INCOME INEQUALITY AND COVID-19 IN THE USA

Ignacio Amate-Fortes[1], Almudena Guarnido-Rueda[2], Diego Martínez-Navarro[3] and Francisco J. Oliver-Márquez[4]

[1] Corresponding author
Associate Professor of Applied Economics
University of Almeria
Department of Economics and Business
Carretera de Sacramento, s/n
04120 – Almeria (Spain)
Phone #: +34 950015780
E-Mail: iamate@ual.es
ORCID: 0000-0003-0209-6731

[2] Associate Professor of Applied Economics
University of Almeria
Department of Economics and Business
Carretera de Sacramento, s/n
04120 – Almeria (Spain)
Phone #: +34 950015780
E-Mail: guarnido@ual.es

[3] Assistant Professor of Applied Economics
University of Almeria
Department of Economics and Business
Carretera de Sacramento, s/n
04120 – Almeria (Spain)
Phone #: +34 950015780
E-Mail: dmn011@ual.es

[4] Assistant Professor of Applied Economics
University of Almeria
Department of Economics and Business
Carretera de Sacramento, s/n
04120 – Almeria (Spain)
Phone #: +34 950015780
E-Mail: fom445@ual.es

ABSTRACT

The objective of this study was to analyze the effects of inequality in income distribution, gender, race and education on incidence and mortality rates of COVID-19. For this purpose, a cross-sectional model was estimated for a sample of 2805 counties in the USA. The results obtained allow us to conclude that inequality in all its aspects posed a risk factor for incidence rate and, particularly, for mortality from COVID-19. Other results obtained show that access to healthcare, education attained, ease of adaptation to teleworking, vaccination and healthy lifestyle habits were key elements in the fight against the pandemic.

KEYWORDS

COVID-19, Inequality, Income, Racial segregation, Gender, Education

1. INTRODUCTION

Since the first case of COVID-19 was detected in Wuhan, China, in December 2019, the virus responsible has spread rapidly throughout the world, affecting both rich and poor countries alike.

After more than two years, in August 2022 and according to data from the World Health Organization (WHO), the USA led the ranking of countries most affected by the pandemic. Approximately 92 million US residents had been infected with COVID-19, of whom more than one million had died, making USA the only country in the world with more than one million deaths from the SARS-CoV-2 virus. Of the total number of deaths, about 75% were in people over 65 years of age. The mortality rate was also higher among the Black population than among the White population.

Despite being the world's leading economic power and the country that spends the most on healthcare, according to the 2021 Health Care Index prepared by CEOWorld Magazine, the USA had the thirtieth best healthcare system in the world. This makes it a very inefficient health system in which even today, despite the progress made with Obamacare[1], more than 8% of the US population still has no health coverage.

A macro-level study published in The Lancet highlights how poverty and socioeconomic inequality shorten life more than hypertension, obesity and excessive alcohol consumption, and criticizes the fact that WHO does not include these important determinants in its objectives and recommendations (Stringhini et al., 2017). According to the Effectiveness of Pandemic Management Rate prepared by Mapfre, the Nordic countries occupy the top positions. These countries are characterized, among other things, by low inequality. In this regard, we wonder whether socioeconomic inequality may also be a risk factor for COVID-19, since most of the work has been focused on analyzing the effects that COVID-19 is having on inequality (Blundell et al., 2020; Deaton, 2021). And the authors who have studied the effects of inequality on COVID-19 have analyzed very

[1] Obamacare is the popular name given to The Patient Protection and Affordable Care Act (PPACA), also known as the Affordable Care Act (ACA). It was enacted in March 2010 and reduced the number of uninsured individuals in the USA by about 20 million.

specific aspects of inequality. Therefore, in our opinion, it is very important to continue to deepen the analysis of the impact of inequality on COVID-19.

In this paper, our focus is on inequality in a broad sense, since inequality in income distribution, gender, race and education, can lead to unequal access to health care services, resources, and information. This can result in marginalized populations facing barriers to testing, treatment and preventive measures, which in turn can contribute to higher rates of COVID-19 incidence and mortality. Another novelty of our study is the inclusion of variables that analyze the effects of the labor market, the health system, vaccination status, unhealthy habits and three demographic variables (population over 65 years of age, rural population and university-educated population) on infection and death rates from COVID-19.

Inequality can be studied from several prisms. The aim of this paper is to study the effects of structural inequality on the incidence and mortality rates of COVID-19. Structural inequality refers to systematic and entrenched disparities in the social, economic and political structures of a society that generate and perpetuate inequalities in various areas of life, including health (Bhala et al., 2020). In this regard, the economic literature has paid particular attention to the effects of structural racism on health inequalities (Bailey et al., 2017) and, in particular, on the incidence of COVID-19. In this regard, the more severe effects suffered by African American communities because of this virus are an indicator of the social inequality and exclusion that existed before the COVID-19 crisis (Kim and Bostwick, 2020).

Racial and economic inequality has also been analyzed by other authors, who conclude that inequality has an impact on the population infected and killed by this virus (Abedi et al., 2020). In fact, the most economically disadvantaged are also the most vulnerable to COVID-19 (Patel et al., 2020). Therefore, income inequality positively impacts COVID-19 incidence and mortality rates (Tan et al., 2021; Sepulveda and Brooker 2021). It is important to emphasize that income inequality is an indicator of housing precariousness, smoking, obesity, and pollution, among other factors, which may have an impact on higher incidence and mortality rates of the virus (Wildman, 2021).

However, structural inequality includes more than purely racial or economic inequality and could be defined as "the condition where people have unequal access to valued resources, services, and positions in the society" (Kerbo, 2003, p. 11). Based on this, our work intends to further deepen the analysis of the effects of inequality on the incidence and mortality rates of COVID-19. The great novelty consists of using not only inequality in income distribution or racial inequality, but also gender inequality and inequality in education, with the aim of giving a broader view to the concept of inequality, and thus being able to better measure to what extent inequality is a risk factor for the coronavirus. In addition, the study carried out allows, on the one hand, to identify patterns and trends, that is, the cross-section analysis performed defines how the variables interact, identifying behaviors that are part of structural inequality. In addition, we can also identify the existing gaps and intersectional inequalities that affect different groups in society in different ways, which is why we conducted the study from different inequalities. On the other hand, this work allows us to formulate public policies and actions to correct structural inequality, as a measure to prevent future pandemics.

2. METHODS

The data on infection and deaths analyzed in this paper were obtained from official agencies and refer to the cumulative situation as of the end of July 2022. While we had access to a database of 3218 US counties, which represents almost 100% of all US counties, data on inequality by county was incomplete and only allowed us to analyze a sample of between 2614 and 2805 counties, depending on the inequality measure used in the case of the determinants of the COVID-19 incidence rate, and of between 2251 and 2403 counties when analyzing the mortality rate.

Two cross-sectional linear models were estimated to analyze whether the inequality, understood in a broad sense, observed in each US County had any effect on the incidence of and mortality from COVID-19. First, a basic model was estimated, which was subsequently extended to incorporate variables that measured certain behaviours and demographic variables. Both models were estimated using Ordinary Least Squares, since when the Breusch-Pagan test was performed, the p-value obtained revealed the presence

of heteroscedasticity. The models were estimated without a constant term. Although the decision whether to use a constant term or not is a problem that has generated much discussion (Casella, 1983), there are circumstances in which it is appropriate or even necessary not to use an error term. Where the dependent variable is zero, and if the vector of independent variables is also zero, the error term can be omitted (Eisenhauer, 2003). This is the case in the estimated model where variables such as the incidence rate of the state where the county in question is located or population density are used. If these variables had a value equal to zero, the COVID-19 incidence and mortality rates would also be zero.

The basic model used was as follows:

$$COVID19 = \beta_1 INCIDENCE + \beta_2 INCOME + \beta_3 INEQUALITY + \beta_4 HOSPITALS + \beta_5 UNEMPLOYMENT + \beta_6 WFH + \beta_7 OVERCROWDING + \beta_8 DENSITY + \beta_9 UNISURED + \beta_{10} VACCINATION + \beta_{11} LE + \mu_I \quad (1)$$

Where

COVID19 was the dependent variable.

Two versions of the variable were used: The objective was first to analyze how the independent variables affected the infection rate of the virus and, second, to check how they affected the mortality rate.

In this study, the incidence rate was the cumulative incidence rate of COVID-19 by county. It was defined as the cases detected per 100,000 inhabitants as of the last week of July 2022 and reported to US state and local health agencies.

The mortality rate was the cumulative number of COVID-19 deaths per 100,000 inhabitants by county as of the last week of July 2022 and reported to US state and local health agencies.

INCIDENCE refers to the incidence rate in the US state where the county is located. The inclusion of this variable enabled us to analyze the extent to which the level of infection in a population depends on the level in infection of the region where it was located.

INCOME measures the mean real income per household in the county relative to the mean real income per household in the state. The inclusion of this variable enabled us to study whether poorer populations within a state were more vulnerable to the effects of the pandemic. The data included refers to 2020 and was prepared by the authors from data published by the US Census Bureau. https://www.census.gov (accessed July 21, 2022).

INEQUALITY is the explanatory variable we have focus on. In this paper, and as stated above, we try to analyze inequality in a broad sense, i.e., we have not only analyzed the relationship between COVID-19 incidence and mortality rates and inequality in income distribution, but we also analyze it in relation to gender inequality, racial inequality, and educational inequality. Seven measures of inequality were used for this purpose:

- To measure inequality in income distribution, the Gini index and the 80/20 ratio were used. The Gini index varies between 0 and 1 and the 80/20 ratio is a measure of inequality that relates the percentage of the county's households´ income obtained by the top 20% of income to the bottom 20%. The sources we used here were the American Community Survey 2020 (5-Year Estimates) from the US Census Bureau. https://www.census.gov (accessed July 18, 2022).

- To assess gender inequality, we used the Gender Pay Gap, which measures the average earnings of women in relation to those of men. The source used here was County Health Rankings & Roadmaps 2022, University of Wisconsin Population Health Institute. https://www.countyhealthrankings.org (accessed on July 28, 2022). We also female used the female poverty variable, which refers to the percentage of poor women in relation to the total poor population. The source was our own elaboration based on American Community Survey 2020 (5-Year Estimates) prepared by the US Census Bureau. https://www.census.gov (accessed July 19, 2022).

- Racial inequality was measured by the percentage of the non-White poor population out of the total population below the poverty threshold (source: own elaboration based on American Community Survey 2020 (5-Year Estimates). US Census Bureau. https://www.census.gov (accessed July 19, 2022), and by racial segregation, i.e., the degree to which White and non-White residents live separately from each other within a county. The source here was County Health Rankings & Roadmaps 2022, University of Wisconsin Population Health Institute. https://www.countyhealthrankings.org (accessed July 28, 2022).

- Inequality in education was measured by the percentage of people who have not attained a high school level of education and who are below the poverty line as a percentage of the total poor population. The source here was our own elaboration based on American Community Survey 2020 (5-Year Estimates). US Census Bureau. https://www.census.gov (accessed July 19, 2022.

HOSPITALS was a proxy variable for the human and physical health resources available in the county. Two variables were used in this regard.

- First, the number of primary care physicians per 1,000 inhabitants was used, since they are responsible for detecting, in the first instance, the presence of COVID-19. The source here was our own elaboration based on County Health Rankings & Roadmaps 2022, University of Wisconsin Population Health Institute. https://www.countyhealthrankings.org (accessed July 28, 2022).

- Second, the number of staffed hospital beds per 1,000 inhabitants was used to analyze its effect on the mortality rate, since hospitals are responsible for treating/caring for the most serious cases of COVID-19. The source was our own elaboration from data https://www.covidcaremap.org accessed July 28, 2022.

UNEMPLOYMENT measured the unemployment rate in 2020 by county, i.e., when the pandemic began. Source: US Census Bureau. https://www.census.gov (accessed July 19, 2022).

WFH referred to "working from home," i.e., the percentage of people who teleworked prior to the beginning of the pandemic, specifically in 2018. The goal of using this variable was to measure the adaptability of the labor market to teleworking by county. Source: National Association of Realtors. https://www.nar.realtor/research-and-statistics/research-reports/work-from-home-counties (accessed August 3, 2022).

OVERCROWDING measured the percentage of households living in overcrowded conditions, i.e., in insufficient space to ensure minimum levels of safety and health. Source: County Health Rankings & Roadmaps 2022, University of Wisconsin Population Health Institute). https://www.countyhealthrankings.org (accessed July 28, 2022).

DENSITY was the population density of the municipality in 2020, i.e., the number of inhabitants per km^2. Source: US Census Bureau. https://www.census.gov (accessed July 22, 2022).

UNINSURED referred to the percentage of people under the age of 65 who did not have health insurance in 2019. Source: County Health Rankings & Roadmaps 2022, University of Wisconsin Population Health Institute. https://www.countyhealthrankings.org (accessed July 28, 2022).

VACCINATION measured the percentage of people who, by the end of July 2022, had received the full COVID-19 vaccination schedule, i.e., at least two doses. Source: Centers for Disease Control and Prevention (CDC) and State Governments. https://www.cdc.gov (accessed July 27, 2022).

LE was life expectancy. We used this variable as a proxy measure for the average health status of the county to test whether better health status led to lower rates of COVID-19 infection and mortality. Source: County Health Rankings & Roadmaps 2022, University of Wisconsin Population Health Institute. https://www.countyhealthrankings.org (accessed July 28, 2022).

The extended model used was as follows:

$$COVID19 = \beta_1 INCIDENCE + \beta_2 INCOME + \beta_3 INEQUALITY + \beta_4 HOSPITALS + \beta_5 UNEMPLOYMENT + \beta_6 WFH + \beta_7 OVERCROWDING + \beta_8 DENSITY + \beta_9 UNISURED + \beta_{10} VACCINATION + \beta_{11} SMOKE + \beta_{12} OBESITY + \beta_{13} INACTIVITY + \beta_{14} ALCOHOL + \beta_{15} STI + \beta_{16} RURAL + \beta_{17} UNIVERSITY + \beta_{18} ELDER + \mu_I \quad (2)$$

Where,

SMOKE referred to the percentage of a county's adult population reporting that they smoked every day or some days, and that they have smoked at least 100 cigarettes in their lifetime, in 2019. We wanted to see how smoking might affect COVID-19 infection and mortality rates. Source: County Health Rankings & Roadmaps 2022, University of Wisconsin Population Health Institute. https://www.countyhealthrankings.org (accessed July 28, 2022).

OBESITY was the percentage of the adult population with a body mass index (BMI) equal to or higher than 30 kg/m^2. This variable was used as a proxy measure of poor health status, the result of poor diet and low physical activity, which can have serious health effects, and thus aggravate the consequences of COVID-19. Source: County Health Rankings & Roadmaps 2022, University of Wisconsin Population Health Institute. https://www.countyhealthrankings.org (accessed July 28, 2022).

INACTIVITY was the percentage of adults aged 18 years and older reporting no leisure-time physical activity in the last month during 2019. This variable was used to reinforce the previous one, since a sedentary lifestyle per se worsens health. Source: County Health Rankings & Roadmaps 2022, University of Wisconsin Population Health Institute. https://www.countyhealthrankings.org (accessed July 28, 2022).

ALCOHOL measured the percentage of a county's adult population reporting binge drinking in the past 30 days, during 2019. Source: County Health Rankings & Roadmaps 2022, University of Wisconsin Population Health Institute. https://www.countyhealthrankings.org (accessed July 28, 2022).

STI referred to sexually transmitted diseases measured by the number of newly diagnosed cases of Chlamydia per 100,000 population in 2019. We use this indicator as a proxy measure for the population's disease prevention behavior. This would allow us to analyze whether those counties with a lower rate of sexually transmitted infection also had a lower rate of COVID-19 incidence. Source: County Health Rankings & Roadmaps 2022, University of Wisconsin Population Health Institute. https://www.countyhealthrankings.org (Accessed July 28, 2022).

RURAL was the percentage of people who lived in a rural environment. Source: County Health Rankings & Roadmaps 2022, University of Wisconsin Population Health Institute. https://www.countyhealthrankings.org (Accessed July 28, 2022).

UNIVERSITY measured the percentage of the population with a university education. The data referred to 2020, and this variable was used in all estimations except when inequality in education was used to avoid multicollinearity problems. Source: US Census Bureau. https://www.census.gov (accessed July 21, 2022).

ELDER referred to the percentage of the population over 65 years of age out of the total number of inhabitants. The inclusion of this variable was due to the greater severity with which this population group has endured COVID-19. Source: United States Census Bureau. https://www.census.gov (accessed July 21, 2022).

3. RESULTS

As indicated above, the models were estimated by OLS in its robust version to solve the problem of heteroscedasticity detected. On the other hand, a multicollinearity problem among the explanatory variables was ruled out, since a "Variance Inflation Factor" analysis yielded a value lower than five in each and every one of them. A total of 28 estimates were made, resulting from the use of 7 different inequality measures and the use of the incidence rate on the one hand, and the COVID-19 mortality rate on the other, and the estimation of two models, one basic and the other extended. The results of these

analyses are shown in Tables 1-4. Tables 1 and 2 show the estimates when the COVID-19 incidence rate was used as the dependent variable, while Tables 3 and 4 report the results of the estimation of the models using the virus mortality rate as the dependent variable. Tables 1 and 3 refer to the basic model, while Tables 2 and 4 refer to the extended model.

(insert tables 1, 2, 3 and 4 here)

The results are displayed in the seven columns of each of the tables. Each column refers to the inequality measure used. For each variable, the table provides information on the estimated parameter, i.e., the effect that each explanatory variable has on the incidence rate or on the COVID-19 mortality rate, in addition to the significance coefficient shown in parentheses.

The results obtained from the 28 estimates allow us to conclude, first of all, that the model is robust since there are hardly any significant changes in either the estimated regressors or their significance. Likewise, the quality of the adjustment is good since R^2 ranges between 0.66 (Table 1) and 0.81 (Table 4).

As for the values obtained, in most cases they were those expected a priori. Thus, we find positive and significant effects of the State COVID-19 incidence rate on the county incidence rate and to a lesser extent on the county mortality rate, as also shown in Spain by Amate-Fortes and Guarnido-Rueda (2023). Inequality also showed a positive result, suggesting that this is a risk factor for incidence and, above all, for COVID-19 mortality. Other factors that increased the incidence rate and mortality rate of COVID-19 are overcrowding (as also argued by Mendez et al., 2021), tobacco use (as argued by Gupta et al., 2021) and alcohol consumption (as also shown by Althobaiti et al., 2020).

On the other hand, the results obtained show that among the factors that reduce the incidence and mortality rates of COVID-19 was relative average income, that is, the higher the average wealth of the county in relation to the state, the lower the COVID-19 incidence and mortality rates. In addition, living in rural setting reduced the risk of infection most likely due to less social contact. Likewise, the significant negative sign

obtained for the variable "university", shows that the higher the percentage of the population with university studies, the lower the incidence and mortality rates of COVID-19. Therefore, education, insofar as it makes it possible to find a better job, facilitates teleworking and social distancing measures, as well as healthier habits, is a key element in the fight against COVID-19 (Daly et al., 2020).

Finally, it is important to analyze the results obtained for the variable measuring access to health resources. In the case of primary care, the estimated parameter is always positive. This implies that the greater the number of primary care physicians, the higher the incidence rate. This result, surprising a priori, may be due to the existence of a co-payment ranging from $10 to $80 when visiting a physician in the USA. This means that many people infected with COVID-19 but with mild symptoms do not visit a primary care physician, so that the number of reported cases in the USA is significantly lower than the real number (Noh and Danuser, 2021). Cases that worsen and end in death are not treated in primary care centers but in hospitals. Because of this, we decided to estimate the model, using the number of staffed hospital beds per 1,000 inhabitants as a proxy variable for a county's hospital infrastructure, using the mortality rate as the dependent variable. The estimated parameter for this variable was negative and significant, demonstrating that the greater the number of hospital beds, the more effective the coronavirus is in combating mortality. In contrast to early infection, when COVID-19 symptoms worsen, it may be necessary to go to hospital despite health care co-payments.

These results were confirmed by those obtained for the "uninsured" variable. When the mortality rate was used as the dependent variable, the sign of the estimated parameter was positive and highly significant, so that the higher the percentage of people without health coverage, the higher the COVID-19 mortality rate. Also, the result obtained when we estimate the models with the mortality rate as the dependent variable shows that vaccination is effective against the lethality of this virus, i.e., the higher the percentage of the population that was fully vaccinated, the lower the mortality rate from COVID-19 (Xu et al., 2021).

4. DISCUSSION

Focusing on the main objective of this work, which was to analyze how inequality affects the COVID-19 incidence and mortality, although it is not a measure of inequality, the mean real income of the county in relation to that of the State in which it is located, shows the situation of economic advantage or disadvantage in which the county finds itself in relation to the State. As discussed above, as expected, despite not obtaining a significant result in all the estimates, the negative and significant sign shows a negative relationship between this variable and the incidence and mortality rates of the virus, i.e., those populations that are wealthier in relative terms have been less affected by COVID-19 both in the form of lower rates of infection and lower mortality. This may be because in the poorer counties work is more precarious and the possibilities of undertaking telework and, therefore, maintaining social distance as a preventive measure, are fewer.

This finding is in line with that obtained by other authors, although it differs in terms of the mortality rate (Amate-Fortes and Guarnido-Rueda, 2023). In the case of Spain, these same authors conclude that, because of to the Spanish public health system, which provides healthcare free of charge at his point of access to the population, once the symptoms of coronavirus become severe, the takeup of hospital treatment does not distinguish between rich and poor. In contrast, the results obtained here show that counties with higher relative incomes suffered lower COVID-19 mortality. The results obtained here also align with those observed at the international level. If we look at the Effectiveness of Pandemic Management Rate index prepared by Mapfre, the countries that have best managed the COVID-19 health crisis are countries with above-average per capita incomes, such as South Korea, Norway, New Zealand, Iceland and Denmark, which occupy the top five positions in this indicator. Moreover, the presence of five Nordic countries in the top 10 countries highlights the inverse relationship between inequality in income distribution and pandemic management, as these countries are characterised by very low rates of inequality relative to the global average.

Going deeper into the effects of structural inequality on the incidence and mortality rates of COVID-19, seven measures of inequality were used for each county, with the aim of analyzing not only inequality in income distribution, but also gender inequality,

racial inequality, and inequality in education. Published papers on the effects of structural inequality on COVID-19 have focused primarily on the analysis of racial inequality (Bentley, 2020; Finn and Kobayashi, 2020; Yellow Horse et al., 2021). In all cases, the authors agree on the adverse effects of racial inequality on COVID-19 incidence and mortality.

In our study, with respect to incidence, the 14 estimates show a positive estimated parameter, that is, greater structural inequality, in this case within the county, leads to a higher level of infection, since this greater inequality shows that a significant part of the population does not have the necessary means to follow the COVID-19 prevention measures (Tan et al., 2021; Amate-Fortes and Guarnido-Rueda, 2023). However, the estimated parameter is not significant in all estimates. Thus, income inequality measured through the Gini index does show a positive and significant effect on the COVID-19 incidence rate; that is, the greater the inequality in income distribution within the county, the higher the incidence rate of the virus, since this greater inequality shows that an important part of the population does not have the necessary means to follow the COVID-19 prevention measures, a result also reached by Tan et. Al (2021) and Amate-Fortes and Guarnido-Rueda, (2023). In this sense, precarious working conditions, the stress that these entail, and the comorbidities associated with poverty that may characterize counties with greater inequality could explain these results, as suggested by other authors (Abedi et al., 2020; Patel et al., 2020; Wildman, 2021).

Gender inequality also showed a positive and significant effect on the rate of coronavirus infection. Gender inequality has been little studied in the economic literature as a cause of COVID-19. In fact, most papers have focused on the consequences of coronavirus on such inequality (Dang and Nguyen, 2021). Moreover, the few published papers that have analyzed the differences between men and women in the risk of COVID-19 infection do not find significant differences (Gebhard et al., 2020). In any case, the results obtained in our work are, in our opinion, consistent with the implications of gender inequality. Thus, women tend to have more precarious jobs than men (Paraskevopoulou, 2020), and this greater job precariousness is usually associated with a higher prevalence of chronic diseases (Kim et al., 2008). In fact, as Sobotka et al. (2020) point out, virus

incidence rates are higher in women compared to men at working age, showing the existence of a link between women's job profiles and infection rates.

As for racial inequality, we found a positive effect on the incidence rate of COVID-19, i.e., racial separation by geographic area increases the risk of contagion. As argued by Khanijahani and Tomassoni (2021), the fact that a high proportion of the population in a neighborhood is in a socioeconomically vulnerable situation may be the cause of the increased risk of virus transmission. However, when we measure racial inequality through the percentage of the non-white poor population out of the total population below the poverty threshold, the result obtained does not allow us to conclude that there are racial differences in the poor population at the rate of virus infection.

Inequality in education is also associated with an increased rate of COVID-19. As with gender inequality, the economic literature has focused on studying the effects of the virus on this form of inequality (Doyle, 2020). However, inequality in education also causes the risk of coronavirus infection for the same reasons discussed so far. Greater education allows access to better working conditions where it is easier to adopt preventive measures against COVID-19.

When we use the mortality rate as the dependent variable, the significance of the estimated parameters for the inequality variable is much higher than in the case of the incidence rate, showing that structural inequality is more important for the mortality rate than for the incidence rate. This result aligns with that obtained by other authors (Abedi et al., 2020; Tan et al., 2021). However, the results obtained in our study differ from those reached by other authors (Amate-Fortes and Guarnido-Rueda, 2023) in different contexts, and highlight the implications that different health systems have on the mortality rate of COVID-19. Inequality has not been shown to be a determining factor on COVID-19 mortality in Spain, highlighting the importance of having a good public health system that does not distinguish between rich and poor when it comes to treatment and care for COVID-19. Thus, the Spanish National Health System, responsible for treating the most severe cases through hospital treatment, does not differentiate between individuals by income level, making it an effective mechanism for reducing inequalities in society. In this study, the result is completely different, and highlights the inequality suffered by the

US population in terms of health status both prior to COVID-19 and in terms of access to health care.

5. CONCLUSIONS

Is structural inequality a risk factor for COVID-19 in the USA? This is the fundamental question we have tried to answer in this paper. After estimating a cross-sectional model for almost 100% of US counties, we can answer yes. Inequality, understood in a broad sense involving not only inequality in income distribution but also racial, gender and educational inequality, increases the rate of viral infection and, especially, mortality. Inequality in access to health care and treatment, as well as inequality in the labor market, have been shown to be powerful risk factors for COVID-19, especially for the most serious cases that result in death. For this reason, we believe it is essential that public policies should aim to combat this inequality. Policies and interventions should be designed to address the specific needs and risks of different groups. This might include implementing protective measures in the workplace, facilitating access to testing and vaccination, and promoting the active participation of communities in pandemic-related decision-making to enable more effective and flexible management. Many lives can be saved if inequality is reduced. In fact, vaccination, free and universal for the entire US population, provides a clear example of this, as shown by the negative relationship between the percentage of people with a complete vaccination schedule and the COVID-19 mortality rate.

Even so, prevention continues to be fundamental in mitigating the effects of COVID-19. In this sense, the maintenance of social distance and the adoption of personally protective measures such as mask wearing, again affected by inequality, and the promotion of healthy lifestyles are key policies in the fight against COVID-19.

LIMITATIONS

Like all research, this study has its limitations. First, the data did not allow us to divide the sample by age group or gender, which would have increased the usefulness of the

findings. Likewise, it would have been interesting to have included other measures of inequality, mainly racial and gender inequality, so as to enrich the analysis. In addition, this would have served to better test the robustness of the model. It is also important to note that in future research it would be advisable to be able to use survey data to analyze individual income differences between those who are infected and those who are uninfected. It would also have been desirable to have been able to use a governance variable measuring pandemic response at the county level. However, we were unable to find a suitable variable for each of the counties analyzed. Finally, it would have been interesting to carry out a multilevel estimation, although the data with which we have worked prevent us from doing so.

ACKNOWLEDGEMENT

Ignacio Amate-Fortes and Almudena Guarnido-Rueda are grateful for all the suggestions received during a research stay in the Department of Economics at the University of California, Santa Barbara.

CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

FUNDING

This study was funded by the European Union, Junta de Andalucía and University of Almeria (Reference No UAL-FEDER 2020, UAL2020-SEJ-D1999).

6. REFERENCES

Abedi, V., Olulana, O., Avula, V., Chaudhari, D., Khan, A., Shahjouei, S., Li, J. and Zand, R. (2020). Racial, Economic, and Health Inequality and COVID-19 Infection in the United States. Journal of Racial and Ethnic Health Disparities. https://doi.org/10.1007/s40615-020-00833-4

Althobaiti, Y. S., Alzahrani, M. A., Alsharif, N. A., Alrobaie, N. S., Alsaab, H. O., & Uddin, M. N. (2020, December). The possible relationship between the abuse of tobacco, opioid, or alcohol with COVID-19. In *Healthcare* (Vol. 9, No. 1, p. 2). MDPI.

Amate-Fortes, I., & Guarnido-Rueda, A. (2023). Inequality, public health, and COVID-19: an analysis of the Spanish case by municipalities. *The European Journal of Health Economics*, *24*(1), 99-110.

Bailey, Z. D., Krieger, N., Agénor, M., Graves, J., Linos, N., & Bassett, M. T. (2017). Structural racism and health inequities in the USA: evidence and interventions. *The lancet*, *389*(10077), 1453-1463.

Bentley, G. R. (2020). Don't blame the BAME: Ethnic and structural inequalities in susceptibilities to COVID-19. *American journal of human biology*, *32*(5), e23478.

Bhala, N., Curry, G., Martineau, A. R., Agyeman, C., & Bhopal, R. (2020). Sharpening the global focus on ethnicity and race in the time of COVID-19. *The Lancet*, **395** (May 30), 1673–1676. https://doi.org/10.1016/S0140-6736(20)31102-8

Blundell, R., Costa-Dias, M., Joyce, R. and Xu, X. (2020). COVID-19 and Inequalities. *Fiscal Studies*, 41(2), 291-319. https://doi.org/10.1111/1475-5890.12232

Casella, G. (1983). Leverage and Regression through the Origin. *The American Statistician*, 37(2), 147-152. https://doi.org/10.1080/00031305.1983.10482728

Daly, M. C., Buckman, S. R., & Seitelman, L. M. (2020). The unequal impact of COVID-19: Why education matters. *FRBSF Economic Letter*, *17*, 1-5.

Dang, H. A. H., & Nguyen, C. V. (2021). Gender inequality during the COVID-19 pandemic: Income, expenditure, savings, and job loss. *World Development*, *140*, 105296.

Deaton, A. (2021). *Covid-19 and global income inequality* (No. w28392). National Bureau of Economic Research.

Doyle, O. (2020). COVID-19: Exacerbating educational inequalities. *Public Policy*, *9*, 1-10.

Eisenhauer, J.G. (2003). Regression through the Origin. Teaching Statistics, 25, 76-80.

Finn, B. M., & Kobayashi, L. C. (2020). Structural inequality in the time of COVID-19: Urbanization, segregation, and pandemic control in sub-Saharan Africa. *Dialogues in Human Geography*, *10*(2), 217-220.

Gebhard, C., Regitz-Zagrosek, V., Neuhauser, H. K., Morgan, R., & Klein, S. L. (2020). Impact of sex and gender on COVID-19 outcomes in Europe. *Biology of sex differences*, *11*, 1-13.

Gupta, A. K., Nethan, S. T., & Mehrotra, R. (2021). Tobacco use as a well-recognized cause of severe COVID-19 manifestations. *Respiratory Medicine*, *176*, 106233.

Kerbo, H.R. (2003), *Social Stratification and Inequality: Class Conflict in Historical and Global Perspective*, McGraw-Hill, London.

Khanijahani, A., & Tomassoni, L. (2021). Socioeconomic and racial segregation and COVID-19: concentrated disadvantage and black concentration in association with COVID-19 deaths in the USA. *Journal of racial and ethnic health disparities*, 1-9.

Kim, I. H., Khang, Y. H., Muntaner, C., Chun, H., & Cho, S. I. (2008). Gender, precarious work, and chronic diseases in South Korea. *American journal of industrial medicine*, *51*(10), 748-757.

Kim, S. J. and Bostwick, W. (2020). Social Vulnerability and Racial Inequality in COVID-19 Deaths in Chicago. *Health Education and Behavior*, 47(4): 509-513. DOI: https://doi.org/10.1177/1090198120929677external icon

Mendez, A. D., Escobar, M., Romero, M., & Wojcicki, J. M. (2021). Overcrowding and exposure to secondhand smoke increase risk for COVID-19 infection among Latinx families in the greater San Francisco Bay Area. *Tobacco Induced Diseases*, *19*.

Noh, J., & Danuser, G. (2021). Estimation of the fraction of COVID-19 infected people in US states and countries worldwide. *PloS one*, *16*(2), e0246772.

Paraskevopoulou, A. (2020). Gender and precarious Work. *Handbook of Labor, Human Resources and Population Economics*, 1-18.

Patel, J. A., Nielsen, F., Badiani, A. A., Assi, S., Unadkat, V. A., Patel, B., Ravindrane, R., and Wardle, H. (2020). Poverty, Inequality and COVID-19: The Forgotten Vulnerable. *Public Health*, 183, 110–111. https://doi.org/10.1016/j.puhe.2020.05.006

Sepulveda, E. R., & Brooker, A. S. (2021). Income inequality and COVID-19 mortality: Age-stratified analysis of 22 OECD countries. *SSM-Population Health*, *16*, 100904.

Sobotka, T., Brzozowska, Z., Muttarak, R., Zeman, K., & Di Lego, V. (2020). Age, gender and COVID-19 infections. *MedRxiv*, 2020-05.

Stringhini, S. et al. (2017). Socioeconomic Status and the 25 × 25 Risk Factors as Determinants of Premature Mortality: A Multicohort Study and Meta-Analysis of 1·7 Million Men and Women. *The Lancet*, 389, pp. 1229-1237.

Tan, A. X., Hinman, J. A., Magid, H. S. A., Nelson, L. M., & Odden, M. C. (2021). Association Between Income Inequality and County-Level COVID-19 Cases and Deaths in the US. *JAMA Network Open*, *4*(5), e218799-e218799.

Wildman, J. (2021). COVID-19 and income inequality in OECD countries. *The European Journal of Health Economics*, *22*(3), 455-462.

Xu, S., Huang, R., Sy, L. S., Glenn, S. C., Ryan, D. S., Morrissette, K., ... & Qian, L. (2021). COVID-19 vaccination and Non–COVID-19 mortality risk—seven integrated health care organizations, United States, December 14, 2020–July 31, 2021. *Morbidity and Mortality Weekly Report*, *70*(43), 1520.

Yellow Horse, A. J., Yang, T. C., & Huyser, K. R. (2021). Structural inequalities established the architecture for COVID-19 pandemic among native Americans in Arizona: a geographically weighted regression perspective. *Journal of Racial and Ethnic Health Disparities*, 1-11.

TABLE 1: RESULTS OF THE ESTIMATIONS (INCIDENCE RATE – BASIC MODEL)

	INCOME INEQUALITY		GENDER INEQUALITY		RACIAL INEQUALITY		INEQUALITY IN EDUCATION
	Gini	80/20	GPG	Female poverty	Non-white poverty	Racial segregation	School inequality
Inequality[2]	27251.9*	200.6	5129.6	21987.2***	2839.5	26.39	3149.5*
	(1.92)	(1.23)	(1.45)	(2.86)	(0.56)	(0.88)	(1.72)
State Incidence rate	0.89***	0.93***	0.95***	0.92***	0.98***	0.96***	0.96***
	(6.65)	(7.32)	(9.43)	(8.20)	(11.92)	(11.17)	(9.79)
Mean relative income	-4455.5***	-4128.4***	-3872.2**	-4468.6***	-4377.0**	-4504.6***	-4179.4***
	(-2.75)	(-2.78)	(-2.46)	(-2.87)	(-2.37)	(-2.86)	(-2.75)
Primary health care	3.99**	4.07***	4.22***	4.85***	3.71**	4.15***	4.19***
	(2.50)	(2.59)	(2.87)	(2.92)	(2.14)	(2.83)	(2.82)
Unemployment	-23103.0	-15479.0	-7588.8	-11620.1	-11690.5	-9454.2	-7561.1
	(-1.56)	(-1.10)	(-0.88)	(-1.19)	(-0.74)	(-0.98)	(-0.87)
Work from home	-349.7**	-371.5	-381.1	-318.1	-350.6	-351.6	-357.7**
	(-1.01)	(-1.09)	(-1.17)	(-0.94)	(-0.84)	(-0.80)	(-2.44)
Overcrowding	87837.7**	82366.3**	80486.2**	87834.4**	75750.0***	84694.2**	80507.8**
	(2.36)	(2.39)	(2.36)	(2.46)	(3.06)	(2.52)	(2.33)
Population density	-0.23	-0.25	-0.14	-0.06	-0.20	-0.12	-0.10
	(-0.64)	(-0.63)	(-0.37)	(-0.15)	(-0.45)	(-0.33)	(-0.28)
Uninsured	-35881.3**	-32068.7**	-29648.6**	-31788.7**	-34937.2	-29675.7*	-31848.2**
	(-2.10)	(-1.99)	(-2.11)	(-2.16)	(-1.46)	(-1.95)	(-2.22)
Vaccination	2883.0	2684.5	2823.9	3972.5	1567.5	2398.0	3910.3
	(0.53)	(0.48)	(0.59)	(0.78)	(0.19)	(0.40)	(0.76)
Life expectancy	-2.05	95.74	60.13	-37.35	114.8	109.0	91.27
	(-0.04)	(1.17)	(0.58)	(-0.58)	(1.08)	(1.20)	(1.03)
Number of observations	2805	2801	2804	2805	2793	2647	2801
R^2	0.67	0.67	0.67	0.67	0.67	0.66	0.67

*Significant at 10% **Significant at 5% ***Significant at 1%

[2] These coefficients estimate each specific measure of inequality included in each model and is listed at the top of each column.

TABLE 2: RESULTS OF THE ESTIMATIONS (INCIDENCE RATE – EXTENDED MODEL)

	INCOME INEQUALITY		GENDER INEQUALITY		RACIAL INEQUALITY		INEQUALITY IN EDUCATION
	Gini	80/20	GPG	Female poverty	Non-white poverty	Racial segregation	School inequality
Inequality	11304.3 (1.54)	32.89 (0.47)	5492.4** (2.15)	10700.4 (1.55)	-8626.1*** (-2.59)	27.78** (2.30)	818.6 (0.44)
State Incidence rate	0.92*** (12.77)	0.95*** (13.98)	0.92*** (12.71)	0.92*** (12.14)	0.93*** (14.21)	0.94*** (13.66)	0.96*** (14.79)
Mean relative income	-2270.9* (-1.89)	-1943.6 (-1.52)	-1730.2 (-1.38)	-2596.2** (-2.02)	-1898.5 (-1.47)	-2030.6 (-1.53)	-4758.2*** (-5.94)
Primary health care	2.80*** (2.91)	3.03*** (3.15)	2.99*** (3.18)	3.11*** (3.30)	2.72*** (2.63)	3.02*** (3.16)	2.56*** (2.98)
Unemployment	-24959.1* (-1.73)	-22975.8 (-1.59)	-21197.4 (-1.55)	-21307.8 (-1.55)	-6795.4 (-0.47)	-23070.6 (-1.54)	-20827.6 (-1.50)
Work from home	-301.34** (-2.29)	-287.5** (-2.24)	-315.73** (-2.37)	-305.5** (-2.31)	-345.3** (-2.55)	-341.4** (-2.13)	-357.7** (-2.44)
Overcrowding	30896.6 (1.43)	31947.3 (1.49)	29234.1 (1.39)	31862.1 (1.47)	39414.7* (1.92)	35696.9 (1.59)	39962.9** (2.06)
Population density	0.07 (0.07)	0.10 (0.10)	0.06 (0.06)	0.08 (0.08)	0.40 (0.38)	0.02 (0.02)	-0.25 (-0.34)
Uninsured	-17709.2*** (-3.60)	-16118.2*** (-2.99)	-17138.8*** (-3.21)	-16600.4*** (-3.08)	-3668.5 (-0.39)	-16050.4*** (-2.78)	-18477.7*** (-3.82)
Vaccination	11118.6*** (4.28)	11108.9*** (4.12)	10497.1*** (3.97)	11102.7*** (4.15)	14894.9*** (4.13)	11308.2*** (3.84)	7999.0*** (4.09)
Smoke	12679.1** (2.29)	14462.0*** (2.71)	10757.1** (1.96)	14134.0*** (2.71)	-9710.8 (-0.82)	12433.6** (2.23)	16317.8*** (3.37)
Obesity	3036.3 (0.33)	5505.8 (0.65)	2983.2 (0.34)	-854.2 (-0.09)	7109.5 (0.82)	4558.8 (0.50)	7336.8 (0.88)
Inactivity	68.01 (0.01)	2167.2 (0.30)	2400.0 (0.33)	833.3 (0.11)	12591.7** (1.99)	3092.3 (0.41)	7776.9 (1.11)
Alcohol	14942.5** (2.09)	17461.4** (2.10)	13734.3* (1.71)	12494.2 (1.55)	17256.3** (2.12)	17529.6** (2.01)	16341.2** (2.06)
Sexual transmitted infections	2.44 (1.19)	2.53 (1.26)	2.44 (1.18)	2.71 (1.24)	5.73* (1.92)	2.67 (1.23)	1.92 (0.94)
Rural	-2903.8** (-2.35)	-3114.2** (-2.53)	-2965.5** (-2.39)	-2959.1** (-2.41)	-2908.5** (-2.40)	-2861.6** (-2.23)	-2778.8** (-2.44)
University	-25011.8* (-1.72)	-22642.1* (-1.64)	-25218.1* (-1.86)	-23626.6* (-1.73)	-23546.3* (-1.69)	-21888.0 (-1.56)	

Elder	-20163.8*** (-4.01)	-17532.6*** (-3.09)	-18508.3*** (-3.39)	-19291.5*** (-3.90)	-20343.1*** (-3.84)	-17195.0*** (-2.84)	-22242.3*** (-4.01)
Number of observations	2741	2732	2740	2741	2733	2614	2738
R^2	0.78	0.78	0.78	0.78	0.78	0.77	0.78

*Significant at 10% **Significant at 5% ***Significant at 1%

TABLE 3: RESULTS OF THE ESTIMATIONS (MORTALITY RATE – BASIC MODEL)

	INCOME INEQUALITY		GENDER INEQUALITY		RACIAL INEQUALITY		INEQUALITY IN EDUCATION
	Gini	80/20	GPG	Female poverty	Non-white poverty	Racial segregation	School inequality
Inequality	1149.7*** (6.37)	4.98*** (3.04)	80.99 (1.38)	819.2*** (6.88)	8.13 (0.12)	1.06** (2.33)	227.7*** (5.88)
State Incidence rate	0.006*** (3.35)	0.008*** (4.70)	0.009*** (5.60)	0.008*** (4.46)	0.009*** (6.27)	0.008*** (5.61)	0.009*** (5.64)
Mean relative income	-171.1*** (-8.09)	-158.6*** (-7.94)	-154.3*** (-7.26)	-170.0*** (-8.10)	-159.3*** (-6.33)	-161.0*** (-7.58)	-157.7*** (-7.72)
Hospitals	-0.03*** (3.56)	-0.05*** (-4.61)	-0.05*** (-5.07)	-0.05*** (-4.99)	-0.05*** (-5.25)	-0.05*** (-4.90)	-0.05*** (-5.06)
Unemployment	176.2 (0.78)	736.2*** (3.62)	956.1*** (5.53)	725.9*** (4.08)	953.2*** (3.78)	994.8*** (5.80)	802.9*** (4.77)
Work from home	-6.12** (-1.47)	-7.55* (-1.85)	-7.50* (-1.82)	-5.06 (-1.22)	-7.81 (-1.56)	-8.07 (-1.53)	-5.01 (-1.22)
Overcrowding	-487.5 (-1.06)	-760.4* (-1.74)	-814.6* (-1.87)	-531.4 (-1.18)	-815.0** (-2.45)	-783.1* (1.85)	-926.8** (-2.15)
Population density	-0.005 (-1.13)	-0.003 (-0.70)	0.0003 (0.07)	0.002 (0.51)	0.0007 (0.13)	-0.0005 (-0.11)	-0.00002 (-0.00)
Uninsured	463.2** (2.32)	653.4*** (3.49)	722.7*** (4.24)	621.6** (3.49)	707.9** (2.41)	765.8*** (4.21)	558.3*** (3.22)
Vaccination	-279.1*** (-3.77)	-266.6*** (-3.57)	-266.2*** (-3.84)	-237.2*** (-3.32)	-262.1** (-2.35)	-279.4*** (-3.48)	-230.2*** (-3.18)
Life expectancy	0.52 (0.63)	4.81*** (4.21)	4.37*** (3.18)	-0.16 (-0.16)	5.12*** (3.49)	5.18*** (4.24)	4.27*** (3.55)
Number of observations	2403	2401	2403	2403	2394	2280	2401
R^2	0.73	0.72	0.72	0.73	0.72	0.72	0.72

*Significant at 10% **Significant at 5% ***Significant at 1%

TABLE 4: RESULTS OF THE ESTIMATIONS (MORTALITY RATE – EXTENDED MODEL)

	INCOME INEQUALITY		GENDER INEQUALITY		RACIAL INEQUALITY		INEQUALITY IN EDUCATION
	Gini	80/20	GPG	Female poverty	Non-white poverty	Racial segregation	School inequality
Inequality	487.2*** (4.15)	3.05*** (3.78)	7.79 (0.18)	362.6*** (3.40)	-13.10 (-0.28)	0.42 (1.44)	97.37*** (2.67)
State Incidence rate	0.0009 (0.71)	0.002 (1.59)	0.002 (1.56)	0.001 (0.81)	0.002* (1.70)	0.001 (1.22)	0.002* (1.75)
Mean relative income	16.47 (0.79)	30.20 (1.39)	22.57 (1.06)	4.83 (0.02)	23.44 (1.07)	23.82 (1.11)	-92.36*** (-6.29)
Hospitals	-0.05*** (-5.47)	-0.05*** (-5.54)	-0.05*** (-5.65)	-0.05*** (-5.85)	-0.05*** (-5.62)	-0.05*** (-5.69)	-0.04*** (-5.12)
Unemployment	-327.3 (-1.45)	-230.7 (-1.05)	-158.2 (-0.74)	-153.2 (-0.71)	-142.5 (-0.62)	-111.2 (-0.50)	-111.8 (-0.50)
Work from home	-5.84*** (-2.75)	-5.71*** (-2.72)	-5.38** (-2.49)	-5.91*** (-2.77)	-5.91*** (-2.78)	-6.12** (-2.66)	-7.82** (-3.46)
Overcrowding	-531.7* (-1.92)	-516.5* (-1.85)	-520.5* (-1.85)	-493.5* (1.73)	-488.3* (-1.76)	-510.3 (1.59)	-183.3 (-0.67)
Population density	0.03** (2.12)	0.03** (2.09)	0.03** (2.24)	0.03** (2.17)	0.03** (2.04)	0.03** (2.18)	0.01 (1.21)
Uninsured	371.4*** (4.27)	420.4*** (4.63)	438.3*** (4.76)	415.0*** (4.54)	450.7*** (3.21)	456.0*** (4.71)	309.6*** (3.49)
Vaccination	-18.0 (-0.38)	-2.76 (-0.06)	-6.05 (-0.12)	-25.37 (-0.52)	1.62 (0.03)	-8.87*** (0.18)	-167.9*** (-4.17)
Smoke	283.4** (2.29)	310.6** (2.55)	345.4*** (2.73)	346.0*** (2.84)	312.3* (1.72)	349.8*** (2.79)	441.4*** (3.46)
Obesity	-97.38 (-0.72)	-0.85 (-0.01)	-18.47 (-0.14)	-206.4 (-1.54)	-17.46 (-0.14)	24.61 (0.19)	85.93 (0.68)
Inactivity	456.2*** (3.29)	537.9*** (4.10)	606.1*** (4.58)	517.7*** (3.82)	625.7*** (5.09)	566.5*** (4.29)	748.6 (1.48)
Alcohol	125.4 (1.09)	232.0* (1.85)	227.4* (1.83)	84.0 (0.67)	237.9* (1.86)	220.2* (1.70)	189.3** (2.06)
Sexual transmitted infections	0.03 (1.06)	0.03 (0.97)	0.04 (1.31)	0.04 (1.42)	0.04 (1.04)	0.03 (1.23)	0.01 (0.39)
Rural	-44.38** (-2.23)	-51.12*** (-2.57)	-50.90** (-2.54)	-46.60** (-2.36)	-48.88** (-2.47)	-52.77*** (-2.57)	-39.43** (-2.04)
University	-1105.0*** (-5.45)	-1034.5*** (-5.45)	-965.9*** (-5.14)	-1004.0*** (-5.37)	-961.8*** (-4.97)	-952.0 (-5.02)	

Elder	884.7*** (9.55)	998.4*** (10.04)	1000.8*** (10.29)	935.1*** (10.36)	997.2*** (10.48)	1006.2*** (9.99)	830.3*** (8.15)
Number of observations	2344	2342	2344	2344	2339	2251	2342
R^2	0.81	0.81	0.81	0.81	0.81	0.81	0.81

*Significant at 10% **Significant at 5% ***Significant at 1%