The geometry of Covid-19

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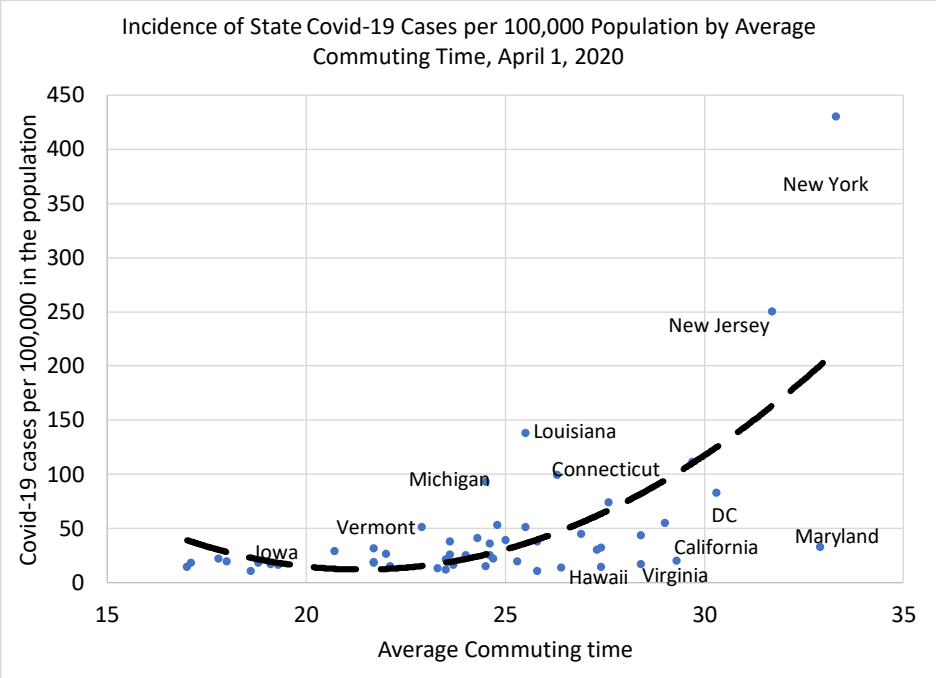
A long time ago in middle school, we learned that the area of circle of radius r was A=πr^2. As a result, when the radius doubles, the area increases by a factor of four. I was reminded of that looking at the map of the number of cases by state. The map illustrated the magnitude of the illness by circles of various sizes. That is an appropriate way to envision the spread of the disease.

Every state has at least one main labor market that aggregates jobs in a relatively small space. Workers access those jobs by commuting from the surrounding area. The bigger the labor market, the greater the radius around the job center filled with commuters. If every commuter takes up the same area of space to live, a radius of 1 has π commuters, a radius of 2 has 4π commuters, a radius of 3 has 9π computers, ….and so on. Suppose that there is a probability, p, that any one commuter has the covid-19 virus. The expected number of infected commuters within radius 1 is $p\pi$. Within radius 2, it is $4p\pi$. Withing radius 3, it is $9p\pi$. All of these commuters are exposed to their own virus sources, and so all of those virus sources converge in the job center. Commuters from places not initially exposed will mix with the exposed commuters from other locations in the circle, and so the virus spreads to all locations in the commuting zone. Hence, the biggest cities are the biggest aggregators of the virus, and their states have the greatest risk of acquiring and spreading the virus.

This simple analysis suggests that there will be a quadratic relationship between virus infection rates and the average length (radius) of commute. The figure shows the simple plot of state covid-19 cases per 100 thousand in the population against state average commuting time. The simple geometrical model of viral infection is apparent.



The average commuting time by state explains 45% of the variation in the rate of viral infections per capita. On average, an additional minute of commuting time results in 9 more cases per 100 thousand as of April 1. That rate will be increasing as the incidence of the disease continues to increase.

While the average commuting time explains a substantial share of the state virus infection rate, it is interesting to see what does not. Whether or how soon a state adopted a 'shelter-in-place' rule did not have a significant effect on the rate of infection. One reason is that even the states that did not adopt the 'shelter in place' rule have made substantial restrictions on mobility. A second is that the early state adopters were all experiencing the worst of the covid-19 illness rates, and so only the least affected failed to adopt. In the end, after controlling for commuting time, state policy made no difference in the per capita case rate as of April 1. Similarly, the age distribution of the population made no difference.

We can show how well or how badly a state is doing relative to the simple disease incidence rate on the graph. States that locate above the line have more incidence than expected based on their commuting rate. Those below are doing better. The commuting zone that includes New York, New Jersey and Connecticut has been hit particularly hard. The commuting zone that includes Maryland, the District of Columbia and Virginia has done better than expected. California and Hawaii have managed to keep the illness rates below expectations, while Vermont, Michigan and Louisiana are much worse. It is possible that sheltering policies made a difference that is just not yet apparent in the data, but it is more likely that the disease hit New York hardest because as the biggest commuting radius, it had the greatest spread of the disease throughout its commuting zone before the contagion became visible in hospitalizations.

I rank the states on how well they have kept the disease rate below the level expected based on their commuting patterns. Negative values indicate disease rates below expectation. States surrounding Iowa include some of the best performers (South Dakota, Illinois, and Minnesota) and some of the worst (Wisconsin and Missouri). Iowa is right in the middle.

Ranking of states by how well they have limited covid-19 infection rates relative to expected rate due to commuting

Rank	State	% Excess incidence	Rank	State	% Excess incidence	Rank	State	% Excess incidence
1	Maryland	-0.84	18	Montana	-0.31	35	Mississippi	0.35
2	California	-0.80	19	Wyoming	-0.26	36	Missouri	0.35
3	Virginia	-0.79	20	Kentucky	-0.24	37	Colorado	0.42
4	Hawaii	-0.77	21	Alabama	-0.21	38	Oklahoma	0.48
5	West Virginia	-0.73	22	Pennsylvania	-0.18	39	New Jersey	0.54
6	Texas	-0.71	23	Oregon	-0.17	40	Arkansas	0.58
7	South Dakota	-0.63	24	Alaska	-0.16	41	Nevada	0.72
8	Nebraska	-0.53	25	Iowa	-0.11	42	Rhode Island	0.86
9	North Dakota	-0.51	26	Kansas	-0.09	43	Indiana	1.00
10	New Hampshire	-0.51	27	South Carolina	-0.06	44	New York	1.02
11	Florida	-0.49	28	Delaware	-0.05	45	Wisconsin	1.10
12	Georgia	-0.47	29	Massachusetts	0.01	46	Connecticut	1.15
13	Arizona	-0.43	30	Washington	0.11	47	Idaho	1.30
14	North Carolina	-0.42	31	New Mexico	0.17	48	Utah	1.58
15	Illinois	-0.42	32	Maine	0.17	49	Vermont	2.35
16	Minnesota	-0.34	33	Ohio	0.18	50	Michigan	2.61
17	District of Columbia	-0.34	34	Tennessee	0.28	51	Louisiana	2.82