)	Around Toronto ('L' postal codes)	All else
Index score	0.29	0.30	0.27

3) What demographics are associated with vaccination rates at the neighbourhood level, and do these demographics interact with cumulative COVID-19 rates?

When considering Ontario as a whole, cumulative COVID-19 rates in a neighbourhood were positively associated with vaccination rates once poverty rates, age composition, and racialized groups were taken into consideration. The 'M' postal codes had overall higher rates of vaccination compared to other regions. Per cent of South Asian, Black, and Latin American were associated with lower rates of vaccination. Per cent aged 65 and older was associated with higher rates of vaccination. All other associations were insignificant. See Model 1 in Table A1, in the appendix.

However, some of these associations varied by region. Figure 1 shows that in Toronto, and to a lesser extent in the neighbourhoods around Toronto, there is a negative association between COVID-19 rates and vaccination – a seeming mismatch between need and supply. However, in the rest of Ontario, the association is slightly positive; areas that have been hardest-hit by COVID-19 are those that have the highest vaccination rates. There is also a significant interaction between region and neighbourhood poverty (Figure 2), as well as between racial demographics and region (Figure 3). See Tables A1 and A2 in the appendix for regression results.

This paper also checked that the findings for LICO-AT were robust to type of poverty measure. The model was re-run using the low-income measure after tax (LIM-AT), and the models produced very similar results. This was not unexpected since the LICO-AT and LIM-AT were very highly correlated in this dataset (r=0.87, p<.001).

There was also no significant interaction between region and age composition. Areas that had a higher per cent over 65 were more likely to report higher vaccination rates.

Figure 1. The negative association between COVID burden and vaccination is strongest for Toronto.

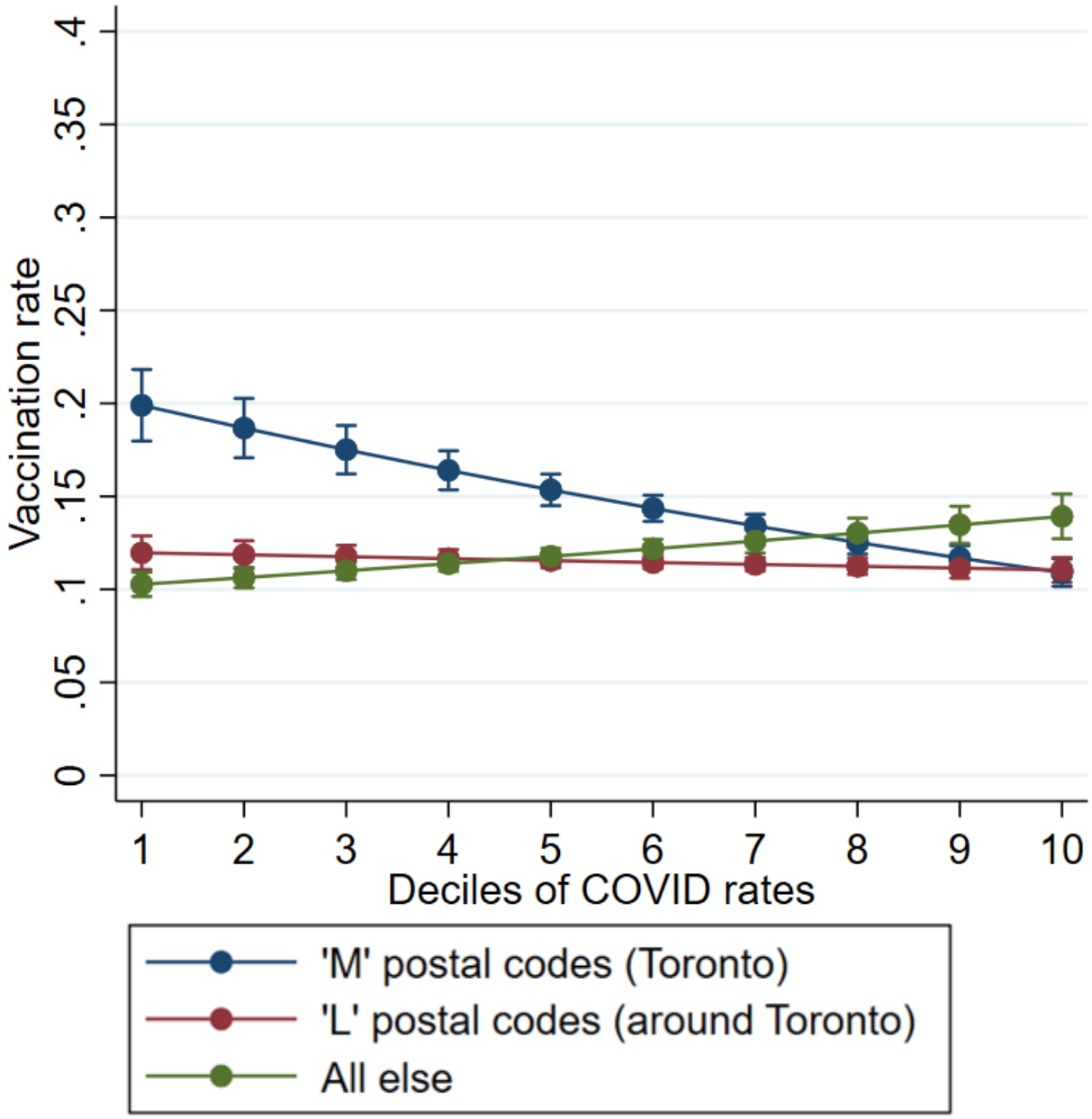


Figure 2. The negative association between neighbourhood poverty (LICO-AT) and vaccination is strongest for Toronto.

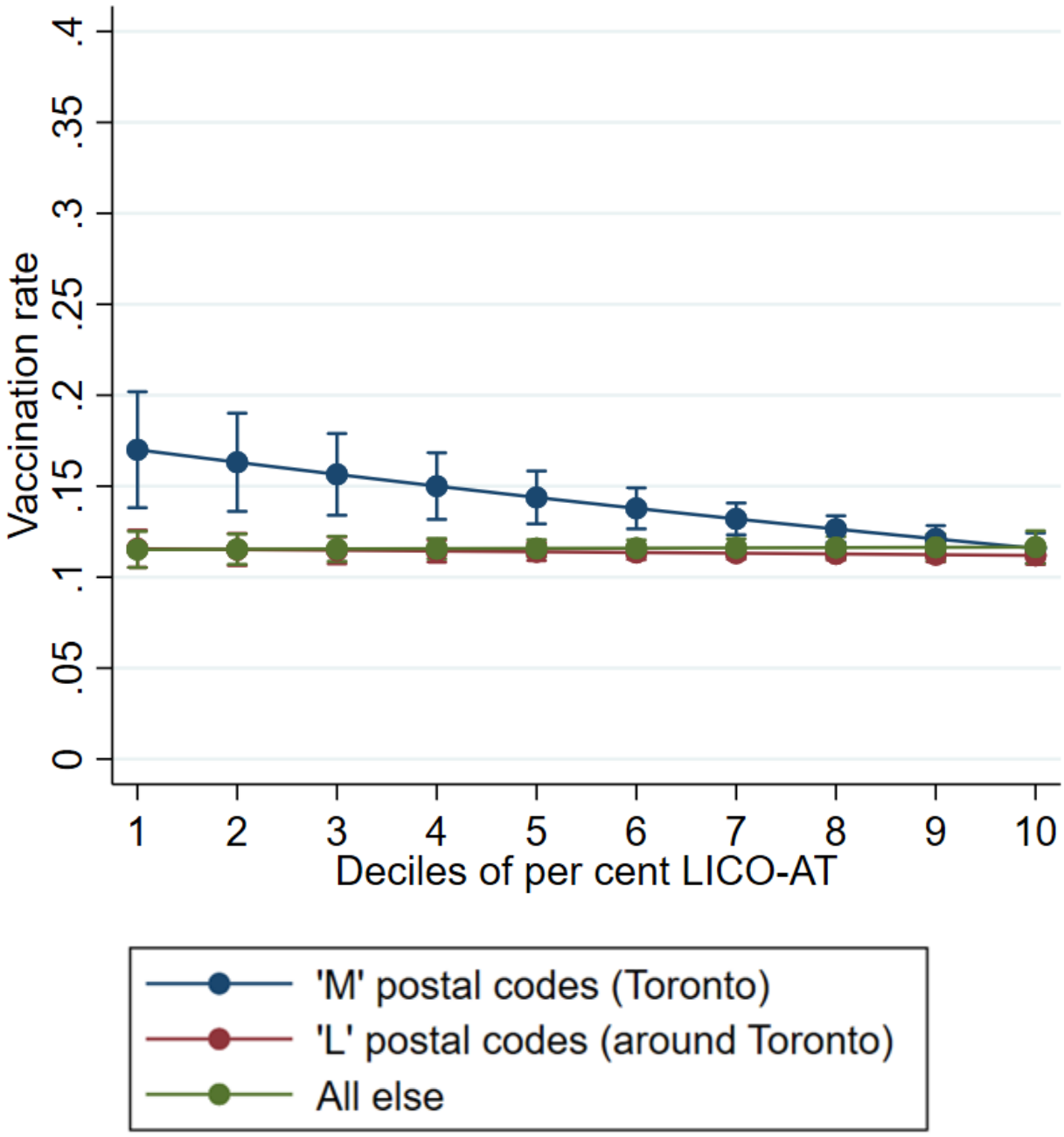
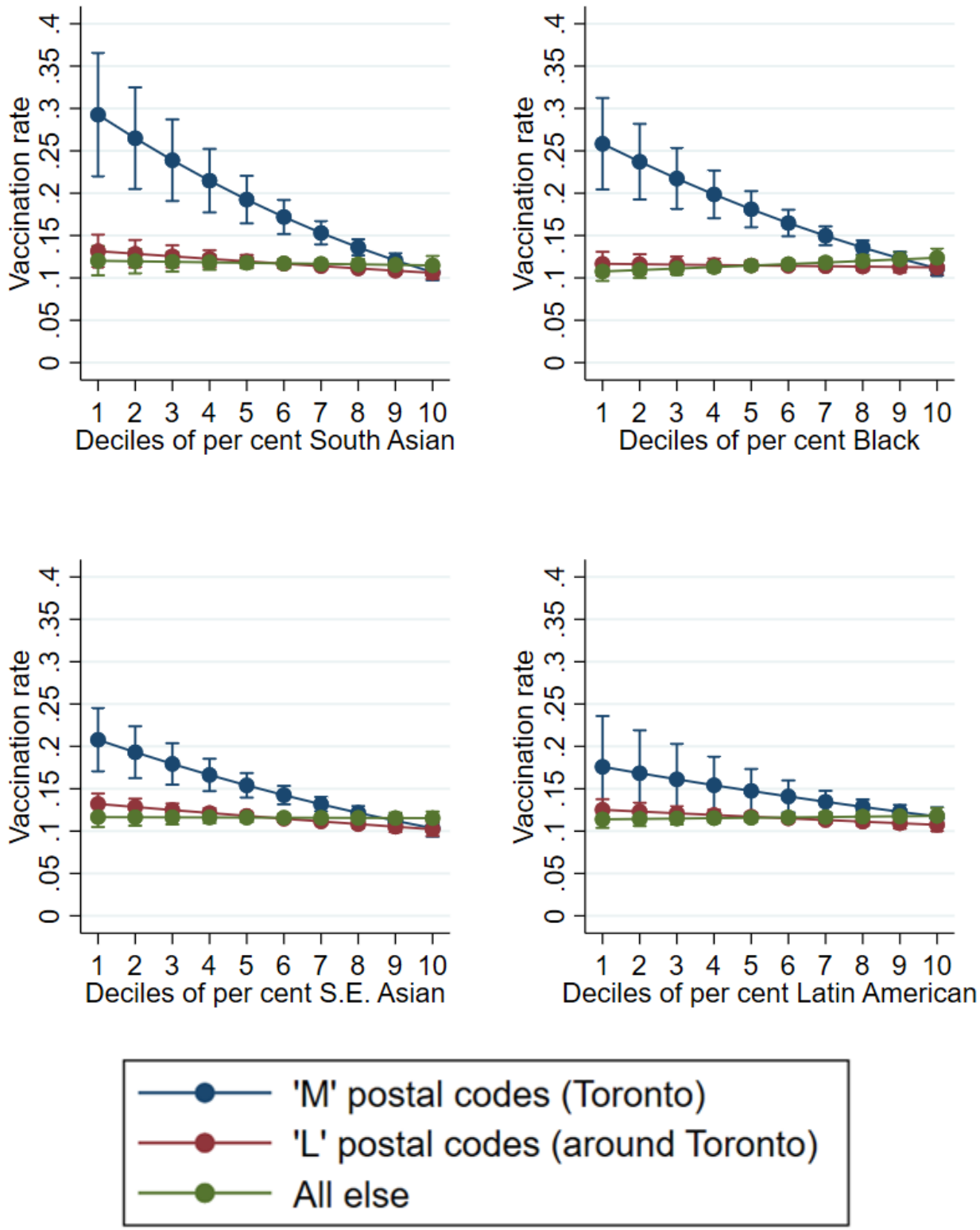


Figure 3. The negative association between various racialized populations and vaccination is strongest for Toronto.



Limitations

This analysis is limited because the measures assume that the two groups being compared are mutually-exclusive, whereas some people may have had COVID-19, and also received the vaccine. More precise estimates would use exclusive categories – and potentially also infection in the past two weeks to calculate exposure of people who are more likely to be currently infectious.

Discussion

These analyses show that Ontario is not concentrating its vaccination efforts in places with the highest rates of illness, and that the province is not distributing vaccines in an equitable way to areas with racialized populations and low-income neighbourhoods. Furthermore, Toronto appears to have distinctly inequitable processes underway, where neighbourhood poverty, racialization, and COVID-19 rates are negatively associated with vaccination rates.

It is unclear whether disadvantage is more harmful in Toronto than in other areas, or whether it is easier for some people to convert their advantages into vaccination in Toronto. It may indeed be a combination of both. However, regardless of this speculation, it is clear that both economic (i.e. neighbourhood poverty) and social (i.e. racialization) status play independent parts in producing inequity. Systemic income inequality, and systemic structural racism are both factors that need to be addressed.

The causes of the regionalized discrepancy between COVID-19 burden and vaccination likely reflects a complex combination of institutional and social factors, including a lack of locations in high-burden areas with the capability to administer the vaccines,[13] inconsistent public health messaging,[14] delays in the rollout of vaccine supplies,[15] and a lack of clear communication to medical professionals.[16] We are capable of managing these challenges and have the resources to close these gaps. Place-based targeting of 'hot spots' for vaccine rollouts are a promising start,[17] but we should also confront social inequities to achieve a rollout that is appropriate to needs. Place-based targeting may also be insufficient if supplies remain inadequate to needs. A future paper will measure our collective progress towards these goals.

APPENDIX: Regression models

Table A1. Generalized linear models predicting rate of vaccination by forward sortation area in Ontario. Results in odds ratios format.

	Model 1	Model 2	Model 3
COVID-19 rate	1.06*	1.17***	1.07**
Per cent LICO-AT	1.00	1.00	1.04
Per cent South Asian	0.94***	0.97*	0.93***
Per cent Chinese	1.00	0.98	1.00
Per cent Black	0.95***	0.97**	0.95***
Per cent South East Asian	0.98	0.97	0.98
Per cent Latin American	0.94***	0.97	0.93***
Per cent aged 65 and older	1.19***	1.22***	1.20***
Region (Ref. = all else)			
'M' postal codes (Toronto)	1.37***	1.36***	1.51***
'L' postal codes (around Toronto)	1.05	0.98	1.03
Interaction terms			
'M' codes and COVID-19 burden		0.78***	
'L' codes and COVID-19 burden		0.86***	
'M' codes and per cent LICO-AT			0.85***
'L' codes and per cent LICO-AT			0.99
N	512	512	512

Note: * p<0.05, ** p<0.01, *** p<0.001

Table A2. Generalized linear models predicting rate of vaccination by forward sortation area in Ontario. Results in odds ratios format.

	Model 4	Model 5	Model 6	Model 7
COVID-19 rate	1.07*	1.07*	1.07*	1.07**
Per cent LICO-AT	1.00	1.00	1.00	1.00
Per cent South Asian	0.94***	1.12	0.93***	0.93***
Per cent Chinese	1.11	0.99	1.00	0.99
Per cent Black	0.95***	0.95***	0.95***	0.95***
Per cent South East Asian	0.97	0.96**	1.00	0.98
Per cent Latin American	0.93***	0.93***	0.95**	0.98
Per cent aged 65 and older	1.20***	1.21***	1.20***	1.20***
Region (Ref. = all else)				
'M' postal codes (Toronto)	1.40***	1.40***	1.37***	1.40***
'L' postal codes (around Toronto)	1.02	1.01	1.04	1.04
Interaction terms				
'M' codes and % South Asian	0.80***			
'L' codes and % South Asian	0.86*			
'M' codes and % Chinese		0.87		
'L' codes and % Chinese		0.91		
'M' codes and % SE Asian			0.94*	
'L' codes and % SE Asian			0.97	
'M' codes and % Lat. Am.				0.93*
'L' codes and % Lat. Am.				0.98
N	512	512	512	512

Note: * p<0.05, ** p<0.01, *** p<0.001

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