Research in Economics xxx (xxxx) xxx

Contents lists available at ScienceDirect

Research in Economics

journal homepage: www.elsevier.com/locate/rie

Socio-economic and environmental factors in the global spread of COVID-19 outbreak

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ARTICLE INFO

Article history:
Received 21 February 2022
Accepted 7 August 2022
Available online xxx

Keywords:
COVID-19
Socio-economic factors
Environmental factors
Government measures, Instrumental variables

ABSTRACT

COVID-19 is a virus with a very fast spread rate in the world. Therefore, knowledge of factors that may explain such spread is paramount. The main objective of this research was to analyze the determinants of the virus spread worldwide. Unlike previous studies that were limited to traditional factors, this research extends the analysis to government measures (quarantine, containment, and response budget) against the spread of the virus. Thus, an econometric model relating the variable of interest to a number of variables was carried out using the Ordinary Least Squares (OLS) and the Two Steps Least Squares (2SLS) methods on a sample of 163 countries. The main findings indicate that economic factors such as the level of development, the degree of trade openness and the response budget to the COVID-19 pandemic, have a positive effect on the spread of the virus. With regard to social factors, the population density and confinement are major causes of the spread of the virus. Finally, temperature contributes to reduce the spread of the virus. These findings are robust to the estimation technique and to the measurement of the spread of the virus considered. In the light to these findings, implications for economic policies have been drawn.

1. Introduction

Similarly to other diseases, the COVID-19 pandemic has a significant impact on economies. According to Baldwin and Mauro (2020), the world has experienced several diseases related to coronavirus that have resulted in global health and economic damages. The best known are the Severe Acute Respiratory Syndrome (SARS) and the Middle East Respiratory Syndrome Coronavirus (MERS-CoV). SARS was a viral disease discovered in China in the late 2002.

During 2002-2003, 8,098 cases of SARS were identified, including 774 deaths. MERS was also a viral respiratory disease caused by a coronavirus that was found in camels in several countries. The first case was identified in Saudi Arabia in 2012 and spread to 27 other countries. Thus, 2,494 individuals have been infected with MER-CoVout of which 858 have died since 2012.

In late 2019, a new coronavirus disease called COVID-19, which appeared in Wuhan, quickly became a pandemic affecting many countries around the world. The COVID-19 pandemic caused more than 701,000 deaths worldwide and infected more than 18.5 million people in early August 2020. Among the affected countries, the United States occupies the first place. In addition to the human sufferings and deaths, this pandemic has led to a general economic recession. Global economic

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https://doi.org/10.1016/j.rie.2022.08.001
1090-9443/© 2022 Published by Elsevier Ltd on behalf of University of Venice.

powers (G7 and China) are among the most affected by the pandemic (Baldwin & Weder di Mauro, 2020). Several scientific works have focused on the analysis of the economic impacts of this disease.

Although quantifying the effects of the virus is useful for economic debates, identifying factors that spread the virus is also relevant. Indeed, in controlling the spread of the virus, several States have invested in taking short and long run measures without any real scientific investigations on the relevance of those measures to limit the spread of the virus. The measures taken include quarantine, confinement, curfews, closure of commercial activities and borders, restrictions on internal movements, closure of schools, etc. All of these measures have economic consequences including the reduction of incomes, increased poverty and inequality. In African Caribbean Pacific countries in particular, many people do not have sufficient resources to survive a long period of confinement. Given that the time needed to contain this virus is unknown, it is important that governments be informed by scientific analysis as they go along in order to take appropriate measures to safeguard economies and support social protection programs. The objective of this research is to analyze the socio-economic and environmental factors in the spread of the COVID-19pandemic around the world.

In line of Keynesian theory (Keynes, 1936), a negative supply shock could in return lead to the spread of the virus given the reduction of economic means in fighting this pandemic. Moreover, this negative shock can be explained by the rationality of investors. In fact, limited by the unavailability of information associated with the evolution of the virus (Simon, 1997), they limit production decisions in a situation of uncertainty. This generalized pessimism from investors, described as *pessimism of animal-spirit*, is also mentionedby Fornaro & Wolf (2020).

Furthermore, in order to contain the negative supply shock related to COVID-19, governments have increased spending on social protection and taken measures to support the economy through businesses. Central Banks also intervened to support their respective economies. These measures have been effective in fighting against new infections, as in the case of Singapore and Hong Kong (Anderson *et al.*, 2020). However, the effectiveness of the measures may not be the same and may also vary from one country to another. Several studies have shown that factors that may explain the spread of the virus are economic (Adda, 2016; Yun *et al.*, 2020), social (Qiu*et al.*, 2020) and climatic (Wang *et al.*, 2020; Martins *et al.*, 2020; Rahman *et al.*, 2021).

Previous analyses were limited to the scale of a country and do not take into account the global dimension of the disease. Therefore, the contribution of this research to the literature is twofold. First, to take into account the disparities in climatic and economic conditions between countries, we used sample of 163 developed and developing countries. Furthermore, this research takes into account the effect of governmental measures (quarantine, containment and the response budget) in explaining the spread of the virus. According to WHO (2020), the COVID-19 pandemic requires sufficient public funding to ensure a comprehensive response. All countries have, at the onset of the pandemic, set up a COVID-19 Budget, financed by public and institutional resources and by private contributions. This required the reprioritizing public spending toward bolstering the economy and the health system, without knowing the effect of this response budget on the spread of COVID-19. Large sums have been injected against the spread of the virus and it is necessary to identify their effect on the spread of COVID-19.

The remaining part of the paper is organized around four sections. The first section addresses the review of literature on the socio-economic, governmental and climatic factors in the spread of virus. The second section outlines the research methodology. In the third section, the main findings are presented and analyzed. Finally, the last section concludes the research and provides implications for economic policies.

2. Literature review

This section outlines the theoretical and empirical debates on the COVID-19 pandemic in the world.

2.1. Review of some theoretical aspects

The COVID-19outbreak is perceived as an exogenous shock that fundamentally disrupted the economy as a whole. The theoretical explanation of this phenomenon is based on the Keynesian theory of supply shocks. Economic supply shocks cause changes in aggregate demand in the context of COVID-19 through several manifestations including work stoppages, layoffs and exit firms (Guerrieri *et al.*, 2020). This situation is caused by markets' incompleteness and the limitation of consumer's liquidity mainly in developing countries. In developed countries, Keynesian supply shocks are perceptible due to the closure of several firms and industries whose opening could generate high contact intensity and subsequently significant contamination. This unexpected crisis with multiple consequences leads economists to review the economic model. Therefore, Fornaro & Wolf (2020) vision an economy representative of the New Keynesian economy. Indeed, they argue that COVID-19has a negative shock on the productivity growth rate. Facing these socio-economic imbalances, endogenous technological changes must be made to thwart the traps of stagnation but especially to increase the resilience of economies. Gourinchas (2020) argues that in the face of significant output losses, macroeconomic reforms must be undertaken to "flatten the recession curve".

The occurrence of COVID-19 caused significant economic fluctuations around the world. For the new classical economy, economic cycles (or fluctuations) are explained by shocks that affect the economy. Although these cycles can be twofold (monetary and real), it is essential to emphasis that the COVID-19outbreak created more real than monetary disturbances with regard to the origins which are mainly technological. Based on the investigations of Kydland & Prescott (1982) on the one hand and Long & Plosser (1983) on the other hand, models based on the real cycle seek to establish that the optimal responses of economic agents to shocks of a real nature can produce cyclical characteristics close to those observed. The whole concern is therefore to find optimal responses in order to deal with an "invisible enemy" with various transmission channels.

2.2. Review of empirical evidences on the spreading factors of COVID-19

The new coronavirus (COVID-19) appeared in China, precisely in Wuhan in December 2019 and then spread globally. This spread was accelerated in early 2020 leading to urgent action by governments. Several socio-economic and environmental factors are responsible for the community, inter-city and inter-country transmission. The following outlines the various determinants related to the spread of the virus highlighted in the literature.

Authors such as Priyadarsini *et al.* (2020) have highlighted some factors responsible for the transmission of the new coronavirus including social distancing and community awareness, age, air temperature, air flow and ventilation, population density and humidity. Overall, the spread would depend on government measures, environmental and socio-economic factors. The diversity of spreading factors requires a thorough knowledge of them in order to significantly influence the intervention policies of concerning actors.

2.2.1. Government measures

The novelty of the virus and the late knowledge of the dangerousness of the pandemic did not allow early preventive measures to be taken in order to stop the progression of the disease around the world. From the first months of 2020, the coronavirus disease qualified by the World Health Organization (WHO) as an epidemic was quickly recognized as a pandemic and subsequently became a global health emergency. Measures were taken progressively and independently by each country to counter the pandemic. These measures included confinement, quarantine and the establishment of a response budget to meet the costs of caring for the disease.

2.2.1.1. Quarantine and confinement. Qiu*et al.* (2020) show that strict quarantine, as one of the public health measures imposed in late January 2020, has significantly reduced the rate of COVID-19 transmission in China. This quarantine was a strong government response that was instrumental in bringing the virus under control in early February 2020. Hellewell *et al.* (2020) also note the effectiveness of the China-wide quarantine policy. They show that the quarantine situation allowed a new outbreak of COVID-19 to be controlled within three months for most of the scenarios considered. In addition, their findings show that the current number of new confirmed cases has been reduced.

Confinement is also adopted and developed as a strategy by states to decelerate the transmission of the virus to the extent that it can occur from one person to another (Riou & Althaaus, 2020). In this sense, several actions have been undertaken by governments, communities, citizens, media and other key influencers. As a result, this has greatly influenced travel and movements to avoid contacts that are sources of COVID-19 spread (ECDC, 2020). In the same vein, Wang *et al.* (2020) suggest that behavioral differences such as restricted indoor winter stay may also have an effect on the spread of COVID-19. For this reason, the WHO through its guidelines has limited international travel from affected areas, clinical isolation or home. Confinement is seen as a measure to stop the disease and strict monitoring to reduce the number of direct contacts and the overall risk of transmission of this acute respiratory infection (WHO, 2020).

2.2.1.2. Setting up a response budget. Since the COVID-19 outbreak, States have taken budgetary measures to deal with this pandemic. These measures are disparate from one country to another with respect to the level of development and the response strategy. Most of the budgetary efforts have been used to build emergency health infrastructure and strengthen the health system in order to reduce the spread of the virus. Thus, Qiu *et al.* (2020) suggest that public health measures put in place through the mobilization of financial resources (Maurer, 2009; White, 2019) that are effective should be strengthened to limit further spread of the virus. However, defining a response budget is not sufficient to stop the pandemic; other complementary measures are paramount. Whitney (2021) showed that North Carolina municipalities revised their budgets to account for the uncertainties of the COVID-19 pandemic. Indeed, most municipalities have estimated a budget shortfall of about 10% on average due to COVID-19 efforts. This situation creates a hiring freeze and a reduction in new investments.

2.2.2. Movement of people

The speed at which the virus spreads is partly related to the movement of people. Several studies have examined the effect of population movements on the spread of COVID-19 (Zhan *et al.*, 2020; Zhang *et al.*, 2020). Qiu *et al.* (2020) compared two half-samples to understand the transmission of the virus. For cities outside Hubei province, the epicenter of the epidemic, the ban on movement of people was found to be effective, compared to cities where the ban was not formalized. Their study was possible thanks to data on real-time population flows between cities. Thus, this variable is considered as a factor having an explanatory power on the transmission of the pandemic between cities, even after controlling for traditional measures of geographic and economic proximity. However, these studies are conducted exclusively at the country level and do not allow us to understand the role of the movement of people in the global spread. For this reason, our study examines the phenomenon globally.

2.2.3. Environmental factors

COVID-19 is transmitted through droplets released by virus carriers and contact persons. Also, the nature of the weather can be a source of disease spread. Thus, environmental variables may help to explain the transmission of COVID-19 (Di Marco *et al*., 2020; Wu *et al*., 2020; National Commission of the PRC, 2020). This has been highlighted in some studies already carried out. Based on spatially disaggregated data over a longer period, and using the instrumental variable approach, Qiu *et al*. (2020) conclude that exogenous temperature, wind speed and rainfall during the previous third and fourth weeks are responsible for new infection situations. They show that a new infection leads to an additional 1,465 cases in a week and the effect on the second week is not definitive. The moving window analysis shows that the infection rate first increases at the end of January and then stabilizes and decreases. However, this causal estimate is slightly lower than the epidemiological studies.

Weather can play a key role in new infections by influencing social activities and virus transmission (Qiu *et al*., 2020). Lowen & Steel (2014) showed that the greater the rainfall, the more humidity can weaken virus transmissions. Indeed, for these authors, heavy rainfall leads to lower temperatures that considerably reduce social activities and thus human contact. In contrast, *Wang et al*. (2020) argue that lower temperatures can also increase the infectiousness of the virus in the environment. Indeed, they show that high temperature and relative humidity reduce COVID-19 transmission with a significance levels of 1%. Similar results have already been found for other viruses. Previous studies have shown that high temperature and humidity reduce the transmission of influenza and SARS (Shaman and Kohn, 2009; Lowen *et al*., 2018; Lipsitch & Vboud, 2009). Exposure to sunlight has also been shown to be effective in reducing the spread of influenza (Slusky & Zeckhauser, 2018), demonstrating the role that temperature could play in the control of pandemic.

Wind is a meteorological variable whose effect on spread of the virus is debatable. Indeed, according to *Qiu et al*. (2020), higher wind speeds and thus ventilated air can disrupt virus transmission. New cases of contamination are generally dependent on the number of people who have already contracted the virus and the environmental conditions.

Priyadarsini & Suresh (2020) sought to analyze the climatic factors influencing the global super-propagation of the outbreak using an approach based on "Total Interpretive Structural Modeling" (TISM). They manage to classify the factors triggering the disease, particularly air temperature, humidity, air flow and ventilation. These factors are more responsible for the increased mortality rate of COVID-19 compared to SARS and MERS. Also, their research has led to understand that temperate countries and the elderly are more vulnerable without ignoring other impact parameters (contact cases, social behavior, etc.). The humidity caused by winter in cold temperate countries leads people to stay indoors more, that increase the possibility of spread among them. Also, people exposed to cold temperature in winter will have a decreased local immune response in the nasal passage, making them more sensitive to viruses such as influenza (Havard Health Letter, 2020). Scientific research has established a direct correlation between temperature and the spatial dispersion of COVID-19. Indeed, the drops expelled from a patient's mouth that can spread over several meters are evaporated in the presence of high temperatures reducing infectiousness (Woodward, 2020; Bannister-Tyrrell, 2020).

Airy environment is generally recommended to annihilate the virulence of the virus. Previous studies have shown that closed areas with low airflow and aeration may increase the risk of COVID-19 infection because the droplets released from coughing and sneezing contribute to strengthen the action of the virus. This has been proven for viral pathologies such as influenza and rhinoviruses. As an example, aerosol transmission is also possible with prolonged exposure to high aerosol concentrations in enclosed spaces (EDC China, 2020). Although the proximity of people in an enclosed space (family setting) does not systematically expose them to the disease. High-risk individuals such as elderly, people with respiratory illnesses, diabetics or immunocompromised people are vulnerable, and the risk of contracting COVID-19 is high if they are placed in enclosed spaces (Boldog*et al*., 2020; Ijaz *et al*., 2020). Wang *et al* (2020) were able to show through linear regression that high temperature and humidity significantly reduce COVID-19 transmission respectively. Indeed, their findings support that one degree Celsius increase in temperature and one percent increase in relative humidity lower R[1]by 0.0225 and 0.0158, respectively. This result is consistent with the fact that high temperature and humidity reduce the transmission of influenza and SARS.

2.2.4. Socio-demographic factors

Among the transmission channels of COVID-19, there are socio-demographic factors. Statistics show that the highest case-fatality rate of COVID-19, reported in different contexts, is found in elderly patients (Onder *et al*., 2020). Indeed, figures show that mortality rates in Italy and China are higher among people from 70 to 80 years old or more (WHO, 2020). One plausible explanation is that old age compromises the body's immunity and self-defense, making this category of people vulnerable to respiratory diseases. In addition, this category of people generally has other health problems such as diabetes and kidney failure that actively participate in weakening the immune system. Wu and McGoogan (2020) cite stress status as an accelerating factor in the death of COVID-19 patients from heart attacks. The challenges of social isolation and mobility are met by elderly in many societies, which may make the situation worse than their low immunity. Some authors argue that the hardest-hit countries also had ageing populations (Gardner *et al*., 2020; Lima *et al*., 2020).

The gathering of people in public places is very often suspected of being responsible for community transmission of the pandemic. Similarly, population density, defined as the number of people living in an area per square kilometer

[1] R indicates how contagious an infectious disease

(Kumar, 2015), appears to be related to COVID-19 infection. Mangen *et al.* (2020) reported the relationship between high population density and the spread of outbreaks. A high density of individuals could increase the virulence of the disease in a context where health measures are ineffective. The high concentration of individuals was quickly prohibited by the implementation of barrier measures such as travel restrictions, early detection, isolation and affected people monitoring, closure of schools, airports, restaurants, shopping centers (Hohel*et al*., 2020; Gilbert *et al*., 2020; Ferguson *et al*., 2020). In the same way, Hu *et al.* (2021) showed that in the U.S. capital city, the population crowding ratio has the most significant influence in the transmission of the pandemic in COVID-19.

Given the high infection rates, WHO has urged states to raise awareness of non-pharmaceutical emergency measures to be taken on the brink of the global spread of the COVID-19 (ECDC, 2020). Thus, social distancing (Ferguson *et al*., 2020) and community awareness have been encouraged and presented as measures to be rigorously observed in order to break the chain of transmission. Social distancing measures and other guidelines to minimize the spread of the disease with confinement measures such as contact tracing are essential (Priyadarsini & Suresh, 2020). These non-pharmaceutical measures aim to minimize physical contact between individuals in order to substantially limit new infections and the rapid escalation of the pandemic (ECDC, 2020).

COVID-19 is a virus whose virulence is accelerated in contexts where hygiene practices are neglected. The adoption of individual and collective hygiene practices is strongly recommended and is seen in the health system as the behavior-dependent solution. In particular, prohibiting gatherings and mandatory hand disinfection is an effective strategy to limit community transmission of viral diseases, especially SARS-CoV-2 (Mathai *et al*., 2020; CDC China, 2020). The primary transmission route of SARS-CoV-2 infection is through respiratory droplets. However, the virus is also detectable in other body fluids and feces (CDC China, 2020).

2.2.5. Economic factors

Several factors have been raised above to help explaining the spread of viral diseases. However, knowledge of economic factors will provide a solid foundation on which to base actions to address the pandemic. According to Stojkoski *et al.* (2020), beyond biological and epidemiological factors, a multitude of social and economic criteria govern the extent of coronavirus spread in the population. However, there is no consensus on the socio-economic determinants explaining the pandemic. Based on country-level data, Stojkoski *et al.* (2020) investigate a potential twenty-nine (29) determinants, describing the full range of socioeconomic characteristics, including health care infrastructure, societal characteristics, economic performance, population structure, number of coronavirus cases per million population (pmp) or number of coronavirus deaths, etc.

The authors use the Bayesian Model Average (BMA) technique to identify the set of factors on which new social and economic measures to prevent future epidemiological impacts are to be taken. In addition, the studies carried out show that epidemics spread faster during economic booms (Adda, 2016) and an increase of employment (Markowitz *et al*., 2010). The intensification of trade (trade openness), which involves the movement of people and goods, is a source of acceleration in the spread of viral diseases (Adda, 2016; Oster, 2012).

3. Methodology

The objective of this article is to analyze the effect of socio-economic and climatic factors in explaining the spread of COVID-19 in the world. Unlike previous studies where the analysis has been focused on a single country or between cities within a country (Adda, 2016: Yun *et al*., 2020; Alipio, 2020), our research covered several countries around the world. This analysis seems relevant to us insofar as since March 11, 2020, the COVID-19outbreak has become a global health emergency (WHO, 2020).

The number of COVID-19cases in a given country can be explained by its socio-economic as well as climatic characteristics. At the time of writing this paper, the number of incident cases continues to increase worldwide and it has been necessary to define a period of analysis that takes into account the situation of the majority of countries for reasons of statistical significance. Thus, the period chose ranges from March 25 to April 25, 2020. This period of one month not only allows to have the situation of the maximum of countries but also to take into account the fact that many countries under analysis would have reached the peak of the outbreak in this period.

Formally, the analysis model is as follows:

$$C_i = \tau + \sum_{k=1}^{q} \vartheta_k X_k + \varepsilon_i$$

$C_i$represents the standard deviation of the number of daily cases in country i, τ is the common effect between countries, X takes into account variables that may influence the spread of the virus in a given country and which are listed in the appendix, $\varepsilon_i$is the error term. The literature shows that these factors are economic, social and climatic at the same time. Table A1 (see appendix) presents the definitions of the variables and the sources of data collected.

3.1. Social factors

- ***Population density***: population density is an important factor in the spread of the virus. Evidence suggests that promiscuity promotes disease, which explains the use of this variable in the research of Yun *et al*. (2020), *Qiu et al*. (2020) in the case of China and Hu *et al.* (2021) in the case of America's capital City.
- ***Confinement** or **quarantine***: A country that adopts confinement or quarantine could reduce the number of cases through physical distancing. There is a long tradition of quarantine, a measure used by some countries with Ebola disease (Cauchemez *et al*., 2014; Adda, 2016). In the case of COVID-19, some countries have favored total confinement while others have opted for quarantine. The inclusion of either measure in the analysis provides an indication of the relevance of such measures in the response to the spread of this disease.

3.2. Economic factors

- ***Level of per capita GDP***: The level of per capita income has been widely used in the previous literature on viral disease transmission (Adams *et al*., 2003; Adda *et al*., 2009; Adda, 2016) and in the specific case of COVID-19 (Yun *et al*., 2020; Alipio, 2020). Indeed, a high income would allow an individual to acquire means of protection or care in case of contagion and then avoid the spread of the disease.
- ***Trade openness***: in contrast with previous research that has privileged distance, this paper takes into account a country's openness to the rest of the world. This openness seems to be an important factor in the transition from epidemic to pandemic. In addition to the commercial openness commonly used (Oster, 2012; Adda, 2016), the incoming flow of tourists is also considered. A high level of trade is associated with a high rate of movement of people between and within countries and increases the prevalence of COVID-19 (Zhan *et al*., 2020, Zhang *et al*., 2020). For this reason, these two variables are used interchangeably and take into account the fact that the first cases were imported from other countries.
- ***Response budget***: Several countries have committed to curbing the spread by putting in place a response plan. Beyond the response plans, the provision of health infrastructure to support patients can justify the level of contamination in a country. For example, Qiu *et al*. (2020) shows that provinces with more doctors have very low contamination rates. Therefore, in addition to the response budget plan, health expenditures are also taken into account. These two variables make it possible to assess the capacity of the health system to deal with existence cases and to prevent new contaminations.
- ***Level of education***: Education determines the perception of the risk of COVID-19transmission (Huynh, 2020), but also the spread of a disease (Baker *et al*., 2011; Stojkoski *et al*., 2020). The level of education would be related to the degree to which an individual respond to promote barrier measures to break the chain of infection.

3.3. Climatic factors

- ***The average of the climatic variables*** (*temperature, rainfall, wind speed*): Climate is considered as an important determinant in the spread of viral diseases. For example, exposure to high temperature helps to contain the evolution of influenza (Adda, 2016; Slusky and Zeckhauser, 2018) and COVID-19 (Qiu *et al*., 2020). While a cold climate gives a virus a chance to survive (Lowen& Steel, 2014), a warm climate reduces this chance as well as outdoor activities and thus the spread of the virus (Wang *et al*., 2020). By taking these variables into account, it is possible to assess their effect on the level of contamination.

Our analysis covers a sample of 163 countries in the world that have had at least one officially reported case of COVID-19 as of March 25, 2020. No other criteria prevailed in the choice of these countries apart from being a country that has registered a case of COVID-19. The data are cross-sectional, with countries having been observed on the same date and over the period of one month for registered COVID-19 cases. The estimation method adopted is the Ordinary Least Squares (OLS). It is a benchmark. The presence of specific effects related to each country in the sample could lead to problems of heteroskedasticity. White's (1980) method is used to ensure the robustness of the estimators. In addition, several explanatory variables in the model are very close to each other, which could create a multicolinearity problem. Finally, unobserved factors would be sources of endogeneity in the model. These econometric problems mean that the Ordinary Least Squares method would produce biased estimators. To solve the endogeneity problems, the Two Steps Least Squares (2SLS) method is used (Baum *et al*., 2003). Variables such as the degree of openness and tourist inflow are used as instruments of endogenous variable. Indeed, over the period of analysis, all countries had closed their borders so that the movement of people was limited.

While the first cases of contamination are mostly imported, the spread of the disease in a country is intrinsically linked to internal factors. For robustness, another dependent variable which is the maximum level of COVID-19 cases reached in each country during the analysis period is used. In the same vein, we introduced interactions between some variables to investigate whether they have an amplifying or moderating effect.

Table 1
Descriptive statistics of variables in the Sample

Variables	Obs.	Mean	St. dev	Min	Max
Trade openness (as a percentage of GDP)	168	89.00	51.70	24.12	412.87
Per capita GDP at constant price 2011	170	20233.14	22237.06	688.41	151323
Response Budget (as a percentage of GDP)	158	2.32	3.41	0	16.22
Level of development	183	0.37	0.48	0	1
Quarantine	168	0.49	0.50	0	1
Confinement	168	0.28	0.45	0	1
Education	134	2.66	0.70	1.21	3.97
Flow of tourists 2018	146	8341074	$1.49\ 10^7$	14000	$8.93\ 10^7$
Temperature	183	17.88	9.52	-5.60	32.35
Wind speed	174	13.79	6.87	3.15	46.80
Population in millions 2019	172	35.05	111.93	0.03	1351.17
Rainfall (en mm)	183	72.41	57.39	0	305.05
Health Budget	162	5.32	2.70	0.19	11.78
Population density2019 in millions	169	203.40	653.10	0	7909.52
Max_covid per million inhabitants	183	52.94	109.5253	0.03	1001.83
Standard deviation of Covid per million inhabitant	183	12.67	29.03005	0.01	284.68
Percentage of population confined (%)	27.98				
Percentage of population in quarantine (%)	49.40				
Percentage of developed countries (%)	36.61				

Source: authors

Table 2
Comparison of variables averages by countries level of development

Variables	Developed countries	Developing countries
Trade openness (as a percentage of GDP)	115.41	75.44
Per capita GDP at constant price2011	41825.91	9626.17
Response Budget (as a percentage of GDP)	4.66	1.14
Quarantine	0.36	0.56
Confinement	0.39	0.22
Education	3.26	2.34
Tourists flows	$1.29\ 10^7$	5317109
Temperature	12.91	20.76
Wind speed	15.36	12.87
Population (in millions)	19.52	43.16
Rainfall (en mm)	60.17	79.47
HealthBudget	6.66	4.68
Population Density	344.29	133.58
Max_covid per million inhabitants	117.01	15.94
Standard deviation of Covid per million inhabitant	28.19	3.71
Percentage of population confined (%)	39.29	22.31
Percentage of population en quarantine (%)	35.71	56.25

Source: authors

4. Main findings

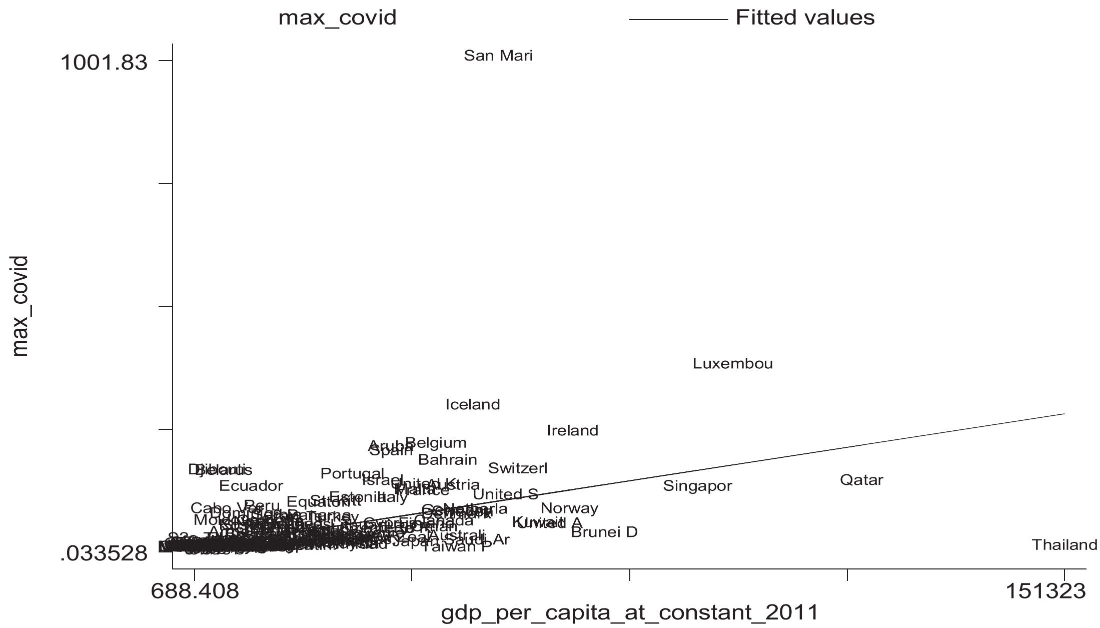
This section presents some stylized facts through the variables used in the analysis before analyzing econometric results. The section 4.1 presents the statistic results and the section 4.2 presents the econometric results.

4.1. Statistic results

4.1.1. Economic variables

Table 1 presents the descriptive statistics of variables used in the analysis. In this table, we highlight the central tendency and dispersion parameters of the economic, climatic and social variables. In the sample, the average per capita GDP at constant price 2011 is equal to US$20,233.14. When carrying out the analysis according to countries level of development, there is a wide disparity between developed and developing countries.

The average per capita GDP is US$41,825.91 in developed countries compared to only US$9,626.17 for developing countries (Table 2). This variable reflects a nation's income level. The implementation of measures to reduce the spread of COVID-19, at the individual, community and collective levels, will be partly related to the level of development of the country Thus, in developed countries, particularly in France and Canada, partial unemployment has been introduced. During this period, employees' salaries are covered by the measures set up by governments. In developing countries, where public deficits are large and debt levels very high, such a measure is hardly conceivable. However, it should be noted that in some countries, government has assumed part of the water and electricity bills for households.



Graph 1. Relationship between max_covid and per capita GDP in 2019 at constant price 2011
Source: authors

The trend in Graph 1 reflects a positive relationship between the per capita GDP of 2019 at constant price 2011 and the spread of COVID-19. This indicates that the COVID-19 virus is spreading rapidly in developed countries. The average degree of economic openness is estimated to 89% of GDP for all the countries in the sample. Openness seems more important for developed countries (115.411% of GDP) than for developing countries (75% of GDP). Developing countries are less integrated into the world economy.

Trade transactions between developing countries and China, on the one hand, and with other developed countries on the other, remain less important than those between China and developed countries. Air links between China and the rest of the world show that there is a strong concentration with regard to Europe and the American continent. Air links between Africa and China remain less important. The strong spread of COVID-19 in the European and American continent can be partly explained by this strong air link between these continents and China, which is the cradle of the epidemic.

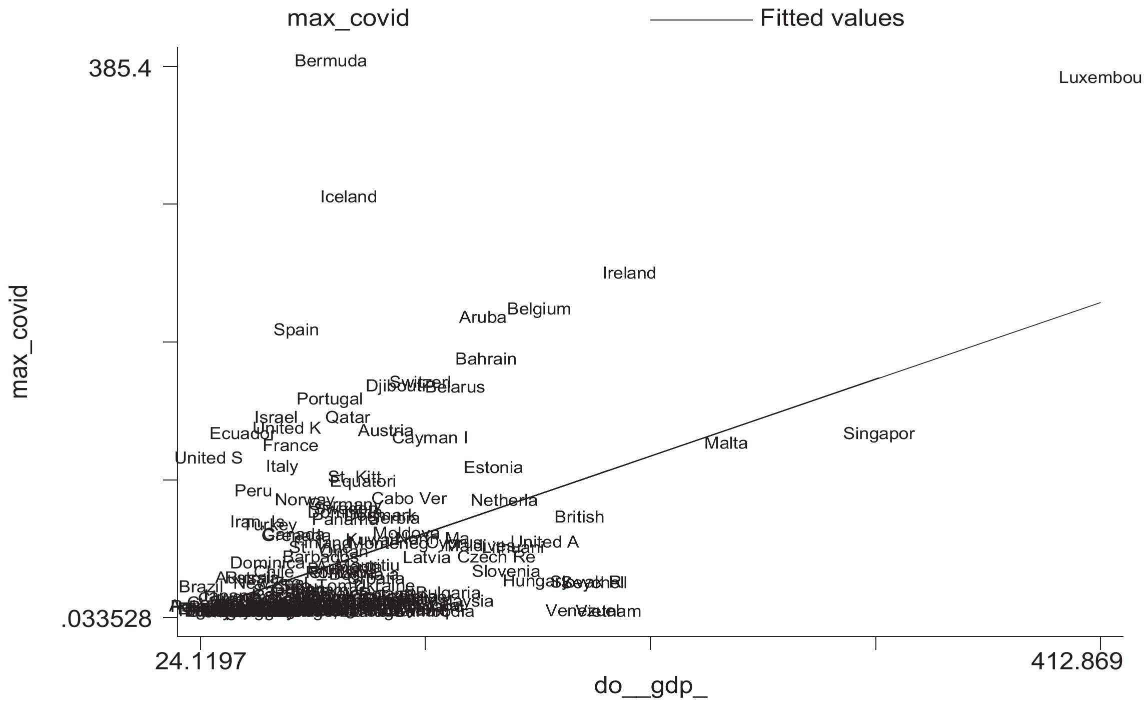
Graph A1 (see appendix) shows a positive relationship between tourist flows and the spread of COVID-19 in the countries sampled. Also, the trend in Graph 2 shows a positive relationship between the degree of openness and the propagation of COVID-19. The average tourist flows in 2018 is estimated to more than 8,341,074 economic agents. However, average tourist flows are twice as high in developed countries (12,900,000) than in developing countries (5,317,109). While tourist flows remain an important element in the economic dynamics of nations, they can also be a vector for the transmission or spread of viral diseases in a world characterized by the free movement of goods and people. Cases of transmission of the virus by importation are not negligible with the COVID-19. In the case of low-income countries as it happens in Burkina Faso, several new cases are imported during the June 2020. Imported cases are becoming more and more numerous than those of community transmission.

4.1.2. Climatic and social variables

The average temperature in the sample is 17.88°C. However, this number hides disparities. In developing countries, the temperature averages around 20.75°C while developed countries experience only 12.91°C in average. The very high temperatures in developing countries seem to be a favorable factor in controlling the spread of COVID-19.

As for social variables, the average population density is 203,401 inhabitants per km^2. In developed countries, this density is 344.28 inhabitants per km^2, while in developing countries it is only 133.583 inhabitants per km^2. The trend in Graph 3reflects a positive evolution between the population density and the spread of the COVID-19. The high concentration of population is likely to make it difficult to apply physical distancing measures recommended by WHO in fighting against the spread of COVID-19. Thus, low densities in some developing countries are beneficial to reducing the spread of the virus.

The average value of educational capital is 2.66 in the overall sample. It is equal to 3.26 in developed countries and 2.34 in developing countries. This reflects a disparity in terms of educational capital between developed and developing countries. Against our expectations, Graph 4 shows an increasing trend between the spread of COVID-19 and the level of education. A high value of educational capital should encourage the adoption of barrier measures and responsible behaviors that reduce the spread of COVID-19.



Graph 2. Link between max_covid and the degree of economic openness
Source: authors

The same trends are observed when considering the variable “Covid standard deviation”. The proportion of the budget allocated to health reflects the effort made by States in the field of health for the benefit of their populations.

This effort is 6.66% in developed countries compared to only 4.68% in developing countries. It reflects the country’s capacity to have health infrastructures adapted to the response. Developed countries seem to have more adapted and greater capacities to deal with the spread of COVID-19. However, Graph5 does not seem to show a negative relationship between the health budget – health expenditure as a percentage of GDP – and the spread of COVID-19. The fact that a country has significant health expenditures should predispose it to deal with the coronavirus pandemic through the existence of adequate infrastructure and response materials. The health budget is structural in nature, unlike the response budget, which is cyclical. However, the latter – the response budget to the COVID-19 – is just as important and plays a role closer to that of the health budget. It is estimated to 2.32% of GDP in our sample. This share is 4.66% of GDP for developed countries compared to 1.14% for developing countries. Health budgets have not been oriented towards financing structural investment in terms of capacity to deal with all forms of epidemics. They are most often used to finance operations and mechanisms for resolving cyclical problems. For example, France had not renewed its stock of masks for several years. It could not meet the high demand for masks at the time that the crisis was critical.

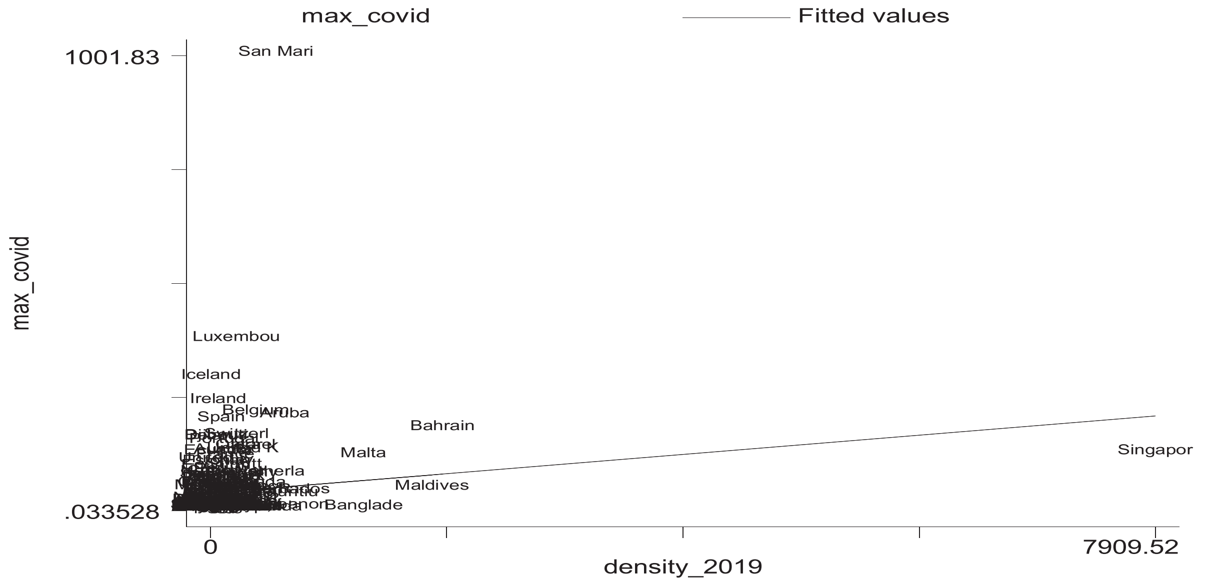
When we consider the COVID-19 standard deviation as our variable of interest, we get results similar to those obtained when using the variable “max-covid” for education and population density.

Table A2 (see appendix) represents the variance covariance matrix using the variable of interest “max-covid” while Table A3 (see appendix) represents the correlation matrix using the variable “COVID-19 standard deviation” instead of “max_covid”.

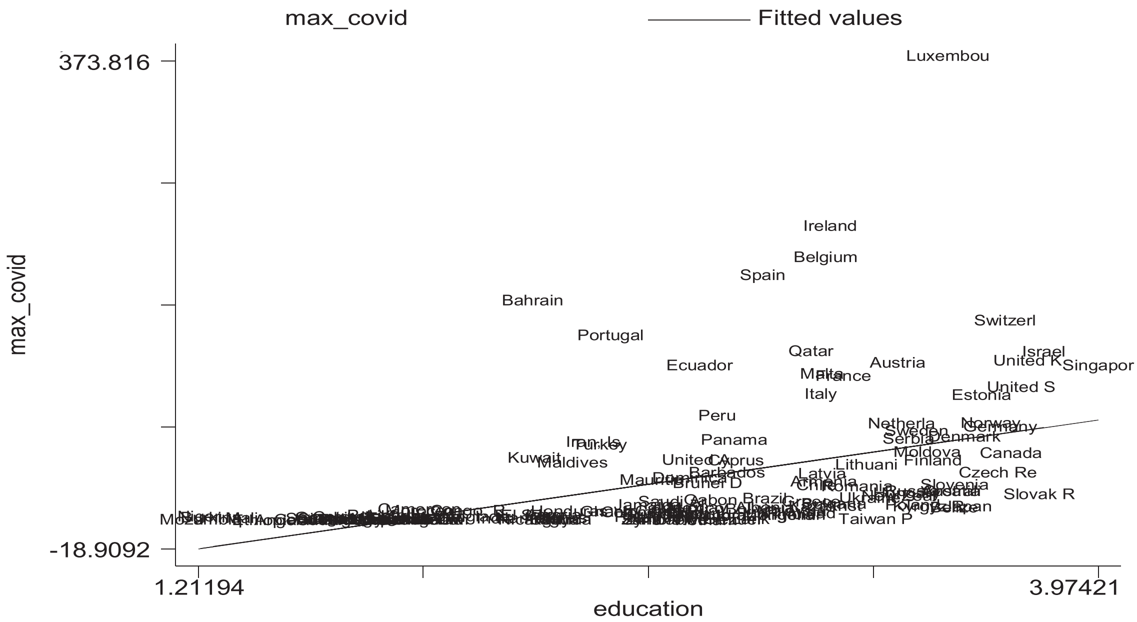
4.2. Econometric results

As indicated in the methodology, we use two estimation methods in this paper to test the robustness of the results: Ordinary Least Squares (OLS) and the Instrumental Variable Method (2SLS). In Table A4 (see appendix), the results of OLS estimation following White’s (1980) approach are presented. Similarly, Table 3 below presents the results of the second estimation approach (2SLS). The analysis in this section is based on these two types of estimation.

The probabilities associated with the Sargan statistics (P-value) are all higher than 5%, which means that instruments used are valid. The estimations carried out do not suffer from any econometric problem. In the following section, we proceed to the interpretation and discussion of our finding.



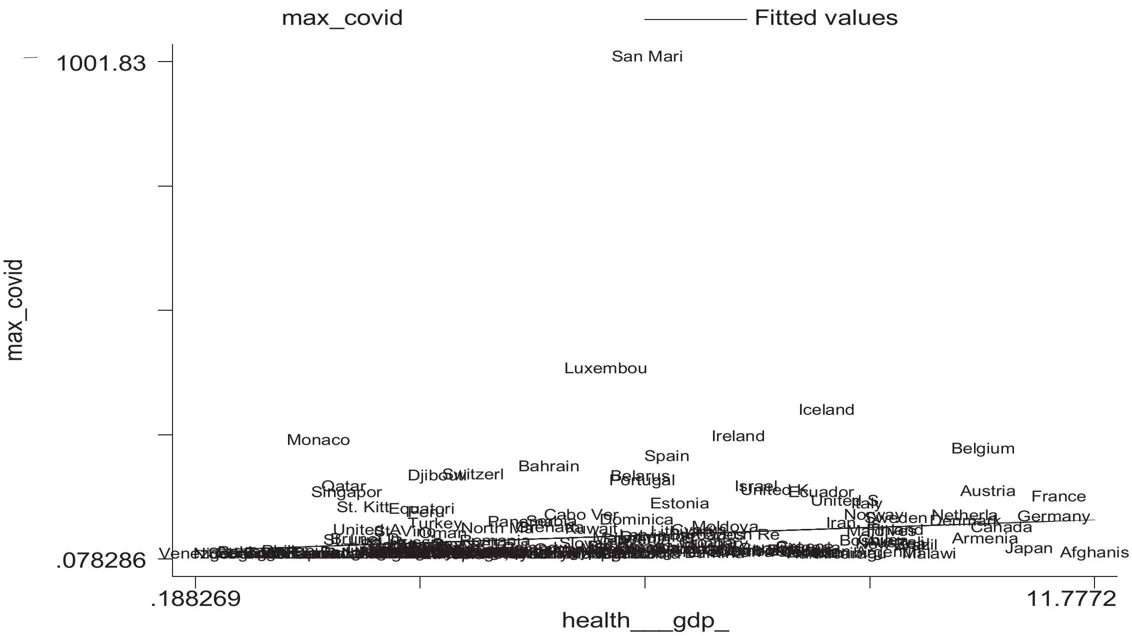
Graph 3. Evolution between Max_covid and population density
Source: authors



Graph 4. Evolution between max_covid and educational capital
Source: authors

4.2.1. Discussion on the determinants of the spread of COVID-19

4.2.1.1. Government measures. The most commonly used government responses to deal with the COVID-19 pandemic are quarantine and confinement. The results of the 2SLS estimations show that quarantine does not affect the spread of COVID-19. On the other hand, the result of the OLS estimation – Model 7in table A4- shows that confinement positively affects the spread of COVID-19. While the effectiveness of quarantine policy at the country level seems to be proven in the research of Hellewell *et al.* (2020) in China, caution should be observed with regard to the continental or intercontinental scale. However, the heterogeneity of the countries in the sample of our study could justify this result. Thus, in order to take this into account, a variable is introduced into the basic model that captures only the effect of confinement in developed countries. This variable, which result in the product of the variables “confinement” and “development level”, has a positive



Graph 5. Evolution between max_covid and health budget
Source: authors

effect on the variables “max-Covid” and “standard deviation of the Covid” measuring the spread of the virus, whether it is the instrumental variable method —model 1 to 4 in table 3— or the OLS method, model 7 in table A4.

This result, which is not very intuitive, could be explained by the fact that households staying confined can be a source of virus spread within family members if and only if there are already infected people among them. Moreover, no tests are done to detect those already infected before considering 'stay at home' measures in developing countries. Life among household is not such as to allow the practice of physical distance of at least one meter. Reversely, this is the time for members to have a more intimate life.

It is proved that confinement has encouraged an increase in domestic violence. In order for confinement to reduce the spread of COVID-19, it must be done with a number of precautions including screening tests before. Confinement may be more effective in the early stages of the outbreak where the risk of having infected people in the household remains low. Once the virus has spread well in the population, confinement would become a source of spread within households.

This result calls into question one of the WHO's positions on confinement, which is that it remains a measure to stop the disease and strict monitoring to reduce the number of direct contacts and the overall risk of transmission of this acute respiratory infection (WHO, 2020).

The results obtained contrast with the conclusions of some authors (Riou & Althaaus, 2020; Wang *et al.*, 2020) who believe that confinement is an effective means of containing the spread of the disease, since it avoids contact from people whose a priori status is unknown. However, our result provides a better understanding less catastrophic health situation experienced in Europe, the United States of America and Latin American countries over the last three months. Moreover, despite the disparate application of confinement in developing countries, African countries have so far been able to decelerate the spread of COVID-19. Not only does confinement appear to be a very expensive approach, but also states in developing countries lack resources to implement it.

4.2.1.2. Economic factors.

i) **Level of development**

The level of development, measured in this research by the per capita GDP at constant price 2011, has a positive and significant effect in the spread of COVID-19 in the world and this according to the two types of estimations made.

The model 5 estimated by the Two Steps Least Squares method (2SLS), shows that the per capita GDP at constant price 2011 has a positive and significant effect at 1% threshold on the spread of the COVID-19 globally. Similarly, in models 8 and 9 in Table A4, using the natural log of the per capita GDP at constant price 2011 estimated by the OLS method confirm the positive and significant effect at 1% threshold of the level of development on the spread of COVID-19.

As already pointed out, there is still no consensus on the socio-economic determinants of the coronavirus pandemic. Based on country-level statistics on the number of coronavirus cases per million population (pmp) or deaths due to the

Table 3
Estimation results (2SLS method)

Variables	2SLS *max_covid* (model 1)	2SLS *St. dv_Covid* (model 2)	2SLS *max_Covid* (model 3)	2SLS *max_Covid* (model 4)	2SLS *St. dv_Covid* (model 5)	2SLS max_covid (Model 12)	2SLS St.devcovid (Model 13)
per capita GDP at constant price 2011	0.00286	0.000747	0.00285	0.00289	**0.000774***	0.0026	0.0007
						(002)	(0.0005)
	(0.002400)	(0.00062)	(0.002361)	(0.00218)	(0.00059)	-0.3908	0.0441
Response budget as percentage of GDP	-0.573	0.0921	-0.493	-1.043	-0.0850	(4.501)	(1.108)
	(4.6212)	(1.0745)	(4.4559)	(4.671)	(1.5302)	0.0026	0.0007
						(002)	(0.0005)
Quarantine	5.971						
	(13.157)						
Confinement	-0.557						
	(8.6588)					-33.92	-8.951
Education	-26.60	-6.365	-26.39	**-39.30****	**-10.01****	(27.77)	(7.365)
	(18.2264)	(4.3080)	(17.29)	(28.9509)	(7.6776)		
Level of development	-42.84	-12.33	-46.37				
	(57.833)	(15.843)	(60.1964)				
Temperature	**-1.117***	-0.239	**-1.121***	**-1.372***	-0.308	-1.0138	-0.239
	(0.6593)	(0.1529)	(0.6581)	(0.7909)	(0.1961)	(0.75)	(0.183)
Wind speed	0.686	0.146	0.730	0.472	0.0731	0.1479	0.0124
	(0.80331)	(0.17675)	(0.75414)	(0.9704)	(0.23396)	(0.85)	(0.212)
Rainfall	-0.119	-0.0415	-0.123	-0.0639	-0.0258	-0.070	-0.027
	(0.104)	(0.02677)	(0.1051)	(0.1475)	(0.03804)	(0.135)	(0.035)
Population (in millions)	-0.00763	-0.00348	-0.0110	-0.000903	-0.000742		-0.001
	(0.0164)	(0.003736)	(0.01493)	(0.0164)	(0.00412)		0.0039
Health expenditures (as percentage of GDP)	3.464	0.458	3.337	2.780	0.331	1.95	0.170
	(3.3282)	(0.7426)	(3.1188)	(2.4547)	(0.5795)	(2.32)	(0.547)
Population density in 2019	0.00586	0.000698	0.00576	0.00201	-0.000364	-0.0044	0.027
	(0.00991)	(0.002637)	(0.01001)	(0.0132)	(0.003569)	(0.15)	(0.021)
Confinement*level of development	**53.00****	**11.67*****	**52.52*****	**35.05***	6.935	29.05	5.818
	(22.9855)	(4.6615)	(19.9672)	(20.3959)	(4.6526)	(19.51)	(4.526)
Quarantine *level of development	0.872	-2.516	6.617	-11.55	-7.511	-12.749	-7.709
	(27.4525)	(5.2541)	(21.054)	(33.2667)	(9.1108)	(31.06)	(8.727)
Temperature*population density in 2019						**-0.0054**	**-0.001**
						0.0035	**0.0007**
Intercept	48.86	14.05	52.30	82.01	22.27*	77.18	20.160
	(34.0285)	(8.5339)	(36.9488)	(56.2173)	(13.384)	(55.31)	(14.023)
Wald chi2	113.10	111.31	113.85	121.36	127.13		
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sargan (score) chi2	1.6801	2.463	1.675	1.207	2.025	0.95	1.85
P value	0.1949	0.1166	0.196	0.272	0.155	0.33	0.1729
Observations	109	109	109	109	109	109	109
R-squared	0.159	0.121	0.160	0.087	0.006	0.2150	0.1172

Source: authors, standard errors in parentheses*** $p<0.01$, ** $p<0.05$, * $p<0.1$
Source: authors

disease, Stojkoski *et al.* (2020) investigate a potential 29 determinants, describing the full range of socio-economic characteristics, including economic performance and population structure. Our results go in the same direction as those found in previous studies, especially the findings that epidemics spread faster in a situation of economic booms (Adda, 2016). Populations with a high standard of living will have privileged relationships with the populations of Wuhan (a developed city), the epicenter of the epidemic. The number of China-Europe and China-America air links is higher than the number of China-Africa air links. Thus, a high level of development may favor the increase of imported cases of COVID-19 and reduce the number of local contamination cases. In addition, in high and middle income countries, governments and populations have not always taken appropriate preventive measures in a timely manner. The example of Ivory Coast is illustrative. However, the speed of spread can be affected by the response capacity of the concerned country to deal with it. In the short run, the spread is strong and in the medium run, it may decelerate depending on the response mechanism developed. Ultimately, the overall outcome would depend on the relative importance of measures taken to stop the contamination.

ii) **Trade openness**

The results from models 6 to 9 estimated by the OLS in Table A4 method show that trade openness has a positive and significant effect at 5% or 10% on the spread of COVID-19 globally. This result is similar to findings supporting that increased trade involving movement of people and goods is a source of spread of viral diseases (Adda, 2016; Oster, 2012). Clearly, countries that are less connected to the epicenter of the outbreak are more likely to be spared by the virus.

There are two types of imported cases of COVID-19: (i) cases imported directly from China (Wuhan) to a specific country, (ii) indirectly imported cases which represent COVID-19 cases imported from a country other than China to the specific country considered. For some countries, importation of both types of COVID-19 is important while for other countries it is one of the two types that are more important for Community transmission. This is why trade openness is revealed as a channel for the spread of COVID-19. Indeed, trade openness implies movements of people, goods and capital. Under these conditions, human contacts and the manipulation of money are frequent and constitute vectors responsible for the spread of the virus.

iii) **The response budget**

Against our expectations, the response budget has a positive effect on the spread of COVID-19 for the selected countries in our sample. Models 8 and 9in Table A4 estimated by OLS show that the budget allocated to reducing the spread of COVID-19 has a positive and significant effect on the spread of the virus. This result is counter-intuitive but can be explained by the poor management of emergency funds. In several States, particularly in developing countries, civil society organizations and lobbies have demanded accountability in the management of these funds. In addition, the resources released to deal with the pandemic have not been used effectively in some countries on the one hand and on the other hand they have not been sufficient to reverse the trend. Furthermore, in developed countries particularly with a good public health system, a substantial share of additional governmental budgets has been spent for economic support programs such as short-time working schemes, financial support for businesses etc. These economic support programs might have only very limited effects on the virus transmission. Finally, in developing countries, part of the COVID-19 budget is used to mitigate the economic consequences of the pandemic. In addition, its resources are most often subject of corruption. This practice also might have very limited effects on the virus transmission.

4.2.1.3. Socio-demographic factors.

i) **Population density**

The results of model 8 estimated by the OLS in Table A4 show that density —ln (density) — is a significant factor in the spread of COVID-19 (max_covid). This result is in line with the findings of Mangen *et al.* (2020) and Hu *et al.* (2021) who support that there is a relationship between high population density and the spread of outbreaks. It also argues in favor of measures to reduce high concentrations of individuals, especially in countries without effective health systems. Barrier measures such as travel restrictions, isolation and the monitoring of affected individuals, closure of schools, airports, restaurants, shopping centers as discussed by Hohel *et al*. (2020), Gilbert *et al.* (2020), and Ferguson *et al.* (2020) are likely to effectively reduce high concentrations of individuals and thus the spread of COVID-19. Such a result suggests the social distancing that had already been discussed by Ferguson *et al.* (2020).

It should be emphasis however, that the variable “population density” was not found to be significant in the spread of COVID-19.

ii) **Education**

Education contributes significantly to reducing the spread of COVID-19 in our sample. The estimation results from models 4 and 5 in Table 3 by the 2SLS method show that education has a significant negative impact at 5% threshold on the spread of COVID-19 (max_covid and standard deviation of covid) globally. This result is also confirmed in models 8 and 9 estimated by the OLS method in Table A4.

A high level of education can promote compliance with barrier measures such as physical distancing, wearing a nose mask, sneezing in the elbow, etc. Generally, individuals with low levels of education are victims of misinformation about COVID-19 and opposing beliefs. The econometric results reinforce the statistical results presented earlier.

4.2.1.4. Climatic variables. Models estimated by the instrumental variables method —models 1, 3 and 4— in Table 3, show that temperature has a negative effect on the spread of COVID-19globally at 10%significance level. The findings through the OLS method —models 6, 8, 9 in Table A4— confirm the previous result. Therefore, temperature is a factor reducing the spread of COVID-19globally. Moreover, Wang *et al.* (2020) have shown that coronavirus cannot survive to temperatures above 25°C. Slusky & Zeckhauser (2018) indicated that exposure to sun is also effective in reducing the spread of influenza. Therefore, temperature plays a significant role in the control of the COVID-19. It worth emphasizing that the mean temperature in the developing country sample is 20.75°C with a standard deviation of 8.30 while it is 12.90°C with a standard deviation of 9.51 in developed countries. Wang *et al.* (2020) argue that lower temperatures may also increase the infectiousness of the virus in the environment. Taking this result into account, we can safely indicate that winter in developed countries has contributed to increase the virulence of coronavirus.

The temperature-related findings can be better understood when taking into account those obtained by Woodward (2020) and Bannister-Tyrrell (2020). Indeed, according to these authors, the droplets expelled from a patient’s mouth, which can spread over several meters, are evaporated in the presence of high temperatures, thus reducing infectiousness.

Among the models estimated by 2SLS and OLS, only one of these models shows that the wind speed acts positively and significantly at 10% threshold in the spread of COVID-19 (max_covid) worldwide. The result related to wind speed supports the idea that the effect of this meteorological variable on the spread is well debatable. Indeed, this is supported by Qiu *et* *al.* (2020) who argue that new cases are generally dependent on the number of people who have already contracted the virus and the environmental conditions.

Rainfall has been found to be insignificant in the global spread of COVID-19. This result relativizes the finding of Lowen & Steel (2014) supporting that the greater the rainfall, the more humidity can weaken virus transmission. In sum, climatic variables with the exception of temperature do not have a significant effect on the spread of the virus. The effect of temperature is consistent with expectations supporting that drops containing germs cannot withstand the heat. Finally, taking into account the interaction between temperature and population density to investigate whether there is an amplification or moderation effect, the results show that there is no effect. The population density does not amplify nor moderate the effect of temperature on the spread of the virus.

5. Conclusion and implications for policies

The spread of the virus and the trouble for States to contain it is a global concern. Some countries have dealt with the control of COVID-19spreading; others are still struggling to do so. The identification of factors that may explain such a phenomenon is paramount.

The main objective of this research was to identify the socio-economic and climatic factors that explain the spread of COVID-19 worldwide. To do so, an econometric model was specified based on the Keynesian theory of supply shock which shows that the spread of the virus would be related to the return effects of the shock. The model was estimated using Ordinary Least Squares and Two Steps Least Squares methods on a sample of 163 countries worldwide.

Our main findings indicate that the spread of the virus is related to economic, social and environmental factors. With respect to economic factors, the main finding is that the level of development, the degree of trade openness and the response budget to COVID-19, positively affect the spread of the virus. With regard to social factors, the results indicate that population density accelerates the spread of the virus and that confinement is not a panacea either. Taking into account environmental factors, it appears that high temperatures contribute to reducing the spread of the virus. These results are robust to the estimation technique and to the measurement of the spread of the virus under consideration.

All this empirical evidence on the socio-economic and climatic determinants in the spread of the virus has implications for economic policies. First, the level of development is not sufficient to decide on the confinement measure. This measure must be put in place as soon as the first cases are reported, regardless of the country's level of development. Secondly, for economic measures (response budget) to have an impact in terms of health, they must be taken with a certain level of transparency to avoid boycotts by population. Finally, although a high level of human capital can reduce the spread, sensitization measures are also necessary in order to provide the population with accurate information on this type of virus.

Data availability statement

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Competing Interest

None.

Appendixes

Graphs A1 and A2, Tables A1–A4

Table A1
Variables and definitions

Variables	Definition	Source
Standard deviation COVID	Measures the standard deviation of official covid 19 cases over the analysis period	Authors, using the WHO daily report, 2019
Max COVID	Maximum level of covid 19 daily cases over the analysis period	Authors, using the WHO daily report, 2019
Confinement	Dummy variable equal 1 if the country in confined over the analysis period and 0 otherwise	IMF website, 2020
Quarantine	Dummy variable equal 1 if the country is in quarantine over the analysis period and 0 otherwise	IMF website 2020
Density	Measures the density of the population as of 2019	IMF, 2017
GDP per capita	Measures the per capita real GDP in purchasing power parity in 2017	IMF, 2017
Trade openness	Measures the sum of exports and imports as a percentage of GDP in 2017	IMF, 2017
Incoming flow of tourist	Measures the number of incoming tourist in the country in 2018	World Bank, World Development Indicators (2020).
Response budget	Represent the total budget of the response plan as a percentage of GDP	World Bank, World Development Indicators (2015).
Education level	Average year of school attendance in 2017	Barro and Lee (2017)
Development level	Dummy variable equal 1 is the country is a developed country and 0 otherwise	UNPD, 2019
Average temperature	Measures the average air temperature during the analysis period	Authors, using the databasewww.weatherbase.com
Average rainfall	Measures the average rainfall during the analysis period	Authors, using the databasewww.weatherbase.com
Average wind speed	Measures the average wind speed during the analysis period	Authors, using the databasewww.weatherbase.com

Source: authors

TableA2
correlation matrix using max_covid

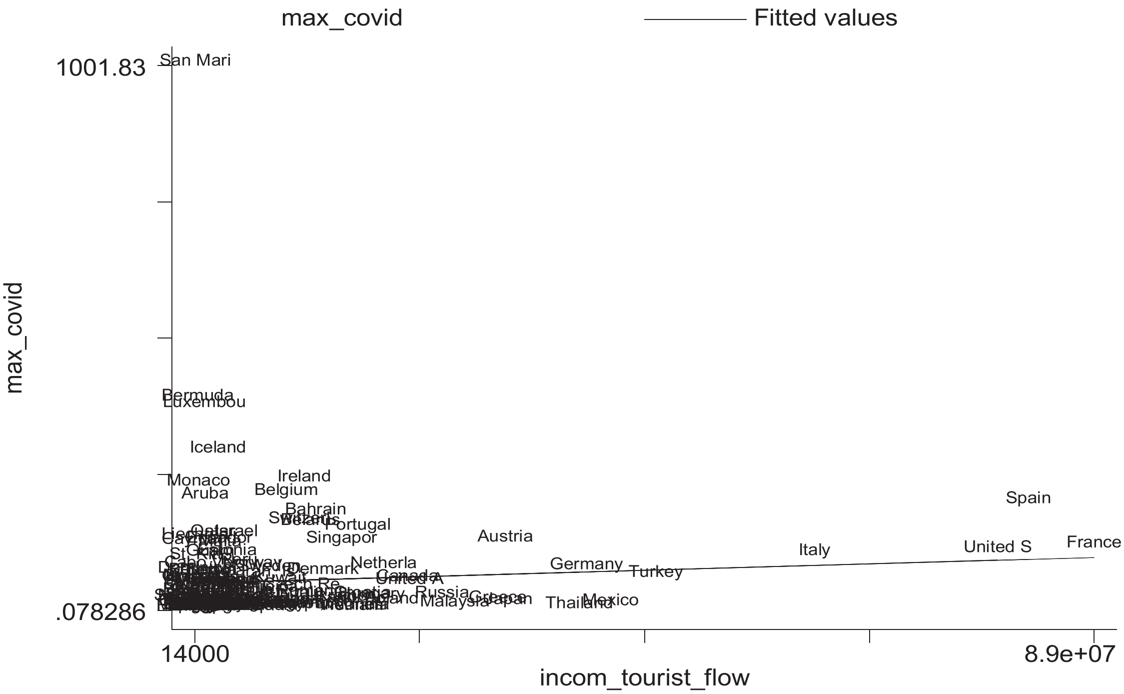
	max_co~d	health~_	Population in million_	precipitation	wind speed	temperature	Level of development	gdp~2011	responsebuget	quarantine	Confinement	education	tourist flow ~2018_
max_covid	1.0000												
health___	0.2524	1.0000											
pop__(million)_	-0.0804	-0.0601	1.0000										
precipitation	-0.1390	-0.1420	0.0061	1.0000									
Wind sp~t	0.1785	0.1277	-0.1344	-0.2863	1.0000								
temperature	-0.3788	-0.4571	0.0792	0.3128	-0.0716	1.0000							
Level of development	0.5558	0.3944	-0.1162	-0.2300	0.1760	-0.4451	1.0000						
gdp_per~2011	0.5703	0.1306	-0.0600	-0.0208	0.0834	-0.2911	0.6306	1.0000					
responsebuget_ ~_	0.5342	0.2624	-0.0448	0.0616	0.0443	-0.2803	0.4783	0.5440	1.0000				
quarantine	-0.0712	-0.1189	-0.0914	-0.0726	0.1465	0.0077	-0.1794	-0.1480	0.0652	1.0000			
Confinement	0.2805	0.1568	0.1786	-0.0598	-0.0431	-0.2652	0.2087	0.1032	0.1726	-0.0344	1.0000		
education	0.4187	0.4238	-0.0724	-0.1124	0.0092	-0.6955	0.6028	0.5172	0.4530	-0.1103	0.1675	1.0000	
tourist flow~2018_	0.3154	0.2734	0.2144	-0.0428	0.0365	-0.2853	0.3386	0.3470	0.3502	0.0456	0.2742	0.3064	1.0000

Source: authors

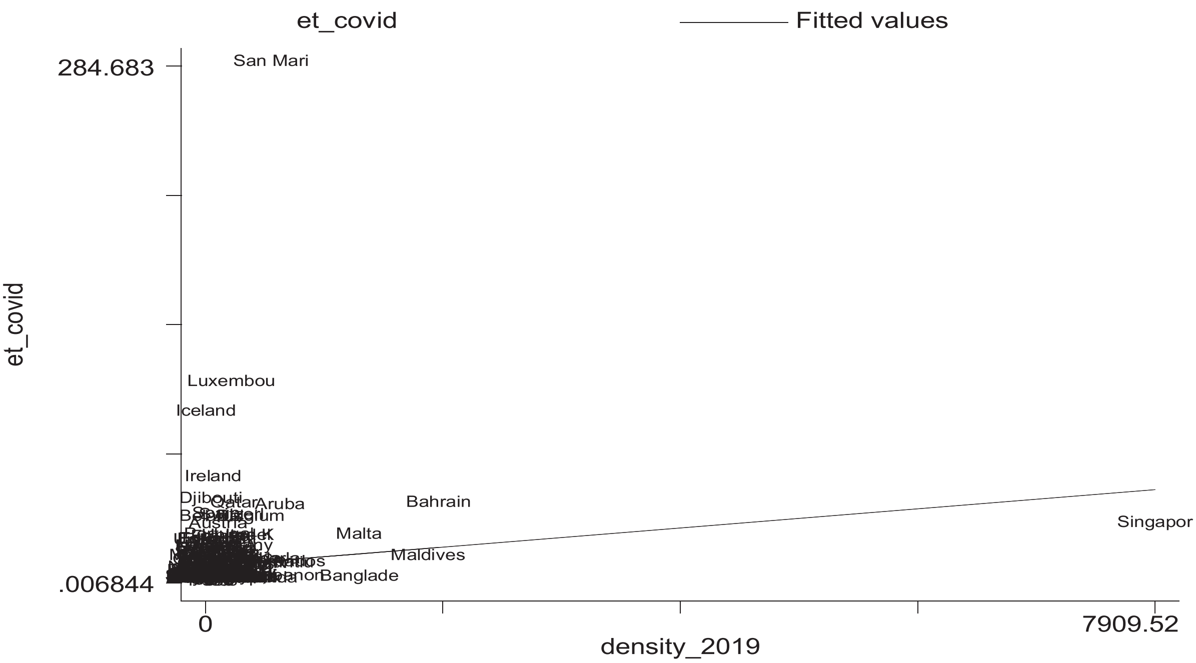
Table A3
.correlation matrix using st.dev_covid.

	St dev_covid	health~_	pop__m~_	precipitation	wind speed	temperature	Level of development	gdp~2011	Response budget_	quarantine	confinement	education	Incoming flow of tourist ~2018_
St dev_covid	1.0000												
health___g~_	0.1697	1.0000											
pop__(million)~_	-0.0826	-0.0601	1.0000										
precipitation	-0.1415	-0.1420	0.0061	1.0000									
Wind speed	0.1576	0.1277	-0.1344	-0.2863	1.0000								
temperature	-0.3374	-0.4571	0.0792	0.3128	-0.0716	1.0000							
Level of development	0.5118	0.3944	-0.1162	-0.2300	0.1760	-0.4451	1.0000						
gdp_per~2011	0.5977	0.1306	-0.0600	-0.0208	0.0834	-0.2911	0.6306	1.0000					
response budget_ ~_	0.5434	0.2624	-0.0448	0.0616	0.0443	-0.2803	0.4783	0.5440	1.0000				
quarantine	-0.1015	-0.1189	-0.0914	-0.0726	0.1465	0.0077	-0.1794	-0.1480	0.0652	1.0000			
confinement	0.2509	0.1568	0.1786	-0.0598	-0.0431	-0.2652	0.2087	0.1032	0.1726	-0.0344	1.0000		
education	0.3931	0.4238	-0.0724	-0.1124	0.0092	-0.6955	0.6028	0.5172	0.4530	-0.1103	0.1675	1.0000	
Incomingflow of toutist~2018_	0.2365	0.2734	0.2144	-0.0428	0.0365	-0.2853	0.3386	0.3470	0.3502	0.0456	0.2742	0.3064	1.0000

Source: authors



Graph A1. .relation betweenmax_covidandincoming flow of tourists 2018.
Source:authors



GraphA2. Evolution. betweenst. dev_covidand density 2019
Source:authors

Table A4
Estimation result (OLS)

Variables	OLS max_covid (model 6)	OLS max_covid (model 7)	OLS max_covid (model 8)	OLS St. devcovid (model 9)	OLS max_covid (Model 10)	OLS St. devcovid (Model 11)
Per capita GDP at constant price à 2011		0.000488 (0.000433)				
Response budget as percentage of GDP		2.649 (2.014616)	**3.217**** (1.820424)	**0.888*** (0. 47836)	**3.252***** (1.861)	**0.904***** (0. 494)
Quarantine	-1.18497 (8.2547)	0.856 (7.943356)	4.765 (8.98518)	-0.0737 (2.017362)	4.675 (9.051)	-0.112 (2.036)
Confinement	-1.84395 (7.8459)	**17.90*** (10.33714)	15.16 (11.81642)	3.696 (2.76042)	14.464 (11.697)	3.392 (2.671)
Education	-19.69082 (12.4388)	-13.08 (9.658322)	**-21.05*** (11.8384)	**-4.950***** (2.693076)	-20.11 (12.644)	**-4.543***** (2.681)
Level of development	5.250789 (15.2028)	17.92 (16.7253)	18.40 (14.18)	2.118 (3.341569)	18.64 (14.241)	2.225 (3.340)
Temperature	**-0.8428*** (0.4868)	-0.678 (0.518149)	**-1.153**** (0.54844)	**-0.222*** (0.1256505)	**-1.09**** (0.568)	**-0.222*** (0.125)
Wind speed	0.5682 (0.6932)	**1.279*** (0.6710947)	0.832 (0.7264)	0.202 (0.1768155)	0.783 (0.719)	0.1808 (0.1676)
rainfall	0.03194 (0.0634)	-0.0100 (0.0616767)				
Population in millions	-0.00885 (0.02316)	-0.000780 (0.0164601)				
Heath expenditure (as percentage of GDP)		2.009 (1.6088128)				
population density in 2019		0.000286 (0.0070092)				
Confinement *level of development	**36.5429*** (20.5974)					
Quarantine *level of development	28.3975 (19.7173)					
Ln(GDP per capita)	14.6516 (6.6412)		**18.22***** (7.070)	**5.042***** (1.80275)	**18.20***** (7.181)	**5.03*** (1.915)
Ln(response budget)	1.2372 (2.1328)					
Ln(health expenditure as % of GDP)	5.5884 (5.4291)		11.05 (7.059)	1.394 (1.715889)	10.60 (6.954)	-1.202 (1.651)
Ln (population density in 2019)	4.2516 (3.0534)		**6.350*** (3.531)	1.015 (0.869677)	**6.968**** (3.473)	1.284 (0.805)
Trade openness (as percentage of GDP)	**0.3672*** (0.1984)	**0.392**** (0.1739961)	**0.355**** (0.176)	**0.108**** (0.02409)	**0.365**** (0.189)	**0.112**** (0.0575)
Incoming flow of tourists 2018		3.96e-07 (4.59e-07)				
Ln(incoming flow)			-5.359 (4.723)	-1.765 (1.2025)	-5.44 (4.816)	-1.800 (1.2242)
Ln(population)			3.422 (3.789)	0.912 (0.959091)	3.649 (4.075)	1.051 (1.051)
Ln (rainfall)			0.239 (3.077)	-0.398 (0.72091)	0.2172 (3.102)	-0.407 (0.7227)
Temperature*ln(population density in 2019)					**-0.0001** **(0.0002)**	**-0.000** **0.00001**
Intercept	**-111.269*** (47.6796)	-11.21 (32.15968)	-96.18 (59.58)	-19.15 (14.4007)	-100.64 (60.76)	-21.095 (14.969)
Observations	110	109	108	108	108	108
R-squared	0.567	0.577	0.569	0.591	0.57	0.594

Source: authors, standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

References

Adda, J., 2016. Economic activity and the spread of viral diseases: Evidence from high frequency data. Q. J. Econ. 891–941.
Alipio, M., 2020. Do socio-economic indicators associate with COVID-2019 cases? Findings from a Philippine study. Find. Philippine Study *April 9, 2020*.
Baker, D.P., Leon, J., Smith Greenaway, E.G., Collins, J., &Movit, M., 2011. The education effect on population health: a reassessment. Popul. Dev. Rev. 37 (2), 307–332.
Baldwin, R., Mauro, B.W.D., 2020. Economics in the Time of COVID-19. Centre for Economic Policy Research CEPR Press London.

Bannister-Tyrrell, M., Meyer, A., Faverjon, C., Cameron, A., 2020. Preliminary evidence that higher temperatures are associated with lower incidence of COVID-19, for cases reported globally up to 29th February 2020. MedRxiv doi:10.1101/2020.03.18.20036731.
Boldog, P., Tekeli, T., Vizi, Z., Dénes, A., Barta, F.A., &Röst, G., 2020. Risk assessment of novel coronavirus COVID-19 outbreaks outside China. J. Clin. Med. 9 (2), 571. doi:10.3390/jcm9020571.
CDC China, 2020. The epidemiological characteristics of an outbreakof2019Novel Coronavirus Disease (COVID19) China Available from.
European Centre for Disease Prevention and Control, 2020. COVID-19 Available at:.
Ferguson, N., Laydon, D., Gilani, G.N., Imai, N., Ainslie, K., Baguelin, M., Bhatia, S., Boonyasiri, A., Perez, Z.C., Cuomo-Dannenburg, G., Dighe, A., Dorigatti, I., Fu, H, Gaythorpe, K., Green, W., Hamlet, A., Hinsley, W., Okell, L., Van Elsland, S., Thompson, H., Verity, R., Volz, E., Wang, H., Wang, Y., Walker, P., Walters, C., Winskill, P., Whittaker, C., Donnelly, C., Riley, S., Ghani, A., 2020. Impact of non-pharmaceutical interventions (npis) to reduce Covid19 mortality and healthcare demand. Imper. Coll. COVID-19 Resp. Team doi:10.25561/77482.
Fornaro, L., Wolf, M., 2020. Technical Report.
Gardner, W., States, D., Bagley, N., 2020. The coronavirus and the risks to the elderly in long-term care. J. Aging Soc. Policy 1–6 pages.
Gilbert, M., Pullano, G., Pinott, i F., Valdano, E., Poletto, C., Boëlle, P-Y., D'Ortenzio, E., Yazdanpanah, Y., Eholie, SP., Altmann, M., Gutierrez, B., Kraemer, MUG., Colizza, V., 2020. Preparedness and vulnerability of African countries against importations of COVID-19: a modelling study. Lancet; 395 (10227), 871–877.
edited by Gourinchas, P-O., Baldwin, R., Mauro, B.W.D., 2020. Flattening the Pandemic and Recession Curves. In: Mitigating the Covid Economic Crisis: Act Fast and Do Whastever It Takes, pp. 31–39 edited by.
Guerrieri, V., Lorenzoni, G., Straub, L., &Werning, I., 2020. NBER Working Paper No. 26918.
Harvard Health, 2020. Harvard Health Letter-March 2020 Available from.
Hellewell, J., Abbott, S., Gimma, A., I Bosse, N., Jarvis, CI., Russell, TW., Munday, JD., Kucharski, AJ, Edmunds, WJ, Funk, S, Eggo, RM., 2020. Feasibility of controlling COVID-19 outbreaks by isolation of cases and contacts. Lancet Glob. Health 8 (4), e488–e496. doi:10.1016/S2214-109X(20)30074-7.
Hu, M., Roberts, J.D., Azevedo, G.P, Milner, D., 2021. The role of built and social environmental factors in COVID-19 transmission: a look at America's capital city. Sustain. Citi. Soc. 65 (1), 1–14.
Huynh, T.L., 2020. The COVID-19 risk perception: A survey on socioeconomics and media attention. Econ. Bull 40 (1), 758–764.
Ijaz, M.K., Brunner, A.H., Sattar, S.A., &Johnson-Lussenburg, C.M., 2020. Survival characteristics of airborne human coronavirus 229E. J. Gen. Virol. 66 (12), 2743–2748.
Keynes, J.M., 1936. The general theory of employment, interest and money. Brace and Company, New York, Harcourt, p. 403.
Kumar, M., 2015. A study of population distribution. Int. J. Latest Technol. Eng. Manag. Appl. Sci. 4 (3), 24–28 2015.
Kydland, F., Prescott, E., 1982. Time to build and aggregate fluctuations. Econometrica 50 (6 November), 1345–1370.
Lima, CKT., Carvalho, PMM., Lima, I A S, Nunes, J V A.O., Saraiva, JS., Souza, R I, Silva, CGL., Neto, MLR., 2020. The emotional impact of coronavirus 2019-ncov (new coronavirus disease). Psychiatry Res., 112915 page.
Lipsitch, M., &Viboud, C., 2009. Influenza seasonality: Lifting the fog. Proc. Natl. Acad. Sci. 106, 3645–3646. doi:10.1073/pnas.0900933106, 2009.
Long, Plosser, 1983. Real Business Cycle. J. Polit. Econ. 91, 39–69.
Lowen, A.C., Steel, J., Mubareka, S., Palese, P., 2018. High temperature (30oC) blocks aerosol but not contact transmission of influenza virus. J. Virol. 82, 5650–5652. doi:10.1128/JVI.00325-08.
Lowen, A.C., Steel, J., 2014. Roles of humidity and temperature in shaping inuenza seasonality. J. Virol. 88, 7692 {7695.
Markowitz, S., Nesson, E., Robinson, J., 2010. Who has a clue to preventing the flu? unravelling supply and demand effects on the take-up of influenza vaccinations. J. Health Econ. 28, 704–717.
Martins, L.D., da Silva, I., Batista, W.V., de Fátima Andrade, M., de Freitas, E.D., Martins, J.A., 2020. How socio-economic and atmospheric variables impact COVID-19 and influenza outbreaks in tropical and subtropical regions of Brazil. Environ. Res. 191, 110184.
Maurer, J., 2009. Who has a clue to preventing the flu? unravelling supply and demand effects on the take-up of influenza vaccinations. J. Health Econ. 28, 704–717.
Onder, G., Rezza, G., Brusaferro, S., 2020. Case-fatality rate and characteristics of patients dying in relation to COVID19 in Italy. JAMA doi:10.1001/jama.2020.4683.
Oster, E., 2012. Routes of infection: exports and HIV incidence in Sub-Saharan Africa. J. Eur. Econ. Assoc. 10, 1025–1058.
Priyadarsini, SL., Suresh, M., 2020. Factors influencing the epidemiological characteristics of pandemic COVID-19: A TISM approach. Int. J. Healthc. Manage. 13 (2), 89–98. doi:10.1080/20479700.2020.1755804.
Qiu, Y., Chen, X., Shi, W., 2019. Impacts of social and economic factors on the transmission of coronavirus disease (COVID-19) in China. medRxiv 2020. doi:10.1101/2020.03.13.20035238, 2020.03.13.20035238.
Rahman, M., Islam, M., Shimanto, M.H., Ferdous, J., Rahman, A.A.N.S., Sagor, P.S., Chowdhury, T., 2021. A global analysis on the effect of temperature, socio-economic and environmental factors on the spread and mortality rate of the COVID-19 pandemic. Environ. Dev. Sustainab. 23 (6), 9352–9366.
Riou, J., &Althaus, CL., 2020. Pattern of early human-to-human transmission of Wuhan 2019 novel coronavirus (2019-nCoV), December 2019 to January 2020. Eurosurveillance 2020 25, 2000058.
Shaman, J., Kohn, M., 2009. Absolute humidity modulates influenza survival, transmission, and seasonality. Proc. Natl. Acad. Sci. USA 106 (2009), 3243–3248. doi:10.1073/pnas.080685210.
Slusky, D., Zeckhauser, R.J., 2018. Sunlight and protection against influenza, Faculty Research Working Paper Series, pp. RWP18–RW007.
Stojkoski, V., Utkovski, Z., Jolakoski, P., Tevdovski, D., Kocarev, L., 2020. The socio-economic determinants of the coronavirus disease (COVID-19) pandemic. arXiv preprint *arXiv:2004.07947*.
Wang, Y, Wang, M., Chen, Y., 2020. Unique epidemiological and clinical features of the emerging 2019 novel coronavirus pneumonia (COVID-19) implicate special controlmeasures. J..Med. Virol. 2020. doi:10.1002/jmv.25748.
Wang, M., Jiang, A., Gong, L., Luo, L., Guo, W., Li, C., Zheng, J., Li, C., Yang, B., Zeng, J., Chen, Y., Zheng, K., Li, H., 2020. Temperature significantly change COVID-19 transmission in 429 cities. medRxiv doi:10.1101/2020.02.22.20025791.
White, C., 2019. Measuring social and externality benefits of influenza vaccination. J. Hum. Resour..
Whitney, A., 2021. Planning for the unknown: local government strategies from the fiscal year 2021 budget season in response to the COVID-19 pandemic. State Local Gov. Rev. 53 (2), 159 –\ 171.
WHO, 2020. Coronavirus disease (COVID-19) outbreak 2020 [cited 2020 March 30]*Available from:*.
Woodward, A., 2020. High temperatures and muggy weather might make the new coronavirus less contagious, a group of experts says. Business Insider India. 2020 [cited 2020 March 30]. Available from: https://www.businessinsider.in/science/news/high-temperaturesand-muggy-weather-might-make-the-new-coronavirus-less-contagious-a-group-of-expertssays/articleshow/74697538.cms/ .
Wu, Z., McGoogan, J, 2020. Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72 314 cases from the Chinese Center for Disease Control and Prevention. JAMA 2020. doi:10.1001/jama.2020.2648.
Zhan, C., Tse, C., Fu, Y., Lai, Z., Zhang, H., 2020. Modeling and prediction of the 2019 coronavirus disease spreading in China incorporating human migration data. PLoS One 15 (10), e0241171. doi:10.1371/journal.pone.0241171.
Zhang, C., Chen, C., Shen, W., Tang, F., Lei, H., Xie, Y., Cao, Z., Tang, K., Bai, J., Xiao, L., Xu, Y., Song, Y., Chen, J., Guo, Z., Guo, Y., Wang, X., Xu, M., Zou, H., Shu, Y., Du, X., 2020. Impact of population movement on the spread of 2019-nCoV in China. SSRN.