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Healthcare Systems and COVID-19 Mortality in Selected OECD Countries: A Panel Quantile Regression Analysis

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Objectives: The pandemic caused by coronavirus disease 2019 (COVID-19) has exerted an unprecedented impact on the health of populations worldwide. However, the adverse health consequences of the pandemic in terms of infection and mortality rates have varied across countries. In this study, we investigate whether COVID-19 mortality rates across a group of developed nations are associated with characteristics of their healthcare systems, beyond the differential policy responses in those countries.

Methods: To achieve the study objective, we distinguished healthcare systems based on the extent of healthcare decommodification. Using available daily data from 2020, 2021, and 2022, we applied quantile regression with non-additive fixed effects to estimate mortality rates across quantiles. Our analysis began prior to vaccine development (in 2020) and continued after the vaccines were introduced (throughout 2021 and part of 2022).

Results: The findings indicate that higher testing rates, coupled with more stringent containment and public health measures, had a significant negative impact on the death rate in both pre-vaccination and post-vaccination models. The data from the post-vaccination model demonstrate that higher vaccination rates were associated with significant decreases in fatalities. Additionally, our research indicates that countries with healthcare systems characterized by high and medium levels of decommodification experienced lower mortality rates than those with healthcare systems involving low decommodification.

Conclusions: The results of this study indicate that stronger public health infrastructure and more inclusive social protections have mitigated the severity of the pandemic's adverse health impacts, more so than emergency containment measures and social restrictions.

Key words: COVID-19, Health care systems, Decommodification index, Panel quantile regression, OECD countries

INTRODUCTION

The pandemic caused by coronavirus disease 2019 (COVID-19) has exerted an unprecedented impact on the health of populations worldwide [1]. By the end of 2021, the total number of infections exceeded 665 million, with an official death toll of approximately 6.7 million. However, it has been suggested that the actual death toll may be more than twice this figure [2]. While much was learned about the virus, effective treatments remained limited and inaccessible to large population segments. Nevertheless, due to the extensive mobilization of resources and massive investments by both governments and non-governmental foundations in certain advanced nations, several vaccines were successfully developed and distributed, albeit disproportionately, to various countries [3].

The emergence of new variants of the virus, such as the

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more lethal Delta variant and the highly contagious Omicron variant, has raised even greater concern. Consequently, it has been prudent for governments worldwide to focus on preventive measures to curb the spread of the virus. These measures primarily aim to ensure that individuals maintain social distancing and adhere to public health guidelines, such as wearing masks in public places and limiting interactions and travel. Simultaneously, efforts were made to minimize the negative effects of these restrictive measures on the economy [4].

The initial reactions and sustained efforts of various governments in response to the pandemic have been overwhelming [5]. Unsurprisingly, the pandemic has affected countries differently, leading to varied governmental responses. In the early stages of the pandemic, all governments prioritized containment and mitigation of virus spread; however, testing and vaccination became increasingly important in later stages [6]. The adequacy and effectiveness of these measures, however, remained to be determined. Indeed, the pandemic served as a monumental test of public health systems and the responsiveness and efficiency of governments. This was particularly notable in advanced countries, where public accountability and media scrutiny are widespread. Despite shared values and highly developed healthcare systems, the adverse health impacts of the pandemic were severe and varied in these advanced countries [7]. In Europe, Germany (with 18 883 total deaths between December 30, 2019 and January 5, 2020) and Britain (with 13 767 total deaths between December 28, 2019 and January 3, 2020) bore the brunt of the pandemic early on. They were followed by Italy (13 483 deaths), France (12 737 deaths) and Spain (8710 deaths) in the initial days of January 2020 [8]. In North America, the United States experienced the most devastating impact, accounting for approximately one-quarter of total global infections and one-fifth of total global deaths [8].

In this study, we focus on the death toll resulting from the pandemic and explore the variations in mortality across several developed nations. We hypothesized that mortality rates were influenced not only by governmental responses to the pandemic but also by the nature of each country's healthcare system. To differentiate between these systems, we employed Bambra [9]'s numerical typology of healthcare systems. Drawing on Esping-Andersen [10]'s concept of decommodification as a means of classifying welfare regimes, Bambra classifies healthcare systems into those with low, medium, and high levels of decommodification in selected Organization for Economic Cooperation and Development (OECD) countries, utilizing a decommodification index. Healthcare systems with a high degree of decommodification offer superior and more equitable access to healthcare, delivering quality care regardless of the patient's financial status.

As such, we hypothesized that the death toll of the pandemic was more pronounced in countries with healthcare systems characterized by a lower degree of decommodification. To test our hypothesis, we considered 2 distinct periods: pre-vaccination (2020) and post-vaccination (2021 and part of 2022). During these eras, countries were profoundly impacted by COVID-19, and both containment measures and vaccines were significantly effective [11]. We employed a panel quantile regression model to elucidate the relationship between mortality and government responses, which included testing, containment, public health measures, and vaccination. We also incorporated categorical dummy variables to represent the type of healthcare system in each country. The total number of infections and the capacity for intensive care were included as control variables.

METHODS

Study Design and Sampling

To categorize the healthcare systems of the countries in our sample, we followed Bambra [9]'s approach. This method builds upon the pioneering work of Esping-Andersen [10], which meticulously considers a variety of distinguishing institutional, political, and economic factors that shape the welfare states in advanced economies within Europe and beyond. This leads to the identification of 3 distinct types of welfare regimes: liberal, conservative, and social-democratic. A key principle in this categorization scheme is decommodification, defined as "the extent to which individuals and families can maintain a normal and socially acceptable standard of living regardless of their market performance" [12]. However, health scholars have criticized Esping-Andersen's typology for its insufficient attention to healthcare services, which play a crucial role in the welfare state of any country [9,13]. This is because the Esping-Andersen model considers only sickness benefits in the welfare mix [9,14].

Bambra [15] asserts that healthcare constitutes by far the largest and most extensive portion of social welfare in many countries. Social welfare mediates the health impacts of socioeconomic position, which are known as social determinants of health, across various population groups [16]. Although she acknowledges the relevance of Esping-Andersen's rationale for healthcare typology, she finds the criteria used for this typology less applicable to healthcare systems. This is because the emphasis is on the decommodification of cash transfers, rather than on service delivery or regulation. Consequently, Bambra expands Esping-Andersen's principle of decommodification to healthcare, defining it as the degree to which an individual's access to healthcare is reliant on their market position [9]. As a result, she identifies 3 indicators that typify a country's healthcare system: (1) the percentage of private health expenditure relative to gross domestic product, (2) the percentage of private hospital beds out of the total number of beds, and (3) the percentage of the population covered by the healthcare system.

The first 2 indicators represent the balance of public and private contributions in both funding and service provision. In contrast, the third indicator provides a broader measure of health decommodification, as it encapsulates overall access to healthcare. As Bambra states, "The larger the size of the private health sector in terms of expenditure and consumption, the larger the role of the market and, therefore, the lower the degree of health decommodification" [9]. Utilizing the composite decommodification index for the same 18 countries that were examined in the original Esping-Andersen typology, Bambra classifies the healthcare systems of these countries into 3 categories: low, medium, and high decommodification. As depicted in Table 1, the index varies from a very low score of 8 for the United States (which is considered an outlier) to a high score of 60 for the United Kingdom, with the majority of countries achieving scores between 30 and 50.

Table 1. Categorization of healthcare systems by decommodification

Country	Decommodification index	Degree of decommodification
United States	8	Low
Australia	20	Low
Germany	27	Medium
Switzerland	29	Medium
Austria	30	Medium
Japan	30	Medium
Netherlands	30	Medium
Belgium	40	Medium
France	40	Medium
Ireland	40	Medium
Italy	40	Medium
Canada	50	High
Denmark	50	High
Finland	50	High
New Zealand	50	High
Norway	50	High
Sweden	50	High
United Kingdom	60	High

Adapted from Bambra C. Soc Policy Soc 2005;4(1):31-41 [9].

Statistical Analysis

To estimate the impact of various factors—such as public health measures, testing, vaccination, and the type of healthcare system—on mortality caused by the pandemic, we utilized a sophisticated panel quantile regression with non-additive fixed effects [17]. This method accommodates country-specific and healthcare system-specific fixed effects and offers estimates for different quantiles of the dependent variable, rather than solely the mean estimates provided by standard regression analysis. This approach is crucial given the varying death tolls across countries [18]. Panel quantile regression enables researchers to assess the impact of a vector of independent variables on the conditional distribution of the target variable (or dependent variable), while controlling for the effects of unobserved heterogeneity. In addition, unlike the conventional method of panel estimation, which includes panel regression with fixed or random effects, panel quantile regression can accommodate outliers and non-linearity in any form. This leads to more reliable and robust results. The concept of incorporating the quantile framework into panel data analysis was initially introduced in the seminal work of Koenker [19]. This idea has since been developed further and applied across a wide range of fields [20-22]. We adopted the approach of Powell [17], as it is a more general panel quantile fixed effects approach. This allows us to interpret the estimates in a manner similar to the cross-sectional quantile estimates. Furthermore, it accommodates both exogenous and endogenous independent variables.

The model was computed for 2 distinct eras: the pre-vaccination period (April 1-December 31, 2020) and the post-vaccination period (January 1, 2021-May 31, 2022). The cut-off date was a result of the unavailability of data beyond this point.

The underlying model for the pre-vaccination period (2020) was defined as follows:

$$LD_{it} = \beta_0 + \beta_1 LC_{it} + \beta_2 LT_{it} + \beta_3 LICU_{it} + \beta_4 LCHI_{it} + \beta_5 DM + \beta_6 DH + \mu_i + \varepsilon_{it} \quad (1)$$

where LD_{it} represents total deaths; LC_{it} denotes total cases; LT_{it} indicates total tests; $LICU_{it}$ illustrates the total number of patients in the intensive care unit (ICU); $LCHI_{it}$ signifies the containment and health index (CHI); and DM and DH represent 2 distinct health typologies. The former includes the countries with a medium decommodification index, while the latter encompasses countries with the highest decommodification index. To control for the dummy variable trap, the binary variable corresponding to countries with a low decommodification index was considered to be the base group and excluded from the model. Finally, μ_i represents the country-specific effects, and ε_{it} serves as the error term. Since the tabulated series are measured differently, all are transformed into logarithmic form to control for dimensional differences.

The post-vaccination model (for 2021 and 2022) resembled the pre-vaccination model, apart from the addition of the variable $LVAX_{it}$. This variable represents the logarithm of the total number of fully vaccinated people, and it is added to the previous independent variable. Hence, equation (1) was modified as follows:

$$LD_{it} = \beta_0 + \beta_1 LC_{it} + \beta_2 LT_{it} + \beta_3 LICU_{it} + \beta_4 LCHI_{it} + \beta_5 DM + \beta_6 DH + \beta_7 LVAX_{it} + \mu_i + \varepsilon_{it} \quad (2)$$

Data Collection and Measurement

We examined several key variables, including total deaths per million population, total cases per million population, total tests per thousand population, and the total number of fully vaccinated individuals per thousand population. We also considered the number of patients per million population in ICUs, using this figure as a measure of the actual utilization of intensive care capacity, rather than the nominal capacity based on the number of beds. It is important to recognize that intensive care involves more resources, including physicians and nurses, than simply the number of beds available. CHI is a composite index comprised of 12 sub-indices, which encapsulate the governmental restrictions implemented to control the virus. These restrictive policies include masking mandates, social distancing measures, and closures. The index also incorporates public health measures such as testing, contact tracing, quarantine and isolation procedures, public information campaigns, and the expansion of healthcare services to manage infections. Higher values of the index signify stricter enforcement of these measures. This index was extracted from the Oxford database [4]. The data for all other variables were sourced from the Our World in Data database [23].

Due to missing data for several variables from a handful of countries, specifically Germany, Japan, New Zealand, Norway, Switzerland, and Sweden, we had to restrict our sample to 12 countries. The excluded countries happened to have healthcare systems with medium to high degrees of decommodification; therefore, their exclusion provides a better representation of the systems in the remaining countries within our sample. To limit the time dimension of the data panel, daily data were aggregated into weekly information. All variables were represented as weekly averages. Table 2 provides a summary of the data utilized in our estimations.

As demonstrated in Table 2, the average weekly number of infections, adjusted for population, varied significantly across countries in 2020. The numbers ranged from a low of 30 in Australia to a high of 1607 in the United States. Notably, these numbers grew in 2021 and 2022 as the pandemic took hold and spread, with a particularly dramatic increase in Australia. The pattern of deaths from 2020 to 2022 varied across countries. In some nations, such as the United Kingdom, the United States, France, and the Netherlands, death rates consistently declined. In contrast, other countries like Canada and Italy saw an increase in the death rate in 2021, followed by a decrease in 2022. Meanwhile, in countries such as Finland, Denmark, and Australia, the death rate consistently rose from 2020 to 2022. Such variation across countries could potentially be attributed to differences in containment measures, protection, vaccination, and viral variants.

In 2020, the average number of tests conducted weekly varied significantly across countries, with Denmark leading the group. In 2021, testing increased substantially in all countries, with Austria and the United Kingdom experiencing the highest increases (by 22 and 5 times, respectively). However, in 2022, the number of tests declined in most countries, with Denmark experiencing the most substantial reduction (approximately 40%). The average weekly number of ICU patients per million population also varied considerably across countries in 2020, with Australia having less than 1 and the United States having nearly 42. In 2021, the numbers increased in the vast majority of countries; however, as anticipated, they decreased in 2022.

The CHI exhibited relatively minimal variation across the countries, and it generally increased in 2021 with the emergence of new COVID-19 variants. The average weekly number of fully vaccinated individuals was relatively consistent across the countries in our sample, with the lowest value in the United States (12.2) and the highest in Denmark and Ireland (14.8). The comparable vaccination rates in these advanced countries could be attributed to relatively equal access to vaccines. However, the vaccination rate markedly declined in all countries in 2022.

Table 2. Population-adjusted weekly average data in 2020, 2021, and 2022

Variables		UK	FIN	DNK	CAN	ITA	IRL	FRA	BEL	NLD	AUT	AUS	USA
Cases	2020	1055	181	761	408	980	495	1005	1538	1223	1095	30	1607
	2021	3099	790	2035	768	1269	2538	1896	2395	2532	1962	248	1930
	2022	5965	6899	18 178	2087	8789	7334	13 919	8032	12 938	15 266	11 513	3992
Deaths	2020	38.4	2.9	6.0	11.0	34.6	12.5	27.0	47.0	18.0	23.0	1.0	29.0
	2021	23.8	3.9	6.5	7.0	20.7	14.6	18.0	14.0	10.0	20.0	1.1	26.5
	2022	15.0	25.0	24.0	13.0	22.6	13.0	17.0	23.0	3.5	16.0	11.9	24.0
Tests	2020	20.0	12.6	50.0	13.0	12.5	13.0	14.8	17.0	9.8	11.8	12.1	21.0
	2021	98.0	21.7	141.0	17.0	36.8	29.5	45.7	34.0	17.0	266.0	32.4	26.7
	2022	74.0	18.0	85.0	11.0	62.0	20.0	53.0	26.0	22.0	326.0	29.7	23.6
ICU	2020	13.5	4.3	5.4	7.0	21.0	7.6	32.0	39.0	20.8	20.0	0.7	42.4
	2021	16.1	5.3	7.1	16.0	23.0	8.0	39.6	35.0	21.0	32.0	3.1	41.5
	2022	6.0	6.5	5.0	15.0	13.5	11.0	34.0	21.0	7.0	19.0	7.0	27.0
CHI[1]	2020	63.5	42.7	52.0	63.1	70.8	63.8	60.4	59.6	56.0	58.6	63.0	64.6
	2021	61.2	50.0	56.4	69.1	73.5	67.2	61.3	61.0	61.6	70.5	66.0	61.2
	2022	38.3	42.5	30.3	50.9	59.3	33.9	46.8	44.7	49.2	60.7	52.7	48.4
VAX	2021	13.5	14.2	14.8	14.7	14.6	14.8	14.1	14.6	12.9	13.6	14.5	12.2
	2022	1.7	2.0	1.5	2.3	2.4	1.5	2.2	3.9	0.4	1.7	3.2	1.7

Cases, deaths, and ICU patient data are presented per million population, whereas tests and VAX data are shown per thousand population.
FIN, Finland; DNK, Denmark; CAN, Canada; IRL, Ireland; FRA, France; BEL, Belgium; NLD, Netherlands; AUT, Austria; AUS, Australia; ICU, intensive care unit; CHI, containment and health index; VAX, vaccination.
[1]CHI is an index with a scale of 0-100. The data for 2020 cover April to December only, while the data for 2022 cover January to May.

Table 3. Quantile estimation results of COVID-19 fatalities for selected OECD countries

Variables	Pre-vaccination (Apr-Dec 2020)**			Post-vaccination (Jan 2021-May 2022)**		
	0.25 quantile	0.50 quantile	0.75 quantile	0.25 quantile	0.50 quantile	0.75 quantile
LC	1.300 (0.029)	1.193 (0.048)	1.117 (0.015)	0.776 (0.015)	0.975 (0.007)	1.060 (0.007)
LT	-0.584 (0.016)	-0.501 (0.114)	-0.706 (0.012)	-0.106 (0.017)	-0.148 (0.003)	-0.052 (0.008)
LICU	-0.193 (0.018)	-0.130 (0.010)	-0.151 (0.018)	-0.747 (0.006)	-0.568 (0.008)	-0.352 (0.009)
LCHI	-2.047 (0.120)	-1.604 (0.301)	-2.863 (0.062)	-0.637 (0.078)	-1.392 (0.015)	-1.854 (0.013)
DM	-0.235 (0.025)	-0.478 (0.090)	-0.625 (0.035)	-0.286 (0.039)	-0.195 (0.021)	-0.176 (0.013)
DH	-0.571 (0.022)	-0.786 (0.115)	-1.017 (0.007)	-0.653 (0.008)	-0.613 (0.014)	-0.409 (0.011)
LVAX	-	-	-	-0.026 (0.003)	-0.024 (0.006)	-0.027 (0.003)

Values are presented as logarithm of total death (standard error).
COVID-19, coronavirus disease 2019; OECD, Organization for Economic Cooperation and Development; LC, log of total cases; LT, log of total tests; LICU, log of the total number of intensive care unit patients; LCHI, log of the containment and health index; DM, dummy variables corresponding to medium; DH, dummy variables corresponding to high decommodification; LVAX, log of the total number of fully vaccinated people.
$^{**}p<0.01$.

Ethics Statement

This study has applied secondary data. There is no need for ethical approval.

RESULTS

This section presents the estimated results for the pre-vaccination (2020) and post-vaccination (2021 and 2022) models for 3 quantiles—25%, 50%, and 75%—of the dependent variable, which is the death toll. As illustrated in Table 3, mortality increased with infected cases across all quantiles for both pre-vaccination and post-vaccination periods. In the pre-vaccination model, the increase in mortality was more proportionate than the increase in infection cases, as indicated by the estimated coefficients (elasticities), which are all greater than 1. However, this effect was less pronounced in the post-vaccination period, underscoring the effectiveness of vaccines. As anticipated, an increase in testing resulted in a decrease in mortality. Generally, the negative impact of testing on mortality was more pronounced in all quantiles during the pre-vaccination period compared to the post-vaccination period. Additionally, a higher number of ICU patients correlated with fewer fatalities. This may initially seem counterintuitive. However, it is important to remember that we are using the number of ICU patients as an indicator of the capacity of intensive care utilization. The decrease in mortality due to increased intensive care capacity was more pronounced for the lower quantiles in both periods. Containment and health measures, which reflect the stringency of health-related government policies, also contributed to a decrease in mortality rates across all quantiles for both periods. These measures had a greater impact across all quantiles prior to vaccination. As anticipated, the introduction of vaccines in 2021 and 2022 resulted in a decrease in mortality across all quantiles, to a nearly identical extent. The effectiveness and protective role of vaccines against COVID-19 infection have been confirmed by Zheng et al. [24].

Our hypothesis concerning the role of healthcare systems is further supported by the finding that countries with healthcare systems characterized by high and medium levels of decommodification had a lower pandemic death toll than countries with low decommodification (the reference category). The estimated coefficients were consistently larger (in absolute values) for countries with a high level of decommodification (DH) than those with a medium level of decommodification (DM) for both periods. Additionally, the impact of healthcare system decommodification on mortality rate increased in absolute value from the lower quantile to the higher quantile in 2020. However, these effects exhibited a decreasing trend following vaccination.

DISCUSSION

Overall, our estimation results, all of which were statistically significant at a 1% significance level, suggest that public health measures such as testing, containment, and vaccination have effectively reduced the pandemic death toll across all 3 quantiles. Testing lowers mortality rates by helping to identify and isolate infected individuals, thereby curbing the viral spread and reducing the number of infections. It also directly decreases mortality by enabling patients with more severe cases to receive hospital treatment. This negative correlation was also identified by Imtyaz et al. [25], who argued that increased testing leads to less viral spread and improved control. Stringent containment measures manage the health impacts of the pandemic by controlling virus transmission, while vaccination coverage safeguards lives by offering robust protection against hospitalization and fatality. Lam et al. [26] verified that such containment measures help prevent virus spread and contain the epidemic. Countries with a higher capacity for intensive care are better equipped to provide lifesaving medical treatment for patients, thereby reducing mortality. This observation supports the findings of Park et al. [27], who maintained that limited ICU bed accessibility leads to increased COVID-19 fatalities.

Furthermore, increased levels of healthcare decommodification have played a role in decreasing the pandemic death toll. Importantly, fundamental indicators of the decommodification of the healthcare system include the scope of public healthcare expenditure and the availability of beds in public hospitals, as well as comprehensive healthcare coverage for the population. Therefore, elevated levels of decommodification, as represented by DH and DM, signify increased public investment in healthcare and the provision of hospital beds. Both of these factors promote equitable healthcare access and lower mortality rates, particularly for marginalized groups and low-income individuals.

Overall, the present study possesses distinct strengths compared to related research conducted since the emergence of COVID-19. Beyond the evident factors such as case numbers and testing, the findings reveal that death rates were affected not only by governmental responses to the pandemic, but also by the nature of each country's healthcare system. Furthermore, this study separated the investigation period into pre-vaccination and post-vaccination phases, aiding in enhancing our comprehension of the impact of vaccination on reducing mortality.

Notably, the data available to us extended only through the first 5 months of 2022, thus providing an incomplete picture of the impacts of the COVID-19 pandemic throughout that entire year. Despite this limitation, we maintain that this study offers important contributions to the empirical literature on the COVID-19 pandemic. Specifically, these insights pertain to the careful selection of relevant emergency measures, as well as the identification and categorization of the underlying healthcare systems.

In conclusion, our findings suggest that an increase in infections correlates with a rise in deaths, while enhanced testing rates and more stringent containment and public health measures exert a significant negative impact on the death rate. The post-vaccination model results demonstrate that higher vaccination rates significantly reduce fatalities. Furthermore, our findings suggest that social democratic countries experience fewer adverse health impacts compared to conservative and liberal countries. The data also suggest that stronger public health infrastructure and more comprehensive social protections have lessened the severity of the pandemic's adverse health impacts on population health more effectively than emergency containment measures and social restrictions.

Future studies can incorporate other distinguishing features of healthcare systems, such as the ease of access to healthcare services, to enhance our understanding of the variation in COVID-19 impact across the OECD countries.

CONFLICT OF INTEREST

The authors have no conflicts of interest associated with the material presented in this paper.

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AUTHOR CONTRIBUTIONS

Both authors contributed equally to conceiving the study, analyzing the data, and writing this paper.

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