RESEARCH ARTICLE

Capacity of transportation and spread of COVID-19—an ironical fact for developed countries

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Abstract

The widespread epidemic of the COVID-19 in developed countries such as Europe and the USA has sparked many speculations. What factors caused the rapid early pandemic of the COVID-19 in developed countries is the main goal of this study. We collected the main disease indicators and various environmental and economic factors in 61 countries around the world. Our results show that the number of cases is positively correlated with the country's GDP. We further analyzed the factors related to the spread of the disease. They indicate a strong positive correlation between the total patient numbers and the number of airline passengers, with an r value of 0.80. There is also a positive correlation between the number of car ownership and the total patient, with an r value of 0.35. Both the flight passengers and car ownership contribute 66% to the number of total patients. The total death numbers and the number of airline passengers are positively correlated, with an r value of 0.71. A positive correlation between the number of car ownership and the total deaths is with an r value of 0.42. The total contribution of both the flight passengers and car ownership to the number of total deaths is 57%. Our conclusion is that the main cause of the coronavirus pandemic in developed countries is related to the transportation. In other words, the number of travelers determined the early coronavirus pandemic. Therefore, it is necessary to strengthen restrictions and screening of passengers at airports, especially international airports.

Introduction

On December 31, 2019, Wuhan first detected and reported unexplained pneumonia. It was later that severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), also named coronavirus disease 2019 (COVID-19) by the World Health Organization (WHO) (Sohrabi et al. 2020), has now spread throughout the world. There is no doubt that such a

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public health emergency will severely hit countries with fragile health systems. However, what surprises people all over the world is that the countries with the strong COVID-19 pandemic turned out to be Italy, Germany, France, and other countries with high economic development in Europe (Yuan et al. 2020). More importantly is that the USA, which has both a strong economy and healthcare system, has the highest infection rate (Cascella et al. 2020). The unanswered question is why COVID-19 is a greater problem in developed countries as opposed to developing countries. Is the speed of the spread of COVID-19 related to specific characteristics of developed countries, and what are these characteristics?

Air transport is the main means of the rapid spread of modern epidemics and large-scale infectious diseases (Mangili et al. 2015). Simultaneously, a British study showed that car ownership is independently associated with health (Ellaway et al. 2016). It is precisely because of the convenience of air and land transportation that most infectious diseases can quickly move from one area to another during the incubation period, which has also become an important challenge in the current public health field.

In order to find the relationship between traffic conditions and COVID-19, we collected data on population geography, economics, air passengers, and ownership of passenger cars in multiple countries in various regions of the world and conducted a comprehensive analysis of these data. The purpose of this study is to compare the data collected from multiple countries with the COVID-19 infection status.

Material and methods

Data collection

As of May 15, 2020, we have collected the number of confirmed cases and deaths in 61 countries with more than 5000 confirmed cases on the Johns Hopkins University website (https://www.jhu.edu/; accessed May 15, 2020). We collected the number of air passengers carried by each country in 2019 (https://www.nationmaster.com/nmx/ranking/number-of-air-passengers-carried; accessed July 20, 2020). Ownership of passenger cars per thousand persons in each country was also collected (https://en.wikipedia.org/wiki/List_of_countries_by_vehicles_per_capita#cite_note-21; accessed July 20, 2020). Other data collected include daily cumulative index (cumulative cases/no. of days between the first reported case and May 15, 2020), total population, date of first case, CO_2 emissions, forest area, economic status (1, low-income economies; 2, lower middle-income economies; 3, upper middle-income economies; 4, high-income economies), GDP, immunization, measles (% of children ages 12–23 months), population density, poverty headcount ratio at $1.90 a day, poverty headcount ratio at $1.90 a day, the

prevalence of HIV, total (% of population ages 15–49), primary completion rate, total (% of relevant age group), primary completion rate, total (% of relevant age group), school enrollment, secondary (% gross), population aged 0–14 (%), population aged 10–24 (%), population aged 15–64 (%), population aged 65 and older (%), and life expectancy at birth. We collected this information of the countries from the World Bank (https://databank.worldbank.org/source/world-development-indicators/preview/on#; accessed 21 July 2020).

Data analyses

Data organization

Data were uploaded to an Excel spreadsheet and analyzed. The disease data included the following: number of confirmed cases, percentage of confirmed cases, number of deaths, percentage of deaths, and 23 economic indicators for 61 countries. Names of the countries are listed in the columns against the data in the rows. A cross-section of r values was performed using the formulas function of Excel. Every item of 4 major disease factors is running against all economic factors, and every economic factor is against all other listed factors (Supplemental Table S1).

Association analysis of disease factors and economic factors

The total patient number and deaths were analyzed against features of developed countries such as GDP, CO_2 emission, and percentage of forest cover area with linear regression models. The percentage of patients with COVID-19 disease among the total population was compared to CO_2 emissions, income economies, and percentage of the population between 15 and 64 years of age, using the linear regression model. Analysis was conducted using correlation formula and chat analysis of Excel.

Analysis of association between transportation factors and COVID-19 pandemic

The passage numbers in flights and car owners were compared to the disease factors of COVID-19 using linear and multiple regression models. Both models were conducted using Excel with the function formula.

Statistical significance

In linear or multiple regression and correlation analyses, we considered an absolute r value equal to or more than 0.7 or -0.7 as a significant correlation, either positive or negative. When an r value is between 0.35 and 0.69 or -0.35 and -0.69, a correlation exists. When r values fell between 0 and 0.35 or 0 and -0.35, we regarded it as no correlation. $P < 0.05$

was considered statistically significant. All the data were collected from every country except poverty headcount ratio at $1.90 a day, the total prevalence of HIV (% of population ages 15–49), and total primary completion rate (% of relevant age group); some of these data are not available for some countries. *P* values and *r* values of coefficients are calculated for each of these factors.

Results

Association between features of COVID-19 pandemic and developed countries

Our analysis indicated that the total patient numbers and deaths are associated with features of developed countries such as GDP, CO2 emission, and percentage of forest cover area (Fig. 1).

1. Our analysis showed a strong correlation with GDP, with an *r* value of 0.818. It also showed a positive correlation with the forest area with an *r* value of 0.413. The number of days from the time the first case was confirmed to the deadline of statistics in various countries showed a negative but not strong influence, with an *r* value of -0.319.
2. The percentage of patients with COVID-19 disease among the total population is positively correlated to CO2 emissions, income economies, and percentage of the population aged between 15 and 64, with *r* values of

0.529, 0.318, and 0.371, respectively. It is negatively correlated to the poverty headcount ratio at $1.90 a day, with an *r* value of -0.357 (Fig. 2). The total percentage of patients with COVID-19 is higher in countries that are wealthier and have a better environment.

3. The total number of deaths caused by COVID-19 disease in a country is positively correlated to GDP, with an *r* = 0.745. The death rate is positively correlated to school enrollment (secondary), percentage of population aged 65 and older, and life expectancy at birth with *r* values of 0.412, 0.464, and 0.383, respectively. It is negatively but not significantly correlated with the days of the late occurrence of the first infected person, with a negative *r* value of -0.326 (Fig. 3).

### Association of transportation factors to the COVID-19 pandemic

Economic features such as the GDP, forest area, CO2 emissions, aging population, and income economies are not the real cause of the COVID-19 pandemic; although there is an association, we further explored the factors that relate to human activities, in particular, air passenger carrying capacity and car ownership (Supplemental Table S2).

Our analysis indicated that there is a strong positive correlation between the total patient numbers and the number of airline passengers (Fig. 4a), with an *r* value of 0.80. There is

Fig. 1 Patient numbers of COVID-19 are positively associated to GDP and forest area of the countries. **a** Positive correlation between patient numbers and forest areas. Vertical axis: forest area (sq. km) (2016). Horizontal axis: total confirmed cases. **b** Positive correlation between patient numbers and GDP. Vertical axis: GDP (current US$) (2018). Horizontal axis: total confirmed cases
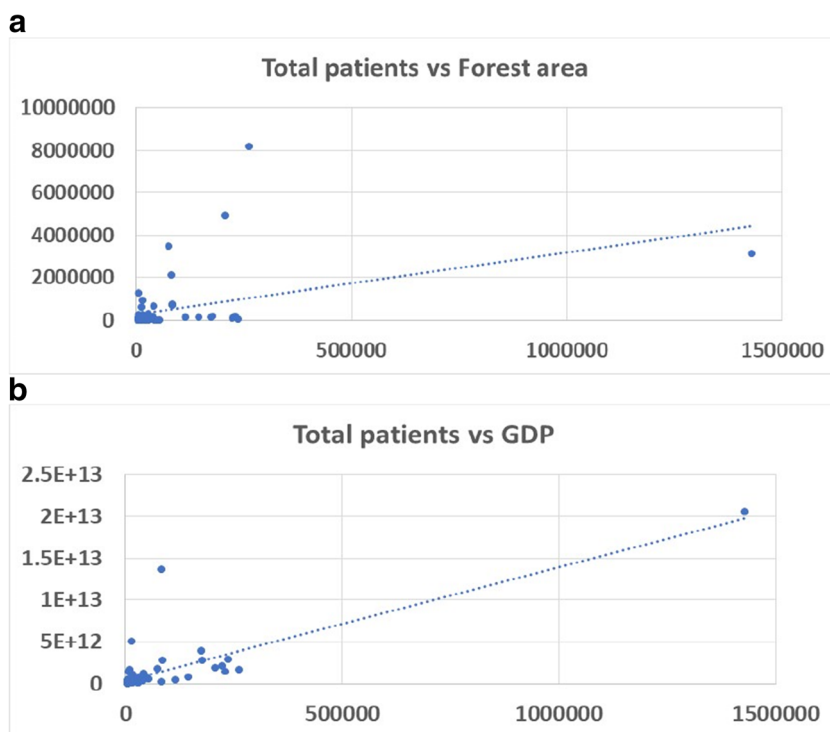
Fig. 2 Total confirmed rate % of COVID-19 patients is positively associated to factors of the developed countries. **a** Positive correlation between confirmed rate % of COVID-19 patients and CO2 emissions. Vertical axis: CO2 emissions (metric tons per capita) (2014). Horizontal axis: confirmed rate % of COVID-19 patients. **b** Positive correlation between confirmed rate % of COVID-19 patients and incomes. Vertical axis: income economies (1, low-income economies; 2, lower middle-income economies; 3, upper middle-income economies; 4, high-income economies). Horizontal axis: confirmed rate % of COVID-19 patients. **c** Positive correlation between confirmed rate % of COVID-19 patients and population age at 15–64. Vertical axis: population aged 15–64, percent, 2019. Horizontal axis: confirmed rate % of COVID-19 patients. **d** Negative correlation between confirmed rate % of COVID-19 patients and poverty level. Vertical axis: poverty headcount ratio at $1.90 a day (2011 PPP) (2016). Horizontal axis: confirmed rate % of COVID-19 patients
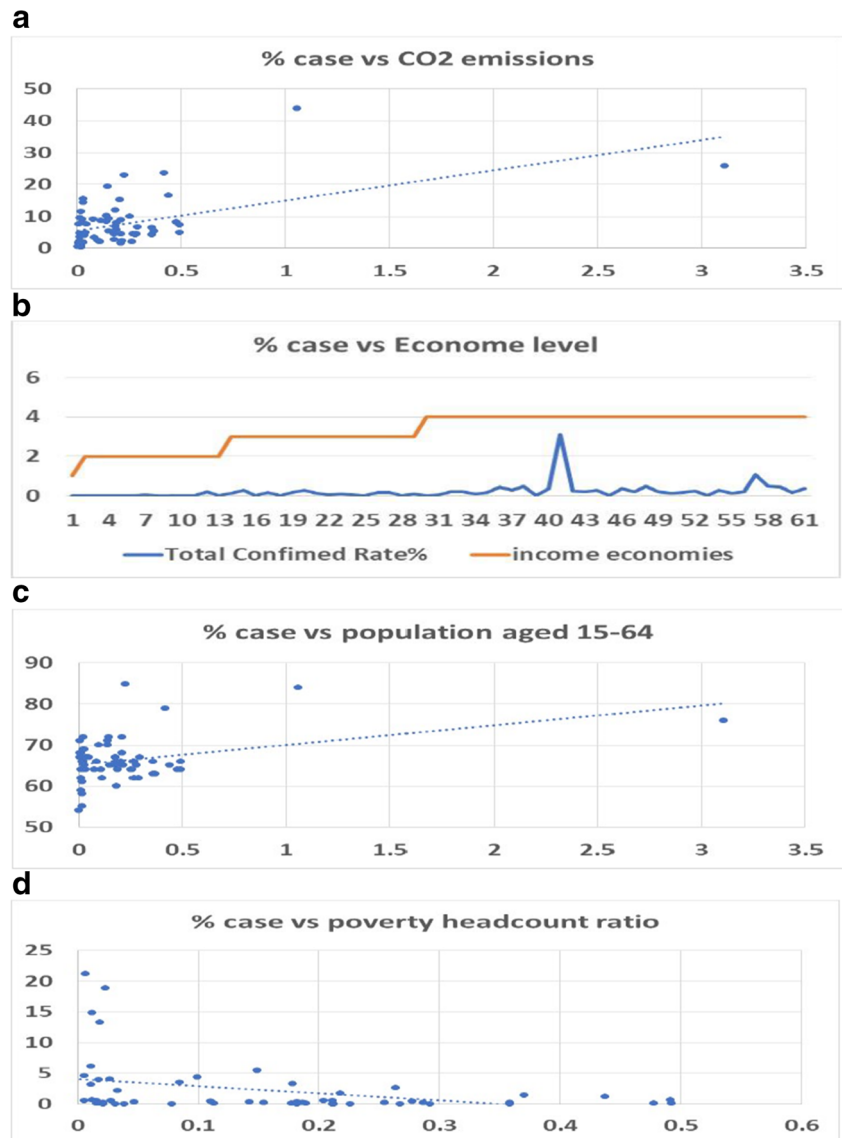
also a positive correlation between the number of car ownership and the total patient (Fig. 4b), with an *r* value of 0.35. Multiple regression analysis resulted in a total contribution of both the flight passengers and car ownership to the number of total patients is 66% (Fig. 4c).

Similarly, there is a strong positive correlation between the total death numbers and the number of airline passengers (Supplemental Table S3) (Fig. 4d), with an *r* value of 0.71. A positive correlation between the number of car ownership and the total deaths is also obtained (Fig. 4e), with an *r* value of 0.42. Multiple regression analysis resulted in a total contribution of both the flight passengers and car ownership to the number of total deaths is 57% (Fig. 4f). Finally, we analyzed the correlation between flight passengers and GDP; we obtained the *r* value of 0.96 (Fig. 5a). Other factors showed a variety of positive correlations to flight passengers and/or car ownerships (Fig. 5b,c,d).

Discussion

Our analysis showed that the economy in the developed countries is correlated with the high level of transportation capacity which in turn serves as carriers for the spread of COVID-19. Because of the need for business activities, airlines and car numbers are dramatically increased in the developed countries. While transportation tools enable business development, these tools also carry people around the world and contribute to exposure to infectious diseases. As GDP is highly correlated to the transportation tools, it is impossible to increase the GDP without increasing the transportation. Thus, the transportation services to humans are a double-edged sword.

The World Health Organization stated that the USA is still the epicenter of the epidemic in a recent press conference and other developed countries, including the UK, France, and Italy, are currently not ideally controlling the epidemic.

Fig. 3 Death numbers and rate of COVID-19 patients are positively associated to economic factors of the developed countries. **a** Positive correlation between confirmed death numbers of COVID-19 patients and GDP. Vertical axis: GDP (current US$) (2018). Horizontal axis: total death numbers of COVID-19 patients. **b** Positive correlation between confirmed death rate % of COVID-19 patients and school enrollment. Vertical axis: school enrollment, secondary (% gross) (2017). Horizontal axis: confirmed death rate % of COVID-19 patients. **c** Positive correlation between confirmed death rate % of COVID-19 patients and aged 65 and older. Vertical axis: population aged 65 and older, percent, 2019. Horizontal axis: confirmed death rate % of COVID-19 patients. **d** Positive correlation between confirmed death rate % of COVID-19 patients and life expectancy. Vertical axis: life expectancy at birth (years), 2019. Horizontal axis: confirmed death rate % of COVID-19 patients
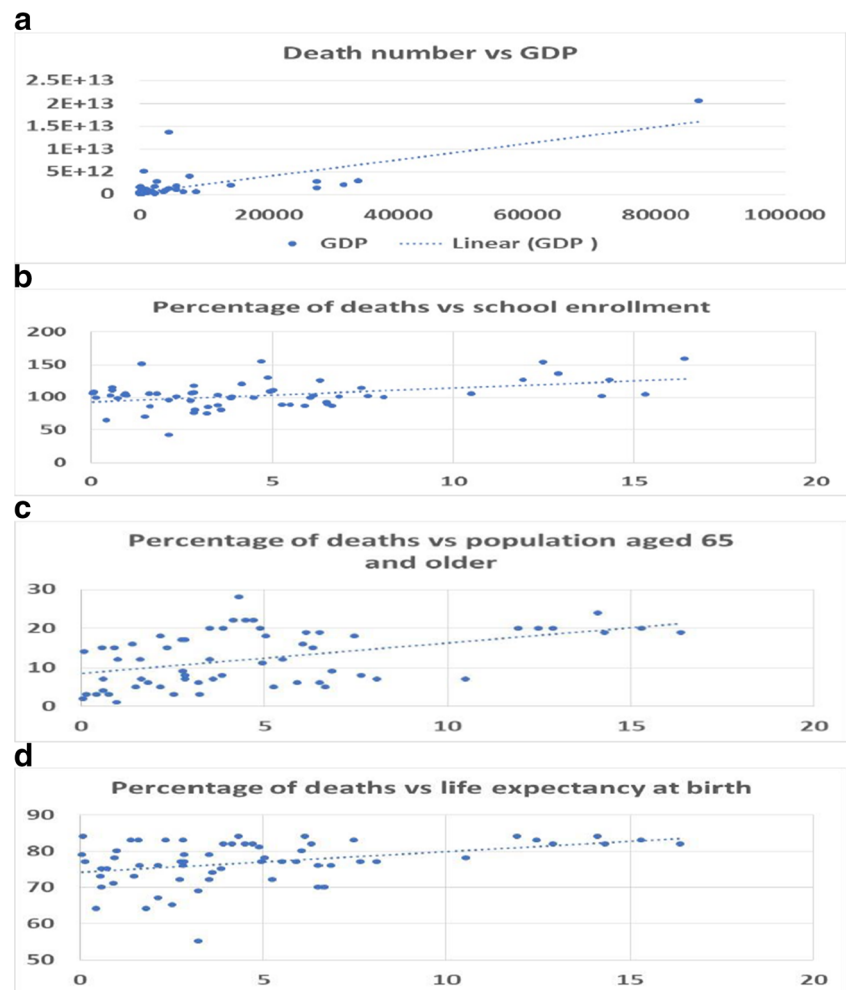
Among all the classic public health measures, the most severe measure is the social isolation of the community (Wilder-Smith and Freedman 2020). However, in Western developed countries, with the development of transportation, people have a high degree of freedom of movement, which makes the implementation of community isolation recommendations for people more difficult.

In general, the impact of the disease, which in developed countries are less threatening to people because of the better health systems, however, COVID-19 is new and threatens human lives in all countries the same, especially in the early time of the pandemic when people do not know any useful treatment measures. Because of its new features of transmission and infection mechanisms, the health systems in the world do not have the tools available to fight it. Luckily, its death rate is not as high as early reported in Wuhan, and the health system around the world has time to develop tools to fight COVID-19 before it kills more people. However, the COVID-19 gives humans a warning: We should not feel too confident about our health systems. If we are not ready,

diseases with high infectivity and high lethality will come and may cause great disasters to human beings in the future.

Cutting off traffic and transportation restrictions can prevent the transmission of infectious diseases, but it is only a short-term solution. Because the development of the economy is dependent on transportation and better transportation tools, the identification of ways to effectively prevent disease transmission while keeping the transportation will be a difficult task of the government and the healthcare system. Although the USA very quickly shut down flights from China to the USA, partially because of its sophisticated transmission mechanism, COVID-19 still found a way to travel from Europe to New York and caused a severe pandemic (Bushman et al. 2020). On the other hand, in developing countries with limited resources, data collection and screening for COVID-19 are not equal to what developed countries are capable of doing. Late when pandemic happens in these countries, COVID-19 may lead to more sicknesses and deaths.

Therefore, if we want to prevent the COVID-19 epidemic from spreading further, we need a successful vaccine. On the

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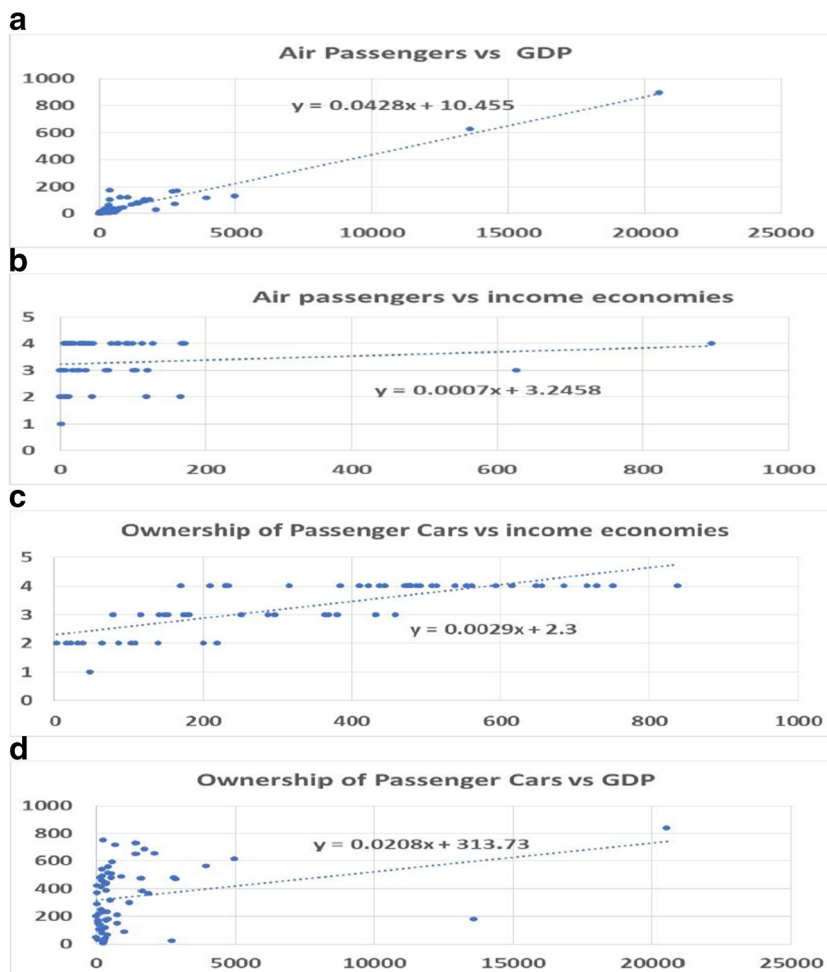
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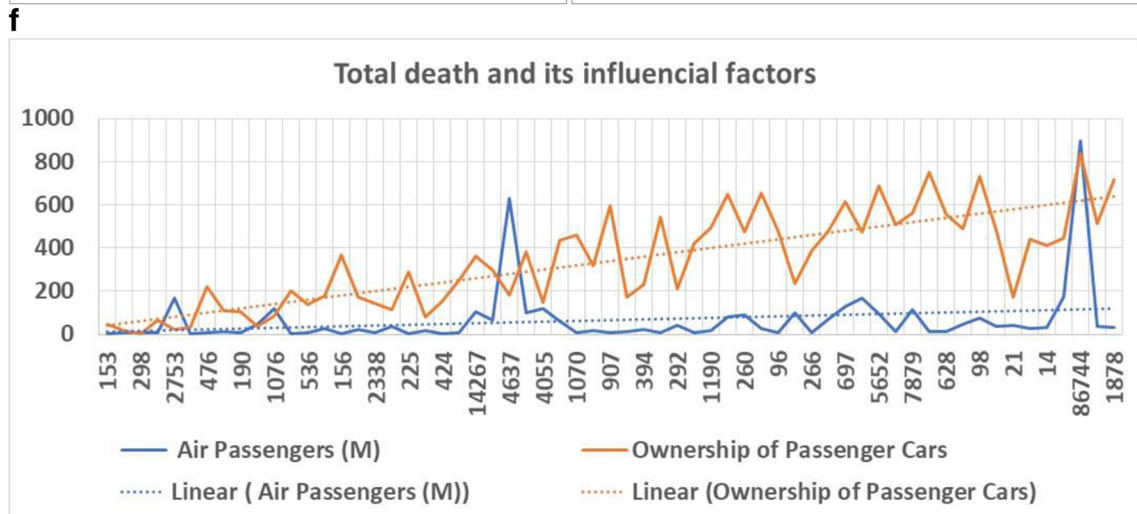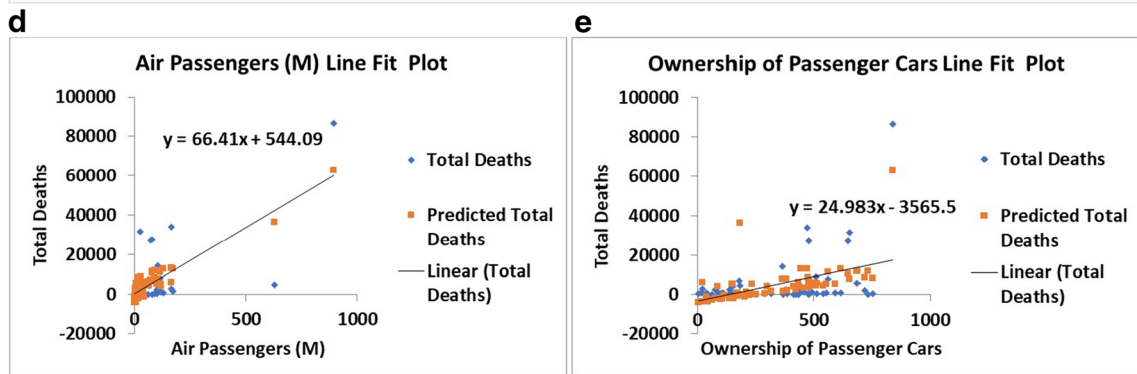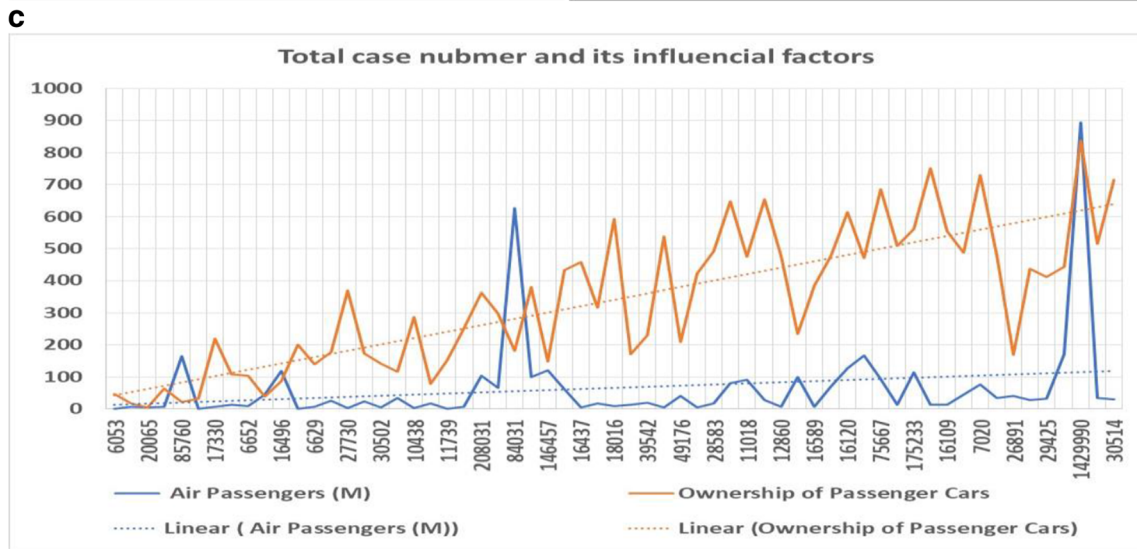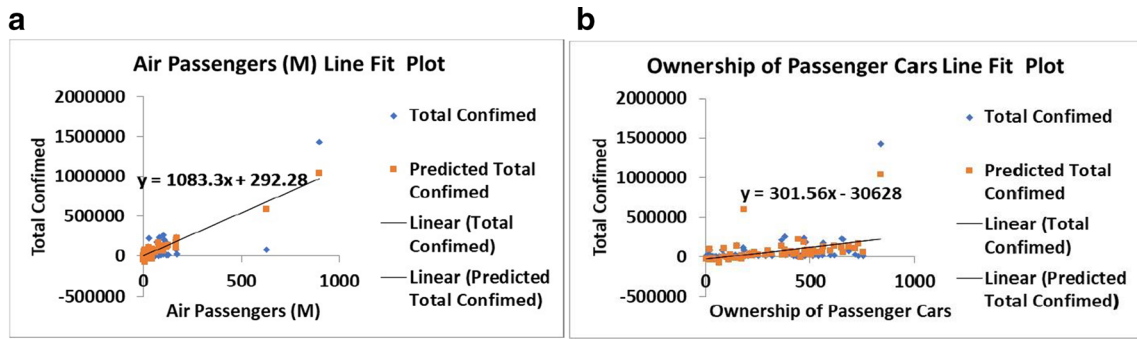
◄ **Fig. 4** Pandemic of COVID-19 patients is positively associated to transportation factors of the developed countries. **a** Line plot of positive correlation between confirmed numbers of COVID-19 patients and air passengers. Vertical axis: number of air passengers carried in 2019. Horizontal axis: total numbers of COVID-19 patients. **b** Line plot of positive correlation between confirmed number of COVID-19 patients and car ownerships. Vertical axis: ownership of passenger cars (units per thousand persons). Horizontal axis: confirmed numbers of COVID-19 patients. **c** Multiple regression correlation ship between confirmed numbers of COVID-19 patients and air passengers and car ownership. Vertical axis: numbers of air passengers or car ownership. Horizontal axis: confirmed number of COVID-19 patients. **d** Line plot of positive correlation between confirmed death numbers of COVID-19 patients and air passengers. Vertical axis: number of air passengers carried in 2019. Horizontal axis: total death numbers of COVID-19 patients. **e** Line plot of positive correlation between confirmed death numbers of COVID-19 patients and car ownerships. Vertical axis: ownership of passenger cars (units per thousand persons). Horizontal axis: confirmed death numbers of COVID-19 patients. **f** Multiple regression correlation ship between confirmed death numbers of COVID-19 patients and air passengers and car ownership. Vertical axis: numbers of air passengers or car ownership. Horizontal axis: confirmed death number of COVID-19 patients

one hand, we should increase the regular screening of travelers and cargo workers and, on the other hand, vaccinate those who are highly mobile, such as international travelers, as soon

as possible. Fortunately, there is already some good news about vaccines, which have achieved exciting effects in preventing COVID-19 and have good safety (Baden et al. 2020; Polack et al. 2020). These studies give us confidence in the future.

Our analysis is based on the data of COVID-19 up to May 15, 2020, COVID-19 may have spread to most countries in the world. Although other factors may influence the spread of COVID-19, we feel that transportation tools play the most important role, in particular the early infection sources dependent on transportation. Local human activities such as social gatherings and inhouse activities may contribute to the local pandemic; however, the worldwide pandemic of COVID-19 has undoubtedly been brought about by air and car transportation.

Conclusions

The advanced transportation systems in the developed countries enabled the rapid pandemic of COVID-19 at an early

Fig. 5 Transportation factors are positively associated to economic factors of the developed countries. **a** Positive correlation between air passengers and GDP. Vertical axis: number of air passengers carried 2019. Horizontal axis: GDP (current US$) (2018). **b** Positive correlation between air passengers and incomes. Vertical axis: levels of income economies. Horizontal axis: number of air passengers carried 2019. **c** Positive correlation between car ownership and incomes. Vertical axis: levels of income economies. Horizontal axis: car ownership. **d** Positive correlation between car ownership and GDP. Vertical axis: car ownership. Horizontal axis: GDP level

time. Prevention of the spread of disease by the transportation system is a difficult task for the world in the future.

Declarations

Ethics approval and consent to participate   Not applicable.

Competing interests   The authors declare no competing interests.

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