Do Population Density, Socio-Economic Ranking and Gini Index of Cities Influence Infection Rates from Coronavirus? Israel as a case Study

Yuval Arbel (✉ yuval.arbel@gmail.com)

Western Galilee College <https://orcid.org/0000-0003-4365-6280>

Chaim Fialkoff

Hebrew University of Jerusalem

Amichai Kerner

Netanya Academic College

Miryam Kerner

Technion, Israel Institute of Technology

Research Article

Keywords: COVID-19, Population Density, Socio-Economic Ranking, Gini Index, Rank-Size Rule

Posted Date: July 8th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-40387/v1>

License: This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Version of Record: A version of this preprint was published at The Annals of Regional Science on August 29th, 2021. See the published version at <https://doi.org/10.1007/s00168-021-01073-y>.

DO POPULATION DENSITY, SOCIO-ECONOMIC RANKING AND GINI INDEX OF CITIES INFLUENCE INFECTION RATES FROM CORONAVIRUS? ISRAEL AS A CASE STUDY

Yuval Arbel,^a Chaim Fialkoff, and Amichai Kerner, and Miryam Kerner*

Abstract

A prominent characteristic of the COVID-19 pandemic is the marked geographic variation in COVID-19 prevalence. The objective of the current study is assess the influence of population density and socio-economic measures (socio-economic ranking and the Gini index) across cities on coronavirus infection rates. Israel provides an interesting case study based on the highly non-uniform distribution of urban populations, the existence of one of the most densely populated cities in the world and diversified populations. The outcomes of our study show that *ceteris paribus*, projected probabilities to be infected from coronavirus *rise* with higher population density and Gini coefficients and *drop* with higher socio-economic ranking of the city. Moreover, when measured by identical units of standard deviations, the contribution of the socio-economic measure is the highest. Findings thus provide a tool to city and public health planners in an effort to address the spatial and socio-economic aspects of the pandemic. Compared with wealthier cities, poorer and denser cities should employ more pre-emptive measures to better enable the early identification of the incidence of COVID-19 in these cities. Finally, from a public health perspective, a densely populated city with a low socio-economic ranking and high income inequality requires immediate intervention in order to mitigate the dissemination of the virus.

Key Words: COVID-19; Population Density; Socio-Economic Ranking; Gini Index; Rank-Size Rule

Current Version: July 8, 2020

JEL Codes: H75, I14, R12

^a Corresponding Author

* Yuval Arbel, Sir Harry Solomon School of Economics and Management, Western Galilee College, Acre 2412101, Israel, email: YuvalAr@wgalil.ac.il; yuval.arbel@gmail.com ; Chaim Fialkoff, Institute of Urban and Regional Studies, Hebrew University of Jerusalem, Mt. Scopus, Jerusalem, 9190501; email: cfialk@gmail.com. Amichai Kerner, School of Real Estate, Netanya Academic College, 1 University Street, Netanya 4223587, Israel, email: kerneram@netvision.net.il. Miryam Kerner, the Ruth and Bruce Rappaport Faculty of Medicine, Technion, Israel Institute of Technology. Email: Miryamke@clalit.org.il. The authors are grateful to Yifat Arbel, Nissim Ben David (the president) and the participants at the “light at the end of the corona tunnel” zoom meeting in Western Galilee College for helpful comments.

1. INTRODUCTION

Coronavirus 2019 (COVID-19) is a declared global pandemic with multiple risk factors (WHO report: coronavirus). A prominent characteristic of the pandemic is the marked geographic variation in COVID-19 prevalence. As of March 2020, several countries - the epicenters of the pandemic - were already badly affected by the pandemic, while others had just confirmed the first few cases. Balsius (2020) attributes this epidemic prevalence to the power law distribution (e.g., Newman, 2005), namely, the correlation between the arrival time of the disease and the COVID-19 prevalence.

Given this geographic variation, it is of interest to examine whether and to what extent infection rates within countries are influenced by differences in urban population densities and socio-economic conditions. Schmitt-Grohé et al. (2020) found no correlation between access to Covid-19 testing and the level of income in New York City. The ten percent of the city's population living in the richest zip codes with 29 percent of the city's income received 11 percent of the Covid-19 tests. The ten percent of the city's population living in the poorest zip codes with only four percent of the city's income, received ten percent of the tests. On the other hand, Clarke and Whitely (2020) argue that economic inequality can help predict COVID19 deaths in the US. Other important factors the authors mention are population densities: "Population density matters as well since inter-personal transmission of the virus will be higher in densely populated areas".

The objective of the current study is assess the influence of these two factors (population density and socio-economic measures)¹ on coronavirus infection rates – the ratio between the number of infected persons to the total city population. These data are calculated based on the

¹ For the definition of socio-economic measure see, for example, ICBS: Characterization and Classification of Geographical Units by the Socio-Economic Level of the Population, 2015. Available at: <https://www.cbs.gov.il/en/publications/Pages/2019/Characterization-and-Classification-of-Geographical-Units-by-the-Socio-Economic-Level-of-the-Population-2015.aspx>

Israeli Ministry of Health report, which is updated as of May 11, 2020. Population densities, socio-economic measures and the Gini index updated to 2018 are based on the Israel Central Bureau of Statistics (CBS) reports. Given the highly non-uniform distribution of population across cities, the existence of one of the most densely populated cities in the world (Bnei Brak) and diversified populations, Israel provides an interesting case study to explore this hypothesis.

The outcomes of our study show that *ceteris paribus*, projected probabilities to be infected from coronavirus *rise* with higher population density and Gini index and *drop* with higher socio-economic ranking of the city. Moreover, when measured by identical units of standard deviations, the contribution of the socio-economic measure is the highest. In an effort to preserve identical infection rates, one standard deviation *rise* in the city's socio-economic ranking is equivalent to 1.6654 standard deviation *drop* in the population density and 1.8779 standard deviation *drop* in the Gini index.

The remainder of this study is organized as follows. Section 2 reports the background and descriptive statistics. Section 3 describes the methodology and section 4 reports the results. Finally, Section 5 concludes and summarizes.

2. BACKGROUND AND DESCRIPTIVE STATISTICS

(2a) Background

Based on the information reported in Appendix B and following Alperovich (1984) and O'Sullivan (2012: 81-82), we ran a rank-size rule test for the 95 Israeli cities.² The conventional empirical model for such a test is given by the following equation:

$$G(P) = AP^{-\alpha} \quad (1)$$

² To the best of our knowledge, this is the first time such a test is carried out under the Israeli setting.

Where $G(P)$ = number of cities with population P or more; P = population of city; A = constant term; α = Pareto exponent. This parameter has important implications in terms of population distribution across cities. As this parameter becomes lower, populations are less evenly distributed across cities. Given more populated and denser cities, one would anticipate a higher coronavirus spread with lower values of α .

The estimation results of equation (1) for the entire population of 255 cities yield:

$$\begin{aligned} \text{proj}[\ln(G(P))] &= 12.48522 - 0.8173233 \ln(P); & R^2 &= 0.9053 \\ &(0.1623) & (0.0166157) \end{aligned}$$

As anticipated, estimation of α is low, and the null hypothesis $\alpha = 1$ is clearly rejected (99% confidence interval of [0.7742, 0.8604]). In his meta analysis, Nitsch (2005) found that in most studies this parameter is above 1.0. As suggested by the strict interpretation of the Zip's law, the implication might be a departure from uniform distribution of population across cities in Israel.

The conditions that fully satisfy the rank-size rule according to which the product $P \cdot G(P)$ equals P_{MAX} , the population in the largest city (Jerusalem – 919,438 inhabitants), are: 1) $\alpha = 1$ and 2) $A = P_{MAX}$. For the entire population, both the separate and the joint hypotheses are clearly rejected (respective calculated p -values: $p = 3.07 \cdot 10^{-23}$; $p = 3.515 \cdot 10^{-13}$ and $p = 2.689 \cdot 10^{-85}$).

Given that our sample is restricted to 95 cities and towns with information about the socio-economic and the Gini index for inequality, the estimation results of equation (1) for the sample of 95 cities and towns yield:

$$\begin{aligned} \text{proj}[\ln(G(P))] &= 14.83515 - 1.042334 \ln(P); & R^2 &= 0.9630 \\ &(0.2253791) & (0.0211988) \end{aligned}$$

where standard errors are given in parentheses. The first test supports the null hypothesis $\alpha = 1$ at the 1% level ($p=0.0487$). However, the null hypothesis $A=\ln(919,438)=13.731532$, and the joint hypothesis $\alpha = 1$ and $A= 13.731532$ are not supported empirically ($p = 3.8444 \cdot 10^{-6}$ and $p = 2.59 \cdot 10^{-48}$, respectively). Compared with the full sample, the Pareto efficiency parameter *rises* with the restriction of the sample. An analysis of the 160 omitted settlements (=255-95) shows that 83.75% of these settlements have population density lower than 3,000 persons per sq. km. Given the selection criteria for the sample (the exclusion of relatively small cities with unknown information regarding socio-economic measures and low infection rates), yielding higher Pareto efficiency parameter, the implication, which is tested directly in subsequent sections, might be that coronavirus spread is higher in denser cities.

(2b) *Descriptive Statistics*

Table 1 reports the descriptive statistics. The mean infected-population ratio in the 95 Israeli cities is 210.90 and the standard deviation is 233.64 per 100,000 persons in the city population. Nazareth, an Arab city, located at the northern statistical region and the 20th most populated in Israel with 77,064 inhabitants, is ranked as the city with the minimum rate of infected persons – 24.65 per 100,000 persons.³ Bnei Brak – an ultra-orthodox (Haredi) Jewish and the 9th most populated city with the highest population density of 26,512 persons per square kilometer, exhibits the maximum rate of 1,463.32 per 100,000 persons in the overall city population (*INFECTED*).

³ In fact, the Arab sector, comprising of 20.7% of the overall Israeli population (Israel CBS: Israel in Figures, 2015) is considered highly successful in keeping low coronavirus infection rates, in spite of the high population densities in Arab cities.

Referring to the population densities, the mean is 4,397 and the standard deviation is 4,223 persons per sq. km.. While Mizpe Ramon in the Negev exhibits the lowest population density of 67 persons per sq. km., Bnei Brak exhibits the maximum population density of 26,512 persons per sq. km. (*POP_DENSITY*). Bnei Brak is considered one of the densest cities in the world with higher population density than Kolkata, India (24,306 persons per sq. km.)⁴ and similar to Port-au-Prince, Haiti (27,395 persons sq. km.)⁵ and Manhattan, New York (27,544 persons per sq. km.).⁶

Referring to the socio-economic ranking on a scale 1 (=the lowest) to 10 (=the highest), the mean rank is 5.01 and the standard deviation is 2.3497. Two ultra-orthodox cities (Modi'in Illit; Beitar Illit) and three Bedouin cities (Hura; Ar'ara (Negev); Rahat) exhibit the lowest socio-economic ranking of 1. Interestingly, these cities display low population density levels (Hura - 2,388; Ar'ara (Negev) – 1,217 and Rahat - 3,403 persons per sq. km). According to the OECD report from 2018: “However, the share of working poor has risen because many workers, notably Israeli-Arabs and Haredim, are in low-paid jobs due to their weak skill sets. Workers from these communities are often trapped in low quality jobs, implying persistent inequality and weak aggregate productivity. Moreover, low social transfers imply that the often large families in these communities face deprivation that contributes to child poverty. High house

⁴ Source: Office of the Registrar General & Census Commissioner, India: West Bangal. It should be noted, however, that while the overall population in Bnei Brak is 193,744 persons, the overall population in Kolkata is approximately 23 times higher – 4,496,694 persons.

⁵ Source: Institut Haitien De Statistique Et de l'Informatique (IHSD): "Mars 2015 Population Totale, Population de 18 Ans et Plus Menages et Densites Estimes En 2015, available at: https://web.archive.org/web/20151106110552/http://www.ihsi.ht/pdf/projection/Estimat_PopTotal_18ans_Menag2015.pdf (last accessed at May 24, 2020). It should be noted, however, that while the overall population in Bnei-Berak is only 193,744 persons, the overall population in Port-au-Prince is approximately fivefold higher - 987,310 persons.

⁶ It should be noted, however, that while the overall population in Bnei-Berak is only 193,744 persons, the overall population in Manhattan is approximately 8 times higher – 1,628,701 persons.

prices also weigh on the social situation and well-being. Without further policy action, these trends are likely to worsen, as Israeli-Arabs and Haredim will constitute half the population by 2059.” (page 10). Two cities are ranked at the maximum 9th scale of the socio-economic measure (Ramat Hasharon; Shoham) and also exhibit respective low population densities of 2,768 and 2,903 persons per sq. km. (*SOCIO_ECONOMIC*).

Finally, the average Gini index across these 95 cities is 0.4099 and the standard deviation is quite low - 0.0422. Jisr az-Zarqa, an Arab village located at the Hadera sub-district exhibits both the lowest Gini coefficient of 0.2745, as well as high population density of 8,944 persons per sq. km. and a low social ranking of 2. Ramat Hasharon displays both the highest Gini index of 0.5167, as well as relatively low population density of 2,768 persons per sq. km. and the maximum social ranking of 9 (*GINI*).

A simple regression analysis applied to the 95 cities and towns for which the socio-economic measures are available demonstrates that:

$$proj(GINI) = 0.3481616 + 0.0123415SOCIO_ECONOMIC; \quad R^2 = 0.4722$$

(0.00748) (0.00135)

where standard errors are given in parentheses. The implication is that the socio-economic index explains 47.22% of the variance of the Gini index and income inequality is expected to grow by 1.234 percent with each additional 1 unit increase in the socio-economic ranking of the city.⁷ As for the relationships between population density and each of these two measures, they are uncorrelated ($p=0.9223$ and $p=0.9698$).

Figure 1 provides box plots of all the variables normalized to the same unit of measurements. The figure clearly demonstrates that while the distributions of the socio economic

⁷ The 99% confidence interval is [0.00878, 0.015899].

measures are symmetrical, the distributions of the rate of infection and population density are skewed to the right, namely, have a right tail. Moreover, compared to the socio-economic measures, the standard deviations of the infection rate and population density, namely, the dispersion of values around the mean, seem smaller.

3. METHODOLOGY

Consider the following fractional logit model (e.g., Papke and Wooldridge (1996); Johnston and Dinardo (1997): 424-426; Wooldridge (2010)) applied to 95 Israeli cities with at least 15 cases of coronavirus infections:

$$Pr(0 < Y < 1) = F(\hat{\alpha}_0 + \hat{\alpha}_1 X_1 + \hat{\alpha}_2 X_2 + \hat{\alpha}_3 X_3) \quad (2)$$

where $Y = INFECTED = \frac{CORONA_CASES}{POPULATION}$, $X_1 = POP_DENSITY = \frac{POPULATION}{KILOMETER^2}$, $X_2 = SOCIO_ECONOMIC$; $X_3 = GINI$; $F(Y_j) = \frac{exp(Y)}{1+exp(Y)}$; $OR = proj\left[\frac{p}{1-p}\right]$; $\alpha_0, \alpha_1, \alpha_2, \alpha_3$ are parameters; and the circumflex denotes estimated parameters.

The advantage of the fractional logit model lies in the fact that when transformed to projected probabilities, projections are bounded to be between 0 and 1. The disadvantage lies in the difficulty to provide direct interpretation to the parameters. Consequently, we also estimate the following Linar Probability model (LPM, e.g., Johnston and Dinardo, 1997:):

$$Y = \alpha'_0 + \alpha'_1 X_1 + \alpha'_2 X_2 + \alpha'_3 X_3 + \epsilon \quad (3)$$

where $\alpha'_0, \alpha'_1, \alpha'_2, \alpha'_3$ are parameters and ϵ is the stochastic random disturbance term.

In an effort to measure the relative contribution of each index to the rate of infection in identical standard deviation units, we run the following standardized beta coefficients regression (e.g., Schroeder *et al.*, (1986): 31-32; Vittinghoff *et. al.*, (2005): 75-76):

$$\mathbb{Z}(Y) = \beta_0 + \beta_1 \mathbb{Z}(X_1) + \beta_2 \mathbb{Z}(X_2) + \beta_3 \mathbb{Z}(X_3) + \mu \quad (4)$$

where $\mathbb{Z}(\cdot)$ is the standardized normal distribution transformation of each variable (e.g., $\mathbb{Z}(V_i) = \frac{V_i - \bar{V}}{\sigma_V}$ for $i = 1, 2, 3, \dots, 95$ where $\bar{V}, \sigma_V$ are the respective mean and standard deviation of the variable V_i); $\beta_0, \beta_1, \beta_2, \beta_3$ are the parameters reflecting the standardized beta coefficients, and μ is the classical random disturbance term

4. RESULTS

Table 1 reports the regression outcomes of equations (2)-(4). According to the outcomes reported in column (2), the three measures explain 39.8 percent of the variance of the dependent variable. Projected probability to be infected *rises* by $2.18 \cdot 10^{-7}$ following a one unit increase in the population density, where socio-economic and Gini coefficients remains unchanged ($p = 5.21 \cdot 10^{-6}$). Projected probability to be infected *drops* by $6.53 \cdot 10^{-4}$ following a one point increase in the socio-economic index, where population density and the Gini index remains unchanged ($p = 7.30 \cdot 10^{-8}$). Finally, projected probability to be infected *rises* by 1.93 percent following a shift from Gini index of zero (total equality) to one (total inequality), where population density and the socio-economic measure remains unchanged ($p = 2.42 \cdot 10^{-3}$).

The bottom of Table 1 reports the $\frac{1}{VIF}$ and *VIF* (Variance Inflation Factor) measures (e.g., Belsley, Kuh and Welsch, 2004). This is a measure for multicollinearity, where $\frac{1}{VIF} = 1 - R^2$ for the three regressions between *POP_DENSITY*, *SOCIO_ECONOMIC* and *GINI* as the dependent

variables against the remaining independent variables. This measure indicates no severe multicollinearity between the two socio-economic measures.⁸

Figures 2, 3 and 4 are based on the regression outcomes given in column (1) of Table (2). The vertical axis in each figure reflects the projected probability to be infected from the coronavirus disease after transformation of the coefficients and their 95% confidence intervals. The horizontal axis in each figure is based on the on sample values of the variables. The figures present the *rise* of coronavirus infection rates from 157 to 64 per 100,000 persons with population density; the *drop* from 526 to 50 per 100,000 persons with socio-economic ranking and the *rise* from 102 to 769 per 100,000 persons with the Gini coefficient.

Based on equation (4) and column (3) in Table 1, in terms of coronavirus infected per 100,000 persons in the population, one standard deviation *rise* in the city's socio-economic ranking is equivalent to $\frac{0.656311}{0.3940823} = 1.6654$ standard deviation *drop* in the population density. Moreover, one standard deviation *rise* in the city's economics and socio-economic ranking is equivalent to $\frac{0.656311}{0.3494891} = 1.8779$ standard deviation *drop* in the Gini index.

Given that high population density represents tall structures, findings provide a tool to city planners in an effort to control viruses spreading. Compared with wealthier cities, poorer and denser cities should employ more pre-emptive measures to better enable the early identification of the incidence of COVID-19 in these cities

⁸ The conventional measure of severe multicollinearity is $VIF \geq 10$, namely, $0.9 \leq R^2 \leq 1.0$.

5. SUMMARY AND CONCLUSIONS

Given the huge geographic variation in COVID-19 prevalence, the objective of the current study is to assess the influence of population density and socio-economic measures on coronavirus infection rates – the ratio between the number of infected persons and the total city population. These are calculated based on the Israeli Ministry of Health report, which is updated to May 11, 2020. Population densities, socio-economic rankings and the Gini index updated to 2018 are based on the Israel CBS reports. Israel provides an interesting case study based on the highly non-uniform distribution of population across cities, the existence of one of the most densely populated cities in the world (Bnei Brak) and diversified populations.

The outcomes of our study show that *ceteris paribus*, projected probabilities to be infected from coronavirus *rise* with higher population density and Gini coefficient and *drop* with higher socio-economic ranking of the city. Moreover, when measured by identical units of standard deviations, the contribution of the socio-economic measure is the highest. In an effort to preserve identical infection rates, one standard deviation *rise* in the city's socio-economic ranking is equivalent to 1.6654 standard deviation *drop* in the population density and 1.8779 standard deviation *drop* in the Gini index.

In the conventional urban economics textbooks, high population density represents multi-story structures with smaller building footprints, where price of land is expensive (at the central cities, e.g., Mills and Hamilton 1989: 425–434; O'Sullivan 2012: 127–151; Arbel, Fialkoff and Kerner, 2019). Consequently, findings provide a tool to city planners in an effort to control viruses spreading. Compared with wealthier cities, poorer and denser cities should employ more pre-emptive measures to better enable the early identification of the incidence of COVID-19 in these cities. Finally, to decrease virus spreading, from a public health perspective, a densely populated

city with low socio-economic ranking and high income inequality requires immediate intervention.

6. CONFLICT OF INTERESTS: All The authors declare there are no conflict of interests. This research is based on publicly available information.

7. REFERENCES

Alperovich, Gershon (1984). The Size Distribution of Cities: On the Empirical Validity of the Rank-Size Rule. *Journal of Urban Economics*, 16: 232-239.

Arbel, Yuval, Fialkoff, Chaim and Amichai Kerner. The Chicken and Egg Problem: Obesity and the Urban Monocentric Model. *Journal of Real Estate Finance and Economics* (2019). <https://doi-org.elib.openu.ac.il/10.1007/s11146-019-09737-5>.

Belsley DA, Kuh E, Welsch RE. *Regression Diagnostics : Identifying Influential Data and Sources of Collinearity*. Hoboken, N.J.: Wiley-Inter science; 2004.

Blasius, Bernd. (2020). Power-law distribution in the number of confirmed COVID-19 cases. Available at: <https://arxiv.org/pdf/2004.00940.pdf>.

Clarke, Harold and Paul Whitely (2020). Economic Inequality Can Help Predict COVID19 Deaths in the US. Available at: <https://blogs.lse.ac.uk/usappblog/2020/05/06/economic-inequality-can-help-predict-covid-19-deaths-in-the-us/>.

Gat, Daniel. Compact Hedonic Model of the Greater Tel Aviv Housing Market. *Journal of Real Estate Literature*, 1996, 4:2, 162–72.

Gat, Daniel. Urban Focal Points and Design Quality Influence Rents: The Case of the Tel Aviv Office Market. *Journal of Real Estate Research*, 1998, 16:2, 229–47.

Israel Central Bureau of Statistics. Israel in Figures, 2015: pages 3; 6. available at: https://www.cbs.gov.il/he/publications/DocLib/isr_in_n/isr_in_n15e.pdf (Last accessed at May 23, 2020).

Israel CBS: Statistical Abstract of Israel, 2019: Population Density per Square Kilometer. https://www.cbs.gov.il/he/publications/doclib/2019/2.shnatonpopulation/st02_23.pdf (Last accessed at May 23, 2020).

Israel Central Bureau of Statistics. Characterization and Classification of Geographical Units by the Socio-Economic Level of the Population, 2015. Available at: <https://www.cbs.gov.il/en/publications/Pages/2019/Characterization-and-Classification-of-Geographical-Units-by-the-Socio-Economic-Level-of-the-Population-2015.aspx>

Johnston, Jack and John Dunardo. *Econometric Methods*, Fourth Edition. McGraw Hill International Edition (1997).

Mills, E. S., & Hamilton, B. W. (1989). Urban Economics (4th ed., pp. 425–434). Appendix A: Simplified Mathematical Model of Urban Structure.

Newman, MEJ, 2005. Power laws, Pareto distributions and Zipf's law. *Contemporary Physics*, 46(5): 323 – 351.

Nistsch, Volker (2005). Zipf zipped. *Journal of Urban Economics* 57 (2005) 86–100.

OECD Economic Survey Israel, March, 2018. Available at: [file:///C:/Users/Yuval/Downloads/OECD%20Economic%20Survey%20Israel%20Overview%20March%202018%20\(1\).pdf](file:///C:/Users/Yuval/Downloads/OECD%20Economic%20Survey%20Israel%20Overview%20March%202018%20(1).pdf) (Last accessed at May 23, 2020).

Office of the Registrar General & Census Commissioner, India: West Bangai.

O'Sullivan, Arthur. Urban Economics, Eight Edition (2012). McGraw Hills International Edition.

Papke, L. E., and J. M. Wooldridge. Econometric methods for fractional response variables with an application to 401(k) plan participation rates. *Journal of Applied Econometrics* 11 (1996): 619–632.

Schroeder, Larry D.; Sjoquist, David L.; Stephan, Paula E. (1986). *Understanding Regression Analysis*. Sage Publications. pp. 31–32. ISBN_0-8039-2758-4.

Schmitt-Grohé, Stephanie; Teoh, Ken & Martín Uribe, 2020. "Covid-19: Testing Inequality in New York City," NBER Working Papers 27019, National Bureau of Economic Research, Inc.

Vittinghoff E, Glidden DV, Shiboski SC, McCulloch CE. *Regression Methods in Biostatistics: Linear, Logistic, Survival, and Repeated Measures Models*. New York, NY: Springer Publishing Co; 2005. 75-76.

Wooldridge, J. M. *Econometric Analysis of Cross Section and Panel Data*. 2nd ed. Cambridge, MA: MIT Press (2010).

World Health Organization (WHO): Coronavirus. Available at: https://www.who.int/health-topics/coronavirus#tab=tab_1 (Last accessed at May 3, 2020).

Table 1: Descriptive Statistics:

Variable	Description	Mean	SD	Min	Max
<i>INFECTED</i>	Ratio between coronavirus infected and total population	$210.90 \cdot 10^{-5}$	$233.64 \cdot 10^{-5}$	$24.65 \cdot 10^{-5}$	$1,463.32 \cdot 10^{-5}$
<i>POP_DENSITY</i>	Population density of the city measured as persons per square kilometer	4,397.17	4,223.07	67	26,512
<i>SOCIO_ECONOMIC</i>	Economic and socio-demographic ranking of the city on a scale between 1=the worst; 10=the best	5.0105	2.3497	1	9
<i>GINI</i>	Gini coefficient of inequality in cities	0.4099	0.0422	0.2745	0.5167

Figure 1: Box Plots of Normalized Variables

Notes: The table and figure refer to 95 main Israeli cities and settlements (including Tel Aviv, Haifa and Jerusalem) for which information based on the three indices is available, and with at least 15 infected from coronavirus disease.

Table 2: Regression Analysis

Method VARIABLES	(1) Fractional Probit <i>INFECTED</i>	(2) LPM <i>INFECTED</i>	VARIABLES	(3) OLS $\mathbb{Z}(\text{INFECTED})$
Constant	-3.499*** (<0.0001)	-0.00369 (0.115)	Constant	NA (0.115)
<i>POP_DENSITY</i>	$1.80 \cdot 10^{-5}$ *** ($6.32 \cdot 10^{-6}$)	$2.18 \cdot 10^{-7}$ *** ($5.21 \cdot 10^{-6}$)	$\mathbb{Z}(\text{POP_DENSITY})$	0.3941*** ($5.21 \cdot 10^{-6}$)
<i>SOCIO_ECONOMIC</i>	-0.0820*** (<0.0001)	-0.000653*** ($7.30 \cdot 10^{-8}$)	$\mathbb{Z}(\text{SOCIO_ECONOMIC})$	-0.6563*** ($7.30 \cdot 10^{-8}$)
<i>GINI</i>	2.255*** (0.000742)	0.0193*** (0.00242)	$\mathbb{Z}(\text{GINI})$	0.3495*** (0.00242)
Observations	95	95	Observations	95
R-squared	—	0.398	R-squared	0.398
$\frac{1}{VIF}(\text{POP_DENSITY})$	—	0.9997	$VIF(\text{POP_DENSITY})$	1.00
$\frac{1}{VIF}(\text{SOCIO_ECONOMIC})$	—	0.5277	$VIF(\text{SOCIO_ECONOMIC})$	1.90
$\frac{1}{VIF}(\text{GINI})$	—	0.5277	$VIF(\text{GINI})$	1.90
$\frac{1}{VIF}(\text{Mean})$	—	0.625	$VIF(\text{Mean})$	1.60

Notes: VIF (Variance Inflation Factor) is a measure for multicollinearity, where $\frac{1}{VIF} = 1 - R^2$ for the three regressions between *POP_DENSITY*, *SOCIO_ECONOMIC* and *GINI* as the dependent variables against the remaining independent variables. $\mathbb{Z}(V_i) = \frac{V_i - \bar{V}}{\sigma_V}$ for $i = 1, 2, 3, \dots, 95$ where $\bar{V}, \sigma_V$ are the respective mean and standard deviation of the variable V_i . Robust *P*-values are given in parentheses. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Figure 2: Infected-Population Rate vs. Population Density

Figure 3: Infected-Population Rate vs. Socio- Demographic Ranking of the City

Figure 4: Infected-Population Rate vs. Gini Index

Notes: Figures 2, 3 and 4 are based on the regression outcomes given in coulmn (1) of Table (2). The vertical axis in each figure reflects the projected probability to be infected from coronavirus disease after trasformation of the coefficients and their 95% confidence intervals. The horizional axis in each figure is based on the on sample values of the variables.

Appendix: Descriptive Statistics Stratified by Cities and Settlements in Israel

Number	Cities and Settlements	Population Rank-Size Distribution	Population (2018)	Infected from Population	Population Density	Socio-Economic Ranking	Gini Index
1	Jerusalem	1	919,438	0.0039742	7,186	2	0.431
2	Tel Aviv	2	451,523	0.001227	8,565	8	0.4773
3	Haifa	3	283,640	0.0006029	4,346	7	0.4745
4	Rishon LeTzion	4	251,719	0.000874	4,246	7	0.4202
5	Petach Tikva	5	244,275	0.0011954	6,730	7	0.4204
6	Ashdod	6	224,628	0.0012777	4,832	5	0.4169
7	Netanya	7	217,244	0.0008194	7,373	6	0.4252
8	Be'er Sheva	8	209,002	0.0008899	1,770	5	0.4303
9	Benei Berak	9	198,863	0.0146332	26,512	2	0.4043
10	Holon	10	194,273	0.000942	10,105	7	0.4043
11	Ramat Gan	11	159,159	0.0012001	9,530	8	0.4448
12	Rehovot	12	141,579	0.00089	5,835	7	0.4364
13	Ashkelon	13	140,968	0.0018657	3,000	5	0.4117
14	Bat Yam	14	128,774	0.00139	15,772	5	0.3649
15	Beit Shemesh	15	118,676	0.0043733	2,958	2	0.4336
16	Kefar Saba	16	100,763	0.0007344	6,897	8	0.4588
17	Herzeliya	17	95,142	0.0011141	4,318	8	0.4897
18	Hadera	17	95,683	0.000533	1,856	6	0.4073
19	Modiin	19	92,406	0.0013094	1,889	8	0.4346
20	Nazareth	20	77,064	0.0002465	5,417	3	0.3882
21	Ramla	21	75,538	0.0008075	6,282	4	0.3478
22	Lod	22	75,726	0.0011753	6,170	3	0.3597
23	Raanana	23	73,999	0.0019054	4,912	8	0.4958
24	Modi'in Illit	24	73,080	0.0056513	14,513	1	0.3846
25	Rahat	25	69,032	0.0009126	3,403	1	0.3356
26	Hod Hasharon	27	62,325	0.0006899	3,149	8	0.4742
27	Givaataim	28	60,212	0.0007141	18,308	8	0.4377
28	Kiryat Ata	29	58,267	0.0004291	3,523	6	0.4127
29	Beitar I'lit	32	56,746	0.005181	11,098	1	0.3781
30	Umm al Fahm	33	55,182	0.0014497	2,080	2	0.3846
31	Kiryat Gat	34	54,973	0.0009823	3,363	4	0.3737
32	Eilat	35	51,935	0.0004814	513	6	0.3662
33	Rosh Ha'ain	36	56,344	0.0009584	3,188	7	0.4199
34	Afula	37	51,737	0.0012564	1,679	5	0.3946
35	Nes Ziona	38	50,214	0.000478	3,121	8	0.4356
36	Acre	39	48,930	0.0005722	3,387	4	0.3785
37	El'ad	40	47,866	0.0080851	13,516	2	0.3895
38	Ramat Hasharon	41	46,720	0.001006	2,768	9	0.5167
39	Karmiel	42	46,124	0.0011491	2,093	6	0.4087
40	Yavne	43	46,705	0.0008136	2,790	7	0.4177
41	Tiberias	44	44,234	0.0037754	2,684	4	0.395
42	Tayibe	45	43,127	0.0011362	2,247	3	0.3814
43	Pardes Hanna-Karkur	48	42,083	0.0004277	1,825	7	0.4445

Number	Cities and Settlements	Population Rank-Size Distribution	Population (2018)	Infected from Population	Population Density	Socio-Economic Ranking	Gini Index
44	Nof Hagalil	51	41,169	0.0008016	1,230	5	0.3848
45	Kiriat Yam	52	39,909	0.0007267	8,668	5	0.3975
46	Kiryat Bialik	53	39,927	0.0004258	4,675	7	0.4203
47	Kiryat Ono	54	39,986	0.0013005	8,678	8	0.4584
48	Ma'ale Adumim	56	38,193	0.0013615	813	6	0.3857
49	Or Yehuda	57	36,864	0.0039334	5,478	6	0.392
50	Zefat	58	35,715	0.002016	1,177	2	0.4245
51	Netivot	59	35,631	0.0028346	3,330	3	0.3876
52	Dimona	60	34,135	0.0008496	195	4	0.4258
53	Tamra	61	33,851	0.0006499	1,139	2	0.3663
54	Sakhnin	64	31,057	0.0005474	3,106	3	0.392
55	Yahud	66	29,930	0.0026729	5,940	8	0.4496
56	Baqa al-Gharbiyye	67	29,393	0.0006804	3,201	3	0.3685
57	Ofakim	70	29,021	0.0015506	2,715	3	0.3799
58	Gedera	71	28,092	0.0019579	2,410	7	0.4257
59	Givat Shmuel	73	26,023	0.0016524	10,118	8	0.4579
60	Arad	75	26,451	0.0007183	249	4	0.4206
61	Migdal Ha'emek	76	25,636	0.0038227	2,903	4	0.3758
62	Sderot	77	26,455	0.0012096	3,984	5	0.3767
63	Mevasseret Zion	80	23,962	0.000626	3,807	8	0.4716
64	Gan Yavne	83	23,752	0.0011367	2,054	7	0.416
65	Zichron Yaakov	87	23,075	0.0016035	728	8	0.5097
66	Beer Yaakov	88	26,122	0.0008422	2,663	7	0.3796
67	Kiryat Shemona	89	22,625	0.000663	1,566	5	0.3746
68	Yokneam Ilit	90	23,311	0.0007293	2,765	7	0.4185
69	Kefar Kasem	90	23,241	0.0007315	2,423	3	0.3497
70	Kefar Yona	92	23,060	0.0006938	1,984	7	0.4193
71	Kiryat Mal'achi	94	23,124	0.0024217	4,912	3	0.3615
72	Kadima-Zoran	96	22,490	0.000667	2,151	8	0.4581
73	Kefar Kenna	96	22,399	0.0007143	2,189	2	0.3864
74	Tirat Ha'carmel	98	22,210	0.0008104	3,598	5	0.3862
75	Shoham	100	20,990	0.0016675	2,903	9	0.4585
76	Hura	101	21,558	0.0063549	2,388	1	0.345
77	Ganei Tikva	111	19,263	0.0024399	8,667	8	0.4558
78	Givat Ada	116	17,922	0.0030131	3,879	5	0.4178
79	Ar'ara (Negev)	119	17,640	0.0013039	1,217	1	0.347
80	Majed-El-Krum	124	15,292	0.0013079	1,624	2	0.3489
81	Jisr az-Zarqa	128	14,692	0.0029948	8,944	2	0.2745
82	Even Yehuda	132	13,700	0.0022628	1,661	8	0.4987
83	Azur	144	12,854	0.0024895	5,747	7	0.3925
84	Dir-El-Asad	147	12,348	0.0123097	2,300	3	0.3723
85	Rechasim	150	12,110	0.0033031	3,631	2	0.4277
86	Gat	152	11,798	0.0019495	1,650	4	0.3812
87	Efrat	171	10,088	0.0063442	1,402	6	0.4622
88	Ba'ana	180	8,299	0.0040969	2,362	2	0.3792

Number	Cities and Settlements	Population Rank-Size Distribution	Population (2018)	Infected from Population	Population Density	Socio-Economic Ranking	Gini Index
89	Kazrin	199	7,132	0.0021032	757	5	0.3747
90	Pki'in (Buke'ia)	215	5,815	0.0025795	1,007	5	0.3966
91	Mizpe Ramon	219	5,221	0.0049799	67	3	0.4101
92	Kiryat Yearim	224	5,565	0.0070081	9,600	2	0.4379
93	Yavneel	226	4,294	0.0041919	138	3	0.4624
94	Harish	234	7,569	0.0021139	514	3	0.3979
95	Immanuel	239	3,693	0.0040617	675	2	0.381

Notes: The sample includes 95 cities and settlements in Israel. Cities and settlements with fewer than 15 infected persons were excluded from the sample.

Figures

Notes: The table and figure refer to 95 main Israeli cities and settlements (including Tel Aviv, Haifa and Jerusalem) for which information based on the three indices is available, and with at least 15 infected from coronavirus disease.

Figure 1

Box Plots of Normalized Variables

Figure 2

Infected-Population Rate vs. Population Density

Figure 3

Infected-Population Rate vs. Socio- Demographic Ranking of the City

Notes: Figures 2, 3 and 4 are based on the regression outcomes given in coulumn (1) of Table (2). The vertical axis in each figure reflects the projected probability to be infected from coronavirus disease after trasformation of the coefficients and their 95% confidence intervals. The horizontal axis in each figure is based on the on sample values of the variables.

Figure 4

Infected-Population Rate vs. Gini Index

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Appendix.docx](#)