Population density index and its use for distribution of covid-19: A case study using Turkish data

Baser, Onur

MEF University, Istanbul, Turkey

22 April 2020

POPULATION DENSITY INDEX AND ITS USE FOR DISTRIBUTION OF COVID-19: A CASE STUDY USING TURKISH DATA

A PREPRINT

Onur Başer, MA, MS, PhD
Professor of Economics, Department of Economics, MEF University, Istanbul, Turkey
Adjunct Professor of Internal Medicine, Medical School, University of Michigan, Ann Arbor, MI
Research Scientist, John. D. Dingell VA Medical Center, Detroit, MI
onur@umich.edu

22 April 2020

ABSTRACT

Since March 2020, Turkey has been experiencing a large outbreak of a novel coronavirus (2019-nCoV). We estimated the population weighted density for each of the 81 cities in Turkey as well as the districts of its three densest cities. Istanbul, a city of 16 million, has a district with a population weighted density more than 5 times higher than New York City, the epicenter of Covid-19 pandemic. By using weighted least squares, we calculated the elasticity of the Covid-19 spread with respect to population weighted density as 0.67. In addition to the density, the proportion of people over 65, the per capita GDP, and the number of total health care workers in each city positively contributed to the case numbers, while education level and temperature had a negative effect. We suggested a policy measure on how to transfer health care workers from different areas to the areas with a possibility of wide spread and rank some of the cities according to their success at minimizing death given their population weighted density.

Introduction

An ongoing outbreak of a novel coronavirus (2019-nCov) was identified only a few days after the World Health Organization (WHO) was alerted about a cluster of pneumonia of unknown aetiology in the city of Wuhan, China on 31 December 2019. [1]. The outbreak appears to have started from a single zoonotic transmission event or multiple zoonotic transmission events at a wet market in Wuhan where game animals and meat were sold [2] and has resulted in 2,501,907 confirmed cases in the world by April 21, 2020. [3].

The start date for the epidemic, total cases, and fatalities were different for each country. As of April 21, 2020, United States is leading with more than 800,000 cases. New York became the epicenter for the disease with more than 250,000 cases. [4] Among the other reasons, what set New York apart from the other cities in USA was its

high population weighted density. The population weighted density can be describes as a weighted average of density across the tracts, where tracts are not weighted by land area but by population. [5]

Density is one of the most fundamental characteristics of an urban area. [6] However, raw population density, simply population divided by count, is not a good measure of the density at which the population lives. [5] Los Angeles is actually denser than New York, but it is hemmed in by mountains, limiting how far the commuting zone can reach. However, according to population weighted density, an average New Yorker lives in a census tract with more than 12,400 people within a kilometer square. That is three times more than the density of Los Angeles County. [7] Especially in pandemies such as coronavirus, where human contact is the main reason for spread, population-weighted densities are better measure than conventional densities, because the variation in density across the subareas matters more than the density in total area. As of April 21, 2020, New York cases were close to 20 times more than the cases in Los Angeles County. [4]

The aim for this paper was first to derive population weighted density for the cities in Turkey and the districts for its major three cities. Then we analyzed the relationship with the density and the spread of coronavirus in those cities controlling for cities' education level, wealth, health care force, temperature, and demographics. Combining with information about its number of its health care workers and fatality statistics, we extend the use of population weighted density to measure the cities' success of ongoing policies and to help as how to transfer the health care force from low spread risk cities to high spread risk cities.

Population Weighted Density in Turkey

Let D be the density of the urban area, which is the total population, P divided by the total area A:

$$D = \frac{P}{A}$$

Let p_i is the population and a_i is the area of subareas, by definition $P = \sum p_i$ and $A = \sum a_i$. Therefore the density for each areas is $d_i = \frac{p_i}{a_i}$. Population-weighted density D_p is the mean of the subareas densities weighted by the population of the subareas:

$$D_p = \frac{1}{P} \sum p_i d_i.$$

Ottensmann [8] showed that the difference between population-weighted density and conventional density is a simple function of the variance in density across the census subareas and conventional density. Craig [5] suggested the amount of differences will depend on the variation in density across the subareas. We would expect similar results for the areas that have been defined in such a ways that they do not include sparsely settled territory. In the USA, this measure has been part of the national statistics since 2010, but it has not been used yet in Turkey.

By using population values from the Turkish Statistical Institution and area values from several websites that use Google Earth, we calculated population weighted density for each city in Turkey. [9] Table 1 shows the ranking and the value for population weighted density for each of the 81 cities in Turkey as well as the ranking of population and raw density population.

Istanbul, with a population of more than 15 million, was ranked as the first city according to population weighted index. On average, residents in Istanbul live with $16,757$ people around their 1 kilometer square. Izmir was the second dense population in Turkey according to population weighted index, although it is in third place when it

Table 1: Ranking of Cities in Turkey by Population Weighted Density

Ranking	City	Population-Weighted Density	Population	Raw Density	Ranking	City	Population-Weighted Density	Population	Raw Density
1	Istanbul	16757.0	1	1	42	Kahramanmaraş	129.0	18	33
2	Izmir	3911.0	3	3	43	Edirne	127.5	48	36
3	Ankara	2470.0	2	8	44	Muğla	126.9	24	34
4	Kocaeli	1916.0	10	2	45	Afyonkarahisar	124.6	31	55
5	Bursa	1903.0	4	7	46	Bartın	121.9	74	31
6	Antalya	1586.0	5	20	47	Karabük	119.8	68	44
7	Adana	1016.0	6	12	48	Adıyaman	119.0	33	30
8	Samsun	727.0	16	16	49	Erzurum	118.6	30	70
9	Yalova	694.0	65	4	50	Uşak	117.1	52	37
10	Gaziantep	685.0	9	5	51	Bolu	95.1	59	65
11	Trabzon	684.0	27	11	52	Çanakkale	93.1	39	49
12	Tekirdag	603.0	23	13	53	Kırklareli	92.6	54	47
13	Mersin	568.0	11	21	54	Iğdır	86.0	75	48
14	Batman	545.0	35	18	55	Çorum	79.4	41	61
15	Sakarya	535.0	22	9	56	Niğde	78.9	53	57
16	Hatay	495.0	13	6	57	Erzincan	75.9	70	79
17	Diyarbakir	479.0	12	22	58	Bilecik	75.2	71	53
18	Kayseri	471.0	15	32	59	Tokat	74.5	34	42
19	Denizli	433.0	21	28	60	Amasya	73.4	57	43
20	Kirikkale	336.0	54	45	61	Kütahya	73.0	38	58
21	Rize	318.0	56	27	62	Aksaray	71.5	47	54
22	Eskisehir	283.0	25	41	63	Sivas	70.6	32	78
23	Ordu	278.0	30	19	64	Sinop	68.5	72	46
24	Aydin	264.0	20	17	65	Kırşehir	66.7	69	67
25	Duzce	262.0	50	15	66	Ağrı	63.9	40	59
26	Malatya	260.0	28	38	67	Bingöl	62.9	64	68
27	Zonguldak	247.0	36	10	68	Artvin	60.0	76	76
28	Osmaniye	218.0	40	14	69	Muş	56.2	49	60
29	Isparta	213.0	45	56	70	Bitlis	51.2	55	62
30	Manisa	181.0	14	23	71	Burdur	50.7	65	66
31	Giresun	178.0	44	40	72	Kastamonu	49.4	51	72
32	Kilis	166.0	78	25	73	Çankırı	42.5	73	75
33	Konya	165.0	7	50	74	Karaman	42.2	67	71
34	Şırnak	161.4	43	35	75	Hakkari	41.3	63	63
35	Van	160.1	19	52	76	Yozgat	36.0	46	69
36	Balıkesir	160.1	17	29	77	Kars	35.9	61	73
37	Siirt	158.3	58	46	78	Gümüşhane	27.2	77	74
38	Elazığ	152.8	37	39	79	Ardahan	24.2	79	80
39	Nevşehir	145.8	60	53	80	Bayburt	23.5	81	77
40	Şanlıurfa	142.9	8	24	81	Tunceli	20.4	80	81
41	Mardin	141.7	26	26					

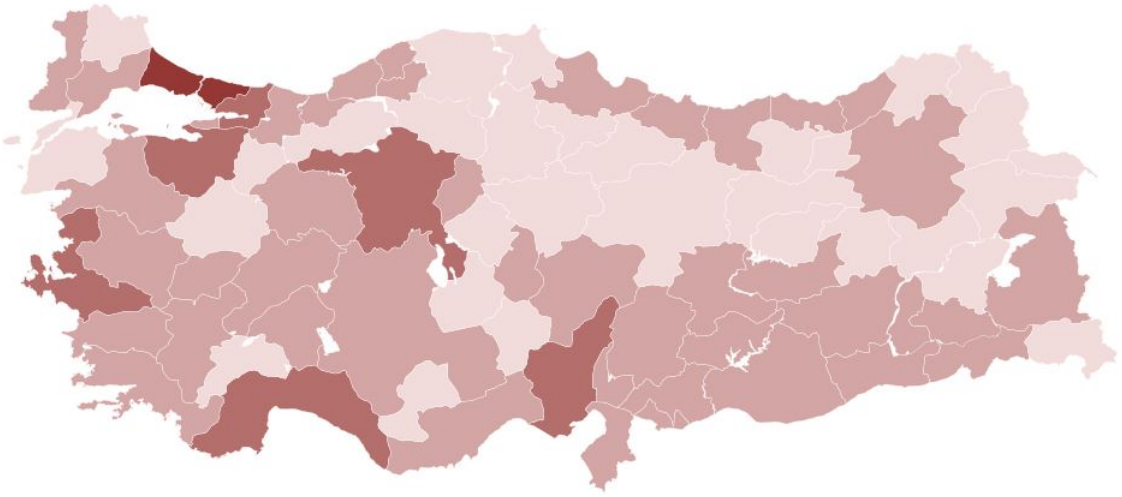


Figure 1: Population Weighted Density Map for Turkey

comes to population and raw density. Ankara was the third dense population, although according to raw density it was as eighth.

We can see how population weighted density has a different ranking than raw density depending on how density of subareas are changed between the cities. For example, Adana has a higher rank than Tekirdağ in terms of population weighted density, although they are very similar according to their raw densities. So, for pandemics such as coronavirus, Adana would be riskier than Tekirdağ in terms of spread of the disease.

Population rankings are also different. Şanlıurfa and Gaziantep are very similar in terms of their population, but the ranking of Şanlıurfa is 40 and Gaziantep is 9 out of the 81 cities according to their population density measures.

Samsun is the 16th city both according to population and population density but its ranking is calculated as 8th according to population density index. In Turkey, we can see that Gümüşhane, Ardahan, Bayburt and Tunceli have the lowest population weighted density.

We also created a population weighted index for each of the subareas in the mostly dense cities, in particular Istanbul, Izmir, and Ankara. By looking at each of the districts in these cities, we were able identify the areas with the highest spread risk. Figure 2 shows the population weighted density of map of Turkey.

The most dense area in Istanbul is the Esenler district. Esenler is the 14th biggest district in terms of its population and 11th biggest according to its raw density. It has couple of subareas that are so dense that it comes as first according to population weighted density. For example, one person in Fatih neighborhood in the Esenler district lives with 86,949 people within one kilometer square. With the same measure, a person in Cifte Havuzlar neighborhood in the Esenler district has only 2008 people within one kilometer square. Therefore, variation among the neighborhoods in the Esenler district is huge, and because of this, its population weighted density is highest in Istanbul. For example, Kadikoy and Esenler are similar in terms of their population and raw density, but the change of population densities among the neighborhoods in Esenler is 35 times more than than change of population densities among the neighborhoods in Kadikoy. Esenler is number 1 and Kadikoy is 21 in ranking according to population weighted density index. On average, a person in Esenler lives with 5 times more people around him than New York-the epi center of coronavirus pandemic. Istanbul is contained to total 39 districts, and 29 of these district has a greater population weighted density than New York. Zeytinburnu, Bahçelievler, Güngören, Bağcılar,

Gaziosmanpaşa, Fatih and Esenyurt was among the most highly dense districts according to population weighted density. Çatalca, Şile and Adalar were at the bottom of the list. (Table 2) Population weighted density map of Istanbul is presented at Figure 2a.

In Izmir, Karabağlar is the number one district according to population weighted density index, even though Karabaglar is not number one according to its population nor its raw population density. The population density value for Karabağlar is higher than 68% of Istanbul's districts. Neighborhoods such as Doganar, Esenlik, and Reis have the highest population density. Konak district comes second with Atamer, its highest density neighboorhood. Aliağa is 15th according to its population and 14th in its raw density, but according population weighted density, its the third dense district in Izmir. Bahcedere neighboorhood, housing prison, has the highest density in Aliağa district. The lowest densities are in Seferihisar, Karaburun, Kınık, and Foça.(Table 3) Population weighted density map of Izmir is presented at Figure 2b.

In Ankara, the capital city of Turkey, Keçiören had the highest population density at 23,396. The neighborhoods of Atapark, Kuşcağız, and Yayla have the highest densities in Keçiören district. Çankaya, the number 1 district according to its population, was number 7 according to population weighted density because Çankaya district does not include sparsely settled territory. Mamak and Sincan were the most dense districts, although neither population or raw density justifies that. Bala, Güdül, Haymana, and Evren were the districts with the lowest population weighted density.(Table 4) Population weighted density map of Ankara is presented at Figure 2c.

Relationship between Population Weighted Density and Spread of Corona Virus in Turkey

Turkey's Health Ministry has released only limited data on the spread of the virus and announced the number of Covid-19 cases in individual cities on two occasions, on April 1st and April 4th. [10] Istanbul, a city of 16 million, accounted for 60 percent of confirmed cases of Covid-19. As predicted by population weighted density, Izmir and Ankara have been declared growing hot spots.

For each city, we calculated the difference to proxy for the spread of the disease in each city. There was a strong positive relationship between population weighted density and and the spread of the disease.(Figure 3) Correlation coefficient was calculated as 0.97 with $p - value < 0.0001$.

Risk factors including education and wealth of each city, number of health care workers, proportion of male population to female population, and proportion of people over 65 years old were available from the Turkish Statistical Institution. For each city we calculated the average temperature in Celcius since 1941 and use it as an additional regressor to control for the effect of temperature on spread of the disease. [11]

On average, a person in Turkey lives with 3,868 people within 1 kilometer square. The average education level is around 7.5 years and 9.12% of the population is 65 years old and over. There is a slightly higher male population than female population and the per capita income is $9,745. There are about 1.9 doctors, 2.37 nurses and 2.22 other health care workers per 1000 people in Turkey. (Table 5)

To determine the relationship between these variables and our outcome variable, corona spread, we consider the following model:

$$y_{ij} = \beta_o + \beta_1 x_{1j} + ... + \beta_k x_{kj} + u_{ij},$$

Table 2: Ranking of Districts in Istanbul by Population Weighted Density

Ranking	District	Population Weighted-Index	Ranking by Population	Ranking by Raw Density
1	Esenler	63446.59	14	11
2	Zeytinburnu	58428.67	24	10
3	Bahçelievler	56462.53	6	3
4	Güngören	52238.11	25	1
5	Bağcılar	45610.71	3	4
6	Gaziosmanpaşa	45463.80	10	2
7	Fatih	42360.19	17	7
8	Esenyurt	41066.24	1	12
9	Kağıthane	40649.17	16	6
10	Şişli	39847.57	27	8
11	Sultangazi	37501.50	7	18
12	Beyoğlu	36994.65	33	9
13	Bayrampaşa	33470.04	28	5
14	Küçükçekmece	32392.30	2	14
15	Maltepe	24677.43	9	
16	Ümraniye	23978.15	5	16
17	Eyüpsultan	23528.64	20	31
18	Üsküdar	22591.29	8	17
19	Avcılar	22276.96	15	24
20	Çekmeköy	21785.33	30	32
21	Kadıköy	20287.20	11	13
22	Ataşehir	20226.28	19	15
23	Sancaktepe	18031.19	18	26
24	Kartal	17943.20	12	19
25	Pendik	17573.22	4	28
26	Beşiktaş	16480.12	36	21
27	Sultanbeyli	16175.04	23	20
28	Bakırköy	14619.51	34	25
29	Beylikdüzü	14517.71	21	23
30	Tuzla	8234.88	29	30
31	Arnavutköy	7994.99	26	36
32	Başakşehir	6752.33	13	27
33	Sarıyer	6667.63	22	29
34	Beykoz	6270.48	32	35
35	Büyükçekmece	6182.57	31	33
36	Silivri	4917.78	35	37
37	Adalar	1572.54	39	34
38	Şile	744.20	38	39
39	Çatalca	408.19	37	38

Table 3: Ranking of Districts in Izmir by Population Weighted Density

Ranking	District	Population Weighted-Index	Ranking by Population	Ranking by Raw Density
1	Karabağlar	27643.80	2	4
2	Konak	26943.73	4	1
3	Aliağa	26702.45	15	14
4	Karşıyaka	24836.21	5	3
5	Buca	22229.55	1	6
6	Balçova	17868.97	17	5
7	Bayraklı	17021.08	6	2
8	Bornova	12345.49	3	7
9	Çiğli	10678.91	7	9
10	Gaziemir	10327.90	10	8
11	Kiraz	9447.53	22	25
12	Menemen	9234.96	9	13
13	Narlıdere	7131.91	19	10
14	Ödemiş	5961.90	11	17
15	Torbalı	5054.34	8	12
16	Tire	4995.11	16	21
17	Beydağ	4358.15	29	27
18	Bergama	4198.12	13	28
19	Menderes	3382.30	14	19
20	Güzelbahçe	2303.81	26	11
21	Bayındır	2286.02	24	26
22	Kemalpaşa	1873.43	12	15
23	Urla	1808.40	18	23
24	Selçuk	1559.79	25	22
25	Dikili	1458.11	23	24
26	Çeşme	1310.65	21	16
27	Seferihisar	812.34	20	20
28	Karaburun	722.07	30	30
29	Kınık	487.90	28	29
30	Foça	463.56	27	18

Table 4: Ranking of Districts in Ankara by Population Weighted Density

Ranking	District	Population Weighted-Index	Ranking by Population	Ranking by Raw Density
1	Keçiören	23396.40	2	1
2	Mamak	21388.52	4	5
3	Sincan	21120.95	6	8
4	Yenimahalle	16563.26	3	3
5	Etimesgut	14629.43	5	4
6	Pursaklar	13300.99	8	7
7	Çankaya	13130.60	1	6
8	Gölbaşı	12024.79	9	9
9	Altındağ	10500.30	7	2
10	Polatlı	8876.34	10	14
11	Kahramankazan	5499.81	12	10
12	Kızılcahamam	4155.93	19	16
13	Şereflikoçhisar	3984.82	16	19
14	Beypazarı	3828.65	13	15
15	Akyurt	3312.14	15	11
16	Elmadağ	3292.41	14	13
17	Çubuk	3289.44	11	12
18	Kalecik	1618.78	22	25
19	Nallıhan	1351.73	20	23
20	Çamlıdere	961.08	23	24
21	Ayaş	562.93	21	22
22	Bala	556.92	18	18
23	Güdül	365.12	24	17
24	Haymana	324.10	17	20
25	Evren	96.70	25	21

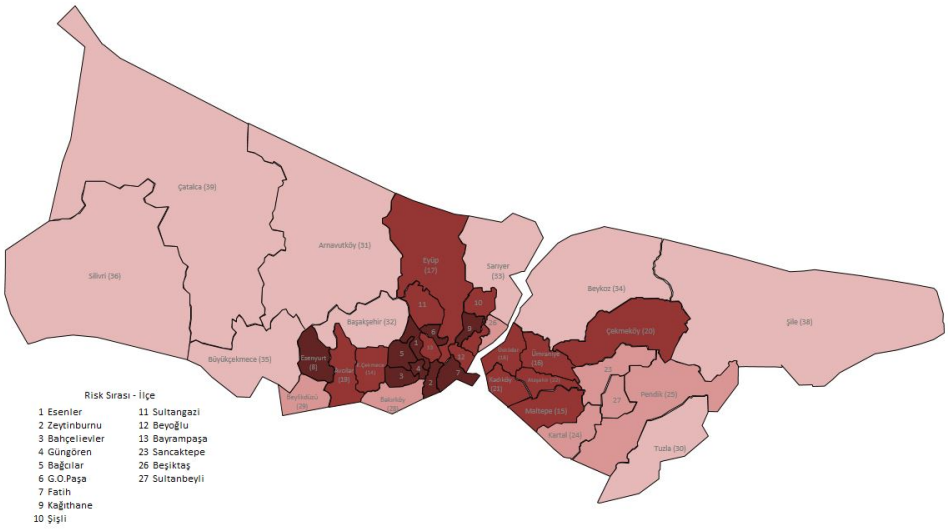
where i indexes n individuals and j indexes m cities. Although y_{ij} varies at the individual level, explanatory variables are at the city level. All of our variables are at the city level. However, note that estimating the model on individuals and clustering standard errors by city would yield the same coefficients and standard errors as estimating city means using analytic weights and standard errors robust to heteroskedasticity. The coefficient $[(k+1) \times 1]$ matrix $\boldsymbol{\beta}$ can be obtained

$$\hat{\boldsymbol{\beta}} = (\tilde{\boldsymbol{X}}'\tilde{\boldsymbol{X}})^{-1}\tilde{\boldsymbol{X}}'\tilde{\boldsymbol{y}},$$

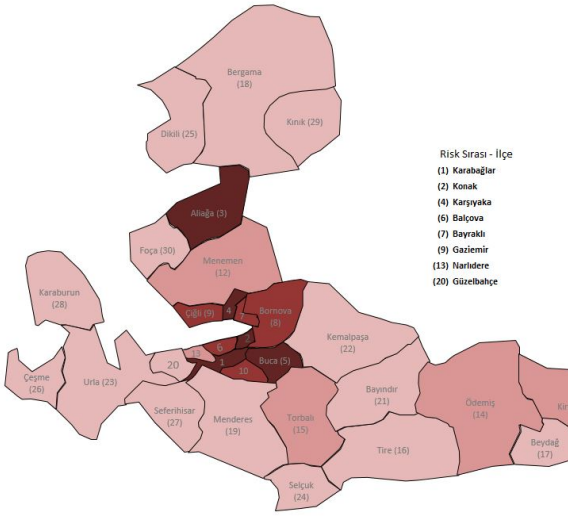
where $\tilde{\boldsymbol{X}}$ and $\tilde{\boldsymbol{y}}$ obtained by multiplying each row of $[n \times (k+1)]$ matrix $\boldsymbol{X}$ and row of $[n \times 1]$ matrix $\boldsymbol{y}$ by $\sqrt{w_j}$, w_j being the number of individuals contributing to the average. For standard errors, the variance-covariance matrix can be calculated as

$$\sum = \frac{1}{(m-(k+1))}\tilde{\hat{\boldsymbol{u}}}'\tilde{\hat{\boldsymbol{u}}}(\tilde{\boldsymbol{X}}'\tilde{\boldsymbol{X}})^{-1},$$

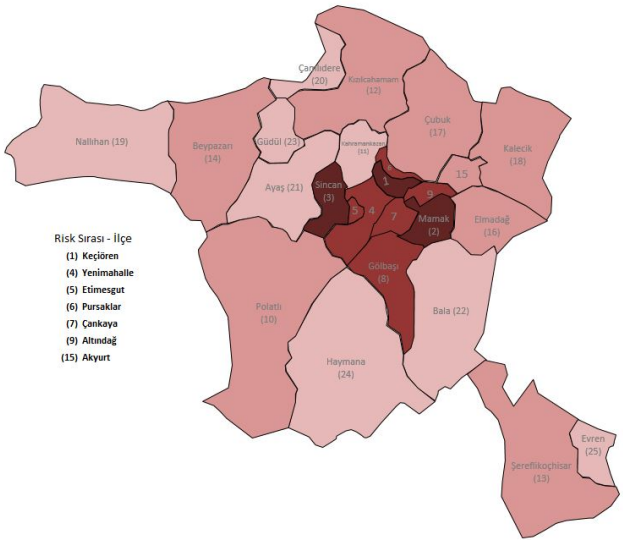
where $\tilde{\hat{\boldsymbol{u}}}$ is equal to row of $[n \times 1]$ matrix $\hat{\boldsymbol{u}}$ multiplied by $\sqrt{w_j}$. [12]



(a) Population Weighted Density for Istanbul



(b) Population Weighted Density for Izmir



(c) Population Weighted Density for Ankara

Figure 2: Population Weighted Density Map for the densest cities in Turkey

After controlling for other factors, weighted regression yield that the elasticity of population weighted density with respect to the growth of coronaspread is calculated as 0.67. (Table 6) 1% increase in population-weighted-density increased the growth of the disease spread by .67%. We found that education and temperature was negatively correlated with the growth of the spread. Cities with higher average education levels associated with lower growth rate of the spread. Each additional year of education contributed to a 45% decrease in the growth rate of the spread. Similarly, cities with higher temperature had lower spread rate. An additional 1 degree celcius decreased the spread rate by 16%. Since the higher health care workers in the city is related with the higher number of testing, we found strong positive correlation between total number of health care workers and the spread of the disease. Cities with 1% higher health care workers were associated with .84% higher disease spread. The proportion of population aged 65 years and older was also positively associated with growth rate of cases. Each percentage point increased the growth rate by 11%. Since Turkey did not restrict the working population to leave their houses, cities with higher per capita GDP were associated with higher number of cases. A 1% point increase in GDP in the cities

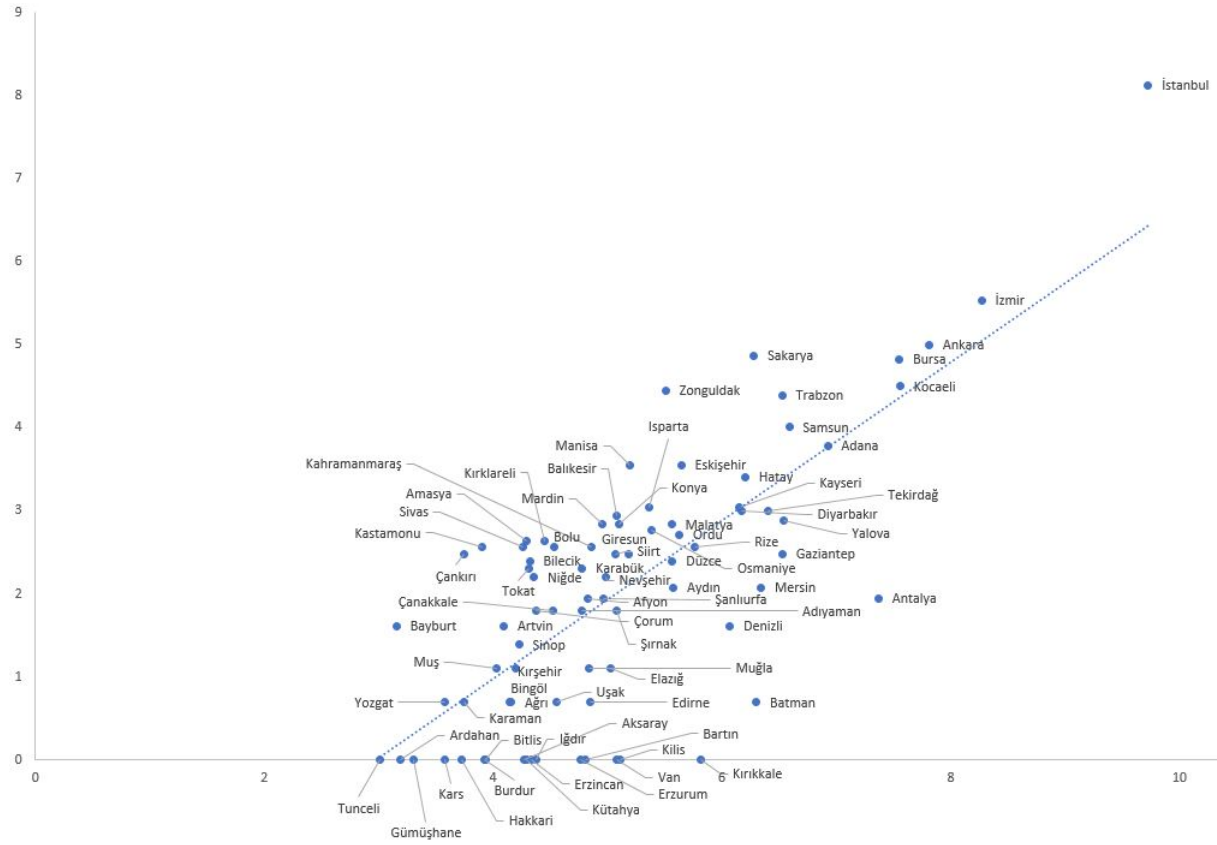


Figure 3: Relationship between Population Weighted Density and the Disease Spread

Table 5: City Characteristics

Demographics	N	Mean	STD	Weighted Mean	Weighted STD
Number of Cities	81				
Population-Weighted-Density		543	1918	3868	6327
Education Level (years)		6.96	.71	7.42	0.96
Temperature(Celcius)		6.70	3.53	7.82	3.02
Doctors		1877	4200	9347	12252
Nurses		2340	4269	9994	12477
Other Health Care Workers		2197	3506	8415	9840
65 and over age		% 10.53	3.58	9.12	3.02
Per capita Income		$7,249	$2,570	$9,745	$4,210
Proportion of Male to Female		1.02	.037	1.01	.02

Table 6: Weighted Regression to Explain Log of Differences in Cases

Variables	Coefficient	Std. Err.	P>|t|
Log (Population-Weighted-Density)	0.67	0.15	0.001
Education	-0.45	0.16	0.007
Log (Total Health Care Workers)	0.85	0.18	0.001
Temperature	-0.16	0.03	0.001
65 and over age	.11	.04	0.005
Log (per capita GDP)	1.12	0.45	0.02
Proportion of Male to Female	4.86	4.08	0.238

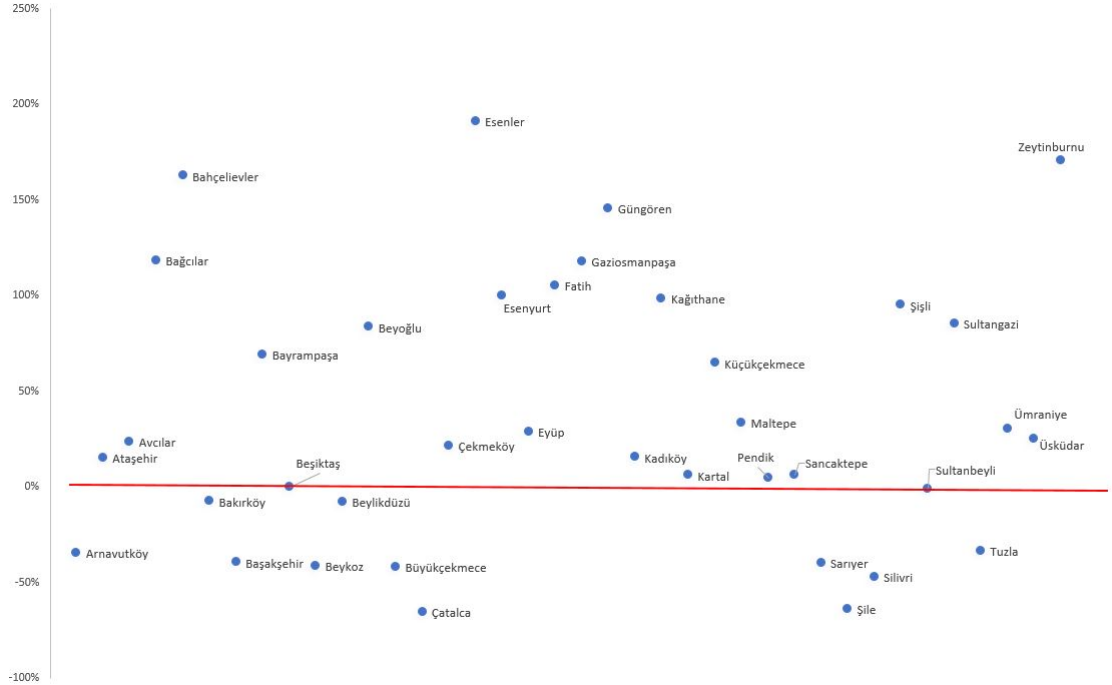


Figure 4: The Expected Percentage increase in district cases in Istanbul relative to Besiktas District.

was associated with a 1.12% increase in the growth rate of the cases. The proportion of male population to female population was not associated with growth rate of the cases. Although the coefficient was positive, i.e. the cities with higher male to female population had higher cases, the variable was not significant. (p=0.238). (Table 6)

For each district in Istanbul, we measured percentage changes in expected cases relative to the district with the average population density. We choose Besiktas district as a reference since population weighted density for district is approximately equal to the density of Istanbul as a whole. For example, Avcilar district's population weighted density is around 10% higher than Kadikoy, so expected cases for Avcilar will be 6.7% higher than Kadikoy. (Figure 4)

Use of Population Weighted Index for Health Policy

In epidemiology, the idea of slowing a virus' spread so that fewer people need to seek treatment at any given time is known as "flattening the curve." The "curve" refers to the projected number of people who will come into contact

with COVID-19 over a period of time. The faster the infection curve rises, the quicker the local health care system gets overloaded beyond its capacity to treat people.

How many people a given patient is likely to infect is defined by the reproductive number. Decreasing this number is the ultimate goal in fighting the pandemic. If it is less than one, then group of infected people would be generating less infection, the curve would flatten, and eventually die down. The reproductive number has four components: *duration, opportunity, transmission probability* and *susceptibility*. [13] The multiplication of each component gives the reproductive number. On average, with COVID-19, *duration* is between 2-10 days estimated by World Health Organization [14] *Opportunity* is a measure of how many people you come into contact with for every day you're infections. *Transmission probability* is a measure of the chance the infection will get across during an interaction and *susceptibility* is a measure of the chance the person at the other end of the interaction will pick up the infection and became infectious themself.

Population Weighted Density increases the *opportunity* component of reproductive number and increases the probability of speeding up the curve. The faster the infection curve rises, the quicker the local health care system gets overloaded beyond its capacity to treat people. More and more new patients may be forced to go without ICU beds, and more and more hospitals may run out of the basic supplies they need to respond to the outbreak.

Istanbul needed to be ready for the outbreak as it has twice the population and one and a half times the population weighted density than New York, the epicenter of the outbreak. From a policy-planning perspective, population weighted density can give a very clear objective: paying attention to the areas with highest population weighted density.

The Turkish government has introduced gradual measures to encourage social distancing, restricted domestic travel, and ordered a curfew for those over 65 and under 20 years old if they are not working. On April 10, Turkey began enforcing lockdowns on weekends in 30 metropolitan areas and Zonguldak, a city with high asthma cases due to mining business. The government also started two new hospitals in Istanbul, planing to transfer health care workers from other cities to Istanbul. Population weighted density can help show how this transfer can be done. We graphed the cities with low risk spread (proxied by low population density) with a high number of health care workers. (Figure 5) The big green cities like Yozgat, Sivas, Tokat are the cities with low population weighted density with relatively high number of health care workers, and the brown small cities like Istanbul, Batman, Kocaeli and Yalova are the ones with high population weighted density with relatively low number health care workers. Possible transfer of health care workers can be done from cities marked by big green bubbles to cities marked by small brown bubbles.

Use of Population Weighted Index to Measure the Success

In terms of success of dealing with the outbreak, we compiled the death data from 8 different cities in Turkey. These were the only 8 cities that make the death data available on a daily basis online. [15] We graphed the series of daily death since March 25, 2020 (two weeks after the first corona virus case) untill April 18, 2020 for last three years. (Figure 6) Sakarya and Istanbul have a different series than the last year. ($p<0.000$) The total deaths are directly linked with the coronavirus as well as those from other causes such as stroke, heart disease, and cancer. Turkey, similarly to some other countries, is only counting cases of Covid-19 that have been confirmed with a positive test result and is not including those that have been clinically diagnosed as Covid-19 but have not been

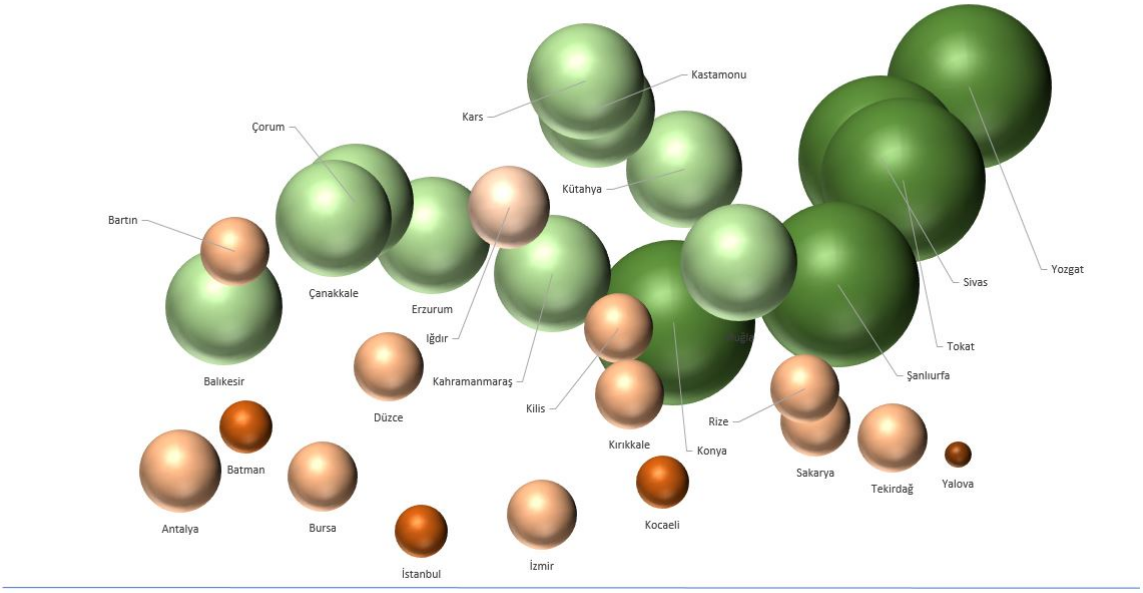


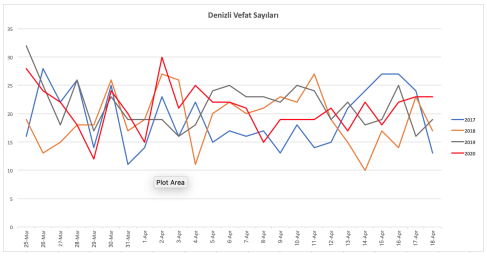
Figure 5: Possible Health Care Workers Transfer Among the Cities during the outbreak

Table 7: Ascending Ranking of Increase in Death between March 15 to April 18 2020 relative to average of last three years, controlling for population weighted density

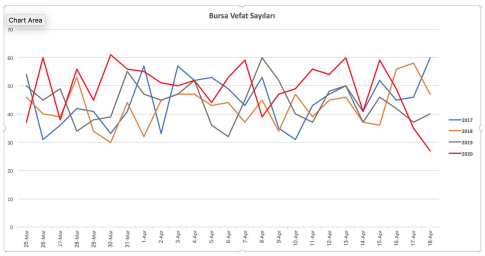
Cities	Success Ranking	Population Weighted Density (Ranking)	Increase in Death	Population Ranking	Population Density
Konya	1	165 (33)	4	7	50
Kocaeli	2	1916(4)	105	10	2
Denizli	3	433(19)	24	21	28
Bursa	4	1903 (5)	133	4	7
Malatya	5	260 (26)	34	28	38
Istanbul	6	16757 (1)	2218	1	1
Kahramanmaraş	7	129 (42)	38	18	33
Sakarya	8	535 (15)	233	22	9

tested positive. While deaths are not necessarily directly attributable to the coronavirus, the numbers indicate fatalities that have coincided with the onset of the outbreak.

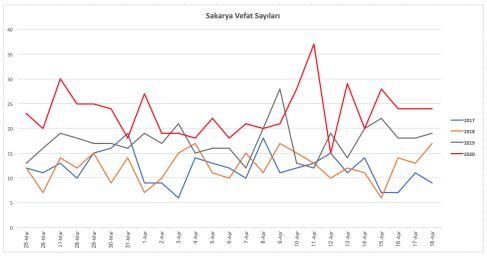
For eight cities we selected, we calculated the increase amount of death relative to average of last three years. We then divided this number with population weighted density to determine, controlling for the density, the proportion death per density measure. We ranked the cities with the lowest proportion as the most successful city by minimizing deadly consequence of the outbreak.(Table 7)



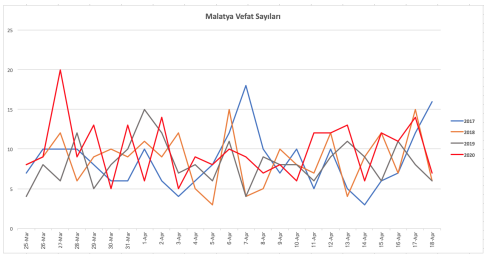
(a) Denizli



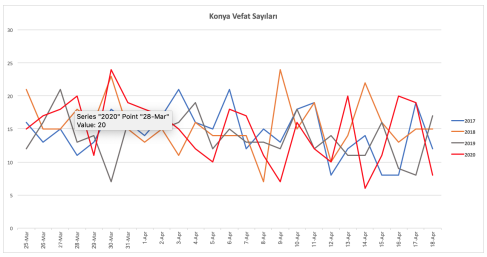
(b) Bursa



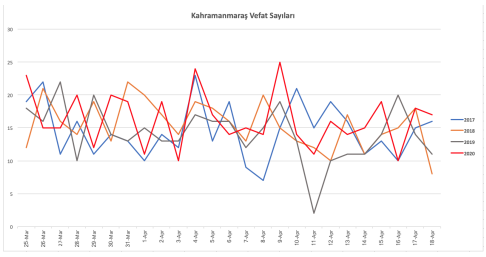
(c) Sakarya



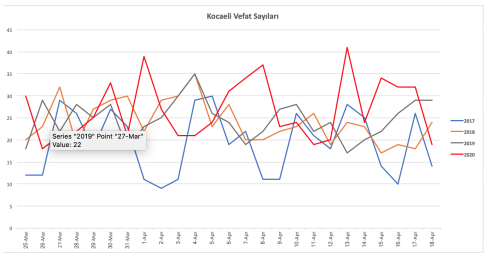
(d) Malatya



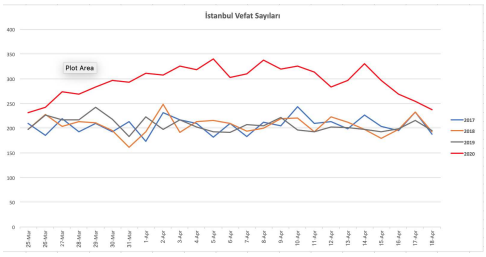
(e) Konya



(f) Kahramanmaraş



(g) Kocaeli



(h) Istanbul

Figure 6: Daily Death for selected cities from March 15 to April 18 for the years 2017 – 2020

Conclusions

We are at the ending of the beginning of outbreak. Most of the data is preliminary and the data that we can use in Turkey is limited. For example, we are missing the proportion of patients with underlying conditions that might decrease the survival rate at each cities. We have seen death toll raise in a cities like Zonguldak where most of the population suffers from chronic lung diseases due to work conditions in the minings located in the city. We have used the death statistics to measure the success of dealing with the outbreak, but any death statistics in the midst of pandemic are tricky to pin down and must be considered preliminary. We have seen most of the countries are improving their death statistics, which they now acknowledge incomplete.

In order to control and manage the outbreak, our analysis suggests that population weighted density can be a useful tool. High density means that people in those areas live very differently from other people. Those who live or work in or near the city shop and commute differently: they are far more likely to walk or take public transit than the rest of the people. The disease spreads faster in the areas with high population weighted areas than elsewhere simply because there is so much human contact.

At this stage, particular attention should be given to the prevention of spreading in the highest dense areas directed by population weighted density. This would help flatten the curve, which assumes that the same number of people ultimately get infected, but over a longer period of time. A slower infection rate means a less stressed health care system, fewer hospital visits on any given day, and fewer sick people being turned away.

References

[1] A. J. Kucharski and C. L. Althaus, "The role of superspreading in Middle East respiratory syndrome coronavirus (MERS-CoV) transmission," *Euro Surveill*, vol. 20, pp. 14–8, Jun 2015.

[2] J. F.-W. Chan, S. Yuan, K.-H. Kok, K. K.-W. To, H. Chu, J. Yang, F. Xing, J. Liu, C. C.-Y. Yip, R. W.-S. Poon, *et al.*, "A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster," *The Lancet*, 2020.

[3] "World Health Organization (WHO). Novel Coronavirus (2019-nCoV) situation report 9. Geneva: WHO; 2020." `https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200129-sitrep-9-ncov-v2.pdf?sfvrsn=e2c8915_2`.

[4] "Worldometers." `https://www.worldometers.info/`.

[5] J. Craig, "Averaging population density," *Demography*, vol. 21, no. 3, pp. 405–412, 1984.

[6] B. Knudsen, R. Florida, K. Stolarick, and G. Gates, "Density and creativity in us regions," *Annals of the Association of American Geographers*, vol. 98, no. 2, pp. 461–478, 2008.

[7] P. Krugman, "Density." `https://krugman.blogs.nytimes.com/2013/04/16/density/`, Apr 2013.

[8] J. R. Ottensmann, "On population-weighted density," *Available at SSRN 3119965*, 2018.

[9] "Turkish statistical instituion." `https://http://www.turkstat.gov.tr/`.

[10] "Ahaber news." `https://www.ahaber.com.tr/galeri/gundem/turkiye-koronavirus-haritasi-canli-il-il-vak`

[11] "Turkish meteorolgy instituion." `https://www.mgm.gov.tr/tahmin/turkiye.aspx/`.

[12] J. M. Wooldridge, "Econometric analysis of cross section and panel data mit press," *Cambridge, MA*, vol. 108, 2002.

[13] A. Kucharski, "Calculating virus spread," 2020.

[14] "The real time world statistics." https://www.worldometers.info/coronavirus/coronavirus-incubation-period//.

[15] "E-devlet turkey." https://www.turkiye.gov.tr/.