



Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.

RESEARCH ARTICLE

Levels of economic development and the spread of coronavirus disease 2019 (COVID-19) in 50 U.S. states and territories and 28 European countries: an association analysis of aggregated data

Lauren Aycock*, Xinguang Chen

College of Public Health and Health Professions & College of Medicine, University of Florida, FL 32610, USA



ARTICLE INFO

Article history:

Received 10 December 2020
Received in revised form 29 December 2020
Accepted 28 January 2021
Available online 9 February 2021

Keywords:

Coronavirus disease 2019 (COVID-19)
Economic development
GDP
United States
European countries
Pandemic

ABSTRACT

Background: The coronavirus disease 2019 (COVID-19) became a global pandemic within several months after it was first reported at the end of December, 2019. Countries in the Northern Hemisphere have been affected the most, including the United States and European countries. Contrary to the common knowledge that infectious diseases are more prevalent in low- and middle-income countries, COVID-19 appears to affect wealthy countries more. This paper attempts to quantify the relationship between COVID-19 infections and levels of economic development with data from the U.S. and Europe.

Methods: Public domain data on the confirmed COVID-19 cases during January 1 and May 31, 2020 by states and territories in the U.S. and by countries in Europe were included. Incidence rate was estimated using the 2019 total population. COVID-19 cases were associated with 2019 gross domestic product (GDP) using regression models after a logarithmic transformation of the data. The U.S. data and European data were analyzed separately, considering significant heterogeneity between the two.

Results: A total of 2 451 691 COVID-19 cases during a 5-month period were analyzed, including 1 787 414 from 50 U.S. states and territories and 664 277 from 28 European countries. The overall incidence rate was 5.393/1000 for the U.S. and 1.411/1 000 for European countries with large variations. Lg (total cases) was significantly associated with lg (GDP) for U.S. states ($= 1.2579, P < 0.001$) and European countries ($= 0.7156, P < 0.001$), respectively.

Conclusion: This study demonstrated a positive correlation between COVID-19 case incidence and GDP in the United States and 28 European countries. Study findings suggest a potential role of high-level development in facilitating infectious disease spread, such as more advanced transportation system, large metropolitan cities with high population density, better domestic and international travel for businesses, leisure, and more group activities. These factors must be considered in controlling the COVID-19 epidemic. This study focuses on the impact of economic development, many other factors might also have contributed to the rapid spread of COVID-19 in these countries and states, such as differences in national and statewide anti-epidemic strategies, people's behavior, and healthcare systems. Besides, low- and middle-income countries may have an artificially low COVID-19 case count just due to lack of diagnostic capabilities. Findings of this study also encourage future research with individual-level data to detect risk factors at the personal level to understand the risk of COVID-19.

1. Introduction

Coronavirus disease 2019 (COVID-19) presents a threat to all people across the globe.¹ The disease is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2, previously provisionally named 2019 novel coronavirus or 2019-nCoV), and it was declared a global pandemic by the World Health Organization (WHO) on March 11, 2020

after the first 4 COVID-19 cases reported on December 29, 2019.¹⁻³ By February 6, 2020, over 28 000 cases had been reported in over 25 countries with 565 deaths.⁴ Based on data from the WHO at the time when this study was completed, a total of 67.3 million were infected with 1.54 million deaths worldwide.⁵ Between-country differences in the COVID-19 pandemic provide an opportunity to examine if levels of development have played a role in fueling the epidemic. Findings from such studies

* Corresponding author: lauren.aycock@ufl.edu.

may provide solid evidence not only advancing our understanding of the epidemic, but also informing interventions to end the COVID-19 pandemic.

Along with spatiotemporal spread, an informative geographic pattern across the globe has emerged: a growing body of literature demonstrates that more COVID-19 cases are reported in countries/regions in the Northern Hemisphere and fewer cases in most countries in the Southern Hemisphere, particularly countries in Africa.¹ This pattern contradicts the common knowledge that infectious diseases are more prevalent in low- and middle-income countries than in high-income countries.⁶ A study conducted in China also revealed a positive relation between gross domestic product (GDP) and total COVID-19 cases with provincial-level data.⁷ Data from European countries suggest a positive association between economic development and COVID-19 case fatality rate (CFR),⁸ but no data on incidence is reported in the literature.

Several mechanisms are proposed to interpret the disproportionately high burden of COVID-19 in more developed countries. Countries with higher GDPs often possess very extensive domestic and international transportation systems, facilitating disease spread across long distances;⁸ these countries also have several highly populated metropolitan areas, shortening social distance and increasing social contacts for disease spread.^{3,7,9-11} In addition, people in high income countries may be less likely to take preventative measures because of their emphasis on personal values above collective values.¹²⁻¹⁴

Informed by studies conducted in China⁷ and supported by findings from individual level data in Europe,⁷ this study will examine if the spread of COVID-19 is associated with the level of economic development in the U.S. with data by individual states and Europe with data at the national level, respectively. The ultimate purpose is to provide new data advancing our understanding of the COVID-19 pandemic and to inform policymakers in both developed and developing countries to make evidence-based decisions and to develop effective strategies for the control and prevention of infectious diseases while developing the economy.

2. Materials and methods

2.1. Data for COVID-19 cases and population

U.S. data of confirmed COVID-19 cases were derived from the U.S. Centers for Disease Control and Prevention (U.S. CDC).¹⁵ Total confirmed cases by state, including the District of Columbia (DC) and Puerto Rico for a total of 52 jurisdictions were acquired and tabulated for analysis. Data for 28 European countries were derived from the European Centre for Disease Prevention and Control (ECDC).¹⁶

Data from January 1 to May 31, 2020 were used. These data reflect the initial “first wave” of the COVID-9 pandemic. All COVID-19 cases were confirmed via polymerase chain reaction (PCR) or molecular amplification test to detect SARS-CoV-2 RNA.

To estimate incidence rate during the study period, 2019 population data for the 50 U.S. states, one district, and one territory were derived from the U.S. Census Bureau¹⁷; population data for the 28 European countries were derived from the World Bank.¹⁸ Since 2020 population data were not available by the time this study was completed, data from 2019 were used as a proxy.

2.2. GDP data

Total GDP (in million USD) by states in the U.S. were derived from the Federal Reserve Economic Data (FRED) Database at the Federal Reserve Bank of St. Louis.¹⁹ Total GDP (in billion USD) for individual European countries were derived from the International Monetary Fund (IMF).²⁰ GDP in 2019 was used as the predictor variable to assess its association with total COVID-19 cases in 2020 as the outcome, avoiding reverse impact of the pandemic on the economy in these study states/countries.

In the analysis, \$1million was used as the unit to measure the 2019 total GDP in the U.S. and \$1 billion USD was used as the unit to measure the 2019 total GDP in European countries. This approach was used to avoid a very small regression coefficient for European data, considering the evidence of a much weaker association between GDP and COVID-19 in European countries than in the U.S.

2.3. Statistical analysis

The 5-month incidence rate of COVID-19 was computed by dividing the total confirmed cases by the total population. The incidence rate was computed for individual states/countries to assess cross-state/cross-country variations in the pandemic. Total COVID-19 cases and total GDPs were plotted first to provide a visual representation of the relationship between the two variables. The plot was made using dual logarithmic scales for both X- and Y-axes.

Informed by the plots, the relationship between GDP and COVID-19 was quantified using the following regression model:

$$\text{Log}(Y_i) = \beta_0 + \beta_1 \log(\text{GDP}_i) + e_i,$$

where Y_i represents total confirmed COVID-19 cases in an individual U.S. state or European country during the study period, GDP_i represents total 2019 GDP of an individual U.S. state or an individual European country, and $e_i = \text{residuals}$; i represents individual U.S. state/European countries.

Data processing and statistical analysis were conducted with commercial software SAS 9.4 (SAS Institute Inc., Cary, NC); plotting was completed using MS PowerPoint. Statistical inference was made at $P < 0.05$ (two-sided) for all modeling analyses.

3. Results

3.1. Incidence rates of COVID-19

Data in Table 1 indicate that the estimated 5-month incidence rate of COVID-19 in the U.S. overall was 5.393/1 000 population. The estimated rates varied dramatically across individual states from 0.429/1 000 in Hawaii to 19.175/1 000 in New York. Likewise, the total GDP by state also varied from \$34 013 million USD in Vermont to \$2 800 505 million USD in California.

Results in Table 2 indicate that a total of 664 277 COVID-19 cases were confirmed and reported from all 28 European countries during the 5-month study period. The incidence rate overall was 1.411/1 000 population. Like in the U.S., there were large variations in the estimated 5-month incidence rates across the 28 countries. The highest rate was 5.207/1 000 for Luxembourg and the lowest rate was 0.001 for Bulgaria. Likewise, the country with the lowest GDP was Malta (GDP = \$15 billion USD) and the country with the highest GDP was Germany (GDP = \$3 862 billion USD).

3.2. Association between GDP and COVID-19

Fig. 1 presents the U.S. data by state/territory. Evidence in the figure suggests a linear and positive association between GDP and total COVID-19 cases on logarithmic scales. Along with increases in lg (total GDP), lg (total COVID-19 cases) increased. Analytical results from the model Equation 1 indicate that the log-transformed data fit the model well ($R^2 = 0.764$) with the estimated beta regression coefficient for lg (GDP) = 1.2579 ($P < 0.001$). According to this result, there would be 10 (1.2579^{10}) more COVID-19 cases during a 5-month period for every \$10 million GDP ($\lg 10 = 1$).

Fig. 2 presents the data for European countries. Overall, there is also a linear and positive association between total GDP and COVID-19 cases. However, there are two groups within these 28 European countries with regard to the association between the two variables – Bulgaria,

Table 1
COVID-19 cases and gross domestic product (GDP), U.S. states and territories.

State	Total population (× 1 000)	Confirmed cases (n)	Incidence rate (/1 000)	Total GDP (million USD)
New York	19 453.6	373 022	19.175	1 772 261
New Jersey	8 882.2	160 445	18.064	634 784
Illinois	12 671.8	120 260	9.490	885 583
California	39 512.2	110 583	2.799	2 800 505
Massachusetts	6 892.5	96 965	14.068	596 593
Pennsylvania	12 802.0	72 282	5.646	808 738
Texas	28 995.9	64 287	2.217	1 843 803
Michigan	9 986.9	57 397	5.747	536 888
Florida	21 477.7	54 764	2.550	1 106 500
Maryland	6 045.7	53 327	8.821	426 747
Georgia	10 617.4	47 009	4.428	625 714
Virginia	8 535.5	45 398	5.319	556 905
Connecticut	3 565.3	42 201	11.837	287 822
Louisiana	4 648.8	39 916	8.586	256 919
Ohio	11 689.1	35 513	3.038	695 362
Indiana	6 732.2	34 574	5.136	379 684
North Carolina	10 488.1	28 589	2.726	591 601
Colorado	5 758.7	26 378	4.581	392 986
Minnesota	5 639.6	25 208	4.470	383 777
Tennessee	6 829.2	23 159	3.391	376 582
Washington	7 614.9	21 702	2.850	612 997
Arizona	7 278.7	19 936	2.739	370 119
Iowa	3 155.1	19 552	6.197	194 658
Wisconsin	5 822.4	18 403	3.161	349 417
Alabama	4 903.2	18 245	3.721	228 143
Mississippi	2 976.1	15 752	5.293	115 971
Rhode Island	1 059.4	14 928	14.092	61 884
Nebraska	1 934.4	14 101	7.290	130 012
Missouri	6 137.4	13 147	2.142	328 401
South Carolina	5 148.7	11 861	2.304	247 544
Utah	3 206.0	9 944	3.102	192 519
Kansas	2 913.3	9 719	3.336	176 493
Kentucky	4 467.7	9 704	2.172	215 399
Delaware	973.8	9 606	9.865	77 082
Washington, D.C.	705.7	8 801	12.470	143 389
Nevada	3 080.2	8 610	2.795	178 199
New Mexico	2 096.8	7 689	3.667	105 143
Arkansas	3 017.8	7 253	2.403	130 954
Oklahoma	3 957.0	6 280	1.587	202 036
South Dakota	884.7	4 993	5.644	54 941
New Hampshire	1 359.7	4 651	3.421	87 634
Oregon	4 217.7	4 243	1.006	253 623
Puerto Rico	3 193.7	3 776	1.182	104 989
Idaho	1 787.1	2 839	1.589	83 666
North Dakota	762.1	2 577	3.382	57 181
Maine	1 344.2	2 349	1.747	67 717
West Virginia	1 792.1	2 010	1.122	78 864
Vermont	624.0	981	1.572	34 013
Wyoming	578.8	903	1.560	40 420
Hawaii	1 415.9	607	0.429	95 744
Montana	1 068.8	515	0.482	52 935
Alaska	731.5	460	0.629	54 386
Total	331 433.2	1 787 414	5.393	21 086 226

Data sources: Total confirmed cases of COVID-19 cases for individual states during January 1 to May 31, 2020 were derived from the U.S. Centers for Disease Control and Prevention; population data were derived from the U.S. Census Bureau; and data for total GDP by state in 2019 were derived from the FRED Database of the Federal Reserve Bank of St. Louis.

Austria and the United Kingdom forms one group and the rest another. Considering these differences, the European data were analyzed in two steps; data for all 28 countries were analyzed first, and secondly analyzed excluding the three countries of Bulgaria, Austria and the United Kingdom.

Analytical results from the model Equation indicate that when all 28 countries are included, the data-model fit is poorer than that for the 25 countries after exclusion of the three countries, with R-square increasing from 0.218 to 0.546. The estimated regression coefficient for the total sample is 0.7156 ($P < 0.001$). The regression coefficient increases to 1.0348 ($P < 0.001$) with the exclusion of Bulgaria, Austria and the United Kingdom. Using results from the 25 countries, with every \$10 bil-

lion increases in total GDP ($\lg_{10} = 1$), there were 1.4 (1.0348^{10}) more COVID-19 cases during a 5-month period.

4. Discussion and conclusion

In this study, we examine the relationship between levels of development and the spread of COVID-19 with data from 50 states plus the District of Columbia and Puerto Rico in the United States and data from 28 European countries. To the best of our knowledge, there is only one similar study conducted in China.⁷ We are the first to conduct such studies with data from the United States and European countries. Findings of our study confirm the observed patterns that levels of develop-

Table 2
COVID-19 epidemic and gross domestic product (GDP) in European Union.

Country	Total population (× 1 000)	Confirmed cases (n)	Incidence rate (/1 000)	Total GDP (billion USD)
Italy	60 297.4	233 431	3.871	2 001
Germany	83 132.8	182 184	2.191	3 862
Netherlands	17 332.9	46 319	2.672	907
Sweden	10 285.5	39 087	3.800	531
Portugal	10 269.4	34 894	3.398	238
Ireland	4 941.4	25 216	5.103	398
Belgium	11 484.1	14 438	1.257	530
Denmark	5 818.6	11 807	2.029	347
Romania	19 356.5	11 790	0.609	250
France	67 059.9	10 072	0.150	2 716
Poland	37 970.9	9 243	0.243	592
Czechia	10 669.7	9 037	0.847	251
Norway	5 347.9	8 438	1.578	403
Finland	5 520.3	7 001	1.268	269
Hungary	9 769.9	3 892	0.398	161
Luxembourg	619.9	3 228	5.207	71
Croatia	4 067.5	2 343	0.576	60
Greece	10 716.3	2 141	0.200	210
Estonia	1 326.6	1 877	1.415	31
Iceland	361.3	1 805	4.996	24
Lithuania	2 786.8	1 667	0.598	54
Slovakia	5 454.1	1 498	0.275	105
Latvia	1 912.8	1 066	0.557	34
Cyprus	1 198.6	950	0.793	25
Malta	502.7	632	1.257	15
United Kingdom	66 834.4	196	0.003	2 831
Austria	8 877.1	19	0.002	446
Bulgaria	6 975.8	6	0.001	68
Total	470 890.9	664 277	1.411	17 432

Data sources: Total confirmed cases of COVID-19 for individual countries during January 1 to May 31, 2020 were derived from European Centre for Disease Prevention and Control; population data were derived from the World Bank; and data for total GDP by states in 2019 were derived from the International Monetary Fund.

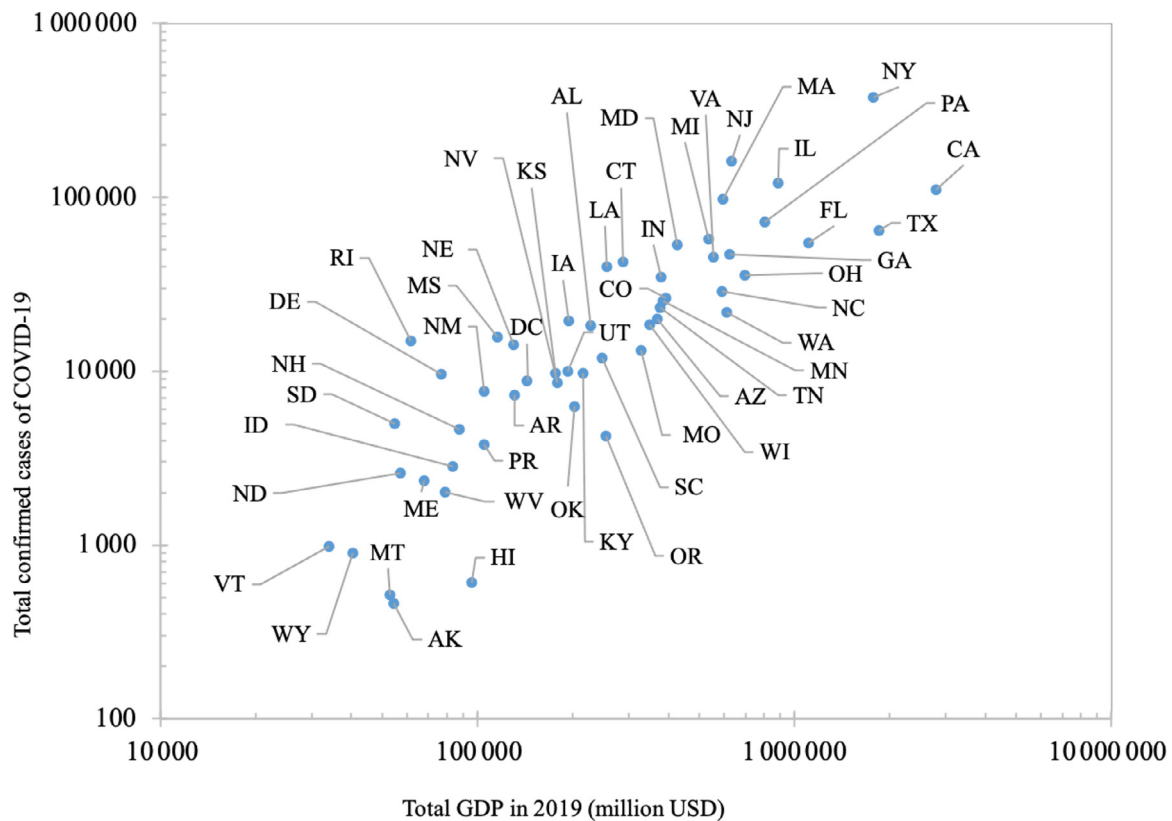


Fig. 1. Association between total GDP and total confirmed cases of COVID-19 in the U.S.
Data source: Total confirmed cases of COVID-19 for individual states during January 1 to May 31, 2020 were derived from the Centers for Disease Control and Prevention; and data for total GDP by states in 2019 were derived from the FRED Database of the Federal Reserve Bank of St. Louis.

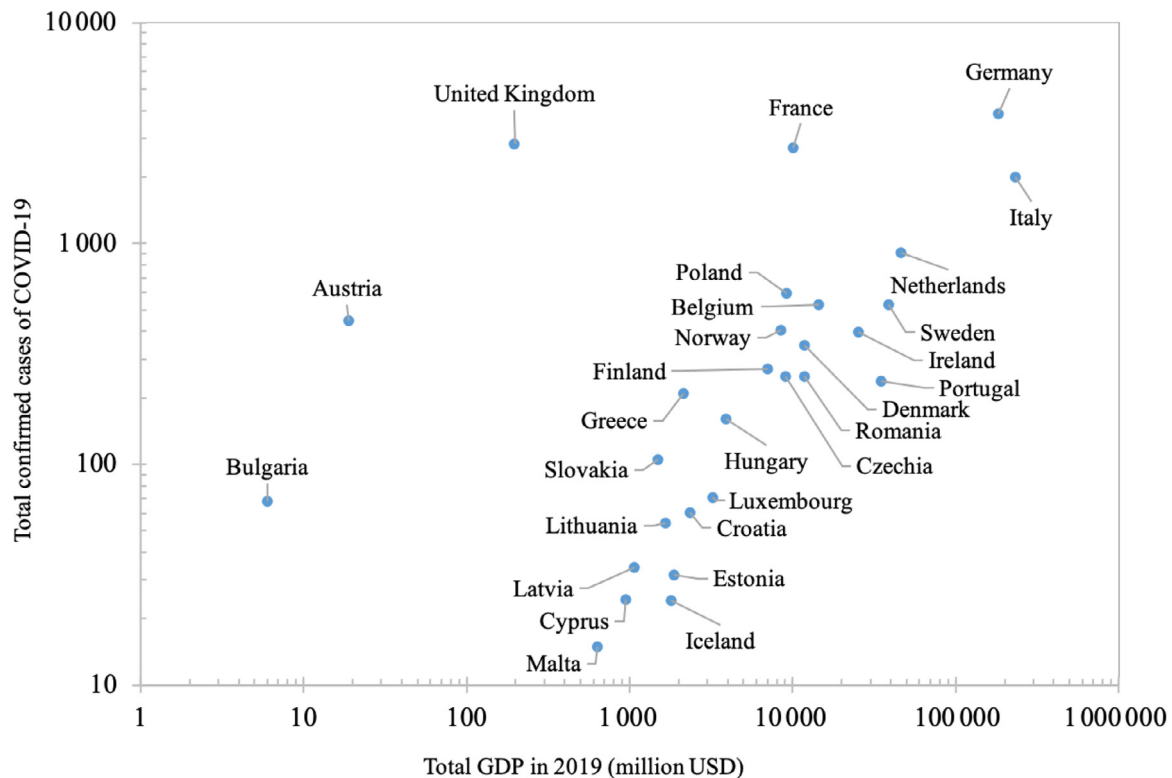


Fig. 2. Association between total GDP and total confirmed cases of COVID-19 (during January 1 to May 31, 2020) in 28 European Countries.

Data source: Total confirmed cases of COVID-19 cases for individual countries during January 1 to May 31, 2020 were derived from the European Centre for Disease Prevention and Control; and data for total GDP by states in 2019 were derived from the International Monetary Fund.

ment can be a risk factor to fuel the COVID-19 pandemic. Policymakers should consider this factor in decision-making and economic development planning.²¹ Health professionals should also consider this factor in research to forecast and control the pandemic.

4.1. Positive association between GDP and COVID-19 cases

Observed results from both European countries and the United States support a positive association between levels of development, as measured by GDP, and the spread of COVID-19, as measured by the total confirmed cases. This study finding is consistent with others in the literature, including a manuscript currently under review that analyzes the relationship between the spread of COVID-19 and GDP within provinces in China.⁷ Higher levels of development can improve quality of life and strengthen healthcare systems against infectious disease; however we cannot ignore that higher level of development may promote the spread of novel infectious diseases like COVID-19.

As described in the Introduction section, economic development leads to advancement in domestic and international transportation, including subway network systems within cities, bullet-trains between cities, and domestic and international flights. Advancement in transportation greatly shortens the distance between people, facilitating the spread of infectious diseases across vast distances within a short period.²² For example, the positive relation between economic development and COVID-19 spread was also reported in the literature.^{3,7,22}

Many people in developed countries live in large metropolitan cities with high population density. Such living arrangements will greatly increase the chance for many uninfected healthy people to get in contact with an infected patient, increasing the speed of disease transmission.^{6,8,10} People living in more developed countries also have more disposable income which can be used for leisurely activities or social-

ization, increasing chances to come into contact with the infected and facilitate disease spread.¹²

4.2. Differences between the U.S. and European countries

In this study, we found several differences in the GDP-COVID-19 relationship between the U.S. and European countries. First of all, the differences among states in the U.S. are smaller than the differences among individual countries in Europe. There is a relatively homogeneous association between GDP and COVID-19 cases in the U.S., but the same relationship among European countries forms two groups. In addition to informing statistical analysis as we did in this study, further research is needed to investigate any potential mechanisms underpinning the differences to inform the COVID-19 pandemic for preventative intervention.

Second, and more importantly, the association between GDP and COVID-19 is much stronger in the U.S. than in European countries. In the U.S., every \$10 million increase in GDP is associated with 10 additional new COVID-19 cases, and this number is only 1.4 per \$10 billion for countries in Europe. Several reasons may explain the U.S.-Europe differences. Unlike many European countries,²³ the healthcare system is decentralized in the U.S., with individual states responsible for managing their own healthcare systems.²⁴ The lack of coordinated actions against the epidemic reduces the efficiency to curb the pandemic. In addition, there is higher income inequality and more limited access to healthcare in the U.S. than among the European countries, which is another factor to consider.²⁵

Besides the structural factors described above, the U.S. federal government may also play a role.²⁶ The Trump Administration was slow to acknowledge the potential impacts of the COVID-19 pandemic, and their reluctance to create federal mandates allowed for a wide range of politicized responses from individual states.

4.3. Implications for COVID-19 control and prevention

In public health research and prevention practice, we often classify infectious diseases as diseases of poverty that are prevalent in low- and middle-income countries.⁷ With state-of-the-art medical facilities, healthcare providers, and seemingly unlimited medical supplies, it seemed impossible that countries like the U.S. would have the greatest suffering from the COVID-19 pandemic compared to the rest of the world with an overwhelming loss of life due to the virus. This perception is challenged by the striking findings from this study: countries with higher incomes in Europe and states with higher incomes within the United States are more likely to be affected by the pandemic of COVID-19.

This finding bears significant implications. It advances our knowledge base regarding infectious disease spread in the 21st century.⁷ “Getting rich” may not prevent us from infectious diseases; on the contrary, it increases risks at the population level. This finding is also important for policymakers at the state and national levels. The best strategy for development would be to pursue a balance between economic growth and people’s health. We need money to solve problems, but efforts to make a country rich can actually become a risk factor for the spread of an infectious disease like COVID-19.

The study finding provides evidence at the aggregate level for health professionals, particularly for those who focus on international and global health. Findings of our study can help monitor and forecast COVID-19 by factoring the impact of economic development at the national level.²¹ In addition to low- and middle-income countries, the global health community should also pay attention to high-income countries. Likewise, within a country, a balanced strategy would be most effective by considering both poorer and richer jurisdictions at the state, county, city, and local community level.

4.4. Limitations and further research

First, this is an ecological study with data from the state and country level. Caution must be used in interpreting the findings of this study to avoid an ecological fallacy. Although countries with higher GDP reported more COVID-19 cases, research with individual-level data indicate high risk of incidence and mortality of more vulnerable sub-populations, such as people from ethnic minorities and/or low income groups.^{25,27-28}

Secondly, while this study focuses on the impact of economic development, many other factors might also have contributed to the rapid spread of COVID-19 in these countries and states, such as differences in national and statewide anti-epidemic strategies, people’s behavior, and healthcare systems. Although the impact of these factors may not be substantial during the short period in the U.S. and Europe, caution is advised when interpreting the results.

One related point worth noting is that data used for this study are based on confirmed COVID-19 cases. Low- and middle-income countries that lacked the capabilities to rapidly scale up the production of accurate SARS-CoV-2 diagnostic PCR tests may have an artificially low COVID-19 case count just due to lack of diagnostic capabilities. Addressing these factors is beyond the scope of this study; however, we need to consider this factor while interpreting and applying the findings from this study.

Lastly, data used for this study are derived from different sources, such as U.S. CDC, ECDC, U.S. Census Bureau, IMF and World Bank. Discrepancies may appear if the same analysis is conducted using data from other sources.

Despite its limitations, this study is the first to model the relationship between GDP and COVID-19 cases with data from 52 United States and territories and 28 European countries. Findings of this study provide evidence encouraging additional research to examine other factors at the national level such as inequities in employment, income, and access to healthcare. Findings of this study also encourage future research with individual-level data to detect risk factors at the personal level to understand the risk of COVID-19.

CRedit author statement

Lauren Aycok: Conceptualization, Data curtion, Writing—original draft, Writing—review & editing. **Xinguang Chen:** Conceptualization, Formal analysis, Methodology, Software, Supervision, Visualization, Writing—original draft, Writing—review & editing.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

- Lai CC, Wang CY, Wang YH, Hsueh SC, Ko WC, Hsueh PR. Global epidemiology of coronavirus disease 2019 (COVID-19): disease incidence, daily cumulative index, mortality, and their association with country healthcare resources and economic status. *Int J Antimicrob Agents.* 2020;55(4):105946.
- Balmford B, Annan JD, Hargreaves JC, Alton M, Bateman JJ. Cross-country comparisons of COVID-19: policy, politics and the price of life. *Environ Resour Econ.* 2020;76(4):525-551.
- Chen X, Yu B. First two months of the 2019 Coronavirus Disease (COVID-19) epidemic in China: real-time surveillance and evaluation with a second derivative model. *Glob Health Res Policy.* 2020;5:7.
- Wu YC, Chen CS, Chan YJ. The outbreak of COVID-19: an overview. *J Chin Med Assoc.* 2020;83(3):217-220.
- WHO Coronavirus Disease (COVID-19) Dashboard. World Health Organization website. <https://covid19.who.int/>. Accessed January 27, 2021.
- Nelson KE, Williams CM. *Infectious Disease Epidemiology.* 3rd ed. Burlington, M.A.: Jones & Bartlett Learning; 2014.
- Mo Q, Chen X, Yu B, Ma Z. Levels of economic growth and cross-province spread of the COVID-19 in China. [published online ahead of print, 2021 Jan 28]. *J Epidemiol Community Health.* 2021; jech-2020-214169. doi:10.1136/jech-2020-214169.
- Sorci G, Faivre B, Morand S. Explaining among-country variation in COVID-19 case fatality rate. *Sci Rep.* 2020;10(1):18909.
- Chaudhry R, Dranitsaris G, Mubashir T, Bartoszko J, Riazi S. A country level analysis measuring the impact of government actions, country preparedness and socioeconomic factors on COVID-19 mortality and related health outcomes. *EClinicalMedicine.* 2020;25.
- Gangemi S, Billeci L, Tonacci A. Rich at risk: socio-economic drivers of COVID-19 pandemic spread. *Clin Mol Allergy.* 2020;18:12.
- Chen DG, Chen X, Chen JK. Reconstructing and forecasting the COVID-19 epidemic in the United States using a 5-parameter logistic growth model. *Glob Health Res Policy.* 2020;5:25.
- Czeisler ME, Tynan MA, Howard ME, et al. Public attitudes, behaviors, and beliefs related to COVID-19, stay-at-home orders, nonessential business closures, and public health guidance - United States, New York City, and Los Angeles, May 5-12, 2020. *MMWR Morb Mortal Wkly Rep.* 2020;69(24):751-758.
- Chan DKC, Zhang CQ, Weman-Josefsson K. Why people failed to adhere to COVID-19 preventive behaviors? Perspectives from an integrated behavior change model. *Infect Control Hosp Epidemiol.* 2020;1-2.
- Pereira B, Stornelli J. Collective health versus individual freedom: goal centrality and political identity shape COVID-19 prevention behaviors. *J Assoc Consum Res.* 2020; 10.1086/711837. doi:10.1086/711837.
- United States COVID-19 Cases and Deaths by State over Time. U.S. Centers for Disease Control and Prevention website. <https://data.cdc.gov/Case-Surveillance/United-States-COVID-19-Cases-and-Deaths-by-State-o/9mfq-cb36>. Accessed December 8, 2020.
- Download historical data (to 14 December 2020) on the daily number of new reported COVID-19 cases and deaths worldwide. European Centre for Disease Prevention and Control website. <https://www.ecdc.europa.eu/en/publications-data/download-todays-data-geographic-distribution-covid-19-cases-worldwide>. Accessed January 27, 2021.
- State Population Totals: 2010-2019. The United States Census Bureau website. <https://www.census.gov/data/tables/time-series/demo/popest/2010s-state-total.html>. Accessed January 27, 2021.
- Population, total—European Union. The World Bank website. <https://data.worldbank.org/indicator/SP.POP.TOTL?locations=EU>. Accessed January 27, 2021.
- United States—Level Economic Data. Federal Reserve Economic Data website. <https://fred.stlouisfed.org/categories/27281>. Accessed January 27, 2021.
- GDP, current prices. International Monetary Fund website. <https://www.imf.org/external/datamapper>. Accessed January 27, 2021.
- Oldekop JA, Horner R, Hulme D, et al. COVID-19 and the case for global development. *World Dev.* 2020;134.
- Liu W, Yue XG, Tchounwou PB. Response to the COVID-19 epidemic: the Chinese experience and implications for other countries. *Int J Environ Res Public Health.* 2020;17(7):2304.
- Missinne S, Meuleman B, Bracke P. The popular legitimacy of European healthcare systems: a multilevel analysis of 24 countries. *J Eur Soc Policy.* 2013;23(3):231-247.

24. Cacace M, Schmid A. The healthcare systems of the USA and Canada: forever on divergent paths? *Soc Policy Admin.* 2008;42(4):396-417.
25. Oronce CI, Scannell CA, Kawachi I, Tsugawa Y. Association between state-level income inequality and COVID-19 cases and mortality in the USA. *J Gen Intern Med.* 2020;35(9):2791-2793.
26. Khosrawipour V, Lau H, Khosrawipour T, et al. Failure in initial stage containment of global COVID-19 epicenters. *J Med Virol.* 2020;92(7):863-867.
27. Gaynor TS, Wilson ME. Social vulnerability and equity: the disproportionate impact of COVID-19. [published online ahead of print, 2020 Jun 22]. *Public Adm Rev.* 2020; 10.1111/puar.13264. doi:10.1111/puar.13264.
28. Nayak A, Islam SJ, Mehta A, et al. Impact of Social Vulnerability on COVID-19 Incidence and Outcomes in the United States. Preprint. *medRxiv.* 2020; 2020.04.10.20060962. doi:10.1101/2020.04.10.20060962.

Edited by Yanjie Zhang